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Agriculture Handbook No. 135

September 1958

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Engineering Handbook

for Soil Conservationists
in the Corn Belt

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U. S. DEPARTMENT OF

BELTSVILLE BRANCH

SOIL CONSERVATION SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

ENGINEERING HANDBOOK FOR SOIL CONSERVATIONISTS IN THE CORN BELT

CONTENTS

Part	Subject	Page	Part	Subject	Page
PART 1 ENGINEERING SURVEYS			PART 8 TERRACING		
1.10	General.....	1-1	8.10	General.....	8-1
1.20	Measurement of Horizontal Distances.....	1-1	8.20	Planning the Terrace System.....	8-2
1.30	Differential Leveling.....	1-7	8.30	Staking Terraces.....	8-5
1.40	Topographic Surveys.....	1-24	8.40	Construction of Terraces.....	8-5
1.50	Job Layout.....	1-29	8.50	Checking Finished Terrace.....	8-10
1.60	Field Books.....	1-38	8.60	Terrace Maintenance.....	8-13
PART 2 PREPARATION OF ENGINEERING DATA SHEETS			8.70	Plowing Terraced Fields.....	8-13
2.10	General.....	2-1	8.80	Preparing Seedbed and Planting Crops on Terraced Land.....	8-17
2.20	Purpose.....	2-1	8.90	Harvesting Crops on Terraced Land.....	8-25
2.30	Information and Materials Needed.....	2-1	PART 9 DIVERSIONS		
2.40	Drawing and Drafting Standards.....	2-4	9.10	General.....	9-1
2.50	Watershed Location Map.....	2-12	9.20	Design of Diversions.....	9-2
2.60	Location Plan.....	2-14	9.30	Layout and Construction of Diversion Channels.....	9-4
PART 3 RAINFALL - RUNOFF - SPRING AND STREAM FLOW MEASUREMENTS			9.40	Maintenance of Diversion Channels.....	9-4
3.10	Erosion Control.....	3-1	PART 10 VEGETATED OUTLETS AND WATERCOURSES		
3.20	Drainage Runoff.....	3-5	10.10	Water Disposal.....	10-1
3.30	Measuring Stream and Spring Flows.....	3-5	10.20	Watercourse Location.....	10-2
PART 4 FARM PONDS			10.30	Design.....	10-2
4.10	General.....	4-1	10.40	Construction of Watercourses.....	10-7
4.20	Selecting the Pond Site.....	4-2	10.50	Sod Chute.....	10-13
4.30	Surveys.....	4-4	PART 11 LAND DRAINAGE		
4.40	Design.....	4-4	11.10	Introduction.....	11-1
4.50	Staking.....	4-19	11.20	Effects and Benefits of Land Drainage.....	11-1
4.60	Construction.....	4-19	11.30	Preliminary Investigation of Drainage Jobs.....	11-5
4.70	Maintenance.....	4-22	11.40	Drainage Outlets.....	11-9
PART 5 SPRING AND HYDRAULIC RAMS			11.50	Open Outlet Ditches.....	11-11
5.10	General, Springs.....	5-1	11.60	Surface Drainage.....	11-27
5.20	Developing a Spring.....	5-1	11.70	Tile Drainage.....	11-58
5.30	General, Hydraulic Rams.....	5-6	11.80	Culverts.....	11-93
5.40	Operation.....	5-6	PART 12 IRRIGATION		
5.50	Design.....	5-6	12.10	General.....	12-1
PART 6 WELLS			12.20	Water Supply.....	12-6
6.10	General.....	6-1	12.30	General Types of Irrigation.....	12-7
6.20	Construction of Well.....	6-1	12.40	Adaptation of Types of Irrigation to the Region.....	12-9
6.30	Selection of Pumps.....	6-6	12.50	Costs of Irrigation Systems.....	12-14
6.40	Power Requirements.....	6-6	PART 13 STREAMBANK EROSION CONTROL		
PART 7 CONCRETE AND MASONRY STRUCTURES			13.10	General.....	13-1
7.10	General.....	7-1	13.20	Investigations.....	13-1
7.20	Component Parts of Structures.....	7-1	13.30	Treatment.....	13-2
7.30	Common Types of Structures.....	7-3			
7.40	Structure Data Sheets and Designs.....	7-7			
7.50	Preliminary Cost Estimates.....	7-14			
7.60	How to Promote Good Quality in Construction.....	7-19			
7.70	Structure Maintenance.....	7-19			

This handbook has been prepared for soil conservationists and other agricultural workers who have little or no training in the field of engineering. Efforts have been directed toward supplying engineering information that they can readily use in developing conservation measures for farmland.

Highly technical engineering information has either been intentionally omitted or is presented in such form that it can be used with a minimum of effort and study. Charts, tables, and illustrations are provided to take the place of narrative material wherever possible.

Users of the handbook should keep in mind that the occasional reference to a drawing or technical note pertains to materials provided by the Soil Conservation Service to its field personnel for their use in carrying out their responsibilities. These additional references will not be available to workers outside the SCS.

This handbook supersedes Agriculture Handbook No. 57, Farm Planners' Engineering Handbook for the Upper Mississippi Region.

PART 1

ENGINEERING SURVEYS

1.10 GENERAL

1.11 Purpose

a. This part of the engineering handbook provides:

(1) Detailed directions for the care and use of surveying instruments by soil conservationists.

(2) Step-by-step description of practical methods of surveying applicable to soil conservation activities.

b. It should be remembered that there can be no substitute for experience in surveying. Skill in surveying comes only with practice as in using a typewriter or driving an automobile. The beginner must continually review surveying procedures and conscientiously try to put them into practice until the operations become very nearly automatic. Above all, he must not become discouraged by initial mistakes. He must check and re-check his work until he is sure it is correct. It has been said "a good engineer is one who assumes he is wrong, tries every way he can think of to prove he is wrong, and when he cannot thus prove he is wrong, cautiously concedes he may be right."

1.12 Scope

Only basic principles of surveying will be explained in Part 1. Details of procedures applicable to a specific practice will be explained in the part of handbook dealing with that practice.

1.20 MEASUREMENT OF HORIZONTAL DISTANCES

1.21 The procedures for measuring horizontal distances by pacing, chaining, and stadia are:

a. Pacing may be used for approximate measurement when an error of two feet per hundred feet is permissible. Measurement by pacing consists of counting the number of steps between two points and multiplying the number by a predetermined "pace factor." Pace factors will usually vary between individuals. Each person having occasion to use this measurement method should determine his individual pace factor.

The pace factor for each individual is the average distance in feet per step. It can best be determined by pacing a measured distance (usually 500 feet) several times. It should be paced enough times so the number of paces for the distance

does not vary over 2 or 3 paces. The "pace factor" then would be the distance in feet divided by the number of paces.

Some people prefer to use a stride in place of a pace. It consists of 2 paces, so the "stride factor" would be two times the "pace factor."

Measurement by pacing for terrace and diversion layouts, preliminary profile work, and gridding for surface drainage surveys, is generally permissible.

b. "Chaining" is the method of measuring horizontal distances with a steel tape. It is the most common method known and should be used for most measurements in order to get required accuracy.

Survey lines are measured or chained by stations. The distance between full stations is 100 feet. For this reason most steel tapes in use are 100 feet long. When a distance is referred to as so many stations, it means that number of 100-foot lengths. The fractional part of a distance between a full station is called a plus station. Fractions of a foot are indicated by decimals, either to the nearest 0.1 foot or 0.01 foot, depending upon the accuracy of measurement required. For example, a point on a line 309.2 feet beyond station 10+00 is indicated as station 13+09.2.

Stakes set along the line are marked with waterproof lumber crayon known as "keel." Markings are placed on the face of stakes so that as a person walks along the line in the direction of progressive stationing, the station markings are readily seen as each stake is approached.

Accurate chaining with a steel tape requires skill on the part of the chainmen in use of plumb bobs, steel marking pins, range poles, hand levels and tension indicator apparatus. No attempt will be made to outline details for highly accurate chaining methods, since most chaining done for small-size conservation jobs will allow an error of 0.3 to 0.5 foot per 100 feet. This handbook is written for execution of the less difficult conservation work (Class E). In order to obtain sufficient accuracy the following should be observed:

Keep tape on line being measured.

Keep uniform tension on tape for each measurement.

"Break" chain on slopes above 10%.

Accurately mark each station.

Keep accurate count of the stations.

The following procedure is generally used for chaining out a line within this accuracy limit.

(1) The line to be measured may be a meandering line along a drainage ditch or gully channel or it may be a straight line in a pre-determined direction. In the former case the measurements are taken parallel, or nearly so, to the meandering line; but in the latter case a range pole is set ahead on the line as far as can be seen, or the direction is marked by a tree, fence post, or other convenient point. This mark is used in sighting in a straight line from the point of beginning.

(2) For purposes of this explanation it will be assumed a straight line is to be measured, and a stake has been set at the point of beginning marked 0+00. (See paragraph 1.37b2 for other methods of stationing the beginning station.)

(3) The head chainman takes the zero end of the tape and advances in the general direction of the line to be measured. When he has gone the length of the tape the rear chainman will have observed that the 100-foot end is opposite the beginning point and he calls out "chain."

(4) The rear chainman then sights in the head chainman on the line to be measured and holds the 100-foot mark of the tape exactly on the beginning stake. The head chainman pulls the tape straight and reasonably tight and sets a stake or pin exactly at the "zero" end of the tape.

(5) The rear chainman calls out the number of his station (in this case 0+00) and the head chainman marks his stake 1+00, indicating one station has been measured.

(6) Both chainmen then move forward along the line to be measured and the rear chainman again calls "chain" when the head chainman has gone forward 100 feet. The line is sighted in, stakes set and marked as before, each time the rear chainman calls off his station to the head chainman and the new station is given the next consecutive number and so marked.

For chaining of this order of accuracy it is not necessary to hold the tape level when measuring up or down slopes under about 6 percent. On grades steeper than 6 percent the uphill end of the tape should be held on the ground and the chainman at the other end should hold the end of the tape so that it is level or at least as high as the chainman can reach and "plumb" down by sighting in. On grades over 10 percent the chain should be "broken" in such convenient lengths that it can be held approximately level, plumbing down to the ground. Figure 1.1 illustrates the process of breaking chain and indicates the errors which can occur if this is not done on steep slopes.

Where a line is to be measured on which no stakes are set the head chainman is responsible for keeping count of the number of stations. The procedure is the same as that used in ordinary surveying by means of 11 chaining pins.

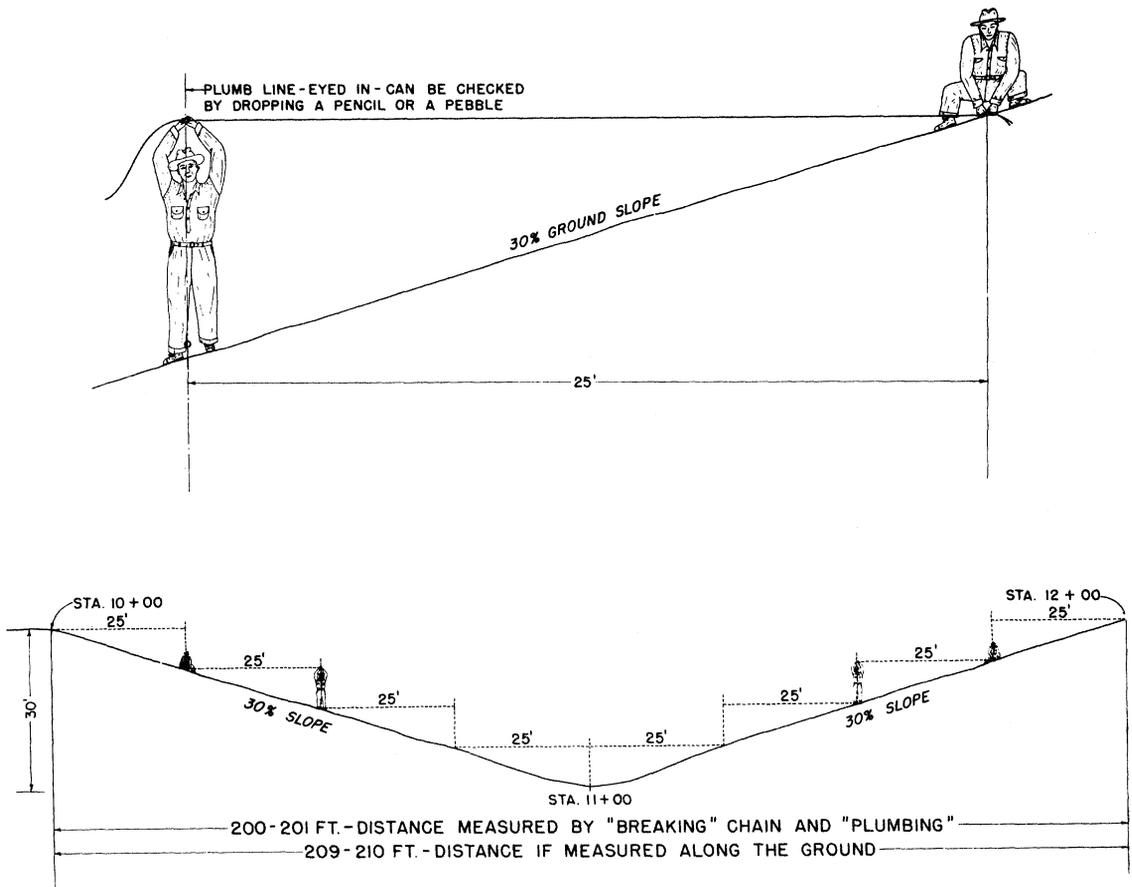


FIGURE 1.1 BREAKING CHAIN

Spikes (20d or larger) may be substituted for chaining pins. Many times the chaining pins are not provided, but the spikes are available or can be readily obtained. A substitute for a chaining pin may also be made from No. 9 galvanized wire. Regardless of the type of pin the procedure is the same and for purposes of explanation it will be assumed that spikes are used.

When chaining is begun he counts out 11 spikes, sticks one in the ground to mark the starting or zero point and puts 10 in a convenient pocket emptied of all other objects. When the first station is lined in and measurement completed the head chainman sticks a spike in the ground at that point and calls or signals to the rear chainman that measurement is completed. The rear chainman then pulls the spike at his location and puts it in one of his pickets that is free from all other objects, then moves forward to the next station at the same time the head chainman is moving forward in readiness for setting the next station. This process is continued until the head chainman uses his last spike. At this station 10 spikes have been used and 1,000 feet has been measured. The head chainman calls "spike" to rear chainman, at which time the rear chainman moves up and delivers

his collected 10 spikes to the head chainman. The head chainman then records station 10+00 in his notebook. This process is continued until measurement of the line in question is completed. Suppose that measurement was completed when the head chainman had 4 spikes left and station 20+00 had been recorded in his notebook. This would mean that 10 minus 4 or 6 spikes had been used ahead of station 20+00 and that the station at the end of the line would be 26+00.

c. Stadia method for measuring horizontal distances requires the use of a transit or level equipped with stadia hairs. There are three horizontal cross hairs and one vertical cross hair in this arrangement. The horizontal cross hairs are so spaced that any intercept between the top and bottom cross hairs when read on a graduated rod such as a level rod or stadia rod, if multiplied by 100, will give the distance between the instrument and the rod. The use of stadia will have little application generally by soil conservationists and will not be discussed further in this handbook. It will be most useful where a large amount of detailed topographic mapping is necessary. In such situations it may be necessary to obtain the services of an engineer to train soil conservationists in applying this method.

1.22 Equipment for Chaining

a. Steel tapes are made of flat steel bands marked in various ways (Figure 1.2). The markings may be etched, stamped on clamps or soldered sleeves, or stamped on bosses. Steel tapes may be obtained in lengths up to 500 feet, although the most commonly used is 100 feet long. Tapes are usually marked at one foot intervals, except the first and last foot, which is generally graduated in tenths and hundredths.

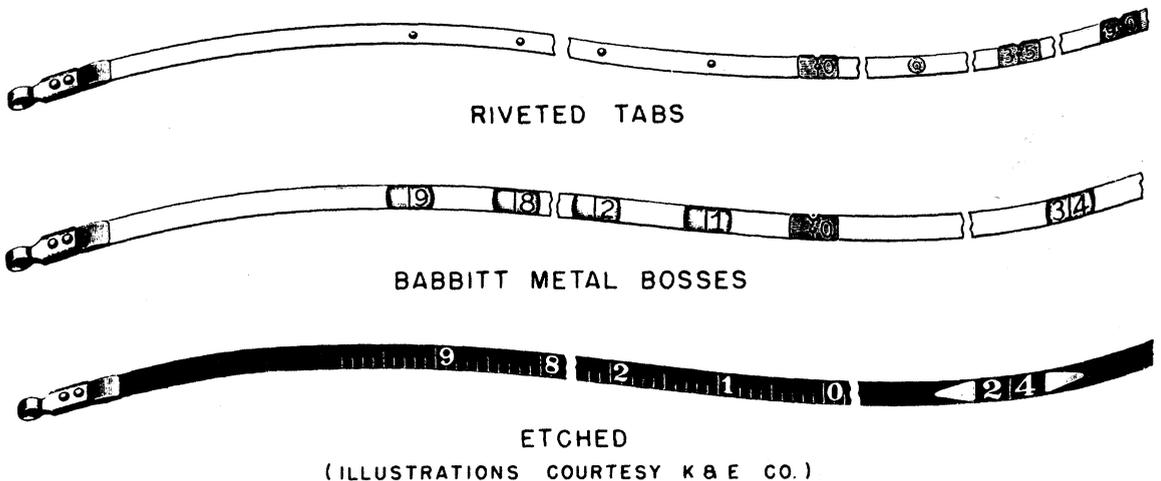


FIGURE 1.2 STEEL TAPE MARKINGS

Some tapes may have an extra foot at one or both ends marked in tenths and hundredths. Tapes marked in feet, inches, and eighths are usually furnished in a leather case and are light-weight steel ribbons as compared with the heavy duty field

engineer's tape. Because of the wide variety in manner of marking tapes whenever a tape is used for the first time, the surveyor should inspect it carefully to determine how it is marked. Tapes using clamped or soldered sleeves for foot markings are commonly used without reels because of their bulkiness when rolled on a reel. Tapes without reels are done up in a figure-of-eight and then "thrown" into a circular shape. The method of "throwing" a tape does not lend itself well to a written description. Hence, the surveyor should learn this procedure from an experienced surveyor.

b. Metallic or woven tapes are made of cloth with fine brass wire woven into them to minimize stretching. They usually come in lengths of 50 feet but may be 25 feet or 100 feet long. They are used for measurements not requiring a high degree of accuracy such as securing dimensions of existing bridge openings, measurement of short distances in taking cross sections or topography, measuring distances for strip cropping layouts, orchard terracing layouts, etc.

1.23 Minor Repairs and Care of Tapes

a. Steel tapes are easily broken if not properly handled. Do not jerk the tape needlessly. Do not step on it or allow vehicles to run over it and do not attempt to bend it around sharp corners. The most common cause of a broken tape is pulling or jerking on it when there is a loop or kink. Slight deformations caused by kinking should be carefully straightened with the fingers.

b. In spite of reasonable care, tapes will occasionally be broken. Each headquarters having an engineer regularly assigned should have a tape repair kit. Repairs should be made under the supervision of an engineer.

c. After each day's use, steel and metallic tapes should be wiped clean and dry with a clean cloth. Steel tapes should be given a light coating of machine oil by wiping with an oily cloth after cleaning. If rust spots are formed during a day's use in wet weather, the tape may be cleaned with wood ashes or a kitchen cleanser. Do not use a coarse abrasive such as sandpaper or emery paper. This will eradicate the markings on the tape.

d. The cost to the Government of a steel tape is about 10 to 15 dollars, depending upon whether a reel is included. The average cost of a metallic tape is about five dollars. The value of this equipment merits good care. In any event, good work can never be done with tools in poor condition. A good workman takes pride in the good condition of the tools he uses.

1.30 DIFFERENTIAL LEVELING

1.31 General

Planning and establishment of all mechanical practices used in soil and water conservation work require information regarding the relative elevation of points on the earth's surface. For example, water will flow from one point to another in a terrace channel only if there is a difference in elevation between the two points. Among other factors, we must know what the difference is in elevation in order to determine how fast the water will flow between the points. Various methods may be used to determine relative elevations, the method selected depending upon the type of work for which the elevations are required.

a. For very accurate work it is necessary to take into account the fact that the earth's surface is spheroidal. Points of equal elevation do not actually lie in a plane but on a spherical surface - that is, points of equal elevation are points which are equal distances from the center of gravity of the earth. In very precise leveling work the curvature of the earth is taken into account. For most soil conservation work, however, this factor may be disregarded. Most leveling work performed by soil conservationists will be considered as "third-order" leveling, in which the permissible "error of closure" in feet can be obtained by multiplying 0.05 by the square root of the length of the circuit in miles. Stated as a formula; permissible error (ft.) = $0.05 \sqrt{M}$ (where M is the length of circuit in miles).

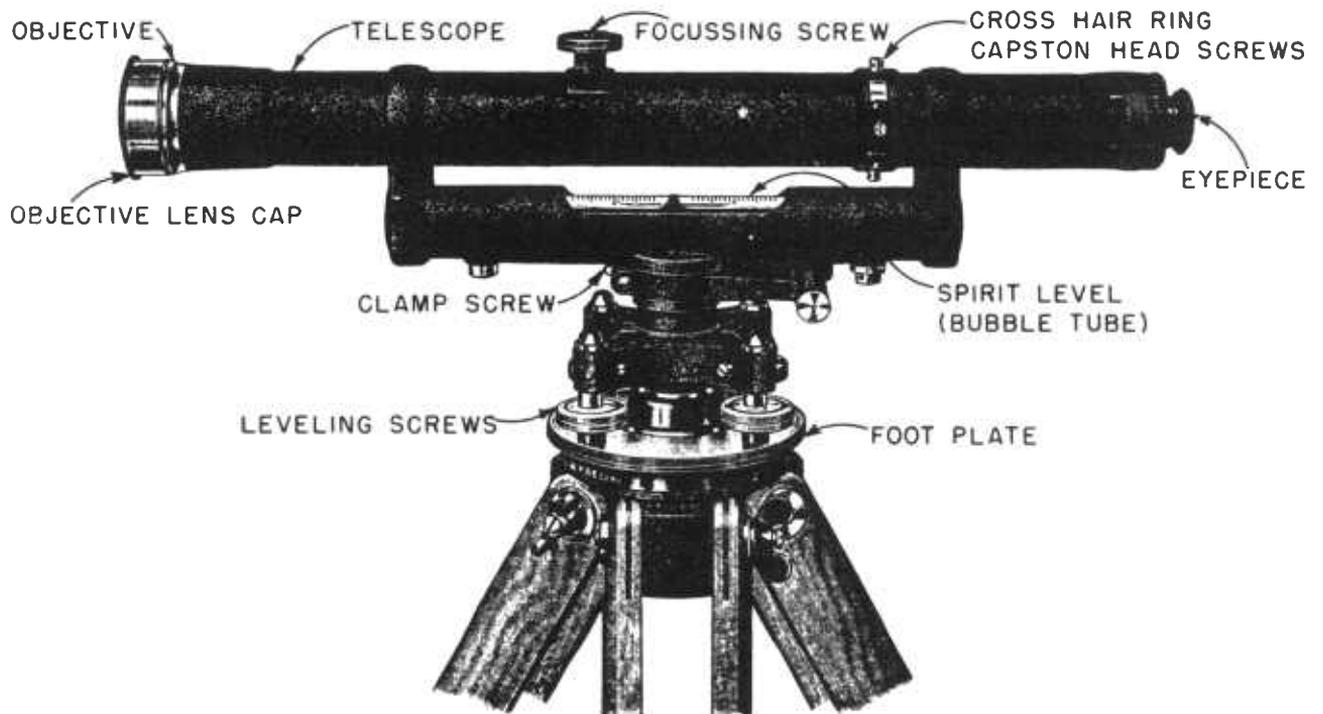
b. Three principal methods are used in determining differences in elevation: Barometric, trigonometric, and differential (or spirit) leveling. Differential leveling is the method most commonly used and is the only one on which procedures will be explained. It utilizes the phenomenon that a spirit level can be used to fix a line of sight perpendicular to the action of gravity - that is, a perpendicular line extending from the spirit level to the center of gravity of the earth. This line of sight can then be used to determine differences in elevation between nearby points on the earth's surface.

1.32 Kinds of Levels and Functioning

a. The four types of levels commonly used include the engineer's wye and dumpy levels, and the two hand levels, the Locke and the Abney.

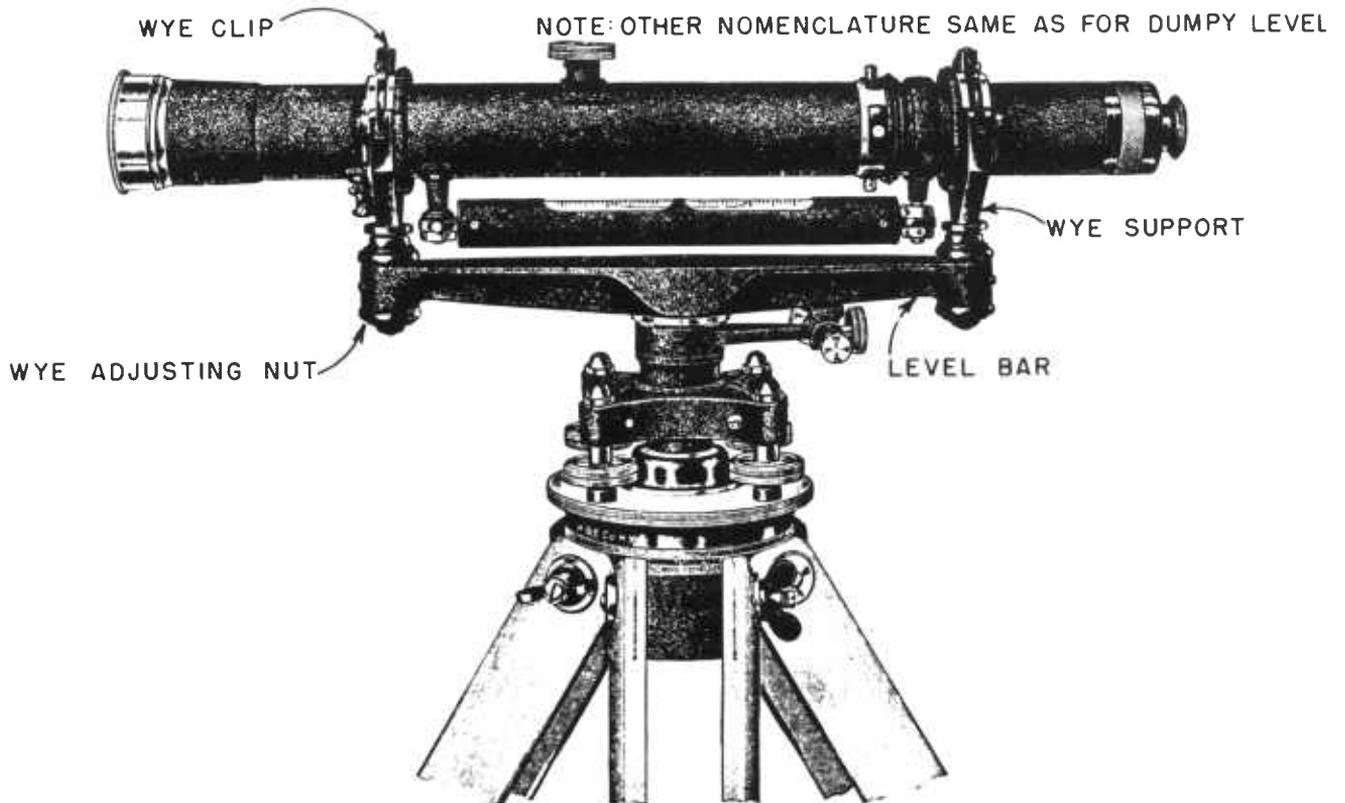
b. The dumpy level, Figure 1.3, because of its sturdiness, convenience, and stability of adjustment, has largely superseded the wye level. The telescope on the dumpy level is rigidly attached to the frame.

c. The wye level (Figure 1.4) is so-called because the telescope rests in Y-shaped supports and can easily be removed.



(ILLUSTRATION COURTESY K & E CO.)

FIGURE I.3 ENGINEER'S DUMPY LEVEL



(ILLUSTRATION COURTESY K & E CO.)

FIGURE I.4 ENGINEER'S WYE LEVEL

d. The Locke hand level (Figure 1.5) is used for rough measurements of differences in elevation. It is used by merely standing



FIGURE 1.5 LOCKE HAND LEVEL

erect and sighting through the eyepiece, holding the tube in the hand, and moving the objective end up or down until the image of the spirit level bubble on the mirror is centered on the fixed crossed wire. The point where the line of sight in this position strikes the rod or other object is then noted. A rough line of levels may be carried with the hand level for a distance of 400 or 500 feet, provided the length of each sight is not over about 50 feet.

Slopes can be measured by use of the Locke hand level by the following procedure:

- Step 1. Determine the height (H) of your eye above the ground at your feet when standing erect. This height can be determined by direct measurement or approximately by subtracting four-tenths (0.4) of a foot from your height. For example, assume (H) = 5.3 feet.
- Step 2. Stand erect, face toward the slope along a given line, and sight the hand level with bubble level on an easily distinguishable object on the surface of the ground.
- Step 3. Pace the distance from the point occupied in Step 2 along the given line to the object observed in Step 2. Let us assume this paced distance is 60 feet.
- Step 4. Determine the vertical rise per 100 feet. This is obtained by multiplying the eye height (H) by 100 and dividing by the slope distance paced.

$$\frac{5.3 \times 100}{60} = 8.8 \text{ ft. vertical rise per 100 ft. or } 8.8\%$$

e. The Abney hand level (Figure 1.6) is constructed and functions in the same manner as the Locke hand level, except that it is equipped with a graduated arc for reading percent of slope. The spirit level is attached to the arc on the Abney level. The user sights through the tube and fixes the line of sight so that it will be parallel to the slope on which it is desired to measure the percent of slope. The indicator is then adjusted

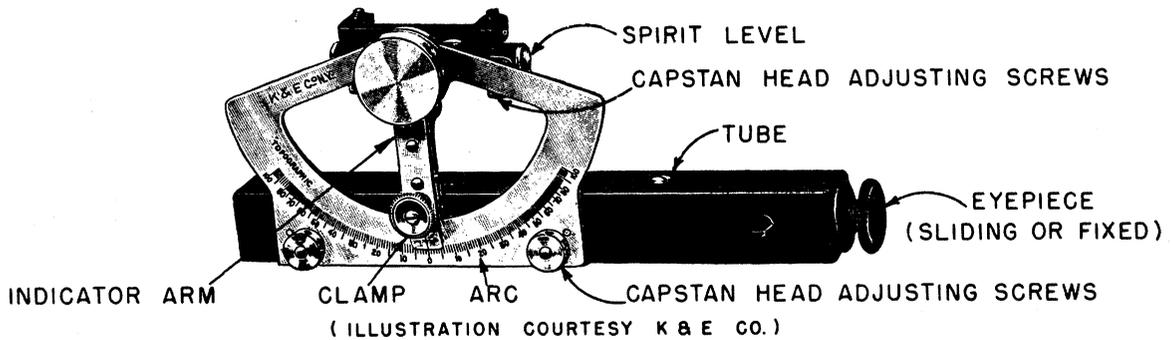


FIGURE I.6 ABNEY HAND LEVEL

with the left hand until the image of the spirit level bubble is centered on the cross wire. The indicator is then clamped and the percent of slope read. It may be used in the same manner as the Locke hand level for running a level line if the indicator is clamped at the zero reading.

f. Both types of hand levels may be equipped with a sliding eyepiece. When the sliding eyepiece is extended, it has the effect of lengthening the line of sight within the tube, thus increasing the accuracy of observations.

1.33 Level Rods and Accessories

a. There are many different kinds of level rods. The types standardized for general use in this Region, Figure 1.7, are as follows:

(1) The Philadelphia type rod is a two-section rod equipped with clamp screws. Its length is approximately seven feet extending to 13 feet, and it is graduated in feet, tenths, and hundredths. It may be equipped with round, oval, plain, or vernier scale target.

(2) The Frisco or California type rod is a three-section rod equipped with clamp screws. Its length is $4\frac{1}{2}$ feet extending to 12 feet, and it is graduated in feet, tenths, and hundredths. This rod is not equipped for use with a target.

(3) The Chicago or Detroit type rod is a three-section rod with metal telescoping joints. The length of each section is approximately $4\frac{1}{2}$ feet extending to $12\frac{1}{2}$ feet. It is graduated in feet, tenths, and hundredths, and is generally not equipped for use with a target.

(4) The stadia rod is a two-piece 13-foot rod joined together with hinges and with a suitable locking device to insure stability, and is complete with metal shoes on both ends. The face is approximately $3\frac{1}{2}$ inches wide, and is

divided into feet and tenths. This type of rod is designed primarily for use in making topographic surveys and is not equipped for use with a target.

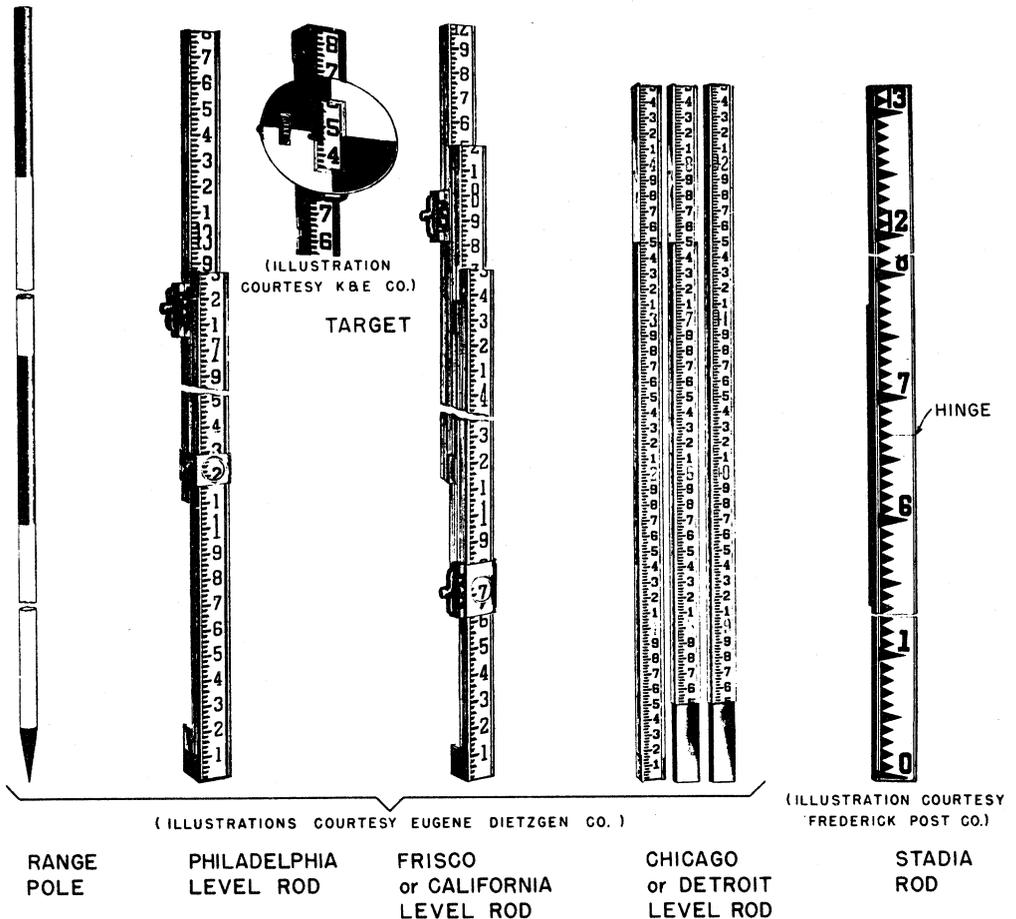


FIGURE 1.7 RANGE POLE AND SURVEYING RODS

b. A lightweight hatchet or hand ax should be carried by the rodman to mark bench marks, for brushing out lines, and for use as a solid turning point.

1.34 Care and Handling of Surveying Instruments

a. General

Surveying instruments are precise, delicate pieces of equipment varying in price from \$75 or \$100 to several hundred dollars. Their cost justifies proper care and protection, and this is necessary in order that the instruments will be kept in accurate adjustment and operating condition for survey purposes. Certain procedures and precautions must be observed in using surveying instruments in order to prevent needless damage, unnecessary wear, and to reduce occurrence of accidents. Instruments in good condition, properly adjusted, are essential to speed and accuracy of field work.

b. Transporting Instruments

Surveying instruments generally are transported to the job by automotive vehicle. The level should be carried in the instrument case, in the cab of the vehicle, preferably on the seat. It should be subject to as little vibration as possible. Level rods should be in cases and carried where they will be protected from weather and where they will not have other material piled on top or against them. Tripods should be similarly protected from damage and the weather.

c. Mounting the Level on the Tripod

(1) The vehicle transporting the equipment to the field carries it to a convenient location near the job. The level is mounted on the tripod at this point and the survey equipment is then carried to the field by the survey party.

(2) The first step in mounting the level is to set up the tripod (Figure 1.8). The tripod cap should be removed and placed in the instrument box to prevent it from being lost. The wing nuts on the tripod should be tightened just enough so that when a tripod leg is elevated it will drop gradually of its own weight.

(3) The level should be carefully removed from the instrument case. It is better to place the fingers beneath the horizontal bar in handling the instrument. See that the instrument is securely attached to the tripod. When screwing the instrument base on the tripod, it should first be turned in the reverse direction until a slight jar is felt, indicating that the threads are properly engaged. It should then be screwed on slowly until it refuses to turn further, but not so tightly engaged that it will be difficult to unscrew when the instrument is to be dismantled.

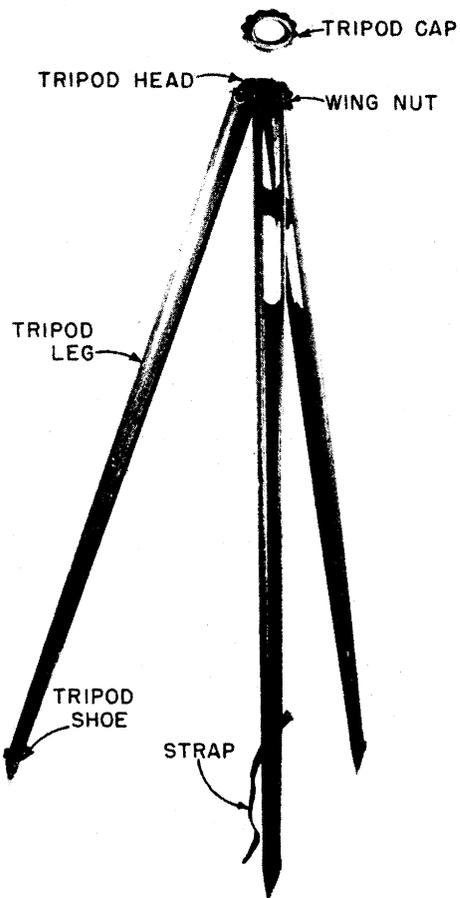


FIGURE 1.8 TRIPOD AND CAP

(4) The object glass cap should be removed and placed in the instrument case for safe keeping, and the sunshade attached to the telescope. Always attach the sunshade, regardless of weather.

d. Carrying the Instrument

(1) The instrument usually is carried to the field on the shoulder. But in passing through doors, woods, or brush hold the instrument head close to the front of the body. Little damage will be done if the tripod legs strike the side of a door jamb or tree but to allow the level to strike against an object is an "unpardonable sin."

(2) Before crossing a fence, reach across and set the instrument on the opposite side with the tripod legs well spread out. Do not allow the instrument to fall.

e. Setting Up Instrument For Field Use

(1) When setting up the instrument in the field, bring the tripod legs to a firm bearing with the foot plate approximately level. Give the tripod legs additional spread in windy weather or in places where the instrument may be subject to vibration or other disturbances. Most tripod shoes are usually provided with a projection which the surveyor can step on to force the tripod shoe firmly into the ground. When setting up on a side hill, place two tripod legs at approximately the same elevation downhill and place the other leg uphill, well extended, so that the foot plate will be approximately level.

(2) In leveling the instrument much needless turning of the leveling screws can be avoided if the tripod is always set up so that the foot plate is nearly horizontal. The leveling screws should be brought to a snug bearing. If they are too loose, the instrument will rock, causing inaccurate readings. If the screws are too tight, the threads may be stripped or the head and frame may be permanently damaged.

f. Precautions and Suggestions in Operating Instruments

(1) From the very beginning cultivate the habit of delicate manipulation of the instrument. Rough and careless handling of field instruments is characteristic of the unskilled surveyor.

(2) Eyepiece. Before beginning observations, the eyepiece must be perfectly focused on the cross hairs. The cross hairs may appear sharp and distinct when the telescope is focused on a distant object, but will move about or appear to jump if the eye is shifted slightly. On the other hand, the telescope may be focused on a distant object, and the cross hairs will not be visible at all. These two

conditions are known as parallax. In normal operation, the eyepiece should be checked for parallax before beginning observations for the day and should be checked several times during the day if the instrument shows a tendency to easily develop parallax. The adjustment is made as follows: Focus the telescope as clearly as possible on a well defined object about 300 feet away. Then hold a sheet of the field book about one foot in front of the objective, and move the eyepiece in or out until the cross hairs appear sharp and distinct against the white background of the field book page. Then re-focus the telescope and observe whether the cross hairs move or jump when the eye is shifted slightly. Repeat this process until the cross hairs do not appear to move when the eye is shifted and a clear sharp image of the distant object appears. To obtain focusing true for natural vision, the eye should be closed several times between observations to allow the lenses of the eye to assume their natural condition. If this is not done, especially by young men, the eye may accommodate itself to the telescope rather than the telescope becoming adjusted to the eye.

(3) Do not tighten clamps too tightly. The ears of clamps and wing nuts are purposely made small, so that it is difficult to turn them too tightly. By experience, learn just how much to tighten the clamps to prevent slipping.

(4) Guarding instrument. NEVER LEAVE AN INSTRUMENT UNGUARDED IN THE FIELD. If damage results in such cases an employee may be held pecuniarily responsible.

(5) Exposure of instruments. Instrument cases usually are provided with a waterproof cover. In threatening weather this bag should be carried to the field and placed over the instrument if it rains. If the instrument becomes wet or dusty, it should be properly cleaned the same day.

g. Storage of Equipment

(1) Always return the instrument to the case when returning from the field. NEVER ATTEMPT TO TRANSPORT AN INSTRUMENT IN A VEHICLE WHEN IT IS MOUNTED ON THE TRIPOD. In placing the level into the case the lid should close freely and easily. If it does not, the instrument is not properly placed on the pads. Never force the lid; look for the cause of the obstruction. Before placing the instrument in the case replace the object glass cap on the telescope and return the sunshade to the case.

(2) Tripod cap (Figure 1.8). The tripod cap should always be placed on the tripod head when the tripod is not in use. The tripod head threads as well as the instrument foot plate threads are of brass which can be easily damaged if struck against a hard object. Inspect the tripod legs and shoes and remove any mud or dirt that may have accumulated in

field use. The leather strap at the foot of the tripod should always be secured when the tripod legs are closed and the tripod is not being used. This is to prevent undue strain on the pins connecting the legs to the tripod head.

(3) Equipment should be stored in a dry place. Level rods, stadia rods, and tripods must be stored in such a manner that they will not warp or become otherwise damaged. They should be fully protected from the elements when not in use. It is better to store level rods flat on at least three supports. Never leave a rod leaning against a wall for long periods. They warp from their own weight. It is satisfactory to store them in a plumb position. A coat of varnish should be maintained on the wooden parts at all times.

h. Cleaning and Inspection of Instrument

(1) In setting up the instrument indoors for inspection or cleaning be careful that the tripod does not spread, dropping the instrument on the floor. Spreading of the legs can be prevented by setting the tripod shoes in holes or cracks in the floor or by tying a cord around and through the openings in the legs so they cannot spread. NEVER LEAVE AN INSTRUMENT STANDING IN A ROOM UNGUARDED.

(2) Cleaning metal parts. Dust and grime which collects on the outside moving parts must be carefully removed from surveying instruments. A light machine oil may be used for softening grime on leveling screws, foot plate threads, clamp screws, and other outside parts which may be cleaned without dismantling the instrument. A drop of oil may be placed on a leveling screw which may then be screwed back and forth to bring out dirt and grime, wiping it off with a clean cloth until the oil comes through clean. It is better not to leave any oil on the instrument. It does not need any lubrication. The oil merely catches and holds dust which abrades the soft brass parts.

(3) Cleaning lenses. Do not remove or rub the lenses of the telescope. These lenses are made of soft glass which scratches easily. They should be dusted with a clean, soft, camel's hair brush, or wiped very carefully with a clean, soft cloth to avoid scratching or marring the polished surfaces.

(4) Beginners should not disturb the capstan head adjusting screws except under the supervision of an engineering specialist. Also, if any screw or other part works harshly, call such defects to the attention of an engineering specialist. If repairs or adjustments cannot be made by the engineering specialist send the instrument to the factory for repairs in accordance with established administrative procedures.

1.35 Hand Signals

a. In order to transmit information between the observer or instrument man and his rodman, the maximum use should be made of hand signals. Any code of signals mutually understood by the instrument man and the rodman is good if it works. The instrument man should be prompt in signalling the rodman when he is finished with the "shot" so that the rodman can move off promptly to the next point.

b. The code of signals illustrated in Figure 1.9 is suggested. This code may be enlarged upon or altered to suit the needs of the job. A definite code should, however, be determined and mutually understood in order to speed up the job.

1.36 Bench Level Circuit

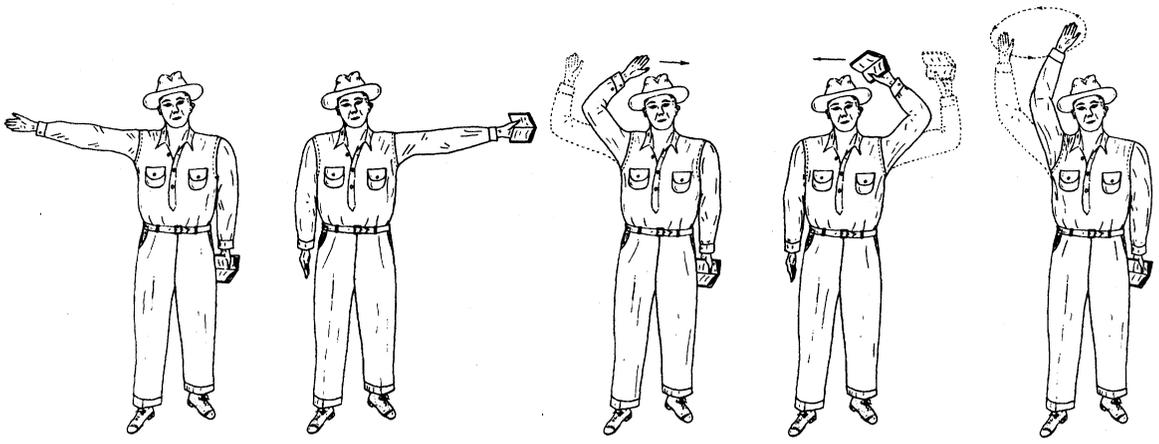
a. The procedure and field notes used in running a bench level circuit may be considered as the basic system for all differential leveling work. The beginner should be thoroughly familiar with this basic system. A bench level circuit is run for the purpose of determining the relative elevations of two or more bench marks. The circuit may start from a highway or USGS bench mark or from some point of assumed elevation. A bench level circuit is frequently run as a part of profile or cross section levels or as a part of a topographic survey. The basic procedure and notes will be the same in any event.

b. On the larger drainage projects it is desirable to run the bench level circuit separately from all the other survey work. If this is not done, and mistakes occur, a great deal of additional work will be required to carry corrections through the survey notes. BENCH LEVELS SHOULD ALWAYS BE "CLOSED" ON THE STARTING POINT. That is, after the last bench mark is set, levels should be run back to the starting point as described in Paragraph 1.36 d (6).

c. Definition of Terms

Referring to Figure 1.10 (page 1-18) and Figure 1.11 (page 1-19), the common terms used in leveling are as follows:

A BENCH MARK (BM) is a point of known elevation of a permanent nature. Such points may be marked with a brass pin or cap set in concrete, a cross or square mark cut on concrete, a long metal stake driven into the ground, a specifically located point on a concrete bridge, culvert, or foundation, or similar objects which are not likely to be disturbed for a long time. Temporary bench marks are points of known or established elevation which will be useful for only a few weeks and may be subject to disturbance if left longer. Such bench marks may be established on wood stakes set near a construction project or on nails driven into trees.



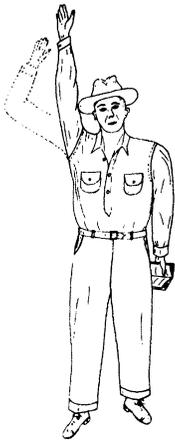
Move in this direction

Move in this direction

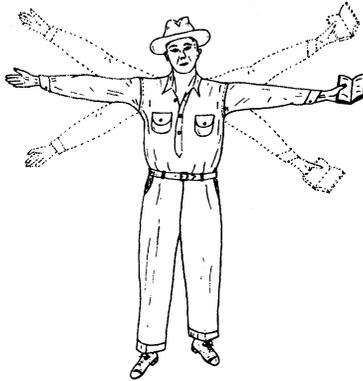
Plumb rod

Plumb rod

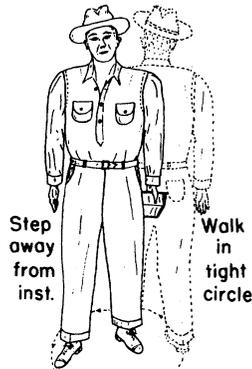
Turning point



Use long rod



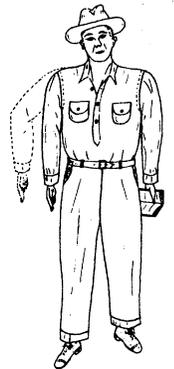
Observation completed
or Move on
or Understood



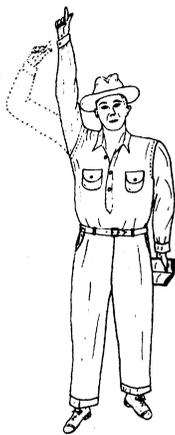
Step
away
from
inst.

Walk
in
tight
circle

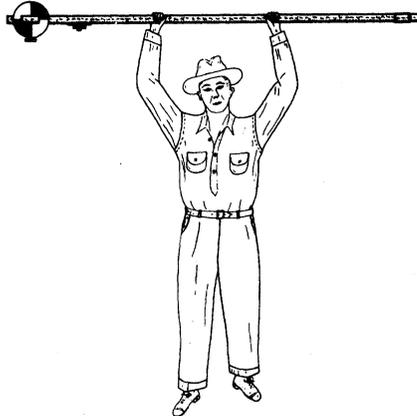
Wrong-face
or Check clamp
or Rod upside down



Move down



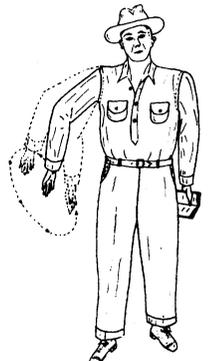
Move up



Turning point
(by rod man)



Wave rod slowly
from side to side



Come in

FIGURE 1.9 CODE OF HAND SIGNALS

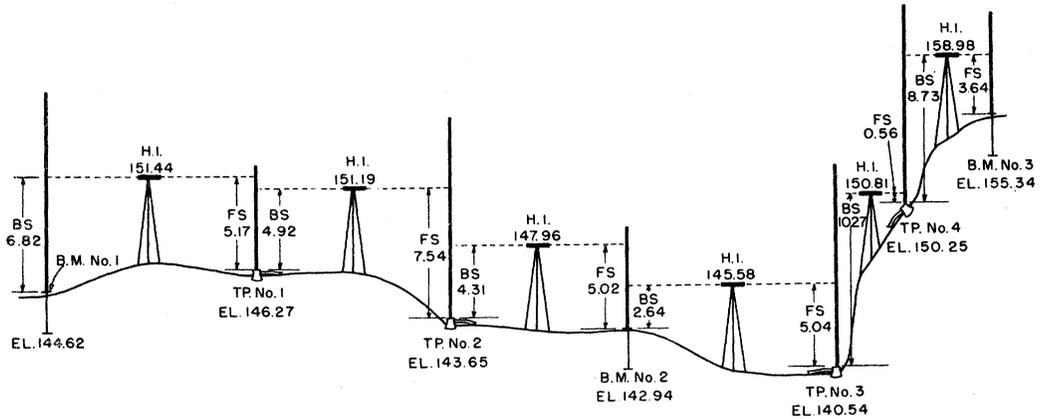


FIGURE 1.10 METHOD-DIFFERENTIAL LEVELING

A TURNING POINT (TP) is a point on which the elevation is determined in the process of leveling, but which is no longer needed after necessary observations have been taken. A turning point should be located on a firm object, whose elevation will not change during the process of moving the instrument set-up. A small stone, fence post, or the head of a hand ax driven into the ground is usually satisfactory for this purpose.

A BACKSIGHT (BS) is a rod reading taken on a point of known elevation. It is the first reading taken on a bench mark or turning point immediately after the initial or a new set-up. The backsight rod reading added to the elevation of the point on which the rod was held gives the height of the instrument.

A FORESIGHT (FS) is a rod reading taken on any point on which the elevation is to be determined. Only one backsight is taken during each set-up; all others are foresights.

HEIGHT OF INSTRUMENT (HI) is the elevation of the line of sight. It is determined by adding the backsight rod reading to the known elevation of the point on which the backsight is taken.

d. Procedure

(1) The level is set up at some convenient point between the starting bench mark and the next bench mark or turning point, but usually not over 300 feet from the starting bench mark. It is difficult to read the level rod at distances over 300 feet. A little practice will reveal what should be the limiting distance for the particular level being used.

(2) The instrument man begins his field notes by recording the following information (Figure 1.11, page 1-19):

(a) Location of survey, including name of farm or farmer and legal description of quarter-quarter section in which the starting point of the survey is located.

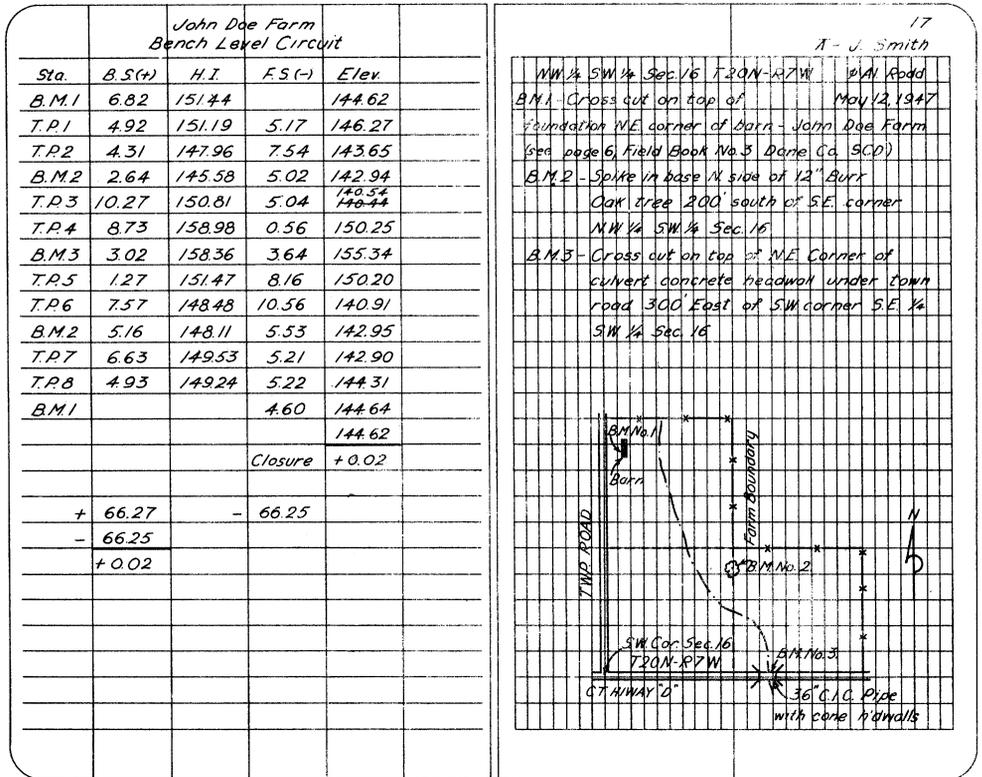


FIGURE 1.11 SURVEY NOTES-DIFFERENTIAL LEVELING

- (b) Type of survey such as "bench level circuit," "cross sections," or similar description.
 - (c) Column headings on left-hand sheet.
 - (d) Names of surveyors.
 - (e) Date of survey.
 - (f) Description of starting bench mark. Include reference to the field book in which the elevation of the bench mark was originally recorded. If it is a new bench mark with an assumed elevation, no such notation need be made; however, this assumed elevation should be in even feet, as 100.00 or 200.00 feet.
- (3) With the rodman holding the rod on the bench mark, the instrument man observes the rod reading and records it in the backsight column opposite the station (Sta.) BM 1. Referring to Figures 1.10 and 1.11 it will be noted that the backsight on BM 1 was 6.82 feet. This reading, added to 144.62 (elevation of BM 1), recorded in beginning the field notes, gives 151.44, the HI, or elevation of the line of sight.

(4) The rodman then moves ahead and picks out a convenient point for a turning point, or drives his hand ax into the ground for this purpose. The instrument man turns the telescope and takes a rod reading on this turning point. He records this reading in the foresight (FS) column opposite turning point (TP) 1. In Figures 1.10 and 1.11 the foresight for TP 1 was 5.17 feet. This reading subtracted from the HI, 151.44, gives 146.27, the elevation of the turning point.

(5) The instrument man then picks up the level, moves ahead, and goes through a process similar to that described above, taking a backsight on TP 1, and a foresight on a new turning point ahead.

(6) After the elevation of the last bench mark has been determined, the survey party runs levels back to the starting bench mark in order to "close" the circuit. Referring to Figure 1.11, it will be noted that the foresight on BM 3, the last BM in the circuit, was 3.64, giving an elevation of 155.34 for BM 3. It will also be noted that the backsight on BM 3 was 3.02 feet. This indicates that after taking the foresight on BM 3 and computing the elevation, the level was pulled up and re-set in a different place. The level should always be pulled up and re-set before starting to run the closing levels back to the starting bench mark. Levels are then run back to the starting bench mark following the same procedure used in running out the original circuit. Note that in a bench level circuit BENCH MARKS SHOULD ALWAYS BE USED AS A TURNING POINT.

(7) After taking the final foresight on the starting bench mark, the "error of closure" can be determined. This is the difference between the actual elevation of the bench mark and the elevation computed from the final foresight. Referring to Figure 1.11, it will be noted that the elevation computed from the final foresight was 0.02 feet too high or +0.02 feet. Length of circuit is approximately 0.5 mile. To determine permissible error use the formula given in 1.31a. Substituting we find permissible error = $0.05 \sqrt{0.5}$ = 0.035. Actual error is 0.02 which is less than that permitted. Level note computations should be checked by adding the backsight and foresight columns as shown in Figure 1.11. The difference should equal the error of closure and should be in the same direction - that is, plus or minus. This check merely proves the accuracy of the addition and subtraction performed in the notes. If the foresights and backsights do not check, it will be necessary to re-check the computation of elevations and heights of instrument until the mistake is found.

1.37 Profiles and cross sections

a. The object of profile leveling is to determine the elevations of the ground at known distances apart and along a selected or predetermined line. These elevations can then be plotted on profile paper at selected scales so that studies can be made relating to grades, depths, high and low spots, and estimating of quantities of cuts and fills. Cross sections are simply profiles taken at right angles to a predetermined base line such as the centerline of a road, ditch, gully, or other arbitrarily selected base line. Cross sections may be run in conjunction with profile levels, or they may be run after the profile line has been staked and profiles taken.

b. Procedures

(1) The procedure in running a profile, and recording field notes, is essentially the same as in running bench levels, except that ground rod readings are taken at full stations and at major breaks in slope. Distances between readings are measured and recorded by full or plus stations. Normally a line on which a profile is to be run is located and stationed before profile levels are taken. It is also possible and sometimes desirable to locate the line, station it out, and take the profile levels in the same operation when a party of three or more men is available.

(2) Wherever possible set a bench mark near the starting point stake. If this cannot be done, it will be necessary to run levels from the nearest bench mark to the starting point. Location of the starting point stake is described in the notes so that it can be re-located if it is pulled out or otherwise lost. The start of the profile should be at a full station. It may be 0+00 or any other selected full station. It is frequently advisable to use a higher station as 10+00 or 20+00 where it is anticipated that it may be necessary to run the profile both ways from the starting point. This is done in order to avoid having to record minus stationing, which is always confusing. The sample field survey notes, Figure 1.12 (page 1-22), illustrate the use of a station other than 0+00 for the starting point. In this case the survey party started at station 20+00, ran the profile back to station 9+00, then started again at station 20+00 and ran the profile down to station 29+00.

(3) After establishing the starting point, the instrument man sets up the level and reads a backsight on the bench mark and determines the HI. He then observes a rod reading with the rod held on the ground at the starting point. He gives a ground rod reading at each full station and of such plus stations as are necessary. Ground rod readings are taken to the nearest 0.1 foot and ground elevations are computed only to the nearest 0.1 foot.

John Doe Farm - Structure #1					
Sta.	B.S.	H.I.	F.S.	Elev.	Avg. Bk. Elev
B.M.#1	1.34	501.34		500.00	
20+00			11.2	490.14	52 496.1
19+50			10.8	490.54	
19+00			10.5	490.8	
18+50			10.3	491.0	
18+00			10.1	491.2	
17+50			9.8	491.5	
17+00			9.4	491.9	
16+20			8.5	492.8	2.5 498.8
16+10			5.9	495.4	
15+00			5.1	496.2	2.1 499.2
14+00			4.2	497.1	1.6 499.7
T.P.#1	9.76	509.22	1.88	499.46	
13+00			11.3	497.9	8.9 500.3
12+20			10.4	498.8	8.3 500.9
^{S. Branch} 11+00			9.2	500.0	7.1 501.5
10+00			8.5	500.7	7.2 502.0
9+00			7.9	501.3	7.0 502.2
8+00			7.4	501.8	6.8 502.4
^{N. Branch} 11+00			9.0	500.2	7.6 501.6
10+00			8.1	501.1	7.0 502.2
9+00			7.6	501.6	6.8 502.4
T.P.#2	9.58	514.70	4.10	505.12	
B.M.#2	5.21	518.55	1.36	513.34	
Σ B.S.	20.68	Σ F.S.	5.734	500.00	
Σ F.S.	7.34			13.34	
Diff.	13.34			513.34	

6

Gully Profile and Cross Sections

Feb. 7, 1946

N.W. 1/4 Sec. 16, T.20N., R.7W.

clear-cold T.J. Smith
Gully @ E. Endry Fence J. Brown

Gully-Overfall

" - "

Junction N. & S. Branch

B.M.#1 - Top of tack ct. 2"x2" stake set 3" above ground - 4' S of corner post on E. endry fence line - Elev. 500.00

B.M.#2 - Top of x on S.E. corner of windmill conc. platform - 30' E & 50' S of barn. Elev. 513.34

John Doe Farm - Structure #1					
Sta.	B.S.	H.I.	F.S.	Elev.	
B.M.#2		518.55		513.34	
T.P.#3	1.19	507.92	11.82	506.73	
B.M.#1			7.90	500.02	
B.M.#1	0.87	500.87		500.00	
21+00			11.1	489.77	
T.P.#4	3.21	493.25	10.83	490.04	
22+00			4.00	489.2	
23+00			4.6	488.6	0.1 493.1
24+00			5.2	488.0	0.3 492.9
25+00			5.7	487.5	1.2 492.0
26+00			6.7	486.5	
27+00			7.7	485.5	1.3 491.9
28+00			8.2	485.0	2.5 490.7
29+00			8.8	484.4	3.0 490.2
B.M.#3	10.72	501.76	2.21	491.04	
B.M.#1			1.77	499.99	
Σ B.S.	14.80	Σ F.S.	14.81		
		Σ B.S.	14.80	0.01	
		Error	0.01		

7

Gully Profile and Cross Sections (cont.-6)

Feb. 7, 1946

B.M.#3 - Top 1/8" nail set top 1 1/2" D. stump
20' W of Gully Junct. - Elev. 491.04

W. Left @ Gully @ 4

20	9	7	0	7	14	18
02	05	40	46	37	15	03

40	20	10	7	0	7	14	20	40
06	17	22	61	67	59	25	19	09

FIGURE I.12 PROFILE SURVEY NOTES

(4) When the rodman has moved along until he is about 300 to 350 feet away from the instrument, a TP is taken on a solid object. The instrument man then moves ahead, sets up, takes a backsight on the TP, computes a new HI, and continues as before. Rod readings and elevations on TPs and BMs should be read and recorded to 0.01 foot. HI elevations should be determined to 0.01 foot but in computing ground elevations use the HI only to the nearest 0.1 foot.

(5) A sketch should be kept on the right-hand page of the field book to indicate changes in direction of the profile line and its relationship to nearby landmarks. Plus stations should always be measured and recorded at all important points along the profile line, such as at branch ditches, tile laterals, gullies, gully overfalls, culverts, bridges, roads, fence lines, and similar features. It is useful to have this information in studying the profile and later in staking construction works on the ground.

(6) Frequently it will be desirable to set a hub stake (2"x2"x16" stake driven flush with the ground) every 500 feet or less in order to "tie in" or relate other survey work to the profile.

(7) The sample survey notes (Figure 1.12) indicate the method of recording cross-section notes when cross sections are run at the same time as the profile. A point is selected along the profile line, for instance, station 23+00 as shown in Figure 1.12, at which it is desired to obtain a cross section. The profile line is used as the base line from which measurements are taken to both sides at right angles to the profile line. A rod reading is taken on the profile line at this point and recorded on the right-hand page opposite the appropriate station. Since this reading was taken on the profile or base line, it is recorded as $\frac{0}{4.6}$ and recorded directly on the centerline of the right-hand sheet of the field book. The rodman then moves out at right angles to the base line to the first major break in the cross section. The rear chainman stands at the centerline or base line, reads and calls off the distance from this point to the rodman. Instrument man reads the rod and records distance and rod reading. The process is continued until the cross section is run out as far as necessary in one direction. The rodman then returns to the base line and a similar process is repeated in the opposite direction. Note that elevations along the cross-section line are not computed in the field unless they will be plotted in the field. This work is usually done in the office.

(8) It is not essential that the zero of the cross sections be the centerline of the gully, ditch, or stream. In some cases the profile line may be along the bank of a ditch. In any case, the zero of the cross sections is on the base line.

It is essential that the instrument man indicate in the field notes the direction of the cross section in such a manner that it will be clear to him or to a draftsman in the office. On ditch, gully, or stream cross sections it is standard practice to refer to "right" and "left" bank, when facing downstream. Where a cross section is taken at a proposed structure site it should be located so that this line may be reproduced later if required. This can be done by setting a hub stake at the zero point of the cross section and one or more additional stakes on the cross section line 30 to 100 feet from the zero point. These stakes should be driven nearly flush with the ground so they will not be disturbed.

(9) Cross sections taken at right angles to a gully, stream, or other meandering watercourse, can only be used for studying the hydraulic characteristics of the watercourse. They cannot be used to construct a topographic sketch. For topographic surveys see part 1.40.

1.40 TOPOGRAPHIC SURVEYS

1.41 Purpose

The purpose of a topographic survey is to secure the necessary data to produce a map or sketch representing three-dimensional relations of a portion of the earth's surface. This map or sketch will include contour lines, location of streams, bridges, culverts, gullies, buildings, fences, ditches, land lines, roads, or other features needed for detail planning or needed to determine how a proposed plan will fit the features.

1.42 Methods of Topographic Surveying

Three methods of topographic surveying are used: The grid system, plane table and alidade, and the transit and stadia.

The grid system is the most simple but generally requires more time than either of the other two methods. The plane table and alidade, and the transit and stadia methods involve the measurement and plotting of horizontal angles and distances and the measurement of vertical angles which are used in computing elevations, whereas the grid system only requires skill in using a level and tape. Where a considerable amount of topographic sketching is required, either the plane table and alidade, or transit and stadia method should be adopted, and the personnel should be trained in the use of this equipment where the need arises. Ordinarily the grid system will be used because a level and a tape are available in every field office, while alidades and transits are not always available. Only the grid system will be described in this handbook.

1.43 Procedure For Making Topographic Surveys by the Grid Method

a. Obtaining topography by use of the grid system consists of selecting and laying out a series of lines on the ground that can be reproduced to scale on drawing paper. All topography, including ground elevation, is then obtained in the field with reference to these lines and later plotted on drawing paper. Contour lines can be drawn in on the drawing by interpolating between plotted ground elevations.

b. In any survey for a topographic sketch, a survey plan must be determined in advance. The following factors should be considered:

- (1) What ground features are conveniently located for use as base lines?
- (2) Can the base lines be reproduced on a drawing in their true relationship to each other?
- (3) How far apart shall grid lines be set?
- (4) How close together will ground elevations need to be taken?
- (5) What is the most efficient procedure to use?

c. In planning the survey procedure it must be remembered that rod readings for elevations cannot be read with accuracy over approximately 300 feet with the ordinary level and level rod. If a stadia rod is used, it can be read at a distance of 500 or 600 feet. Ordinarily there should not be over approximately 200 feet between any two adjacent shots for ground elevations. On very flat uniform terrain this distance might be increased to 300 feet. These factors will help to determine how far apart ground elevations should be taken.

d. In some instances it will be necessary to establish right angles for making grid layouts. If the surveying instrument does not have a horizontal circle for turning off right angles, they can be established by the 3-4-5 method. This method is based on the Pythagorean Theorem, which states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the two legs (Figure 1.13, page 1-26). A marker is set at point "A" at which point it is desired to lay off the right angle.

e. Example:

- (1) A procedure for gridding a field is shown in Figure 1.14, page 1-27, with accompanying field notes in Figure 1.15, page 1-28. It is assumed that a level with a horizontal vernier is available for use in laying out right angles from base lines and grid lines. This gridding procedure has the

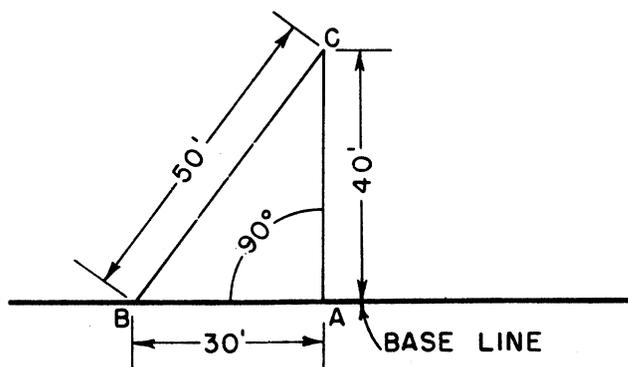


FIGURE 1.13 "3-4-5" METHOD OF LAYING OUT A RIGHT ANGLE

advantage over other systems in that a smaller number of instrument set-ups are required for taking the levels. Also the entire job can be done with a two-man survey party at a reasonable rate.

(2) A particular area is to be gridded for preparation of a topographic map. Inspection of this area on aerial photo showed that north line of area was the farm boundary, was well defined, clear of brush, and would serve best as the base line. Further inspection showed that the south field boundary was parallel to the north boundary and that the east and west sides diverged from the north to the south. Scaling on the photo showed the north side to be about 950 feet long, the south side to be about 1190 feet long, and the east and the west sides to be about 1200 feet long each. With this information it was decided that north and south grid lines at 400 feet and 600 feet from the northwest corner of the field should be staked. It is generally desirable to establish such grid lines near center of field to be gridded. By the same reasoning it was decided that east and west grid lines at 600 feet and 800 feet respectively from the base line should be staked. With this plan decided on and roughed out on a work photo or sketched on a piece of paper, the two-man survey party went to the field.

(3) First an on-site check was made to determine if this gridding plan was workable. No trees, hills, or other obstacles were noted that would prevent use of the plan. A sketch of the field and grid plan, Figure 1.15, was made in the field notebook. A range pole was set in the northwest corner of field at point A,2. This point was called A,2 so that no minus coordinates would have to be used. Had it been called A,0 or A,1 the point at the southwest corner of the field might be G, (0-1) or some other minus designation. Distances of 400 feet and 600 feet from A,2 were chained off eastward along the base line and a range pole set at A,6 and a stake set at A,8.

(4) The level was then set up over stake A,8, sighted on

John Dookes Farm
Survey for Tile Drainage System

Notes for Topography

BM #1 4.38 104.38 100.00

N.W. Cor. Fld 40' 5" Low point
Line A $\frac{2}{4.8}$ $\frac{4}{4.7}$ $\frac{5+20}{5.3}$ $\frac{6}{4.9}$

W Fld boundary
Line B $\frac{6}{5.0}$ $\frac{5}{5.1}$ $\frac{4}{4.8}$ $\frac{2}{4.6}$ $\frac{1+70}{4.5}$

W Fld bndry 70' 5" Low point
Line C $\frac{1+50}{4.9}$ $\frac{2}{5.0}$ $\frac{4}{5.2}$ $\frac{5+30}{5.8}$ $\frac{6}{5.3}$

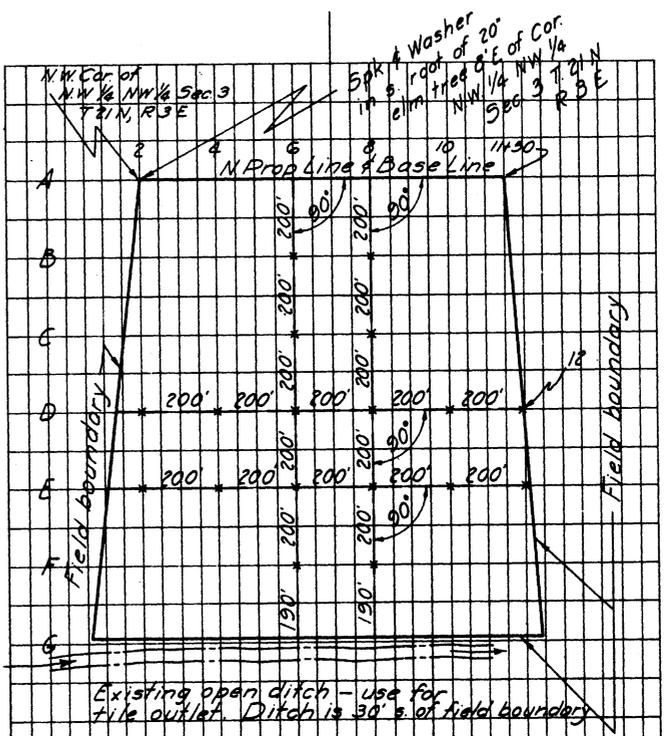
T.P 5.02 104.30 5.10 99.28

E Fld bndry
Line A $\frac{8}{4.7}$ $\frac{10}{4.8}$ $\frac{11+50}{5.2}$

E Fld bndry
Line B $\frac{11+70}{5.4}$ $\frac{10}{5.2}$ $\frac{8}{5.0}$

E Fld bndry
Line C $\frac{8}{5.1}$ $\frac{10}{5.3}$ $\frac{11+85}{5.5}$

Complete by making necessary turns and taking ground shots on lines D, E & F, starting at east side of field and working toward the West side. Take shots along line G & ditch bottom profiles before turning back to BM #1



Sketch of Grid Layout

Jackson Co. S.G.D. Date: 6/18/51
Illinois T. Scope
I. Rodd
Weather: Mild, Calm & Warm

FIGURE 115 SURVEY NOTES FOR GRIDDING

range pole at A,2 and a 90 degree angle turned off, and a range pole sighted in and set at point G,8. This established direction for grid line 8. Line 8 was then chained off, beginning point A,8 and working toward range pole at point G,8. Four foot high stakes were set at 200 foot intervals along the line. Rear chainman lined-in each stake by eye between succeeding stake and range pole at G,8. The distance between points F,8 and G,8 was found to be 190 feet, and so noted on field book sketch.

(5) Next a distance of 200 feet was chained off along south line from point G,8 to G,6 and a stake set at G,6. Line 6 was then staked, starting at point G,6 chaining off 190 feet and lining stake between G,6 and range pole previously set at A,6 at other end of field. Staking of line 6 was continued at 200 foot intervals to range pole at A,6. This completes lines 6 and 8.

(6) Grid lines D and E were staked next. Level was set up over point D,8 and a 90 degree angle turned off from line 8. Four foot high stakes were set at 200 foot intervals, starting measurement from level at point D,8 and staking to east field boundary, then returning and staking to west field boundary. Line E was staked in a similar manner.

(7) With the four grid lines staked, the elevation shots for entire field can be completed without further use of tape and with a minimum of pacing measurements, simply by locating any other points by lining in by eye from the N & S and E & W stakes. Obviously the grid line stakes must be distinguishable for several hundred feet. A field up to 60 acres in area can be gridded with a four line layout such as this. A three-man party can lay out and stake these lines in less time than it takes two men but probably not as efficiently. A pick-up truck or other type motor vehicle can be used to advantage in setting of range poles and distributing stakes when crops and other field conditions will permit. Survey notes, Figure 1.15, illustrates a commonly used method of keeping notes for this type of survey. Note the intermediate shots that are not on regular grid points. Most all gridding will require some intermediate shots to locate and get elevations in low spots, high spots, existing ditches, etc.

1.50 JOB LAYOUT

1.51 Purpose

The purpose of job layout is to transmit information from engineering plans to the job site or ground that will locate the works and provide such lines, grades, and elevations needed for construction of the job. This procedure is commonly called staking a job for construction. Generally it requires the use of surveying instruments. All engineering works require job layout for construction.

1.52 Procedures

a. Layout procedures will vary with the type, size, and complexity of a job. For example, layout for contouring is generally done by pacing distances and setting line and grade stakes with the aid of a hand level; whereas, layout for construction of a structure will require relocation of survey lines, and setting centerline and elevation stakes. This must be carefully done with a transit or engineer level and measurements accurately made with a steel tape

b. Layout procedure for a job will also be dependent to some extent on construction methods and types of equipment used. A layout man should contact the person or contractor that is to do the construction, to discuss detailed layout. An agreement on a layout procedure should be reached before any construction stakes are set. Some experienced contractors will need but few main stakes to build a job; on the other hand, some contractors will need stakes for all details.

c. Setting slope stakes.

(1) Setting slope stakes for earth fill, ditch construction, and most all other types of jobs that involve earthwork, is part of a layout procedure that is widely used. Following is an example of setting slope stakes for farm pond earth fill construction. This procedure can be adapted for use in setting slope stakes for open ditch, side spillway, and any other earth work that requires placing or excavating earth on a predetermined slope.

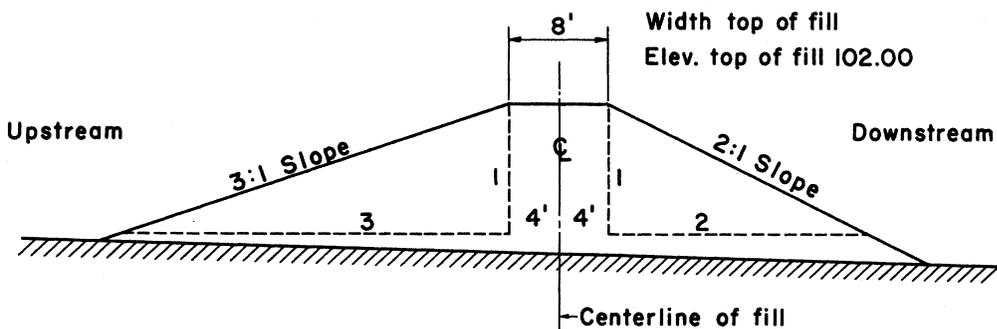
(2) Assume that an earth fill is to be staked and that the following information is given: (Figure 1.16, page 1-31)

Top width of fill	- 8 ft.
Upstream fill side slope	- 3:1
Downstream fill side slope	- 2:1
Elevation top of settled fill	- 102.0
Location and elevation of B.M.	- As determined
Fill centerline previously marked with appropriate stakes	

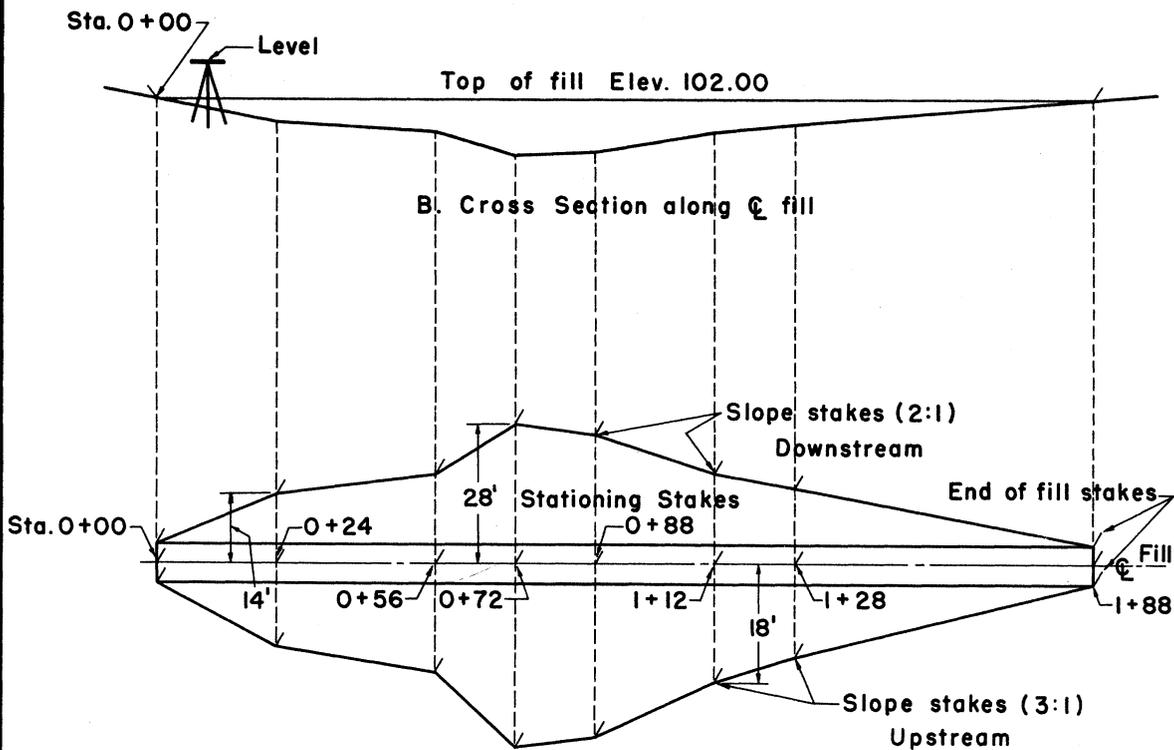
(3) The following steps describe the procedure:

(a) Run levels from B.M. to a convenient point at the fill site. The last HI must be above elevation of top of fill before proceeding with slope stake setting.

(b) Compute difference between elevation of HI and top of fill. Start staking at end of fill opposite emergency or auxiliary spillway.



A. Cross Section Perpendicular to $\text{C}\ell$ fill



C. Location of Slope Stakes

FIGURE I.16 METHOD OF SETTING SLOPE STAKES

(c) Move the level rod up or down the hillside along centerline of fill until a point is found where the rod reading is the same as computed in (2) above. This locates the end of fill. Set a stake at this point and mark it 0+00.

(d) Set a stake at each side of station 0+00 at right angles to centerline of fill at a distance of 4 feet. These stakes mark the top width of fill and serve as slope stakes at this point.

(e) Measure distances from station 0+00 down the hillside and along centerline of fill to points of obvious breaks in ground slope as at 0+24, 0+56, etc. in Figures 1.16 (page 1-31) and 1.17 (page 1-33). Set temporary stakes at these points and mark the stationing on them.

(f) Take a rod reading at the first stake (0+24 in example) on centerline of fill. Record reading. Set upstream slope stake first (3:1 slope). The rod reading is found to be 7.3. Compute elevation of ground, $104.7 - 7.3 = 97.4$. Compute fill height, $102.0 - 97.4 = 4.6$ feet.

(g) For the first trial, measure a distance at right angles to centerline stake of $3 \times 4.6 + 4 = 13.8 + 4 = 17.8$ feet (use 18 feet). Take a rod reading at this point. In example the reading is found to be 7.0. Compute ground elevation at the 18 foot point, $104.7 - 7.0 = 97.7$. Compute fill height, $102.0 - 97.7 = 4.3$ feet. Compute distance slope stake should be out for this fill height, $4.3 \times 3 + 4 = 12.9 + 4 = 16.9$ feet (use 17 feet). But this point is actually 18 feet out, so move the rod back toward centerline 1 foot so that it is 17 feet from centerline and take another rod reading. In example this reading was found to be 7.0; thus, the last computation will hold and the slope stake is set at 17 feet from centerline. Record the distance, rod reading, and elevation.

(h) This or any other process is a cut-and-try method. A little practice will develop judgment in how to make these distance adjustments so that a minimum of time will be required to find the location for the slope stake. The same procedure is used to set the downstream stake at station 0+24. Remember to use two times fill height plus half the fill top width for downstream slope stake location. After the two stakes are set at station 0+24, the same procedure is used to set the remainder of slope stakes. Study Figure 1.16, page 1-31, and field notes Figure 1.17, page 1-33, in order to follow through on the complete job of fill staking. Staking of spillways usually follows fill staking.

FIGURE I.17 SURVEY NOTES FOR SETTING SLOPE STAKES

John Doe Farm Pond						
Sta.	B.S.	HI	Fs	Fill ht.	Elev.	Slope stake Dist from \mathcal{E}
BM #1	4.71	104.71			100.00	
0+00 \mathcal{E} end fill			2.7	0.0'	102.0	4' US 4' DS
0+24 \mathcal{E}			7.3	4.6'	97.4	
	Upstream		7.0		97.7	17'
	Downstream		7.5		97.2	14'
0+56 \mathcal{E}			9.3	6.6'	95.4	
	US		8.8		95.9	22'
	DS		9.5		95.2	18'
T.P #1	4.42	98.48	10.65		94.06	
0+72 \mathcal{E}			8.1	11.6'	90.4	
	US		7.4		91.1	37'
	DS		8.6		89.9	28'
0+88 \mathcal{E}			7.2	10.7'	91.3	
	US		6.8		91.7	35'
	DS		7.7		90.8	26'
1+12 \mathcal{E}			3.3	6.8'	95.2	
	US		3.0		95.5	24'
	DS		3.6		94.9	18'
T.P #2	10.39	107.04	1.83		96.65	
1+28 \mathcal{E}			10.2	5.2'	96.8	
	US		9.9		97.1	19'
	DS		10.5		96.5	15'
1+88 \mathcal{E} end of fill			5.0	0.0	102.0	4' US 4' DS
BM #1			7.03		100.01	

Slope stakes notes

For Job location see page 9 this Field book
 BM #1 for description see page 9 this " " " "
 Elev top Fill 102.0 Date: 6/13/51

T.T. Scope
 J. Rodd
 Notes T.5 scope

Downstream 0+24 slope stake
 102.0
 97.4
 4.6 Fill ht @ \mathcal{E}
 3 3:1 slope
 13.8
 4 1/2 top width
 17.8 Try 18'
 7.0 rod rdg. @ 18' = elev 97.7

Upstream 0+24
 Slope stake is located in similar manner except use 2:1 Slope.
 Slope stakes, also located in similar manner at all other stations.

102.0
 97.7
 4.3 = Fill ht @ 18'
 3
 12.9
 4
 16.9' but shot is @ 18'
 Try shot @ 17' = 7.0
 Last computation holds
 Set slope stake @ 17' from \mathcal{E}

Sample computations. These are the usualy done on exterior slope stakes and discarded after computations are completed.

1.53 Determination of Earth Quantities

a. Most engineering jobs involving earth moving require that the quantities placed or excavated be determined. Earth quantities are used in estimating of costs of a job during planning stages and as an item of work in taking bids and making subsequent payment for completed earth work.

b. Quantity determinations will be made by use of the end area method for computing earth fill and earth excavation. This method assumes that the volume between two successive cross sections is equal to the average of their end areas multiplied by the distance between them. Expressed as a formula,

$$V = l \times \frac{A_1 + A_2}{2} .$$

V is the volume in cubic feet, A_1 and A_2 are the end areas of the respective cross sections in square feet, and l is the distance between the two cross sections in feet. But earth quantities are to be expressed in cubic yards, thus the volume computed by the above formula will be divided by 27.

c. Tables have been developed to assist with the application of the end area method to earth problems.

(1) Earth dams - In computing yardage for an earthfill a tabular form should be used to record the information as shown below.

Station (1)	Fill Height Ft. (2)	Cu. Yds. Per Ft. (3)	Average Fill Cu. Yds. (4)	Distance Ft. (5)	Fill Cu. Yds. (6)
0+00	0.0	0			
0+24	4.6	3.4	1.7	24	40.8
0+56	6.6	5.9	4.6	32	147.2
0+72	11.6	15.9	10.9	16	174.4
0+88	10.7	13.8	14.8	16	236.8
1+12	6.8	6.1	9.9	24	237.6
1+28	5.2	4.0	5.0	16	80.0
1+88	0.0	0	2.0	60	120.0
			Total volume of fill 1036.8		

First run an accurate cross section along the centerline of the proposed fill. Plot and divide it into segments, making each break in ground line a division point as shown in

Figure 1.16, page 1-31. In column (1) record the station of each break or division point. In column (2) record the centerline fill height at each division point. In column (3) record the information obtained from the table Figure 1.18, page 1-36. Column (4) record the average cubic yard figure between the two successive stations. In column (5) record the distance in feet between stations. In column (6) record the product of (4) and (5). The sum of column (6) is the total cubic yards of fill in the earth dam.

(2) Excavating open ditches. In computing yardage for an open ditch a tabular form should be used to record the information. Cross sections of the proposed ditch should be taken at regular intervals and at critical points. These should be plotted on cross section paper and a planimeter used to determine the end area in square feet at that point. A tabular form to record the information is shown below.

Station (1)	End Area Sq. Ft. (2)	Sum of End Areas (3)	Cu. Yds. Per 100 Ft. Length (4)	Distance in Stations 100 Ft. Length (5)	Cut Cu. Yds. (6)
8+00	32				
9+00	54	86	159.3	1	159.3
.
.
.
.
10+00	62				
10+34	56	118	218.5	0.34	74.3

In column (1) record the station of each cross section taken. In column (2) record the end area in square feet of each cross section. In column (3) record the sum of the end areas between the two successive stations. In column (4) record from the table on Figure 1.19, page 1-37, the amount of cubic yards per 100 feet of length for the corresponding sum of end areas. In column (5) record the distances in stations between cross sections by 100 foot lengths; i.e., 34 feet = 0.34 for table. In column (6) record the product of (4) and (5). The sum of column (6) is the total cubic yards in the excavation.

EARTH FILL YARDAGES END AREA METHOD

ESTIMATE OF CU. YDS. OF FILL PER LIN. FT. OF LENGTH IN EARTH DAMS WITH VARYING HEIGHTS AND TOP WIDTHS

FILL HEIGHT IN FEET	SLOPES 3 TO 1 AND 2 TO 1										SLOPES 3 TO 1 AND 2 TO 1										SLOPES 3 TO 1 AND 2 TO 1										SLOPES 3 TO 1 AND 2 TO 1									
	TOP WIDTH OF FILL - 6 FEET										TOP WIDTH OF FILL - 8 FEET										TOP WIDTH OF FILL - 10 FEET										TOP WIDTH OF FILL - 12 FEET									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1	.3	.3	.4	.4	.5	.5	.6	.6	.7	.7	.4	.5	.5	.6	.6	.7	.8	.8	.9	.9	.5	.6	.6	.7	.7	.8	.9	.9	1.0	1.0	.5	.6	.7	.7	.8	.9	1.0	1.1	1.1	1.2
2	.8	.9	.9	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1
3	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	1.9	2.0	2.1	2.2	2.3	2.5	2.6	2.7	2.8	2.9	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.2
4	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	2.7	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.8	4.0	4.1	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.1	4.3	4.4
5	3.4	3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.6	3.8	3.9	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.8	4.2	4.3	4.5	4.6	4.8	4.9	5.0	5.2	5.3	5.5	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9
6	4.7	4.8	5.0	5.1	5.3	5.4	5.5	5.7	5.8	6.0	5.1	5.2	5.4	5.5	5.6	5.8	5.9	6.0	6.1	6.3	5.6	5.8	5.9	6.1	6.2	6.4	6.5	6.7	6.8	7.0	6.0	6.2	6.3	6.5	6.6	6.8	7.0	7.1	7.3	7.4
7	6.1	6.3	6.4	6.6	6.7	6.9	7.1	7.2	7.4	7.5	6.6	6.8	6.9	7.1	7.3	7.5	7.6	7.8	8.0	8.1	7.1	7.3	7.5	7.6	7.8	8.0	8.2	8.4	8.5	8.7	7.6	7.8	8.0	8.2	8.4	8.6	8.7	8.9	9.1	9.3
8	7.7	7.9	8.1	8.2	8.4	8.6	8.8	9.0	9.1	9.3	8.3	8.5	8.7	8.9	9.1	9.3	9.4	9.6	9.8	10.0	8.9	9.1	9.3	9.5	9.7	9.9	10.0	10.2	10.4	10.6	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3
9	9.5	9.7	9.9	10.1	10.3	10.5	10.7	10.9	11.1	11.3	10.2	10.4	10.6	10.8	11.0	11.2	11.4	11.6	11.8	12.0	10.8	11.0	11.2	11.5	11.7	11.9	12.1	12.3	12.6	12.8	11.5	11.7	11.9	12.2	12.4	12.6	12.8	13.0	13.3	13.5
10	11.5	11.7	11.9	12.1	12.3	12.6	12.8	13.0	13.2	13.4	12.2	12.4	12.7	12.9	13.1	13.4	13.6	13.8	14.0	14.3	13.0	13.2	13.5	13.7	13.9	14.2	14.4	14.6	14.8	15.1	13.7	13.9	14.2	14.4	14.7	14.9	15.1	15.4	15.6	15.9
11	13.6	13.8	14.1	14.3	14.6	14.8	15.0	15.3	15.5	15.8	14.5	14.7	15.0	15.2	15.5	15.7	15.9	16.2	16.4	16.7	15.3	15.6	15.8	16.1	16.3	16.6	16.8	17.1	17.3	17.6	16.1	16.4	16.6	16.9	17.1	17.4	17.7	17.9	18.2	18.4
12	16.0	16.3	16.5	16.8	17.0	17.3	17.5	17.8	18.0	18.3	16.9	17.2	17.4	17.7	17.9	18.2	18.5	18.7	19.0	19.2	17.8	18.1	18.3	18.6	18.8	19.1	19.4	19.6	19.9	20.1	18.7	19.0	19.2	19.5	19.8	20.1	20.3	20.6	20.9	21.1
13	18.5	18.8	19.1	19.3	19.6	19.9	20.2	20.5	20.7	21.0	19.5	19.8	20.1	20.3	20.6	20.9	21.2	21.5	21.7	22.0	20.4	20.7	21.0	21.3	21.6	21.9	22.1	22.4	22.7	23.0	21.4	21.7	22.0	22.3	22.6	22.9	23.2	23.5	23.8	24.1
14	21.3	21.6	21.9	22.2	22.5	22.8	23.0	23.3	23.6	23.9	22.3	22.6	22.9	23.2	23.5	23.8	24.1	24.4	24.7	25.0	23.3	23.6	23.9	24.2	24.5	24.9	25.2	25.5	25.8	26.1	24.4	24.7	25.0	25.3	25.6	26.0	26.3	26.6	26.9	27.2
15	24.2	24.5	24.8	25.1	25.4	25.7	26.0	26.3	26.6	26.9	25.3	25.6	25.9	26.2	26.5	26.9	27.2	27.5	27.8	28.1	26.4	26.7	27.0	27.4	27.7	28.0	28.3	28.6	29.0	29.3	27.5	27.8	28.2	28.5	28.8	29.2	29.5	29.8	30.1	30.5
16	27.2	27.5	27.9	28.2	28.5	28.9	29.2	29.5	29.8	30.2	28.4	28.7	29.1	29.4	29.8	30.1	30.4	30.8	31.1	31.5	29.6	30.0	30.3	30.7	31.0	31.4	31.7	32.1	32.4	32.8	30.8	31.2	31.5	31.9	32.2	32.6	32.9	33.3	33.6	34.0
17	30.5	30.9	31.2	31.6	31.9	32.3	32.6	33.0	33.3	33.7	31.8	32.2	32.5	32.9	33.2	33.6	33.9	34.3	34.6	35.0	33.1	33.5	33.8	34.2	34.5	34.9	35.2	35.6	35.9	36.3	34.3	34.7	35.0	35.4	35.8	36.2	36.5	36.9	37.3	37.6
18	34.0	34.4	34.7	35.1	35.4	35.8	36.2	36.5	36.9	37.2	35.3	35.7	36.1	36.4	36.8	37.2	37.6	38.0	38.3	38.7	36.6	37.0	37.3	37.7	38.1	38.5	38.8	39.2	39.6	39.9	38.0	38.4	38.8	39.2	39.6	40.0	40.3	40.7	41.1	41.5
19	37.6	38.0	38.4	38.8	39.2	39.6	39.9	40.3	40.7	41.1	39.1	39.5	39.9	40.3	40.7	41.1	41.4	41.8	42.2	42.6	40.3	40.7	41.1	41.5	41.9	42.4	42.8	43.2	43.6	44.0	41.9	42.3	42.7	43.1	43.5	43.9	44.3	44.7	45.1	45.5
20	41.5	41.9	42.3	42.7	43.1	43.5	43.9	44.3	44.7	45.1	43.0	43.4	43.8	44.2	44.6	45.0	45.4	45.8	46.2	46.6	44.4	44.8	45.2	45.7	46.1	46.5	46.9	47.3	47.8	48.2	45.9	46.3	46.7	47.1	47.5	47.9	48.3	48.7	49.1	49.5

FIGURE 118 EARTH FILL YARDAGES - END AREA METHOD

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

0	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100	0	0
0.0	972	918	864	810	756	702	648	594	540	486	432	378	324	270	216	162	108	54	0	0.0
1.9	973	919	865	811	757	703	649	595	541	487	433	379	325	271	217	163	109	55	1	1.9
3.7	974	920	866	812	758	704	650	596	542	488	434	380	326	272	218	164	110	56	2	3.7
5.6	975	921	867	813	759	705	651	597	543	489	435	381	327	273	219	165	111	57	3	5.6
7.4	976	922	868	814	760	706	652	598	544	490	436	382	328	274	220	166	112	58	4	7.4
9.3	977	923	869	815	761	707	653	599	545	491	437	383	329	275	221	167	113	59	5	9.3
11.1	978	924	870	816	762	708	654	600	546	492	438	384	330	276	222	168	114	60	6	11.1
13.0	979	925	871	817	763	709	655	601	547	493	439	385	331	277	223	169	115	61	7	13.0
14.8	980	926	872	818	764	710	656	602	548	494	440	386	332	278	224	170	116	62	8	14.8
16.7	981	927	873	819	765	711	657	603	549	495	441	387	333	279	225	171	117	63	9	16.7
18.5	982	928	874	820	766	712	658	604	550	496	442	388	334	280	226	172	118	64	10	18.5
20.4	983	929	875	821	767	713	659	605	551	497	443	389	335	281	227	173	119	65	11	20.4
22.2	984	930	876	822	768	714	660	606	552	498	444	390	336	282	228	174	120	66	12	22.2
24.1	985	931	877	823	769	715	661	607	553	499	445	391	337	283	229	175	121	67	13	24.1
25.9	986	932	878	824	770	716	662	608	554	500	446	392	338	284	230	176	122	68	14	25.9
27.8	987	933	879	825	771	717	663	609	555	501	447	393	339	285	231	177	123	69	15	27.8
29.6	988	934	880	826	772	718	664	610	556	502	448	394	340	286	232	178	124	70	16	29.6
31.5	989	935	881	827	773	719	665	611	557	503	449	395	341	287	233	179	125	71	17	31.5
33.3	990	936	882	828	774	720	666	612	558	504	450	396	342	288	234	180	126	72	18	33.3
35.2	991	937	883	829	775	721	667	613	559	505	451	397	343	289	235	181	127	73	19	35.2
37.0	992	938	884	830	776	722	668	614	560	506	452	398	344	290	236	182	128	74	20	37.0
38.9	993	939	885	831	777	723	669	615	561	507	453	399	345	291	237	183	129	75	21	38.9
40.7	994	940	886	832	778	724	670	616	562	508	454	400	346	292	238	184	130	76	22	40.7
42.6	995	941	887	833	779	725	671	617	563	509	455	401	347	293	239	185	131	77	23	42.6
44.4	996	942	888	834	780	726	672	618	564	510	456	402	348	294	240	186	132	78	24	44.4
46.3	997	943	889	835	781	727	673	619	565	511	457	403	349	295	241	187	133	79	25	46.3
48.1	998	944	890	836	782	728	674	620	566	512	458	404	350	296	242	188	134	80	26	48.1
50.0	999	945	891	837	783	729	675	621	567	513	459	405	351	297	243	189	135	81	27	50.0
51.9	1000	946	892	838	784	730	676	622	568	514	460	406	352	298	244	190	136	82	28	51.9
53.7	1001	947	893	839	785	731	677	623	569	515	461	407	353	299	245	191	137	83	29	53.7
55.6	1002	948	894	840	786	732	678	624	570	516	462	408	354	300	246	192	138	84	30	55.6
57.4	1003	949	895	841	787	733	679	625	571	517	463	409	355	301	247	193	139	85	31	57.4
59.3	1004	950	896	842	788	734	680	626	572	518	464	410	356	302	248	194	140	86	32	59.3
61.1	1005	951	897	843	789	735	681	627	573	519	465	411	357	303	249	195	141	87	33	61.1
63.0	1006	952	898	844	790	736	682	628	574	520	466	412	358	304	250	196	142	88	34	63.0
64.8	1007	953	899	845	791	737	683	629	575	521	467	413	359	305	251	197	143	89	35	64.8
66.7	1008	954	900	846	792	738	684	630	576	522	468	414	360	306	252	198	144	90	36	66.7
68.5	1009	955	901	847	793	739	685	631	577	523	469	415	361	307	253	199	145	91	37	68.5
70.4	1010	956	902	848	794	740	686	632	578	524	470	416	362	308	254	200	146	92	38	70.4
72.2	1011	957	903	849	795	741	687	633	579	525	471	417	363	309	255	201	147	93	39	72.2
74.1	1012	958	904	850	796	742	688	634	580	526	472	418	364	310	256	202	148	94	40	74.1
75.9	1013	959	905	851	797	743	689	635	581	527	473	419	365	311	257	203	149	95	41	75.9
77.8	1014	960	906	852	798	744	690	636	582	528	474	420	366	312	258	204	150	96	42	77.8
79.6	1015	961	907	853	799	745	691	637	583	529	475	421	367	313	259	205	151	97	43	79.6
81.5	1016	962	908	854	800	746	692	638	584	530	476	422	368	314	260	206	152	98	44	81.5
83.3	1017	963	909	855	801	747	693	639	585	531	477	423	369	315	261	207	153	99	45	83.3
85.2	1018	964	910	856	802	748	694	640	586	532	478	424	370	316	262	208	154	100	46	85.2
87.0	1019	965	911	857	803	749	695	641	587	533	479	425	371	317	263	209	155	101	47	87.0
88.9	1020	966	912	858	804	750	696	642	588	534	480	426	372	318	264	210	156	102	48	88.9
90.7	1021	967	913	859	805	751	697	643	589	535	481	427	373	319	265	211	157	103	49	90.7
92.6	1022	968	914	860	806	752	698	644	590	536	482	428	374	320	266	212	158	104	50	92.6
94.4	1023	969	915	861	807	753	699	645	591	537	483	429	375	321	267	213	159	105	51	94.4
96.3	1024	970	916	862	808	754	700	646	592	538	484	430	376	322	268	214	160	106	52	96.3
98.1	1025	971	917	863	809	755	701	647	593	539	485	431	377	323	269	215	161	107	53	98.1
0	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100	0	0

AMOUNT OF CUBIC YARDS IN 100 FEET OF LENGTH FOR SUM OF END AREAS IN SQUARE FEET

Figures inside the double lines are sum of end areas in square feet.

Figures outside the double lines are in cubic yards.

To find the cubic yards in a 100 foot length for a given sum of end areas, locate this sum inside the double lines, then read the figure outside the double lines at the top or bottom and add to this the figure outside the double lines to the right or left.

EXAMPLE

An open ditch to be excavated has 32 square feet of cross-sectional area to be removed at Sta. 8 / 00 and 54 square feet of cross-sectional area to be removed at Sta. 9 / 00. Sum of end areas equals 86 square feet. To find cubic yards of material to be excavated locate 86 square feet in body of table, read 100 at top of column plus 59.3 at right, or a total of 159.3 cubic yards to be excavated per 100 lineal feet.

At Sta. 10 / 00 the end area is 62 square feet and at Sta. 10 / 34 the end area is 56 square feet. Sum of end areas is 62 / 56 = 118 sq. ft. Locate 118 in body of table, read 200 at top of column plus 18.5 at right or a total of 200 / 18.5 = 218.5 cu. yds. per 100 feet. Sta. 10 / 00 to 10 / 34 = 34 feet. Amount to be excavated is equal to 218.5 x 0.34 = 74.3 cu. yds.

YARDAGE CHART BY SUM OF END AREAS			
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
CARTOGRAPHIC APPROVAL:	TECHNICAL APPROVAL:		
<i>T. W. Wood</i>	<i>E. Freyburger</i>		
COMPILED:	TRACED:	CHECKED:	DATE
<i>R.M.H.</i>	<i>K.L.B.</i>		5-49
DRAWING NO.			
			3-N-19167

1.60 FIELD BOOKS

1.61 Purpose

Engineering field books are used for recording of original survey notes, and layout and construction data. This classifies them as valuable documents because of the time and expense involved in obtaining such data. An ordinary field book is worth from \$200 to \$1000 when it is filled with notes properly recorded, depending upon the type of surveys recorded. It seems only reasonable that a document of such value should be carefully preserved so that it can be of value for future use. Losing a field book is a "cardinal sin" to a surveyor. It should not be used for scratch computations or notes which have no permanent value pertaining to engineering surveys. Less expensive notebooks should be used for such purposes.

1.62 Types

There are two types of field books in general use: The loose-leaf, and the leather or paper bound field book. Several kinds of line rulings are available. However, the kind in general use is that shown in Figure 1.15, page 1-28, Survey Notes for Grid-ding.

1.63 Identifying and Indexing

a. The outside cover of each field book should be numbered consecutively for each field office in which the book is kept (Figure 1.20, page 1-39.) The same number may be placed on the bound edge for ease in filing. The district, county, and state should also be shown. This identification should be lettered in India ink. Each field book should be further identified so that it can be returned to the proper headquarters if lost (Figure 1.20). The wording should be lettered in India ink on the inside of the front cover or the flyleaf of the field book.

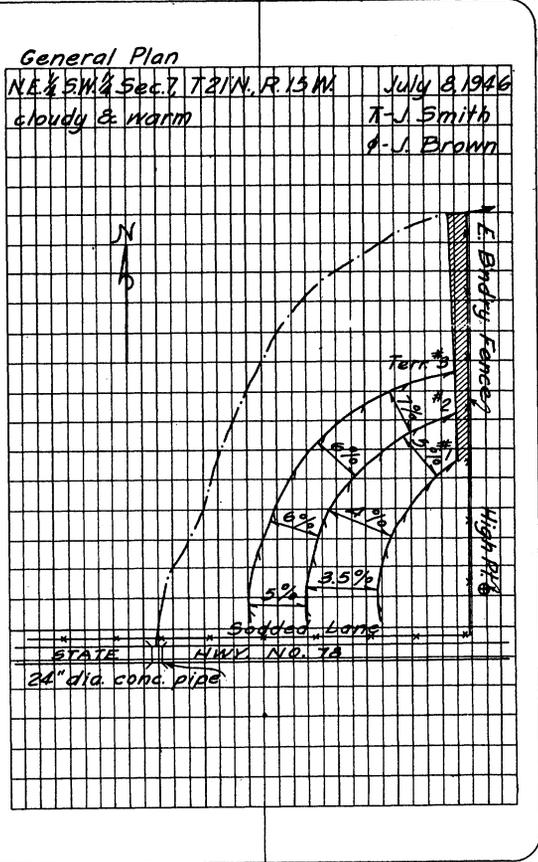
b. The first four pages of the bound field book should be reserved for the index (Figure 1.21, page 1-39). The following pages should be numbered consecutively in the upper right-hand corner of each page. Note that "page" in a field book means the combination of the six ruled columns on the left and the cross section paper on the right.

c. Loose-leaf field books have not been widely used in soil conservation work until recently. The use of this type of field book permits the use of several different systems of indexing and filing. It is recommended for use only on individual farm jobs. Bound field books should be used for all group enterprise jobs. All pages of a loose-leaf field book pertaining to a particular farm job should be properly identified, indexed, stapled together, and filed in the technician's folder for that farm. The sheets should also be stapled in the folder for safe keeping.

John Doe Farm - Terrace System					
Terrace No.	Slope Above Avg.	Vertical Interval Avg.	Horiz. Interval Avg.	Grades in %	Length in Feet
1	1%	1.7	170	0.2 to 0.4	900
2	4%	3.6	90	0.2 to 0.4	1050
3	6%	4.5	75	0.2 to 0.5	1300

Soil Types - Muscatine, Tama Group - 9
Land Use - Cultivated - C.C.-S.G.-H.
Slopes 1-7%

slopes relatively uniform - erosion is noticeable, but not serious - terracing needed and worthwhile.



John Doe Farm - Terrace System						
Terrace No. 1						
Sta.	Staking		Checking		Ridge	
	F.S.	B.S. / H.I.	F.S.	Elev.	F.S.	Elev.
		7.5 / 107.5				100.0
0+00	8.7		7.5	100.0	6.5	101.0
0+50	8.0		7.3	100.2	5.9	101.6
1+00	7.8		7.2	100.3	5.9	101.6
1+50	7.6		7.0	100.5	5.7	101.8
2+00	7.4		6.8	100.7	5.5	102.0
2+50	7.2		6.6	100.9	5.3	102.2
3+00	7.0		6.5	101.0	5.2	102.3
3+50	6.85		6.3	101.2	5.1	102.4
4+00	6.7	8.8 / 103.5	6.8	100.7	5.7	101.8
4+50	6.55		8.0	101.5	6.8	102.7
5+00	6.4		7.5	102.0	6.6	102.9
5+50	8.35		7.2	102.3	6.3	103.2
6+00	8.2		7.5	102.0	6.2	103.3
6+50	8.1		7.8	101.7	6.4	103.1
7+00	8.0		8.2	101.3	6.8	102.7
7+50	7.9		7.2	102.3	5.9	103.6
8+00	7.8		7.0	102.5	5.8	103.7
8+50	7.7		7.0	102.5	5.6	103.9
9+00	7.3		6.8	102.7	5.4	104.1

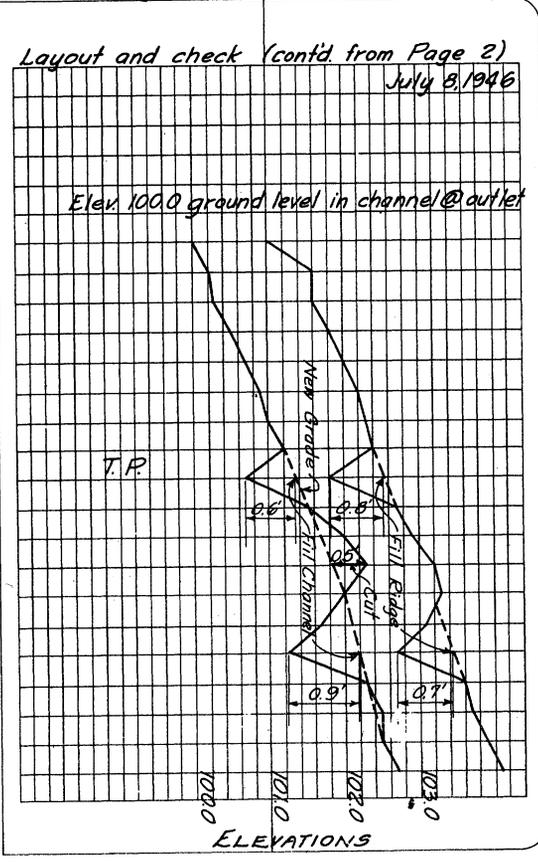


FIGURE 1.22 SAMPLE NOTES - TERRACE LAYOUT

PART 2

PREPARATION OF ENGINEERING DATA SHEETS

2.10 GENERAL

This part of the handbook is intended to:

- (1) Show the purpose for data sheets and plans.
- (2) Provide general information for preparation of data sheets.
- (3) Give Service standards for data sheets and drawings.

2.20 PURPOSE

The purpose of data sheets and plans in soil and water conservation work is to:

- (1) Provide an orderly procedure and approach for analysis and solution of a problem.
- (2) Provide details for construction of the planned measure or works. A data sheet is defined as a drawing or set of drawings on which is placed: First, all field survey and hydrologic data needed for the purpose of analyzing a specific problem and planning a sound, economical, and practical solution; second, outline or plan of contemplated works in true relation to other plotted data.

A set of drawings that include data sheets with necessary details and specifications for construction is known as data sheets and plans. Such data sheets and plans must meet the needs, be complete and within an accuracy consistent with the type of works planned. It has been demonstrated that time spent on preparation of data sheets and careful analysis of problems will result in savings to cooperators and a credit to the Soil Conservation Service.

2.30 INFORMATION AND MATERIALS NEEDED

2.31 Information Needed

a. Information required to meet data sheet needs varies with the type and size of job. Sample data sheets are included in various other parts of the handbook such as Farm Ponds, Structures, Drainage, etc. These will assist the planner in deciding on the information needs. Generally an engineer will be responsible for preparation of the data and detail plans for the more difficult jobs, while planners and aids will be mostly concerned with the Class E jobs.

The best test for determination of whether a set of data sheets and plans contain all information required to meet the needs intended is to assume that a qualified individual, who has never

seen the site and does not know local conditions, has the data sheets and plans handed to him for use in staking the job and supervising construction. He may ask the following questions:

- (1) Can the farm be located from the plans?
- (2) Can the site on the farm be located from the plans?
- (3) Can survey lines be relocated and the job staked and constructed at the exact location and elevation as intended?
- (4) Are specifications for all the various parts of the works included?
- (5) Are quantities and bills of materials included?

When these questions can be answered in the affirmative the data sheets and plans generally contain all needed information.

b. Data sheets and plans of completed works will be maintained as records. All engineering works, regardless of size, type, or kind of material used, will require maintenance. An "as built plan" is invaluable for use in making sound maintenance recommendations. As built plans are also useful for study of structural design improvement, hydraulic performance and adaptation of hydrologic data to local conditions. They may also be invaluable in cases of legal disputes.

2.32 Material Needed

a. Many references will be made to the Regional Cartographic Handbook in the following discussion on materials. It is essential that such references be studied along with this handbook, so as to gain a thorough understanding of the subject.

Following is a list of materials needed in preparing engineering data sheets and plans: (see Section 2, Part XI, Cartographic Handbook for information on use and care of drafting equipment)

- (1) Profile tracing paper in which the sheet is ruled, as illustrated in Figure 2.1, page 2-3.
- (2) Plan-profile tracing paper in which the upper one-half of the sheet is blank and the lower one-half is ruled, as illustrated in Figure 2.1.
- (3) Cross section tracing paper in which the sheet is ruled as shown in Figure 2.1.
- (4) Plain tracing paper, which is obtained in various sizes (Figure 2.2, page 2-3).

(See Section 8, Part VIII, Cartographic Handbook on above.)

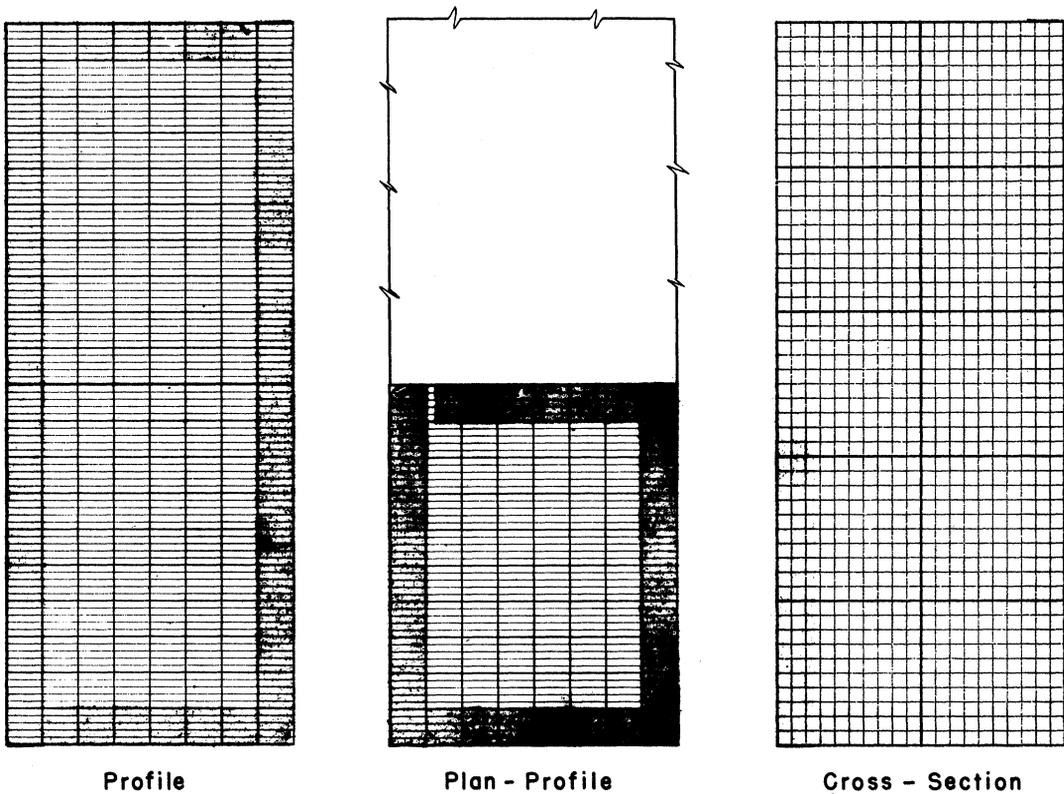


FIGURE 2.1 SAMPLE RULING OF PAPER

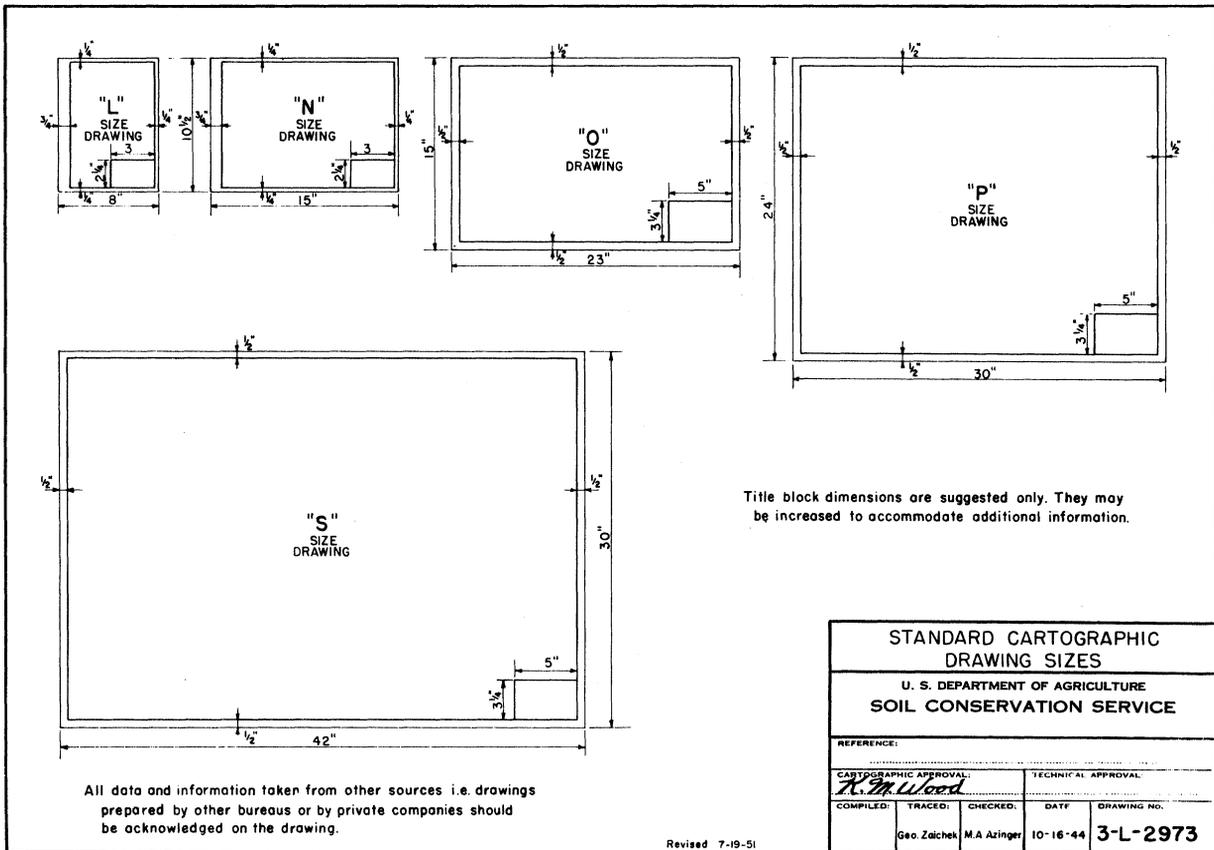


FIGURE 2.2 STANDARD DRAWING SIZES

- (5) F, H, or HB pencils
- (6) 30° - 60° and 45° triangles
- (7) T-square (optional)
- (8) Bow compass (optional)
- (9) Sandpaper pad
- (10) Engineer's scale, boxwood
- (11) Ruby and art gum erasers
- (12) With the possible exception of a ruling pen and a planimeter, no other materials should be needed by a farm planner or aid in the preparation of any data sheets which either might be expected to prepare.

As the names imply, the plan-profile and cross section papers are used in plotting profiles and cross sections. The plain tracing paper is used for drawing of topographic sketches, large scale plan views, and for layouts for which there is not sufficient space on the plan portion of the plan-profile sheets. All data sheets pertaining to one job should be on the same size paper for appearance and filing convenience. The smaller size "L," "N," and "O" plain sheets are used for small tiling jobs or other small jobs where all the necessary data can be placed on one of these small size sheets.

2.40 DRAWING AND DRAFTING STANDARDS

2.41 General

a. Engineering data sheets and other drawings prepared by field personnel are not expected to be of a quality in drafting technique expected of a skilled draftsman. However, field personnel whose duties require the preparation of engineering data sheets or other drawings, are expected to perform such work in legible, neat, orderly, and understandable manner. The appearance of the drawings will affect the degree of confidence with which they are received by persons outside the Service.

b. Lettering. Section 4, Part XI, Cartographic Handbook, gives instructions on the style of lettering used on drawings in this Region and information on how to improve your lettering. All lettering and numbers within the body of engineering data sheets should be 3/20" high for capitals and 1/10" high for lower case letters. On the profile paper this is equivalent to three of the finest lines high for capital letters and two lines high for lower case letters. Titles used outside the title block should be all capitals 1/4" high (five of the finest lines on the profile paper). Avoid the use of lettering any smaller than specified above; otherwise it will be difficult to read if the drawings are reduced in size by photostat reproduction.

c. Title Block. Every engineering data sheet or engineering drawing of any nature must have a title block. The title block is intended to present the following information in compact form:

Subject of the drawing.

Plot of land to which it applies (when applicable).

The Department and Service responsible for preparing the drawing.

The soil conservation district, county, and state.

The names of the persons who surveyed, designed, drew, and checked the drawing, together with the dates each performed.

Signature of the responsible person who approved the plan.

The regional drawing number is assigned by the Cartographic Division for filing purposes.

The standard title block is shown in Figure 2.3, page 2-6. The drawing paper referred to in Figures 2.1 and 2.2 may or may not have the title block printed on the sheets. The title block can be secured with gummed backs from the Cartographic Division by ordering Drawing No. 3-L-14504. These gummed title blocks can be glued on data sheets. They must always be placed in the lower right-hand corner. Obviously, they cannot be used if the drawing is to be blue-line printed.

d. Use of Pencil. Nearly all field drawings will be done in pencil. See Section 2, Part XI, Cartographic Handbook. With reasonable care, a very creditable drawing can be turned out in pencil. If the proper weight lines are used, good photostat reproductions can be made. The exclusive use of pencil eliminates a great deal of work involved in making ink tracings. In some cases, however, it may be necessary to do considerable trial layout work in pencil on a contour sketch, as in an orchard contour or terrace system. In such cases it will be desirable to ink in the contours before beginning the trial layout work to avoid continual erasing of the contour lines.

e. Symbols. Map symbols are to be in conformance with symbols shown in Figure 2.4, page 2-7. Soil boring symbols are to be in conformance with those shown in Figure 2.6. A legend explaining the symbols used must be put on data sheets or engineering drawings.

f. Scales. Bar scales should always be included for maps on engineering data sheets. This is necessary because the original scale of engineering data sheets and drawings is very often reduced or enlarged when reproduced. A map scale given, for

COOPERATOR	<i>J. E. Doakes</i>	SEC.	<i>14</i>	T.	<i>21</i>	R.	<i>2E</i>
COOPERATING WITH	<i>Grand River S.C.D.</i>						
COUNTY	<i>James</i>	STATE	<i>Michigan</i>				
SURVEYED	<i>P. J. Scope</i>					DATE	<i>1-13-53</i>

TILE DRAINAGE SYSTEM				
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE				
REFERENCE: <i>Field Book No. 12</i>				
CARTOGRAPHIC APPROVAL <i>H. H. Wood</i>			TECHNICAL APPROVAL <i>X. F. Smith</i>	
DESIGNED <i>John Doe</i>	DRAWN <i>John Smith</i>	CHECKED <i>John Doe</i>	DATE <i>1-13-52</i>	DRAWING NUMBER <i>3-(Leave Blank)</i> SHEET 1 OF 3

FIGURE 2.3 STANDARD TITLE BLOCK

instance, as one inch equals 100 feet, would have no meaning after the drawing had been reduced to half size by photostat. A bar scale, however, is reduced the same as the rest of the drawing. Bar scales should be drawn similar to those shown as "Duroseal Graphic Scales" on the last page of Section 12, Part VIII, Cartographic Handbook. These scales can be used on drawings to be photostated. It is unnecessary to include bar scales on profiles, cross sections, and boring logs because stationing and elevations are shown in each case.

g. North Arrows. North arrows should be shown near each watershed map, location plan, and contour map. A standard style north arrow is shown on the last page of Section 12, Part VIII, Cartographic Handbook. It is general practice among field engineers to use their own style north arrow, and this is acceptable so long as it is not too elaborate.

h. Legal Descriptions. The legal description of the section in which the main engineering works is located must be shown in the space provided in the title block. In addition, each watershed map, location plan, and contour map should be tied into section or quarter section lines properly identified (see Figure 2.5, page 2-8).

i. Bench Marks. Their location and identification must be shown on all plans and maps.

SOIL CONSERVATION SERVICE

STANDARD MAPPING SYMBOLS FOR FARM CONSERVATION PLANNING MAPS AND ENGINEERING DRAWINGS

BOUNDARY LINES

Watershed or Area	
Section Line	
Farm Boundary No Fence	
Permanent Fence	
New Fence	
Crop Boundary No Fence	
Field Boundary No Fence	

HIGHWAYS & RAILROADS

All Weather Road	
Dirt Road	
Private or Field Road	
Bridge	
Single Track Railroad	
Double Track Railroad	

LAND USE SYMBOLS FOR SMALL AREAS ONLY

Cultivated Land	L
Woodland	F
Permanent Pasture	P
Idle Land	X
Buildings and Lots	H
Orchards	O
Permanent Hay (Grass and Legume)	N
Wildlife	V
Unclassified	U

DRAINAGE

Continuous Stream, Large	
Continuous Stream, Small	
Intermittent Stream	
Stream Disappears on Flat	
Stream Disappears in Sink	
Large Deep Gully	
(Gully, Cannot Cross with Farm Implements)	
(Gully, Can Cross with Farm Implements)	

DRAINAGE (Continued)

Levee	
Spring	
Lake or Pond	
Intermittent Lake or Pond	
Marsh	
Terrace	
Diversion	
Grassed Watercourse	
Terrace Outlet	

PERMANENT STRUCTURE

MISCELLANEOUS SYMBOLS

Mine, Quarry, Gravel Pit	
Cemetery	
Church	
School House	
Occupied Residence, Store	

ADDITIONAL SYMBOLS TO BE USED TO SHOW ENGINEERING WORK ON AGREEMENT MAPS OR ENGINEERING DRAWINGS

North Arrow	
Section Center	
Section Corner	
Existing Tile	
Proposed Tile	
Break in Tile Size	
Break in Grade	
Relief Well	
Breather	
(Existing Open Ditch) (Less than 4' Deep)	
(Proposed Open Ditch) (Less than 4' Deep)	
(Existing Open Ditch) (4' Deep or Over)	
(Proposed Open Ditch) (4' Deep or Over)	

3-L-17108

FIGURE 2.4 STANDARD MAPPING AND DRAWING SYMBOLS

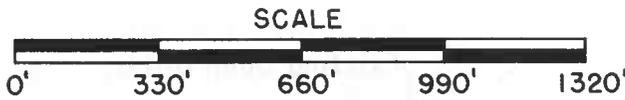
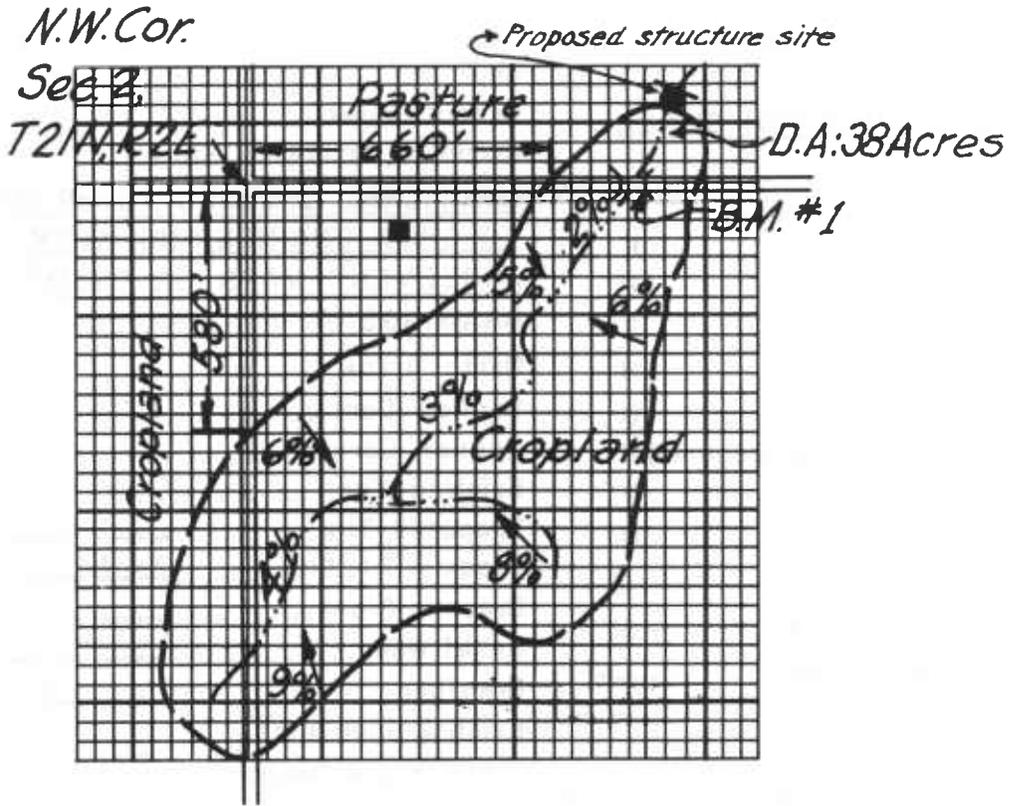
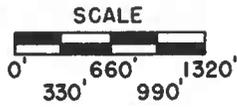
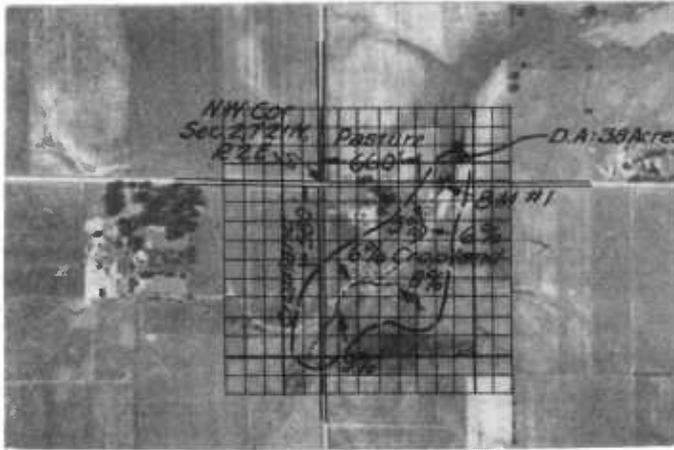


FIGURE 2.5 PROPORTIONING METHOD OF SCALE ENLARGEMENT

2.42 Profiles

a. Scales

All profiles should be drawn on profile paper or plan profile paper. Horizontal scales should be 1 inch = 20, 40, 80, 100, 200, or 400 feet, and the vertical scales should be 1 inch = 2, 4, or 8 feet. Only the heaviest lines ($2\frac{1}{2}$ " squares) are marked. Using the above horizontal scales, these heaviest lines would be 50, 100, 200, 250, 500, or 1,000 feet apart. These lines are marked in stations. Using the above vertical scales, the heaviest lines ($2\frac{1}{2}$ " squares) would be 5, 10, or 20 feet apart, and elevations marked on these lines at full 5-, 10-, or 20-foot intervals.

b. Plotting

In selecting profile scales and starting points for plotting profiles, first determine from the field notes the total length of profile to be plotted and the total difference in elevation. Then select a horizontal scale and horizontal starting point so that the entire profile will be well spaced on the profile sheet, taking into account any other material planned to be drawn on the profile sheet. Then select a vertical scale and a vertical starting point so that the entire profile will be well spaced on the paper vertically, again considering any other material contemplated to be drawn on the profile paper. Briefly, this is a process of blocking out roughly the entire profile so that it will all be on the sheet, well spaced, and with sufficient room for other material to be drawn in later.

After selecting the starting point on the paper, the profile points are plotted from the field survey notes. Adjacent ground line points are connected with very light straight lines, using a triangle as a straight edge, then traced over free hand to make final lines.

Where approximately parallel profile lines are to be plotted on the same profile as where a ditch bottom and banks are to be shown, banks are named right and left, looking downstream.

Designed grade lines, such as proposed bottom of ditch or bottom grade of prepared tile line, are drawn in by using a triangle as a straight edge and connecting computed plotted points with a straight line.

2.43 Cross Sections

All cross sections should be plotted on cross section paper (10 x 10 to the inch). They must be plotted as viewed looking downstream. Where the top width of the cross section does not exceed 280 feet, the cross section should be plotted to the same horizontal and vertical scale, 1 inch = 5 feet, or 1 inch = 10 feet, thereby giving an undistorted cross section. Where

the top width exceeds 280 feet, these scales should be altered so that the full cross width can be drawn within the width of the sheet. In such cases, the vertical scale should be 1 inch = 5 or 10 feet, and the horizontal scale should be 1 inch = 20 or 50 feet. The profile station at which each cross section was taken should be indicated directly under each cross section. At least two elevation markings should be shown for each cross section drawn, so that the vertical scale will be clearly indicated. Horizontal markings must also be shown for each cross section. Bar scales are not used on cross sections.

2.44 Soil Boring Logs

a. Soil boring logs are used to:

- (1) Analyze foundation conditions for contemplated structures and ponds.
- (2) Analyze drainability of soils for contemplated open ditch and tile drainage jobs.
- (3) To determine the presence of quicksand, rock, or other undesirable sub-surface conditions in connection with open ditch or tile drainage.

b. The boring logs should be plotted on the data sheet profiles or on the cross sections at the location where they were taken whenever space is available. When space is not available, spot the location on the cross section or profile and plot the boring logs, with proper identification, to one side. In either case, the logs should be plotted on the same datum used for the profiles or cross sections. Standard legend for boring logs shown in Figure 2.6, page 2-11, will be used.

c. A further description of the various materials shown on the standard is as follows:

Muck. Black or dark brown, well decomposed organic soil material accumulated under conditions of imperfect drainage. Light and fluffy when dry. May contain some clay and sand.

Peat. Dark brown or brown, slightly decomposed organic soil material accumulated under conditions of imperfect drainage. Remnants or original vegetation may be distinguished, frequently fibrous and matted.

Silt Loam. A silt loam is a soil having a moderate amount of fine grades of sand and only a small amount of clay, over half of the particles being of the size called "silt." When dry it may appear quite cloddy but the lumps can be readily broken, and when pulverized it feels soft and floury. When wet the soil readily runs together and puddles. Either dry or moist it will form casts that can be freely handled without breaking. If squeezed between thumb and finger it will not "ribbon" but will give a broken appearance.

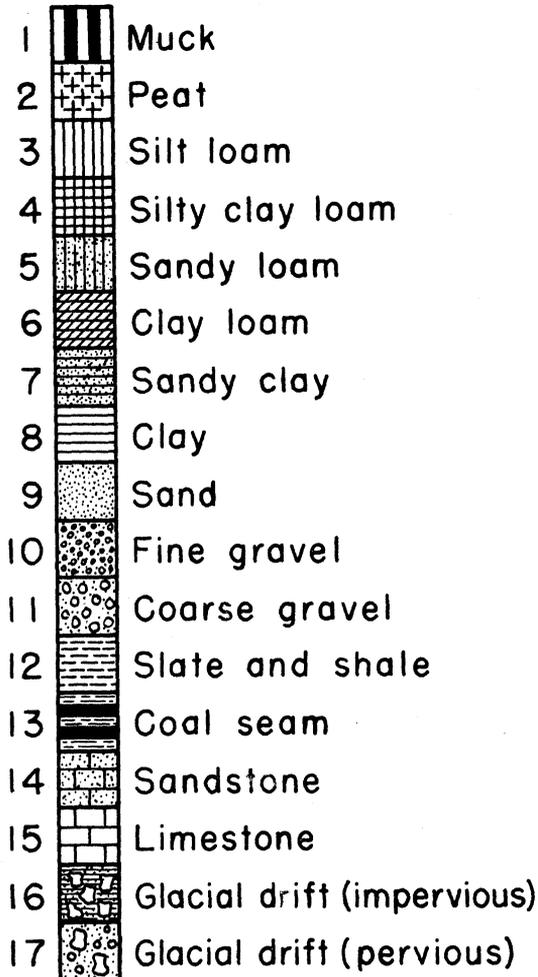


FIGURE 26 LEGENDS FOR SOIL BORINGS

Silty clay loam. A soil having a moderate amount of clay and the fine grades of sand with over half the particles being silt. When dry it appears cloddy and the lumps break with difficulty. When pulverized it feels soft and floury and cannot be readily distinguished from a silt loam. When wet the soil is slightly plastic. It can be made into casts which can be freely handled without breaking. When squeezed between the thumb and finger it will form a thin "ribbon" which will break readily. The surface of the "ribbon" will be flaky rather than smooth as in the clay.

Sandy loam. A sandy loam is a soil containing much sand but which has enough silt and clay to make it somewhat coherent. The individual sand grains can readily be seen and felt. Squeezed when dry, it will form a cast which will readily fall apart, but if squeezed when moist a cast can be formed that will bear careful handling without breaking.

Clay loam. A clay loam is a fine-textured soil which breaks into clods or lumps that are hard when dry. When the moist soil is pinched between the thumb and finger, it will form a thin "ribbon" which will break readily, barely sustaining its

own weight. The moist soil is plastic and will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into a heavy compact mass.

Sandy clay. A soil containing a small amount of silt and a moderate amount of sand, and at least half of the soil particles of the size called clay. When dry the soil forms hard clods. These will break into small granules under force. This texture is best recognized in the moist condition. When pinched between the thumb and finger, it will form a thin "ribbon" but the surface will be rough and gritty due to sand particles.

Clay. A clay is a fine-textured soil that forms very hard lumps or clods when dry and is quite plastic and usually sticky when wet. When the moist soil is pinched out between the thumb and fingers it will form a long, flexible "ribbon."

Sand. Sand is loose and single grained. The individual grains can readily be seen or felt. Squeezed in the hand when dry, it will fall apart when the pressure is released. Squeezed when moist, it will form a cast, but will crumble when touched.

Fine gravel. Resembles sand but the individual particles will range in size up to that of the ordinary garden pea.

Coarse gravel. Resembles fine gravel but the particles are larger. The size is usually an inch or less but may range up to the size of a hen's egg. Material larger than this would interfere with the operation of a trenching machine in drainage work.

Slate and shale. Finely stratified or laminated beds of fine-textured material as silt or clay. Slate is much more dense and compact than shale.

Coal seam. Includes layers of variable thickness of coal.

Sandstone. Rocks of variable thickness. The sand particles can usually be distinguished. This rock may be dense and hard and resistant to crushing, or it may be readily broken down by a small amount of force.

Limestone. A dense compact rock usually white, gray, or blue-gray in color. In some cases, individual crystal structure may be identified. Can be distinguished from sandstone by use of diluted hydrochloric acid (1/10 normal solution) which produces an effervescence in the limestone.

Glacial drift (impervious). Includes glacial deposits, both stratified and unstratified; composed largely of clay, gravel and boulders, and may include some silt and sand.

Glacial drift (pervious). Includes glacial deposits, both stratified and unstratified; composed largely of sand and silt, gravel and boulders; contains small amounts of clay material.

2.50 WATERSHED LOCATION MAP

2.51 A watershed location map may be defined as a map that shows contributing watershed boundary and the location, by symbol, of the proposed works. It must also show all other information that is pertinent to analysis and design of the proposed works. Such information may include some or all of the following:

- a. Average slopes of various reaches of the principal water-courses.
- b. Average slope of the land in various parts of the watershed. (Generally this can be gotten from the conservation survey map.)
- c. Land-use plan broken down into cultivated timber and pasture areas. (This may be in tabulated form.)

- d. Area of each of the predominant soil types or groups within the watershed. (This may be in tabulated form.)
 - e. Location of proposed work by symbol.
 - f. Location and size of bridges, culverts, and other structures that affect or are affected by the proposed works.
 - g. Names and extent of property ownership within the watershed.
 - h. Location of roads and buildings; also railroad drainage ditches, telephone and pipe lines when any of these affect or are affected by the proposed works.
 - i. Stationing along the route the profile was taken at points such as road crossings, property lines, junction with water-courses, and at any other points which will help in identification of points on the map with points on the plotted profiles.
 - j. Section corner or section center and legal description.
- 2.52 Watershed location maps in some form are required for all proposed works. The size and scale should vary with the size of the watershed and information needed. Generally the map should be not less than four inches square on the data sheet. It should be prepared to one of the following scales:

1 inch = 165 feet or 32 inches = 1 mile

1 inch = 330 feet or 16 inches = 1 mile

1 inch = 660 feet or 8 inches = 1 mile

1 inch = 1320 feet or 4 inches = 1 mile

- 2.53 A watershed location map is generally prepared by one or a combination of the following methods:
- a. Inking information on aerial photo and cementing photo on data sheet.
 - b. Tracing direct from aerial photo on data sheet.
 - c. Enlarging aerial photo data by proportioning on cross section paper or enlarging direct with panograph. In either case the watershed and location map is traced on the data sheet from the enlargement. Figure 2.5, page 2-8, shows enlargement method by proportioning on cross section paper.

The following may be used as a guide for determination of a suitable scale:

Up to 10 acres	- 1 inch = 165 feet
10 to 40 acres	- 1 inch = 330 feet
40 to 160 acres	- 1 inch = 660 feet
160 to 640 acres	- 1 inch = 1320 feet

2.60 LOCATION PLAN

2.61 A location plan is a drawing used for detail planning and staking out the job. Generally it is drawn to a scale larger than the watershed and location map. A location plan should generally show the following:

- a. Location of survey centerline or other survey lines with ties to permanent objects.
- b. Location of proposed works with reference to survey lines.
- c. Location and elevation of BMs.
- d. Outline of existing watercourses, ditches, or tile lines when these affect designs.
- e. Location of soil borings.
- f. Location of existing fences, property lines, buildings, roads, culverts, bridges, springs, wells, borrow pits, etc.
- g. Contour lines.

2.62 The difference between a watershed location map and a location plan is that a watershed and location map shows information needed for analysis and solution of a problem, along with the general location of the proposed works, while the location plan shows information needed for detail planning and details for staking out the proposed work.

2.63 The scale for a location plan drawing will vary with the kind and size of job. The following may be used as a guide:

- a. For structure - 1 inch = 10, 20, 30, or 40 feet, with contour lines shown at 1 to 5 feet vertical intervals.
- b. For drainage (open ditch, surface ditch and tile) Class E jobs - 1 inch = 100, 200, 330, or 660 feet.
- c. For drainage (open ditch, surface ditch) Class D and larger jobs - 1 inch = 100, 200, and up to 1,000 feet.
- d. For drainage (tile) Class D and larger - 1 inch = 100 or 200 feet.

- 2.64 A location plan may be combined with a watershed location map on some of the smaller jobs, especially on small drainage work. Discretion should be exercised in making such a combination, inasmuch as all information needed must be on such a map. It must be clear, understandable, and so placed without undue cluttering on the drawing.
- 2.65 Drawings in outline form with space provided for recording planning, layout, and construction details are available. These should be used where applicable as data sheets and plans. Their use will be confined to the less complex jobs that require only the data suggested in order to do a sound job of planning and construction. For examples of this type data sheet see Figure 4.13, page 4-20, and Figure 7.7, page 7-11. These are called "Fill in Data Sheets."

PART 3

RAINFALL-RUNOFF-SPRING AND
STREAM FLOW MEASUREMENTS

3.10 EROSION CONTROL

3.11 Relationship of Rainfall to Runoff

a. Runoff is that portion of the rainfall which leaves a field either by surface flow or by sub-surface such as through tile or springs.

3.12 Factors Affecting Runoff

a. The rate and intensity of rainfall varies over the region. It is usually expressed in inches per hour. The variation of rainfall in the region is expressed as a factor. (Figures 3.1 and 3.2.) See rainfall factor "R" in small map. This factor multiplied by figure selected from charts based on ΣW and watershed area will give you total runoff "Q" for the area which is the rate of runoff in cubic feet per second.

b. Other factors affecting runoff are:

Relief (slope of the land)

Soil infiltration

Vegetal cover

Surface storage

These are adequately defined in Figures 3.1 and 3.2. Proper values are selected, based on watershed characteristics, and these are added together to get ΣW which is shown in example, Paragraph 3.14. ΣW is called the summation of watershed characteristics.

3.13 Rainfall Frequency

a. Rainfall frequency can be defined as a relative figure based on probability. In other words, the probability of a big rain conducive to high runoff falling on a watershed is much greater in a 50-year period than it is in a 25- or 10-year period. Therefore, runoff for 50-year design is greater than for 25-year, and 25-year in turn is greater than for 10-year. Runoff for 10- and 50-year frequencies can be obtained from Figures 3.1 and 3.2.

b. 10-year frequency should be used:

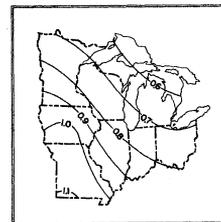
In figuring the size of grassed waterways.

**RUN-OFF CHART FOR DESIGN OF GRASS WATERWAYS
BASED ON 10 YEARS FREQUENCY AND RAINFALL FACTOR OF 1.0**

DRAINAGE AREA IN ACRES	WATERSHED CHARACTERISTICS										
	30	35	40	45	50	55	60	65	70	75	85
			P ₁₀ =	CUBIC	FEET	PER	SECOND				
4	5	7	8	9	10	11	13	15	17	20	24
6	6	8	10	11	13	16	18	21	24	28	34
8	7	9	12	13	17	20	24	28	32	37	44
10	8	10	14	16	21	25	30	35	40	46	53
12	9	11	16	19	24	29	35	41	48	54	62
14	10	13	18	22	28	33	40	47	55	62	71
16	11	15	20	25	31	38	45	53	62	70	80
18	12	17	22	28	34	42	50	59	79	78	89
20	14	19	24	31	38	46	55	65	76	86	98
25	16	22	28	36	46	55	66	78	90	103	118
30	18	25	32	42	53	64	77	91	105	120	139
35	20	28	36	47	60	73	87	104	120	137	159
40	22	32	41	53	68	82	98	117	135	154	179
45	24	36	46	59	76	91	109	130	150	171	200
50	26	40	51	65	83	100	119	142	165	188	220
60	30	45	59	76	97	117	139	165	193	221	259
70	34	50	66	87	110	133	159	188	221	253	298
80	38	55	74	97	123	149	179	211	248	285	338
90	42	60	81	107	136	166	199	234	274	317	378
100	46	65	88	117	150	182	218	256	300	348	418
120	53	75	102	135	175	213	256	300	351	410	487
140	60	85	116	154	200	244	293	344	401	471	556
160	67	95	129	172	224	275	329	388	451	529	625
180	73	105	142	190	248	305	364	432	500	585	694
200	79	115	155	207	271	334	398	476	550	640	764
220	85	124	168	224	294	363	432	516	598	693	832
240	91	132	180	241	317	392	464	556	645	746	899
260	97	141	192	257	340	421	496	595	691	799	964
280	102	149	204	273	362	450	528	634	736	852	1028
300	108	158	216	289	384	480	560	672	781	905	1090
320	114	167	228	305	407	505	591	709	824	956	1150
340	119	175	240	321	429	530	623	746	867	1007	1210
360	124	184	253	337	451	555	654	783	909	1058	1270
380	129	192	265	355	473	580	684	820	952	1109	1330
400	135	200	277	371	494	605	713	856	994	1160	1390
420	141	208	288	386	515	629	741	891	1035	1209	
440	146	216	299	401	535	653	769	926	1076	1257	
460	151	224	310	416	554	677	797	961	1117	1303	
480	156	232	321	432	572	700	825	996	1158	1348	
500	161	239	332	447	590	723	853	1030	1199	1392	
520	166	246	342	462	607	746	881	1064	1238	1435	
540	171	253	352	476	624	769	909	1098	1277	1478	
560	176	260	362	490	641	791	937	1131	1315	1521	
580	181	267	372	504	658	813	965	1164	1350	1563	
600	185	274	382	518	675	835	993	1197	1386	1605	

HOW TO USE CHART

Determine numerical characteristic of watershed. From the chart under this numerical characteristic and opposite the drainage area read the probable run-off for a Rainfall Factor of 1.0. Multiply this number by rainfall factor of your work unit. This will give the required c.f.s. for waterway design.



RAINFALL FACTORS "R"

LOCATE YOUR WORK UNIT ON ABOVE RAINFALL MAP AND DETERMINE RAINFALL FACTOR. WORK UNIT RAINFALL FACTOR _____

RUN-OFF CHART FOR DESIGN OF GRASS WATERWAYS

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

REFERENCE:

CARTOGRAPHIC APPROVAL: <i>J. M. Wood</i>		TECHNICAL APPROVAL: <i>Edward Freyburger</i>	
COMPILED: P.J.	DRAWN: D.Lewandowski	CHECKED: J.D.P.	DATE: 6-7-45
		DRWG. NO. 3-L-14054	

DESIGNATION OF WATERSHED CHARACTERISTICS	RUN-OFF-PRODUCING CHARACTERISTICS			
	100 EXTREME	75 HIGH	50 NORMAL	25 LOW
RELIEF	(40) Steep, rugged terrain, with average slopes generally above 30%	(30) Hilly, with average slopes of 10 to 30%	(20) Rolling, with average slopes of 5 to 10%	(10) Relatively flat land, with average slopes of 0 to 5%
SOIL INFILTRATION	(20) No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity.	(15) Slow to take up water; clay or other soil of low infiltration capacity, such as heavy gumbo.	(10) Normal; deep loam with infiltration about equal to that of typical prairie soil.	(5) High; deep sand or other soil that takes up water readily and rapidly.
VEGETAL COVER	(20) No effective plant cover; bare or very sparse cover.	(15) Poor to fair; clean-cultivated crops or poor natural cover; less than 10% of drainage area under good cover.	(10) Fair to good; about 50% of drainage area in good grassland, woodland, or equivalent cover; not more than 50% of area in clean-cultivated crops.	(5) Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover.
SURFACE STORAGE	(20) Negligible; surface depressions few and shallow; drainage ways steep and small; no ponds or marshes.	(15) Low; well-defined system of small drainage ways; no ponds or marshes.	(10) Normal; considerable surface-depression storage; drainage system similar to that of typical prairie lands; lakes, ponds and marshes less than 2% of drainage area.	(5) High; surface-depression storage high; drainage system not sharply defined; large flood-plain storage or a large number of lakes, ponds or marshes.

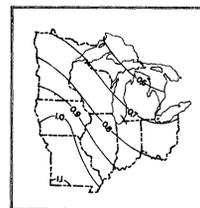
FIGURE 3.1 RUNOFF CHART FOR DESIGN OF GRASSED WATERWAYS

**RUN-OFF CHART FOR DESIGN OF PERMANENT STRUCTURES
BASED ON 50 YEARS FREQUENCY AND RAINFALL FACTOR OF 1.0**

DRAINAGE AREA IN ACRES	WATERSHED					CHARACTERISTICS							
	25	30	35	40	45	50	55	60	65	70	75	85	100
	F ₅₀ CUBIC FEET					PER SECOND							
4	5	7	10	11	13	14	15	18	21	24	28	34	36
6	6	8	11	14	15	18	23	25	30	34	40	48	51
8	7	10	13	17	18	24	28	34	40	45	52	62	66
10	8	11	15	19	24	29	35	43	50	58	66	75	81
12	9	12	17	22	28	34	41	50	59	68	78	88	97
14	10	14	19	25	32	39	47	57	68	78	90	101	112
16	11	15	21	28	36	44	53	64	76	87	100	114	127
18	12	17	24	31	40	49	59	71	84	96	110	126	142
20	13	19	26	33	43	53	64	77	92	105	120	138	155
25	16	22	31	40	52	64	78	93	110	128	146	168	190
30	18	25	36	47	60	75	91	109	128	149	172	198	225
35	20	28	41	53	68	86	104	124	146	170	196	228	260
40	22	31	45	59	76	97	117	139	164	190	221	257	295
45	24	34	49	65	84	107	130	154	182	210	245	286	330
50	26	37	53	71	92	117	142	168	200	230	267	315	365
60	29	43	62	82	108	136	165	197	234	270	314	366	435
70	32	49	70	93	123	155	188	226	268	310	360	425	505
80	36	54	78	104	137	173	211	255	301	350	406	478	570
90	40	59	85	114	151	193	233	281	334	389	448	530	635
100	43	64	92	124	165	210	255	307	365	426	490	590	700
120	49	74	107	144	192	246	300	359	427	500	574	690	825
140	55	84	121	164	218	281	345	410	487	570	658	790	950
160	61	94	134	183	243	315	390	460	547	640	740	890	1070
180	67	103	147	202	268	349	430	510	607	710	820	990	1190
200	73	111	160	220	292	383	470	560	667	780	900	1080	1310
220	78	119	173	237	316	416	510	610	724	845	980	1170	1420
240	83	127	186	254	340	449	550	660	781	910	1060	1260	1530
260	88	135	199	271	363	481	590	704	838	970	1134	1350	1640
280	93	143	211	288	386	513	630	748	894	1030	1207	1440	1750
300	98	151	223	305	409	545	670	792	950	1090	1280	1530	1860
320	103	159	235	322	432	576	705	836	1000	1150	1350	1620	1970
340	108	167	247	339	455	604	740	880	1050	1210	1420	1710	2080
360	113	174	259	356	478	633	775	924	1100	1270	1490	1800	2190
380	118	182	270	373	501	662	810	967	1150	1330	1560	1890	2290
400	123	190	281	390	523	691	845	1010	1200	1390	1630	1980	2390
420	128	197	292	405	544	720	880	1048	1248	1448	1694	2064	2490
440	133	204	303	420	565	748	915	1086	1296	1506	1758	2148	2590
460	137	211	314	435	586	776	950	1124	1344	1564	1822	2232	2690
480	141	218	325	450	607	803	985	1162	1392	1622	1886	2316	2790
500	145	225	335	465	628	830	1020	1200	1440	1680	1950	2400	2885
520	149	232	345	480	648	856	1050	1238	1486	1734	2010	2476	2980
540	153	239	355	495	668	882	1080	1276	1532	1788	2070	2552	3075
560	157	245	365	510	688	908	1120	1314	1578	1842	2130	2628	3170
580	161	250	375	525	708	934	1140	1352	1624	1896	2190	2704	3265
600	165	255	385	540	728	960	1170	1390	1670	1950	2250	2780	3360

HOW TO USE CHART

Determine numerical characteristic of watershed. From the chart under this numerical characteristic and opposite the drainage area read the probable run-off for a Rainfall Factor of 1.0. Multiply this number by rainfall factor of your work unit. This will give the required c.f.s. for permanent structure design.



RAINFALL FACTORS "R"

LOCATE YOUR WORK UNIT ON ABOVE RAINFALL MAP AND DETERMINE RAINFALL FACTOR

WORK UNIT _____
RAINFALL FACTOR _____

RUN-OFF CHART FOR DESIGN OF PERMANENT STRUCTURES

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

REFERENCE

CARTOGRAPHIC APPROVAL: <i>T. M. Wood</i>	TECHNICAL APPROVAL: <i>Edwin Freyburger</i>
COMPILED: <i>P. J.</i>	DRAWN: <i>R. B. A. H. R.</i>
CHECKED: <i>J. D. P.</i>	DATE: <i>6-4-47</i>
	DRWG. NO. <i>3-L-1508A</i>

FIGURE 3.2 RUNOFF CHART FOR DESIGN OF PERMANENT STRUCTURES

In figuring diversions where vegetated outlets are provided.

c. 50-year frequency should be used on all structures impounding water or involving spillways constructed of permanent materials.

3.14 Example for figuring runoff for a structure of permanent materials. Use 50-year frequency.

Watershed

93 acres drainage area

60 acres cropland (strip cropped)

33 acres pasture

6% average slope

Soil - average loam

Waterways - well defined

Then from Figure 3.2, ΣW equals:

Relief for average slope 6%	12
Soil infiltration for average loam	10
Vegetal cover - 10 for strip cropped area and 5 for pasture area	
Interpolating $\frac{(10 \times 60) + (5 \times 33)}{93}$	8
Surface storage well defined drainage system	<u>15</u>
ΣW	45

Then from Figure 3.2 for 50-year frequency, runoff from chart with a ΣW of 45 and 90 acres = 151.

Then if structure were to be constructed in Ashland County, Wisconsin,

$$R = 0.7$$

$$Q = (151) (0.7)$$

$$= 106 \text{ cu. ft. per sec.}$$

The design of waterways follows the same procedure using Figure 3.1.

3.20 DRAINAGE RUNOFF

3.21 General

The basic difference between runoff for erosion control and for drainage is in degree of protection provided. In erosion control work, such as in the design and construction of earth dams, momentary peak flows must be provided for so as to prevent damage from overtopping. In drainage runoff, on the other hand, these momentary peaks are allowed to flood out over the land. Usually slopes are not great enough for serious erosion to result, and the water is removed at a rate great enough to permit its removal before crop damage results.

3.22 For quantities of runoff for open ditch or tile, see Part 11.

3.30 MEASURING STREAM AND SPRING FLOWS

3.31 General

A ready way to measure stream flow is needed in preliminary planning when a stream is to be used for irrigation or a spring is to be used for a water supply.

Two types of weirs are adapted to measuring the flow of small streams. They are:

- a. Rectangular weir
- b. 90° V notch

3.32 The rectangular weir is adapted to measuring fairly large stream flows. The discharge is dependent upon both width and depth of the weir. Therefore, no attempt will be made to set up tables for this type of weir. If the flow of the stream is such that it is necessary to use this type of measuring equipment an engineer should be consulted.

The 90° V notch weir is probably best for measuring small flows common on low stream or small spring flows. It can be made by cutting a triangular 90° notch in a wooden bulkhead, as illustrated in Figure 3.3.

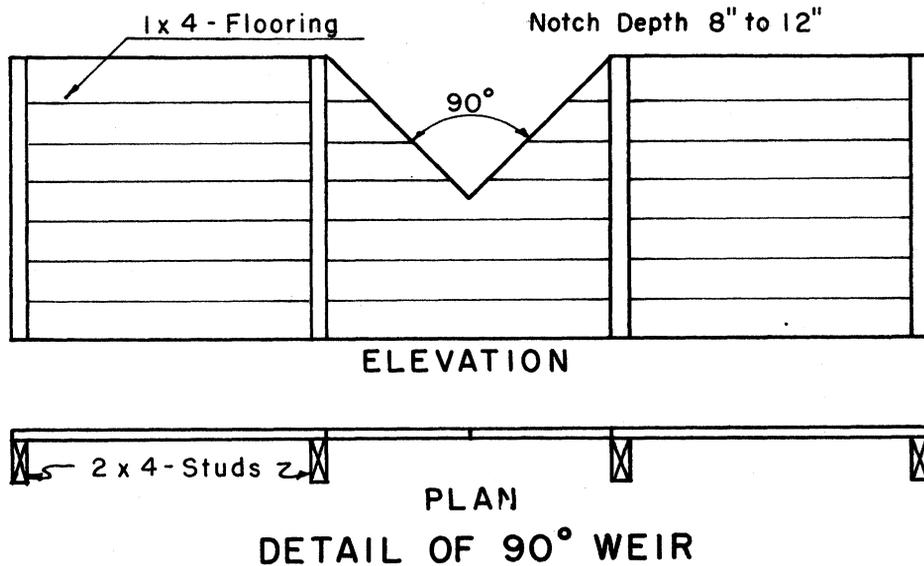


FIGURE 3.3 CONSTRUCTION DETAILS FOR 90-DEGREE TRIANGULAR NOTCH

The depth of the notch may be from 8" to 12" deep. The material should be one-inch flooring or other tongue and grooved material. Posts (2x4) should be placed at the end and on each side of the notch. It must be made deep enough to go into the ditch bottom a sufficient distance to prevent undercutting and wide enough to tie into the banks. The amount of water flowing can be obtained from the table on the next page by merely observing the depth of flow. If foot gauges are placed on each side of the weir a convenient method for leveling weir and reading water stages will be provided.

The best method to prevent seepage under the weir is to tack a piece of canvas below the weir on upstream side.

One precaution, if discharge figures are to be accurate, is to provide enough distance below the weir so that it will flow without submergence of the downstream side. The bottom of the V must be above the water on the downstream side.

DISCHARGE TABLE FOR 90-DEGREE TRIANGULAR NOTCH							
Head in feet	Head in inches	Discharge		Head in feet	Head in inches	Discharge	
		gal. min.	second- feet			gal. min.	second- feet
0.20	2-3/8	21	0.046	.61	7-5/16	327	.730
.21	2-1/2	23	.052	.62	7-7/16	341	.760
.22	2-5/8	26	.058	.63	7-9/16	354	.790
.23	2-3/4	29	.065	.64	7-11/16	369	.822
.24	2-7/8	32	.072	.65	7-13/16	383	.854
.25	3	36	.080	.66	7-15/16	398	.887
.26	3-1/8	39	.088	.67	8-1/16	413	.921
.27	3-1/4	43	.096	.68	8-3/16	428	.955
.28	3-3/8	47	.106	.69	8-1/4	444	.991
.29	3-1/2	52	.115	.70	8-3/8	462	1.03
.30	3-5/8	56	.125	.71	8-1/2	475	1.06
.31	3-3/4	61	.136	.72	8-5/8	493	1.10
.32	3-13/16	66	.147	.73	8-3/4	511	1.14
.33	3-15/16	71	.159	.74	8-7/8	529	1.18
.34	4-1/16	77	.171	.75	9	547	1.22
.35	4-3/16	83	.184	.76	9-1/8	565	1.26
.36	4-5/16	88	.197	.77	9-1/4	583	1.30
.37	4-7/16	94	.211	.78	9-3/8	601	1.34
.38	4-9/16	101	.226	.79	9-1/2	623	1.39
.39	4-11/16	108	.241	.80	9-5/8	641	1.43
.40	4-13/16	115	.256	.81	9-3/4	663	1.48
.41	4-15/16	122	.272	.82	9-13/16	681	1.52
.42	5-1/16	130	.289	.83	9-15/16	705	1.57
.43	5-3/16	137	.306	.84	10-1/16	722	1.61
.44	5-1/4	145	.324	.85	10-3/16	744	1.66
.45	5-3/8	154	.343	.86	10-5/16	767	1.71
.46	5-1/2	162	.362	.87	10-7/16	790	1.76
.47	5-5/8	171	.382	.88	10-9/16	812	1.81
.48	5-3/4	181	.403	.89	10-11/16	834	1.86
.49	5-7/8	190	.424	.90	10-13/16	861	1.92
.50	6	200	.445	.91	10-15/16	883	1.97
.51	6-1/8	210	.468	.92	11-1/16	907	2.02
.52	6-1/4	220	.491	.93	11-3/16	934	2.08
.53	6-3/8	231	.515	.94	11-1/4	956	2.13
.54	6-1/2	242	.539	.95	11-3/8	982	2.19
.55	6-5/8	253	.564	.96	11-1/2	1010	2.25
.56	6-3/4	265	.590	.97	11-5/8	1037	2.31
.57	6-13/16	277	.617	.98	11-3/4	1064	2.37
.58	6-15/16	289	.644	.99	11-7/8	1090	2.43
.59	7-1/16	301	.672	1.00	12	1118	2.49
.60	7-3/16	314	.700				

FIGURE 3.4 DISCHARGE TABLE FOR 90-DEGREE TRIANGULAR NOTCH

PART 4

FARM PONDS

4.10 GENERAL

4.11 Scope and Limitations

a. Farm ponds or reservoirs are:

Retention reservoirs in which the primary purpose is the storage of water for future use.

Detention reservoirs in which temporary flood-storage reduces the peak flow immediately below the pond.

b. The farm planner is limited in designing ponds as outlined in Regional Memorandum No. 60 (Revised).

4.12 Uses

a. Farm ponds are constructed most frequently for storage of stock water. The amount of storage should be sufficient to allow for seepage and evaporation losses and also to satisfy the requirements for stock water for an extended drouth period. Seepage and evaporation amount to approximately three feet or more annually, unless unusual soil and climatic conditions prevail at the pond site. Stock water requirements may be estimated by using a value of 15 gallons of water per day per animal unit for a drouth period of approximately six months. In figuring animal units, cattle and horses are estimated at one animal unit per head, while sheep and hogs are calculated at one-tenth animal unit each.

b. Where storage is to be used for irrigation, great care should be taken to insure that sufficient water is available to provide an adequate amount for each acre to be irrigated. See Part 12, "Irrigation," for details.

c. Water storage may be invaluable for protection in case of fire. In order to be effective, water must be applied at a rate of approximately 500 gallons per minute. This would mean a supply of over .092 acre-foot for an hour. Minimum for fire, 50,000 gallons (after losses).

d. Where pond storage is to be used for spray water in addition to stock water, very little, if any, additional capacity needs to be considered. The amount required for spray water (.02 acre-foot per acre of orchard) is relatively small, and the demand usually comes at a time of year when frequent rains will replace this withdrawal.

e. One of the uses of the farm pond, rating high in farmer interest, is recreation and production of fish for food. For this purpose the farm pond should have a surface area of not less than one-quarter of an acre and an average depth of 6 feet with 8 to 10 feet of depth in 25 percent of the area.

f. Where local conditions permit, ponds may be designed as detention reservoirs by providing more than the usual amount of temporary storage above the crest of the mechanical spillway. They should be designed in accordance with procedures outlined in paragraph 4.42 for watersheds under 30 acres. For larger watersheds, flood routing curves should be prepared by an engineer.

g. There is a growing demand for farm ponds to be used as a home water supply. The dangers of pollution and the difficulty of proper chlorination and filtration make this use doubtful. Most State boards of health strongly oppose the use of open surface storage as a source for a household water supply.

4.20 SELECTING THE POND SITE

4.21 Watershed

a. There are many advantages to a site near the farm buildings. Such a location makes fire protection more effective and provides a supply of water at the farmstead for livestock and for other uses at a minimum of expense and difficulty. A location near the buildings also is more readily available for recreational purposes and the pond is more likely to be inspected and properly maintained. There are instances, of course, where it is desirable to locate the pond in a remote part of the farm in order to provide stock water for an isolated pasture area.

b. In selecting a pond site, the possibilities of pollution of the water supply should be considered. Not only should drainage from a barnyard be avoided, but drainage from land not under the farmer's control is frequently questionable, because it may be a source of contagion (Bang's disease, cholera, etc.) to livestock. A watershed wholly within the farm is to be desired.

c. The pond watershed preferably should have a high percent of vegetative cover, so that siltation of the impounded area will be kept to a minimum. The watershed should have 50 percent or more in grass cover, if possible, and any rolling areas not in vegetation should be under conservation treatment that will give effective control.

d. The watershed should be large enough to provide the required amount of water but it should not be disproportionately large in comparison to the impounded area. A proper relationship between pondage area and watershed area, therefore, is desirable. If a ratio of one acre of pond surface to less than six acres of watershed exists, there may be difficulty in keeping the pond

filled during extended periods of dry weather, or in case of abnormal use. Where a ratio of one acre of pond surface to more than 20 acres of watershed exists, the water disposal problem will be complicated and expensive because of excessive spillway costs, and excessive siltation of the impounded area is likely to occur. These latter sites should be investigated and designed by an engineer.

e. Exposure of the impounded area with reference to the prevailing winds should also be considered. Every effort should be made to locate the pond so that the prevailing wave action is away from the fill.

4.22 Fill Site

a. A location should be selected where the effective depth would be eight to ten feet over at least twenty-five percent of the pond at normal water level. A pond with less depth will not provide cool enough temperature for fish and would frequently not provide enough capacity after seepage and evaporation losses had been met.

b. Select sites that will provide a maximum amount of storage with the least amount of fill.

c. An earth fill is no better than its foundation. A good foundation would be a slowly pervious material not only under the fill but under the pond water area as well. Fill foundations should be avoided where there is shallow cover to rock, sand, or gravel. If a fill is to be built under these conditions, special precautions will be necessary. Peat and marl areas should be avoided as fill foundations.

d. Wherever possible, select a site that will provide a natural vegetative spillway.

e. Good fill material is important in constructing farm ponds. A supply should be readily available to the fill site. Any combination of a rather wide range of mixtures of fine gravel, sand, silt, and clay in such proportions that a minimum of voids exist, will be excellent fill material for dams within the scope of the farm planner's authority to approve. The following or similar soils will be suitable for fill material:

Shelby silt loam
Carrington silt loam
Miami silt loam
Milaca silt loam
Wellston silt loam

The following or similar soils are poor fill material:

Any sandy loam
 Boxtton gravelly silt loam
 Ida silt loam
 Cincinnati silt loam
 Any soil containing alkali

4.30 SURVEYS

4.31 Watershed

a. The procedure for the watershed survey is given in Part 1. The acreage of the watershed, average percent slope, cover, and soil type should be obtained and recorded.

4.32 Fill Site

a. The survey should include a profile, cross section, and soil borings on centerline of fill and at intervals in the pond area. Contour lines should be used where an accurate figure for flood storage capacity is required. See Part 1 for the procedure to be followed for making a survey of the fill and pond site.

4.40 DESIGN

4.41 Choice of Spillways

a. The kind of spillway to be used will depend on the size of watershed and site conditions. Generally watersheds from 10 to 30 acres will require a combination of mechanical and vegetative spillways. This is desirable because it eliminates a prolonged trickle flow which might damage the sod. Watersheds under 10 acres often require only a good vegetative spillway. Watersheds over 30 acres will require the services of an engineer for spillway design.

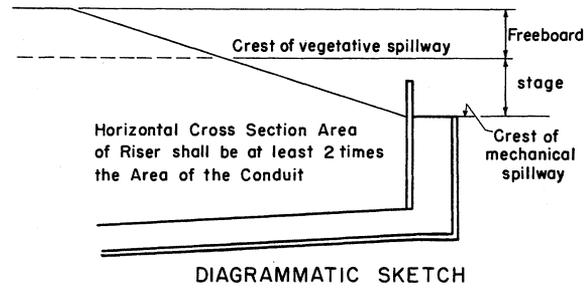
4.42 Mechanical Spillway

a. In using stage design table, Figure 4.1, the size of the spillway tube and its capacity to carry runoff is fixed (either 8- or 10-inch pipe). Therefore, design enough flood storage to take care of the rest of the normal runoff. The table shows the relationship between the pond area (surface area of the pond at the elevation of the crest of the mechanical spillway), the acres of drainage area, and the stage (depth of water above the mechanical spillway necessary to provide the required storage).

b. To solve a particular problem determine the flood characteristics (ΣW) of the watershed from Figure 4.1. Estimate the surface area of the pond at the elevation at which you expect to place the crest of the mechanical spillway. Find the acres in the drainage area. Start on the left side of the table at a point indicated by the size of the drainage area and its flood

ACRES & WATERSHED	W	POND AREA (acres)																	
		0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.25	1.50	1.75	2.0	2.25	2.5	2.75	3.0
		STAGE (feet)																	
30	70										3.0	2.75	2.5	2.0	1.75	1.5	1.25	1.25	1.0
	60								3.0	2.75	2.50	2.0	1.75	1.5	1.25	1.25	1.0		
	50	Maximum stage for this chart is 3.0 feet							3.0	2.5	2.25	2.25	2.0	1.5	1.25	1.25	1.0		
	40	Higher values require design by field engineer.				3.0	2.75	2.5	2.0	2.0	1.75	1.5	1.25	1.0	1.0	1.0			
25	70							3.0	2.75	2.5	2.25	2.0	1.5	1.5	1.25	1.0			
	60						3.0	2.75	2.5	2.25	2.0	1.75	1.5	1.25	1.0				
	50				3.0	2.75	2.5	2.25	2.0	2.0	1.75	1.25	1.0						
	40			3.0	2.5	2.0	1.75	1.75	1.5	1.25	1.0	1.0	1.0						
20	70					3.0	2.75	2.5	2.25	2.0	1.75	1.5	1.25	1.0					
	60					3.0	2.5	2.25	2.0	1.75	1.5	1.25	1.0						
	50				3.0	2.5	2.0	1.75	1.75	1.5	1.25	1.0							
	40		3.0	2.75	2.25	1.75	1.5	1.25	1.25	1.0	1.0	1.0							
15	70				3.0	2.5	2.25	1.75	1.75	1.5	1.25	1.0							
	60			3.0	2.5	2.25	1.75	1.5	1.5	1.25	1.25	1.0							
	50		3.0	2.75	2.0	1.75	1.5	1.25	1.25	1.0	1.0								
	40	2.5	2.25	1.75	1.5	1.25	1.0	1.0	1.0										
10	70	3.0	2.75	2.5	2.0	1.5	1.25	1.25	1.0										
	60	2.75	2.5	2.0	1.75	1.25	1.25	1.0											
	50	2.25	1.75	1.5	1.25	1.0	1.0												
	40	1.25	1.0	1.0	1.0														
5	70	1.5	1.25	1.25	1.0														
	60	1.0	1.0	1.0															
	50																		
	40																		

The minimum stage given by this chart is 1.0 foot. If the determined stage falls below this value use 1.0'.



PROBLEM

Find Required Stage. Drainage Area 20 Acres. Pond Area 0.7 Acres.
Runoff Producing Characteristics - Weighted Values
 Relief: rolling land average slope 8% 16
 Infiltration upland prairie soil brown silt loam 10
 Vegetal cover: 100% pasture and woodland 5
 Surface storage: well defined system of small (drainage ways) 13
 $\Sigma W = 44$

Solution
 from table above, for
 $\Sigma W 50 \quad s = 1.75$
 $\Sigma W 40 \quad s = 1.25$
 difference 0.50
 Interpolating
 $\Sigma W 4 \quad s = 0.4 \times 0.5 = 0.20$
 $\Sigma W 40 \quad s = 1.25$
 $\Sigma W 44 - \text{Design Stage} = 1.45$

Design Storm = Approx. Q₅

DESIGNATION OF WATERSHED CHARACTERISTICS	RUN-OFF - PRODUCING CHARACTERISTICS			
	100 EXTREME (40)	75 HIGH (30)	50 NORMAL (20)	25 LOW (10)
RELIEF	Steep, rugged terrain, with average slopes generally above 30%.	Hilly, with average slopes of 10 to 30%.	Rolling, with average slopes of 5 to 10%.	Relatively flat land, with average slopes of 0 to 5%.
SOIL INFILTRATION	No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity.	Slow to take up water; clay or other soil of low infiltration capacity, such as heavy gumbo.	Normal; deep loam with infiltration about equal to that of typical prairie soil.	High; deep sand or other soil that takes up water readily and rapidly.
VEGETAL COVER	No effective plant cover; bare or very sparse cover.	Poor to fair; clean-cultivated crops or poor natural cover; less than 10% of drainage area under good cover.	Fair to good; about 50% of drainage area in good grass land, woodland, or equivalent cover; not more than 50% of area in clean-cultivated crops.	Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover.
SURFACE STORAGE	Negligible; surface depressions few and shallow; drainage-ways steep and small; no ponds or marshes.	Low; well-defined system of small drainage-ways; no ponds or marshes.	Normal; considerable surface depression storage; drainage system similar to that of typical prairie lands; lakes, ponds and marshes less than 2% of drainage area.	High; surface-depression storage high; drainage system not sharply defined; large flood-plain storage or a large number of lakes, ponds or marshes.

STAGE REQUIREMENTS FOR FARM PONDS

U.S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL <i>R. M. Wood</i>		TECHNICAL APPROVAL <i>Edwin Freyburger</i>	
DESIGNED <i>A. Moratz</i>	DRAWN <i>D. F. L.</i>	CHECKED <i>E. Freyburger</i>	DATE <i>7-24-51</i>
			DRAWING NUMBER 3-L-26438

FIGURE 4.1 STAGE REQUIREMENTS FOR FARM PONDS

producing characteristics (ΣW). Then read horizontally to right. Under the column for the size of the pond area obtain the required stage for the pond.

Where the solution indicates a stage greater than three feet it becomes a special design and a structure data sheet as given in Part 2 will be required.

To obtain the difference in elevation between the crest of the mechanical spillway and the top of the settled fill, add a minimum freeboard of 2 feet to the stage.

c. Example:

Watershed - acres drainage area - 10 acres.

Normal flood producing characteristics ($\Sigma W=50$).

Area of the pond at the crest of mechanical spillway - 0.4 acre.

The stage will be found from Figure 4.1 as 1.25 feet. Then 1.25 feet stage plus 2 feet freeboard gives 3.25 feet from mechanical spillway to the top of the settled fill.

d. Inlet specifications and details for 8- and 10-inch pipe spillways are given in Figures 4.2, 4.3, 4.4, or 4.5. (See pages 4-7, 4-8, 4-9, and 4-10.)

e. Outlet specifications and details for 8- and 10-inch pipe spillways are given as follows:

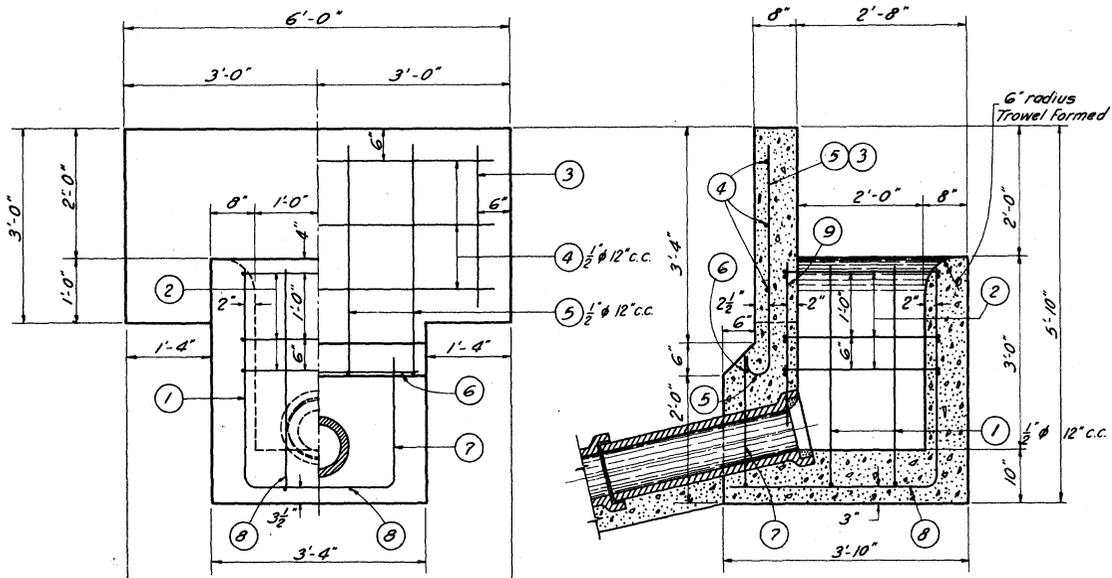
For reinforced concrete outlet - Figure 4.6 (page 4-11)

For plain concrete outlet - Figure 4.7 (page 4-12)

For concrete block outlet - Figure 4.8 (page 4-13)

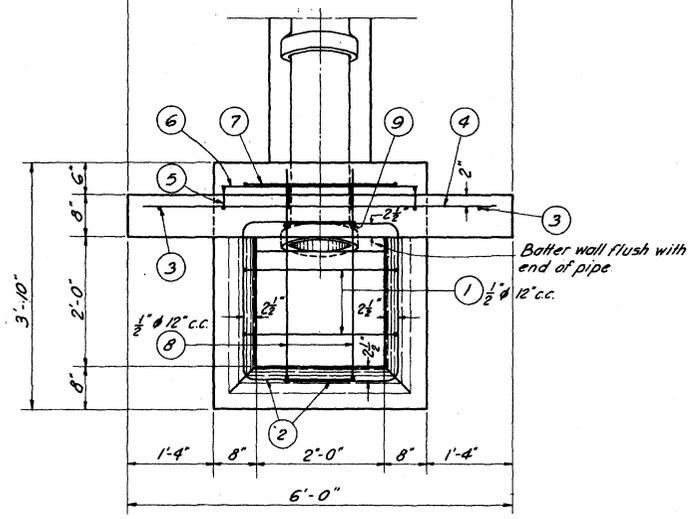
For a timber support propped outlet - Figure 4.9 (page 4-14)

f. Anti-seep collars and tile cradling specifications are given in Figures 4.10 and 4.11. (See pages 4-15 and 4-16.) If total length of tile or conduit pipe is not more than 60 feet, one anti-seep collar will suffice. It should be placed approximately 4 feet upstream from the centerline of the fill. A good rule-of-thumb method for locating anti-seep collars where the total spillway length is more than 60 feet is to place them at the $1/3$ and $2/3$ points or slightly above. Anti-seep collars for metal pipes shall be of the same material as the metal pipe. Metal pipe should not be cradled.



HALF ELEVATION FRONT
HALF ELEVATION REAR

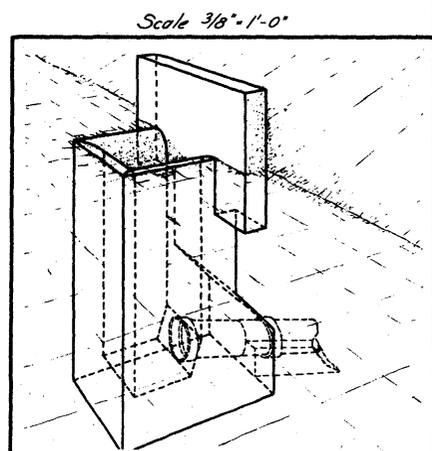
SECTION ON CENTERLINE



PLAN

QUANTITIES

VOLUME OF CONCRETE 1.6 CU. YDS.
TOTAL WEIGHT OF STEEL 80 POUNDS

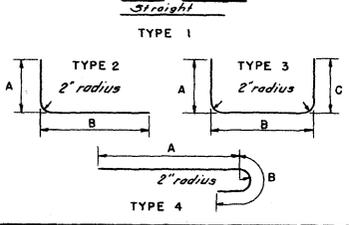


Revised 1-13-52

STEEL SCHEDULE

MARK	QUAN	SIZE	LENGTH	TYPE	A	B	C	TOT. FT
1	2	1/2"	9'-0"	3	3'-4"	2'-4"	3'-4"	18'-0"
2	6	"	6'-0"	3	1'-9 1/2"	2'-5"	1'-9 1/2"	36'-0"
3	2	"	2'-6"	1	-	-	-	5'-0"
4	3	"	5'-6"	1	-	-	-	16'-6"
5	4	"	4'-3"	4	3'-6"	0'-9"	-	17'-0"
6	1	"	3'-0"	1	-	-	-	3'-0"
7	1	"	6'-6"	3	2'-1"	2'-4"	2'-1"	6'-6"
8	2	"	6'-6"	2	3'-2"	3'-4"	-	13'-0"
9	2	"	2'-6"	1	-	-	-	5'-0"

BAR TYPES

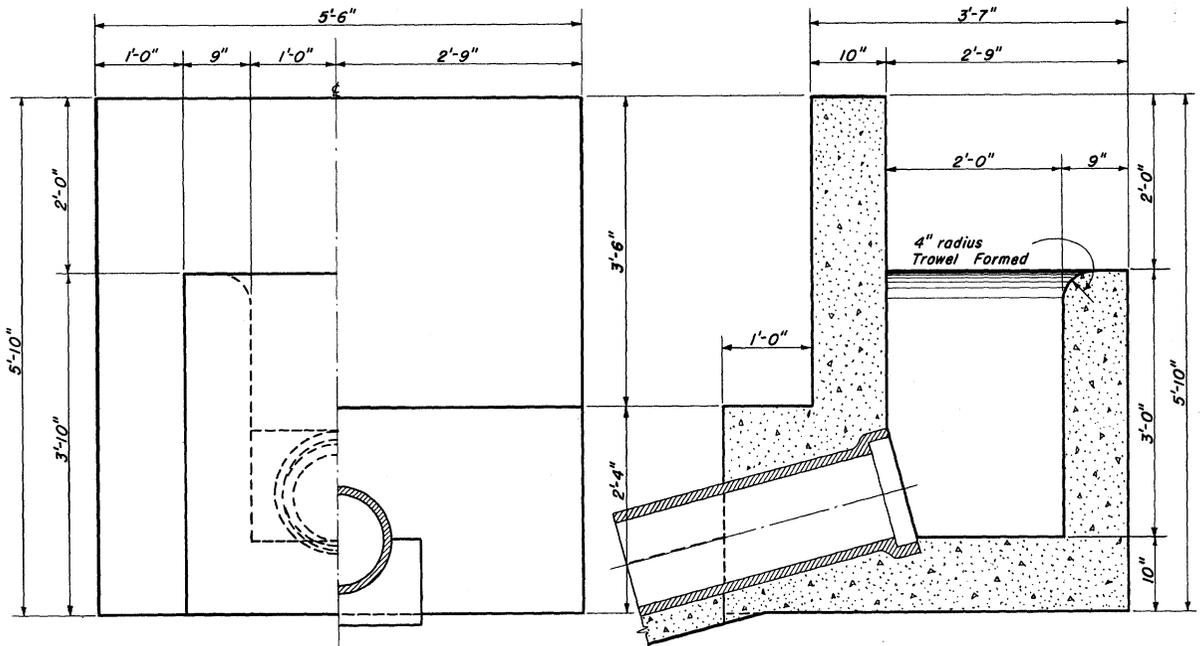


REINFORCED CONCRETE-BOX TYPE INLET FOR 8" TO 18" TILE OR TUBE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL:	
N. W. Wood		Edwin Freyburger	
DESIGNED:	DRAWN:	CHECKED:	DATE:
A.F. Moratz	D. Lewandowski	A.F. Moratz	6-18-46
DRWG. NO.		3-L-12313	

FIGURE 4.2 REINFORCED CONCRETE-BOX TYPE INLET FOR 8" TO 18" TILE OR TUBE

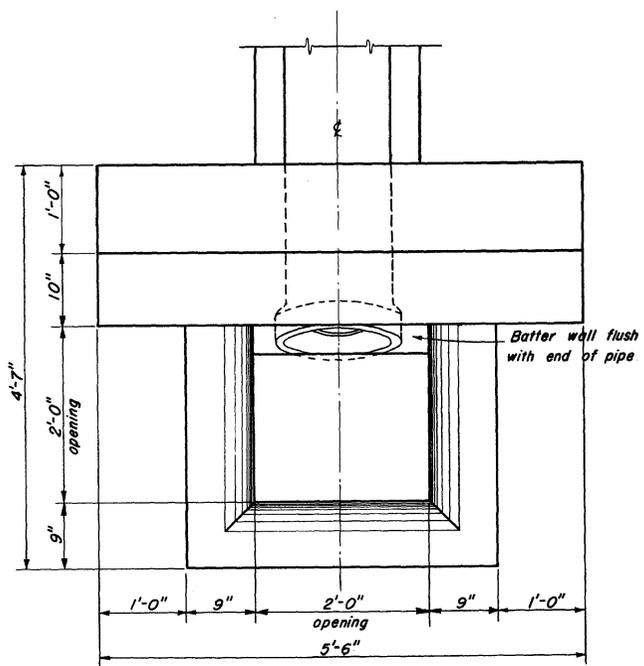


**HALF
ELEVATION
FRONT**

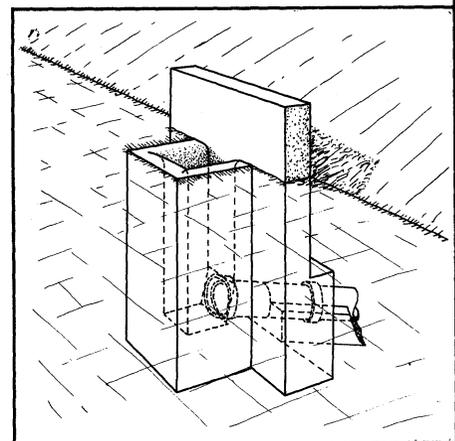
**HALF
ELEVATION
REAR**

SECTION ON CENTERLINE

VOLUME OF CONCRETE 2.3 CU. YDS.



PLAN



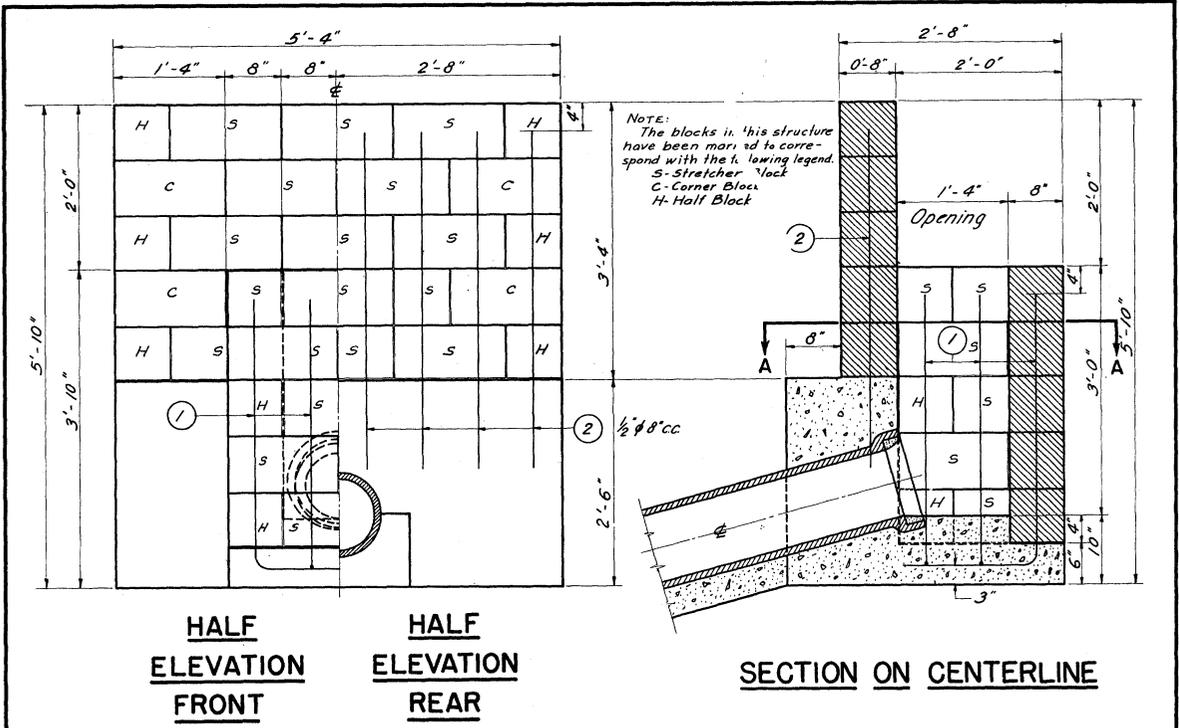
**PLAIN CONCRETE-BOX TYPE INLET
FOR 8" TO 18" TILE OR TUBE**

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL: <i>Kenith McLeod</i>		TECHNICAL APPROVAL: <i>Edwin Freyburger</i>		
DESIGNED: A.F. Moratz	DRAWN: R.C. Murphy	CHECKED: A.F. Moratz	DATE: 5/24/46	DRWG. NO. 3-L-12483

Scale - 1/2" = 1'-0"

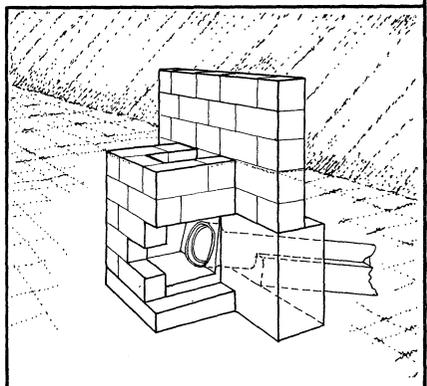
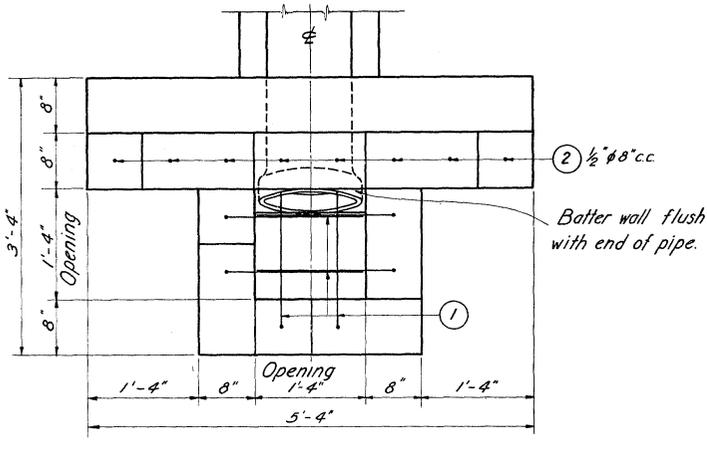
FIGURE 4.3 PLAIN CONCRETE-BOX TYPE INLET FOR 8" TO 18" TILE OR TUBE



Note: Cores in the concrete blocks shall be filled with concrete. This concrete shall be firmly tamped around the reinforcing steel. When filling the block cores each pour shall stop 4" below the top of the top course of blocks to form a construction joint for subsequent pours. At the top of the wall the concrete shall be finished flush with the top of the blocks or higher as indicated by the plans.

QUANTITIES

VOLUMES OF CONCRETE:	
BASE POUR	0.7 CU.YDS.
BLOCKS - CORE FILL	0.2 " "
MORTAR	0.05 " "
CONCRETE BLOCKS -	
STRETCHER BLOCKS	31 EACH
HALF BLOCKS	10 "
CORNER BLOCKS	4 "
OR 40 STRETCHER BLOCKS	
REINFORCING STEEL	42.8 POUNDS



CONCRETE BLOCK-BOX TYPE INLET FOR 8" TO 12" TILE OR TUBE

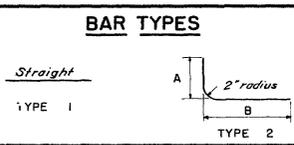
U. S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE

Revised 8-7-47 L.H.M.
 Revised 12-31-52 R.B.

Scale 1/2" = 1'-0"

STEEL SCHEDULE

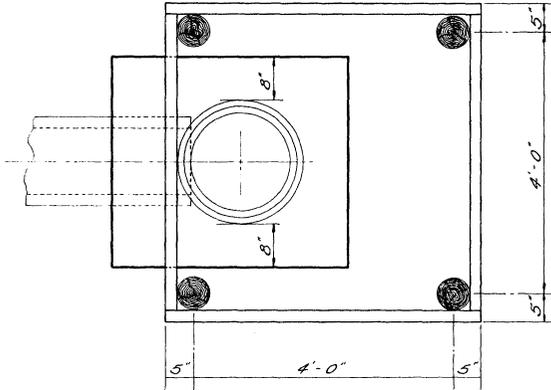
MARK	QUAN.	SIZE	LENGTH	TYPE	A	B	C	TOT. FT.
1	6	1/2"	5'-0"	2	1'-9"	3'-3"	-	30'-0"
2	8	1/2"	4'-3"	1	-	-	-	34'-0"



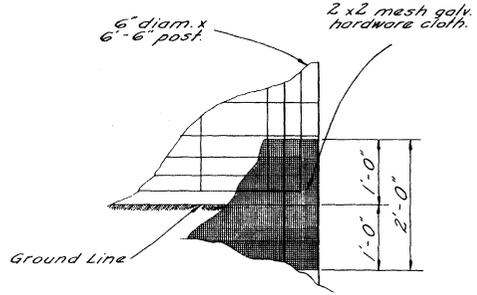
CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL:	
DESIGNED BY:	DRAWN:	CHECKED:	DATE:
A.F. Moratz	D. LEWANDOWSKI	A.F. Moratz	6-3-46
		DRWG. NO.	
		3-L-12433	

FIGURE 4.4 CONCRETE BLOCK-BOX TYPE INLET FOR 8" TO 12" TILE OR TUBE

NOTE: This inlet may be used only where one section of pipe riser is required



PLAN



DETAIL OF FISH SCREEN

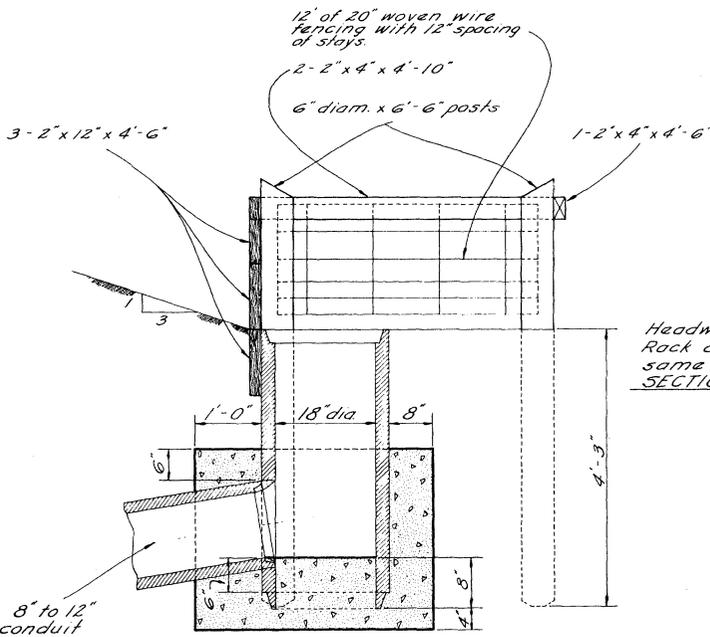
Use only where specified

MATERIALS FOR INLET

1-18" x 4' Tongue and groove reinforced concrete pipe.

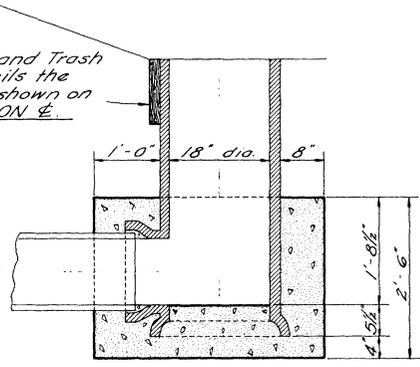
0.9 cu. yds. concrete

All other indicated materials.



SECTION ON C-C

Headwall and Trash Rack details the same as shown on SECTION ON C-C



ALTERNATE SECTION ON C-C

Using a 18+12 T section of vitrified clay pipe

NOTE: Hole to be cut in pipe before pouring base. The pipe should be packed with a dense soil mixture before cutting to prevent cracking. The joint between the conduit and riser shall be wetted and grouted with a sand-cement mix and formed as shown. Special sections with a side opening formed to fit conduit can be obtained from most pipe manufacturers.

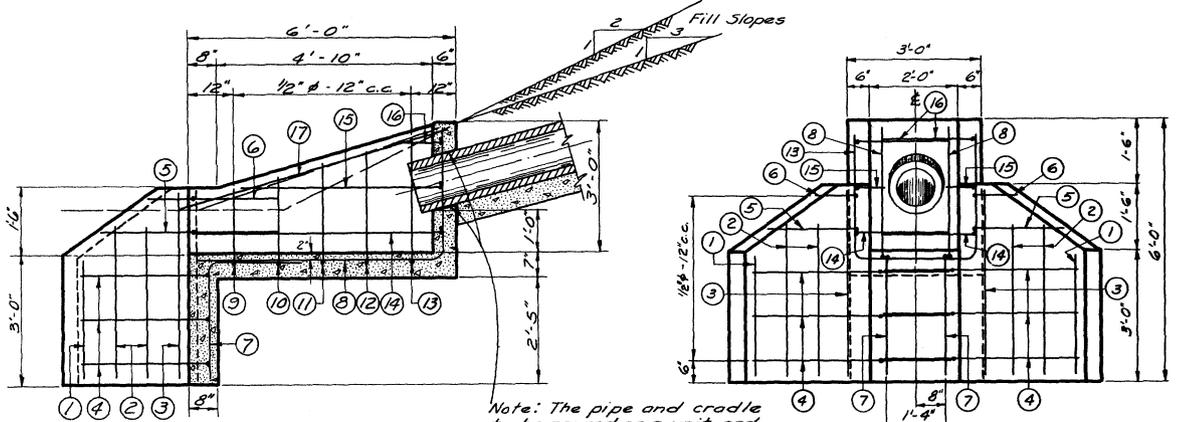
Scale 3/8" = 1'-0"

TRASH RACK AND PIPE RISER FOR PIPE DROP INLET SPILLWAY

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL <i>A. M. ...</i>			TECHNICAL APPROVAL <i>Edwin ...</i>		
DESIGNED A. Moratz D. Palsin	DRAWN C. York	CHECKED F. Henry	DATE 11-9-51	DRAWING NUMBER 3-L-12312	SHEET OF

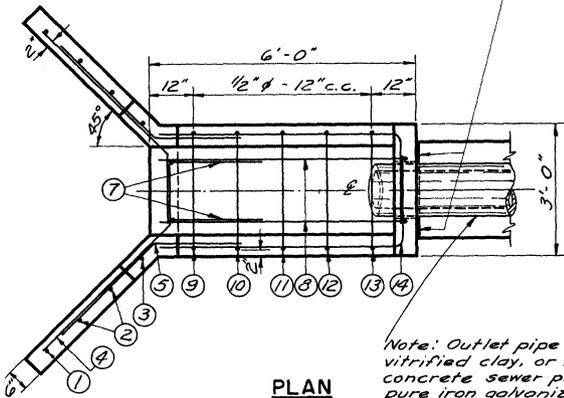
FIGURE 4.5 TRASH RACK AND PIPE RISER FOR PIPE DROP INLET SPILLWAY



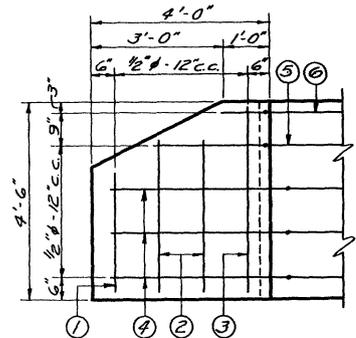
SECTION ON CENTERLINE

FRONT ELEVATION

Note: The pipe and cradle to be poured as a unit and separated from the Outlet by a 1/2" band of premolded asphaltic expansion joint filler.



PLAN



WINGWALL ELEVATION

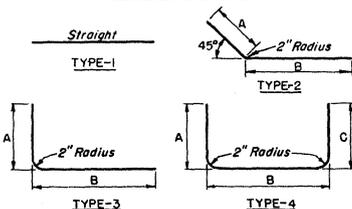
Note: Outlet pipe shall be vitrified clay, or reinforced concrete sewer pipe, bonded pure iron galvanized or cast iron pipe.

SCALE: 1/4" = 1'-0"

QUANTITIES

VOLUME OF CONCRETE 1.8 CU. YDS.
TOTAL WEIGHT OF STEEL 123.0 POUNDS

BAR TYPES



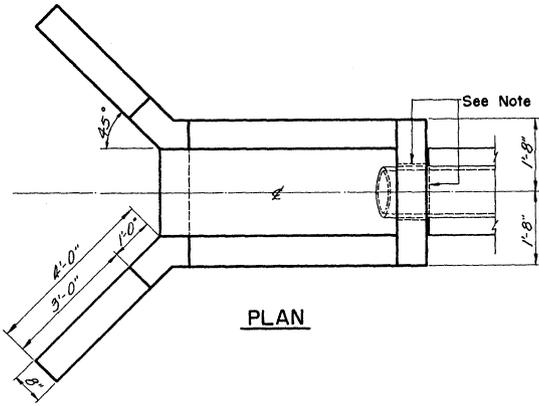
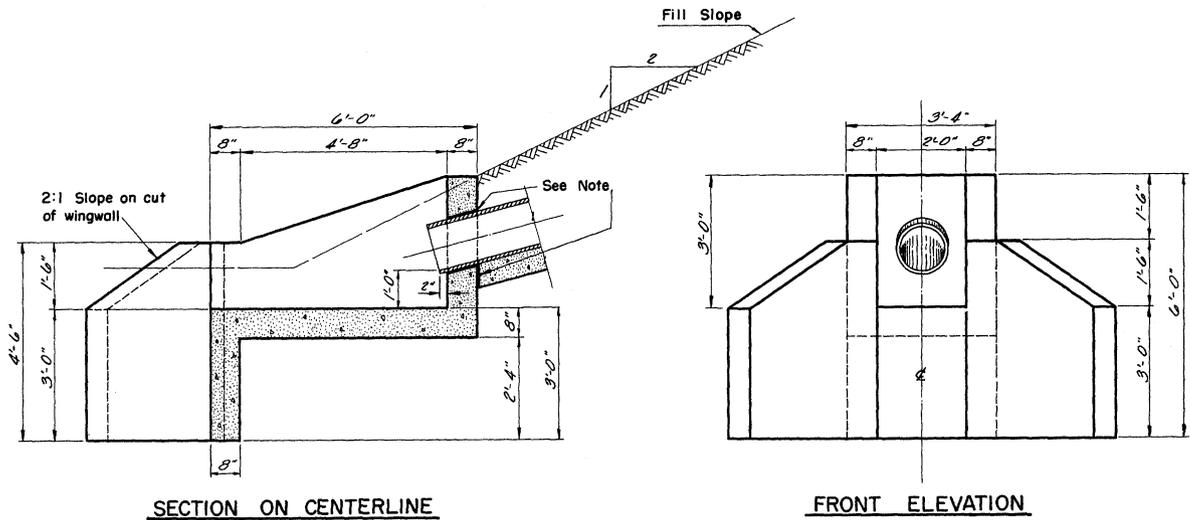
STEEL SCHEDULE									
MARK	QUAN.	SIZE	LENGTH	TYPE	A	B	C	TOT. FT.	
1	2	1/2" #	2'-9"	1				5'-6"	
2	4	"	3'-6"	1				14'-0"	
3	2	"	4'-0"	1				8'-0"	
4	6	"	5'-8"	2	1'-6"	4'-2"		34'-0"	
5	2	"	5'-0"	2	3'-0"	2'-0"		10'-0"	
6	2	"	3'-0"	2	1'-0"	2'-0"		6'-0"	
7	2	"	4'-6"	3	2'-6"	2'-0"		9'-0"	
8	2	"	8'-6"	3	3'-0"	5'-6"		17'-0"	
9	1	"	6'-0"	4	1'-8"	2'-8"	1'-8"	6'-0"	
10	1	"	6'-8"	4	2'-0"	2'-8"	2'-0"	6'-8"	
11	1	"	7'-4"	4	2'-4"	2'-8"	2'-8"	7'-4"	
12	1	"	7'-10"	4	2'-7"	2'-8"	2'-7"	7'-10"	
13	1	"	8'-4"	4	2'-10"	2'-8"	2'-10"	8'-4"	
14	2	"	7'-6"	3	5'-6"	2'-0"		15'-0"	
15	2	"	5'-3"	3	4'-7"	0'-8"		10'-6"	
16	2	"	3'-0"	3	1'-0"	2'-0"		6'-0"	
17	2	"	6'-3"	1				12'-6"	

REINFORCED CONCRETE OUTLET FOR 8" TO 12" PIPE

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL:			
DESIGNED: A. Moratz		DRAWN: A.M.E.			
CHECKED: D. Polzin		DATE: 2-28-51		DRWG. NO. 3L-12499	

FIGURE 4.6 REINFORCED CONCRETE OUTLET FOR 8" TO 12" PIPE

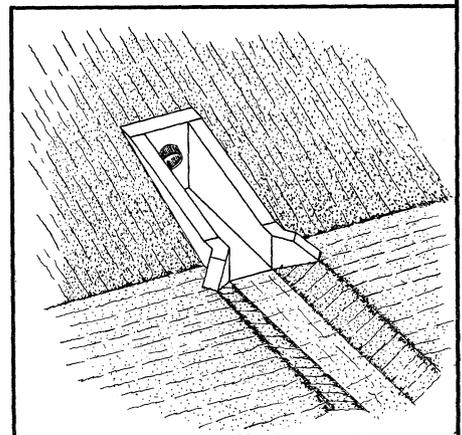


Scale: 1/4" = 1'-0"

Note:
The pipe and cradle are to be placed as a unit and to be separated from the Outlet by a 1/2" band of premolded asphaltic expansion joint filler.

QUANTITIES

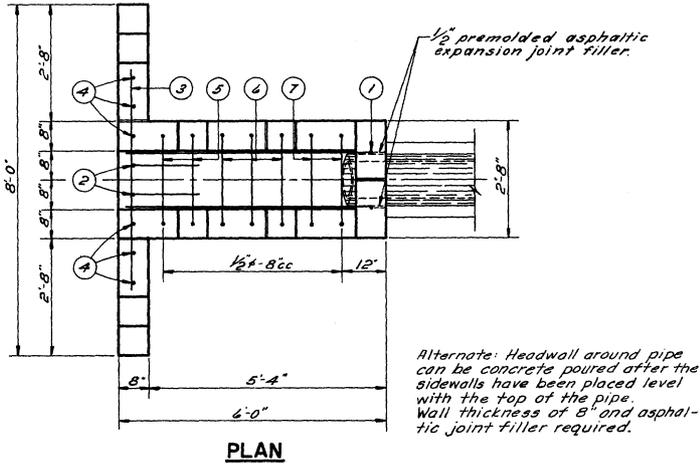
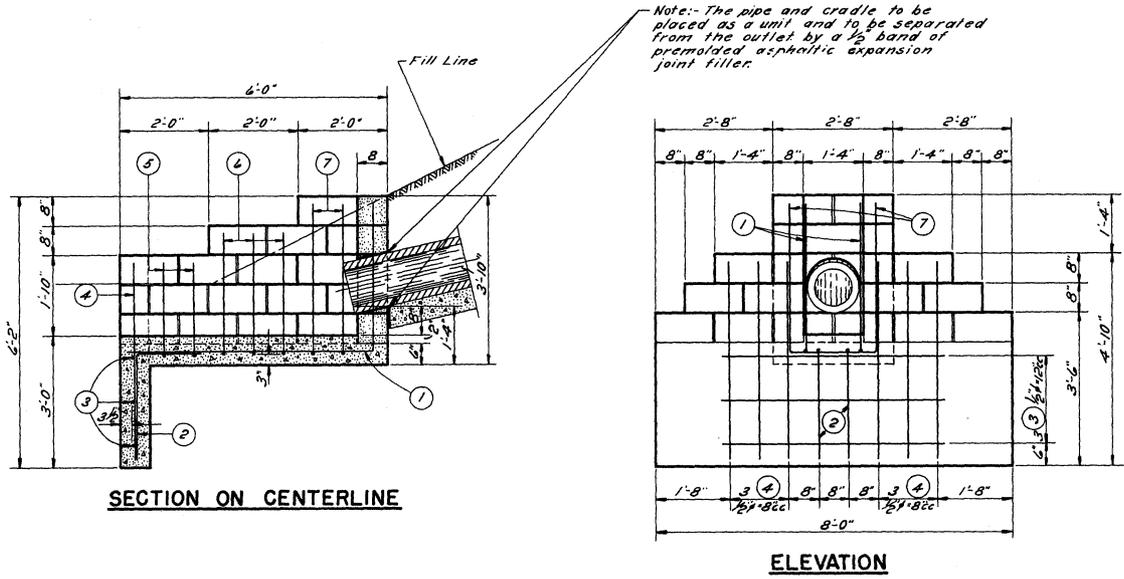
VOLUME OF CONCRETE 2.4 CU. YDS.



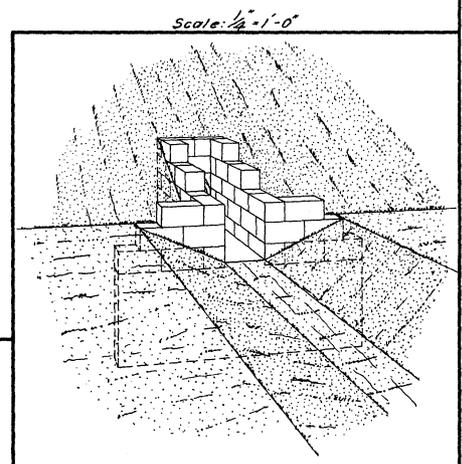
**PLAIN CONCRETE OUTLET
FOR 8" TO 12" PIPES**
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL			TECHNICAL APPROVAL		
<i>R. M. Wood</i>			<i>Edwin Freyburger</i>		
DESIGNED	DRAWN	CHECKED	DATE	DRAWING NUMBER	
A. MORATZ	R.G. MURPHY	D. POLZIN	2-28-51	3-L-12517	

FIGURE 4.7 PLAIN CONCRETE OUTLET FOR 8" TO 12" PIPE

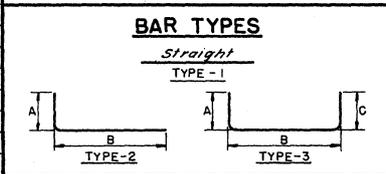


NOTES:
 All joints 1/4" thick.
 First course of blocks to be laid in freshly poured concrete slab.
 Cores to be filled with concrete and firmly tamped around the reinforcing steel.
 At the top of the wall the concrete shall be troweled flush with the top of the blocks.
 The mortar shall be 1 part portland cement to 3 parts sand.
 All concrete blocks shall be placed in a water bath a minimum of 10 minutes immediately before laying in the wall and the cores shall be thoroughly sprinkled previous to placing the concrete core fill.



STEEL SCHEDULE							
MARK	QUAN	SIZE	LENGTH	TYPE	A	B	TOI FT
1	2	1/2" #	8'-9"	2	3'-3"	5'-6"	17'-6"
2	2	"	3'-9"	2	1'-6"	2'-3"	7'-6"
3	3	"	5'-0"	1			15'-0"
4	6	"	4'-6"	1			27'-0"
5	2	"	6'-0"	3	2'-0"	2'-0"	12'-0"
6	3	"	7'-6"	3	2'-9"	2'-0"	22'-6"
7	2	"	8'-6"	3	3'-3"	2'-0"	17'-0"

QUANTITIES		
VOLUMES OF CONCRETE:		
BASE POUR	0.86	CU. YDS.
CORE FILL (BLOCK)	0.30	" "
MORTAR	0.05	" "
CONCRETE BLOCKS:		
STRETCHER BLOCKS	29	EACH
CORNER BLOCKS	18	"
REINFORCING STEEL	80	POUNDS



CONCRETE BLOCK OUTLET FOR 8" TO 12" PIPES

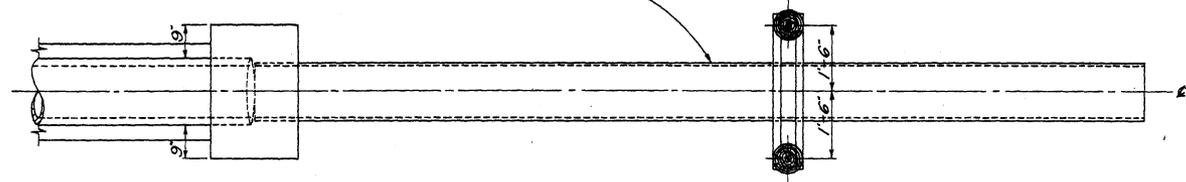
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

DESIGNED		DRAWN		CHECKED		DATE		DRAWING NUMBER	
A. NORATZ		R. G. JESKE		D. POLZIN		2-28-51		3-L-12511	

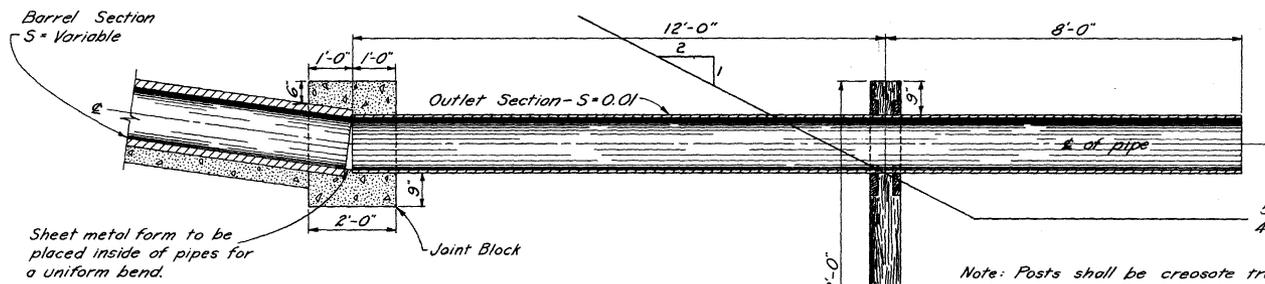
CARTOGRAPHIC APPROVAL: *A. M. Wood*
 TECHNICAL APPROVAL: *Edwin F. Furburger*

FIGURE 4.8 CONCRETE BLOCK OUTLET FOR 8" TO 12" PIPE

Asphalt coated, pure iron corrugated pipe with paved invert, or other pipe of comparable strength and durability.

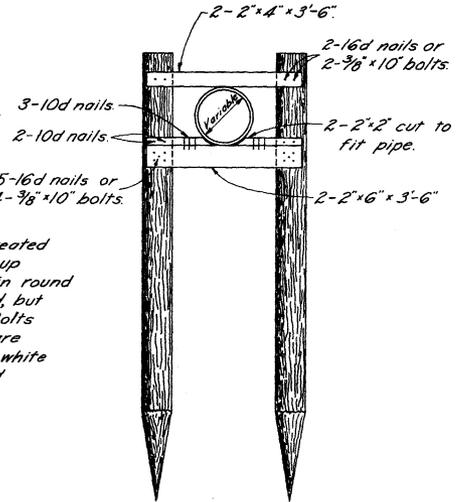


PLAN



SECTION THRU C OF PIPE

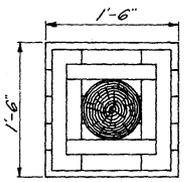
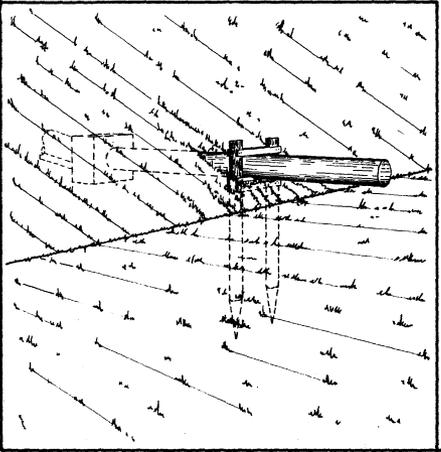
Sheet metal form to be placed inside of pipes for a uniform bend.



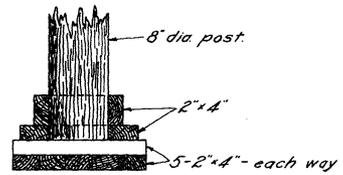
ELEVATION OF BENT

Note: Posts shall be creosote treated 8" dia round or 6" solid or built-up square. Notching required only in round posts. Galvan. nails are preferred, but common nails are satisfactory. Bolts shall be used where the posts are white or ponderosa pine, red or white cedar. Bolts may be substituted for nails with any kind of post.

SCALE - 1/4" = 1'-0" UNLESS SHOWN



PLAN



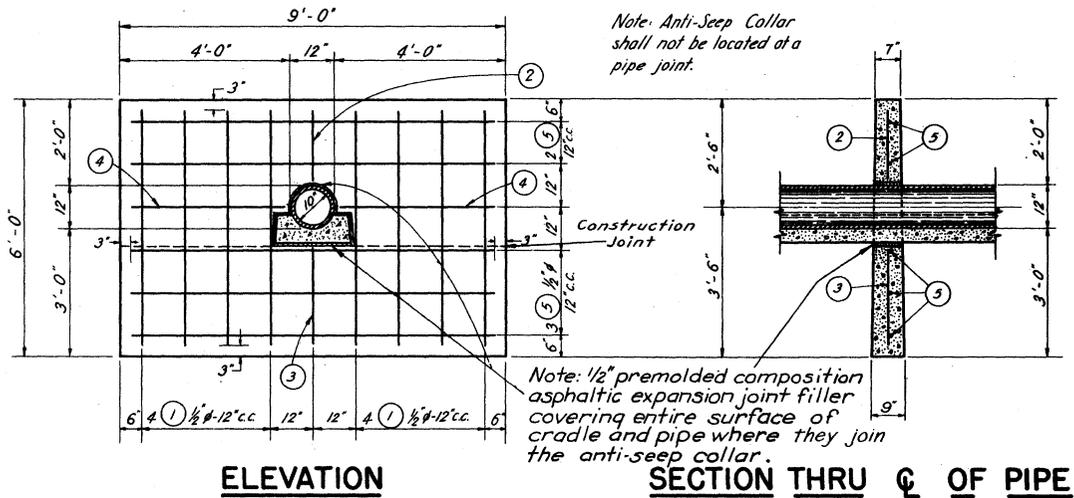
SECTION ON C

ALTERNATE BASE

For excavated footings
SCALE - 1/2" = 1'-0"

TIMBER SUPPORT PROPPED OUTLET FOR 8" TO 15" PIPES			
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
CARTOGRAPHIC APPROVAL <i>R. M. Wood</i>		TECHNICAL APPROVAL <i>Edwin Jaenburger</i>	
DESIGNED <i>A. F. Moratz</i>	DRAWN <i>R. H. H.</i>	CHECKED <i>D. R. Polzin</i>	DATE 2-28-51
DRAWING NUMBER		DRAWING NUMBER	
		3-L-12523	

FIGURE 4.9 TIMBER SUPPORT PROPPED OUTLET FOR 8" TO 15" PIPES



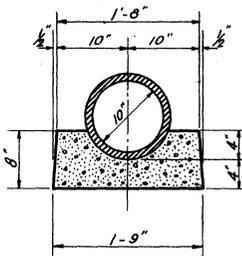
ELEVATION

SECTION THRU ϕ OF PIPE

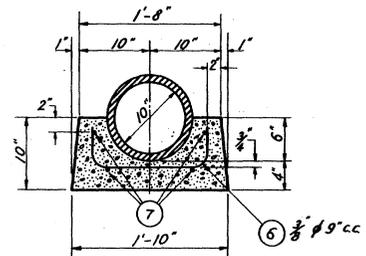
DETAILS OF ANTI-SEEP COLLAR

All Steel $\frac{1}{2}$ " ϕ

Scale : $\frac{1}{4}$ " = 1'-0"



TYPE 2



TYPE 3

CONCRETE CRADLE

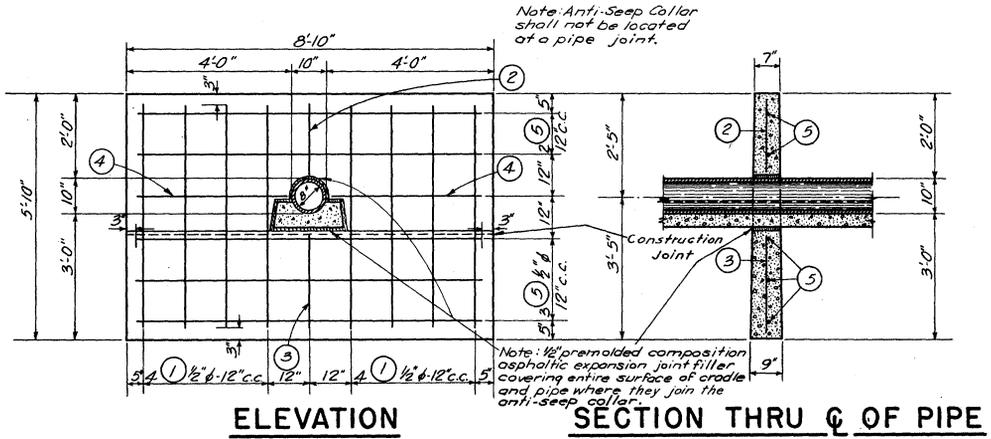
All Steel $\frac{3}{8}$ " ϕ

Scale : $\frac{1}{2}$ " = 1'-0"

Revised 2-28-51

STEEL SCHEDULE							QUANTITIES			CRADLE & ANTI-SEEP COLLAR FOR BARREL OF 10" PIPE DROP INLET	
MARK	QUAN.	SIZE	LENGTH	TYPE	A	B	C	TOT. FT.	VOLUME OF CONCRETE:	REGION 3	REGIONAL OFFICE
1	8	$\frac{1}{2}$ " ϕ	5'-6"	1	-	-	-	44'-0"	ANTI-SEEP COLLAR - EACH 1.35 CU. YDS.	U. S. DEPARTMENT OF AGRICULTURE	
2	1	"	1'-6"	1	-	-	-	1'-6"	TYPE 2 CRADLE - PER LIN. FT. 0.035 CU. YDS.	SOIL CONSERVATION SERVICE	
3	1	"	2'-3"	1	-	-	-	2'-3"	TYPE 3 CRADLE - PER LIN. FT. 0.045 CU. YDS.	TECHNICAL APPROVAL:	
4	2	"	3'-6"	1	-	-	-	7'-0"	STEEL - COLLAR - EACH 64.8 POUNDS	DESIGNED: <i>James M. Wood</i>	
5	5	"	8'-6"	1	-	-	-	42'-6"	STEEL - CRADLE - PER LIN. FT. 2.6 POUNDS	DRAWN: <i>E. J. Lowmuck</i>	
6		$\frac{3}{8}$ " ϕ	2'-3"	2	0'-5 1/2"	1'-4"	0'-5 1/2"			CHECKED: <i>D. R. Polkin</i>	
7		"	20'-0"	1						DATE: 5-22-46	
										DRWG. NO. 3L-12542	

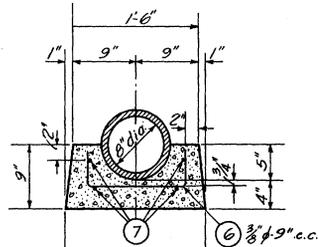
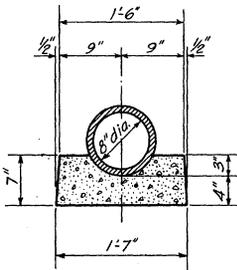
FIGURE 4.10 CRADLE AND ANTI-SEEP COLLAR FOR BARREL OF 10" PIPE DROP INLET



DETAILS OF ANTI-SEEP COLLAR

All Steel $\frac{1}{2}$ " ϕ

Scale : $\frac{1}{4}$ " = 1'-0"



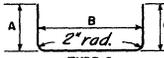
CONCRETE CRADLE

All Steel $\frac{3}{8}$ " ϕ

Scale : $\frac{1}{2}$ " = 1'-0"

STEEL SCHEDULE								
MARK	QUAN	SIZE	LENGTH	TYPE	A	B	C	TOT. FT.
1	8	1/2" ϕ	5'-4"	1	-	-	-	42'-8"
2	1	"	1'-8"	1	-	-	-	1'-8"
3	1	"	2'-3"	1	-	-	-	2'-3"
4	2	"	3'-6"	1	-	-	-	7'-0"
5	5	"	8'-4"	1	-	-	-	41'-8"
6		3/8" ϕ	2'-0"	2	0'-5"	1'-2"	0'-5"	
7		"	20'-0"	1				

QUANTITIES	
VOLUME OF CONCRETE:	
ANTI-SEEP COLLAR-EACH	1.3 CU. YDS.
TYPE 2 CRADLE-PER LIN. FT.	0.03 CU. YDS.
TYPE 3 CRADLE-PER LIN. FT.	0.04 CU. YDS.
STEEL-COLLAR-EACH	63.7 POUNDS
STEEL-CRADLE-PER LIN. FT.	2.4 POUNDS

BAR TYPES	
Straight	TYPE 1
	TYPE 2

CRADLE & ANTI-SEEP COLLAR FOR BARREL OF 8" PIPE DROP INLET				
REGION 3		REGIONAL OFFICE		
U. S. DEPARTMENT OF AGRICULTURE				
SOIL CONSERVATION SERVICE				
CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL:		
<i>N. M. Wood</i>		<i>Edwin Freyburger</i>		
DESIGNED: R.F. Roberts	DRAWN: L.H. Wenkel	CHECKED: A.F.M. & M.C.	DATE: 12-18-45	DRWG. NO. 3-L-12541

Revised 2-28-51

FIGURE 4.11 CRADLE AND ANTI-SEEP COLLAR FOR BARREL OF 8" PIPE DROP INLET

g. All metal pipe shall have watertight joints, bands, and connections in accordance with the manufacturer's recommendations for watertight pipe lines. Concrete or vitrified pipe should be bell and spigot, number one grade, free from cracks or breaks. Joints should be sealed with mortar (three parts sand to one part cement). All concrete should be proportioned 1:2:4 (one part cement, two parts sand, four parts gravel). If a farm source of sand and gravel is used, the material should be clean (not over two percent silty material) and well graded. The presence of silt or clay can be determined by rubbing some of the sand in the hands. If stains, which feel smooth or silky, appear on the hand, it is likely that too much silt or clay is present. The concrete should be mixed as dry as possible, using not more than $5\frac{1}{2}$ gallons of water per bag of cement. Where the plan calls for reinforcing steel, do not permit the substitution of old water pipe, wire, or other metal material. Reinforcing steel, and reinforcing steel only, must be used. Reinforced concrete designs, especially the "thin wall sections" used in pipe drop inlet structures, are based on the steel having reinforcing steel characteristics and require that the steel be placed reasonably accurately, as shown on the drawings. Where it is not possible to get the diameter steel called for in the drawings, it is possible to use slightly smaller or slightly larger diameters. In this case, however, it is necessary that an engineer revise the spacing of the bars.

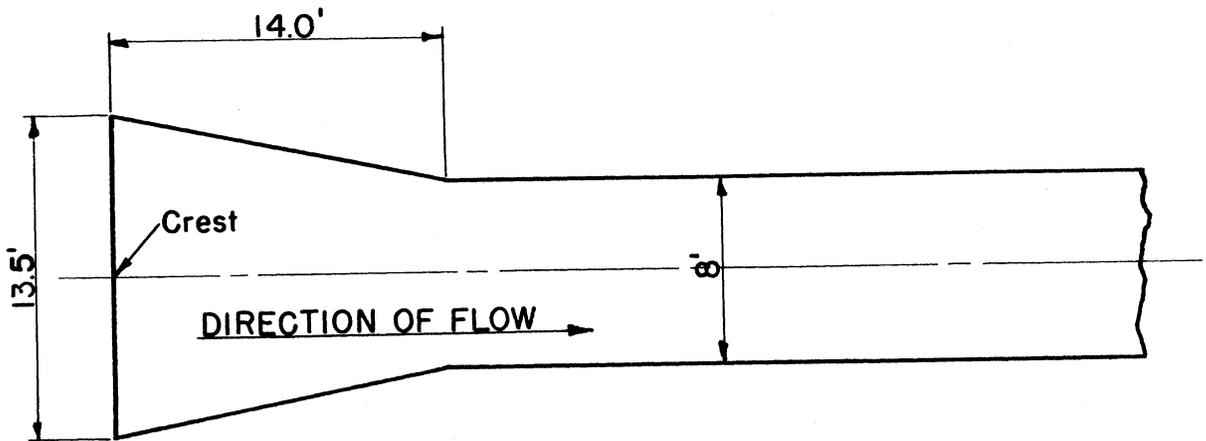
4.43 Vegetative Spillway

a. From procedures outlined in Part 3 determine the required amount of runoff, using a 10-year frequency rain (see Figure 3.1, page 3-2). Then design the vegetative outlet according to instructions in Part 10, Vegetated Outlets and Watercourses, to carry this amount of runoff. The addition of a trickle tube is usually desirable as it eliminates small flows which might damage the sod. Use a slope of not less than 0.5% as the minimum grade of the outlet and a value of not less than 8 feet for the minimum width. The depth of flow should not exceed nine inches at the crest of the vegetative spillway (three inches if the pond is to be used for fish production). Consideration should also be given to entrance width of the sod spillway for good flow conditions. The proper width of the entrance can be determined by using the formula $Q = 2.75 L h^{3/2}$ or written another way $L = Q$ divided by $2.75 h^{3/2}$, where L is the entrance width of the channel and h is the assumed depth of flow at the entrance to the channel. Simplifying the formula given above:

For entrance flow 0.75' deep, $L = 0.56Q$
 For entrance flow 0.50' deep, $L = 1.03Q$
 For entrance flow 0.25' deep, $L = 2.92Q$

If the calculated width at the crest of the vegetative spillway is greater than the width of the channel below, then the rate of convergence should not be greater than 0.4 foot per foot of length as measured along the centerline of the channel. See example in Figure 4.12 (page 4-18).

SPILLWAY WIDTH REDUCTION



$$13.5' - 8' = 5.5' \quad \frac{5.5'}{0.4} = 13.75 \text{ or } 14' = \text{length of spillway}$$

required to accomplish the desired reduction in width

FIGURE 4.12 VEGETATIVE SPILLWAY ENTRANCE

4.44 Fill

- a. The top width of the fill is generally governed by the construction equipment used. For small farm tractors a minimum width of 6 feet is permissible. Ordinary earth moving equipment will require an 8-foot top. If it is to be used as a roadway, this should be increased to at least 12 feet.
- b. Side slopes of the fill should not be less than 3:1 (three feet horizontal to one foot vertical) on the pond side, and not less than 2:1 on the opposite side.

4.45 Freeboard

- a. A minimum of 2 feet of freeboard should be allowed between the crest of the vegetative spillway and the top of the fill.

4.46 Water Supply Pipe

- a. A water supply pipe with a minimum diameter of $1\frac{1}{4}$ " should be used. A smaller pipe tends to clog.
- b. Some form of filter should be used on the upper end of the supply pipe.
- c. A method of draining the pipe below the shut-off valve on the fill should be provided to prevent freezing.
- d. Where the pond is to be stocked with fish it may be advisable to increase the size of pipe to allow for draining the pond.

4.47 Record of Design

a. Fill in all pertinent information and calculations in duplicate on the farm pond data sheet, Figure 4.13, page 4-20. One copy is for the cooperator and the other is filed with the office copy of the farm conservation plan.

4.50 STAKING

4.51 Fill

a. Stake the centerline of the fill and core trench. In most cases this will be the same centerline. Place top width stakes at each end of fill with reference stakes beyond the disturbed area.

b. Set toe of fill stakes (see Part 1.52).

4.52 Vegetative Spillway

a. If a natural spillway is available, it should be used. Where this is not the case, centerline and cut stakes should be set for constructing the spillway.

4.53 Mechanical Spillway

a. Set centerline and grade stakes for the tube; set location and elevation stakes for the inlet and outlet, and location stakes for the anti-seep collars.

4.54 Water Supply Pipe

a. Set alignment stakes for supply pipe and location, and elevation stakes for the inlet and filter. Set stakes for location of anti-seep collars, spacing them as shown on the Farm Pond data sheet (Figure 4.13). These will be 16 to 20 feet apart.

4.60 CONSTRUCTION

4.61 Clearing Fill Site, Pond, and Borrow Areas

a. Clear all trees, shrubs, and other obstructions from the pond area. Also remove all trees, stumps, other vegetation, and highly organic soil from the fill and borrow areas, placing it where it will not interfere with equipment operation. This latter material should be used as a top dressing to complete the fill and assist in establishing vegetation.

4.62 Core

a. Excavate the core trench to a minimum depth of three feet and a minimum bottom width of four feet, or to the more impervious material underlying the base of the dam. Excavate the core trench along the centerline extending the full length of the dam.

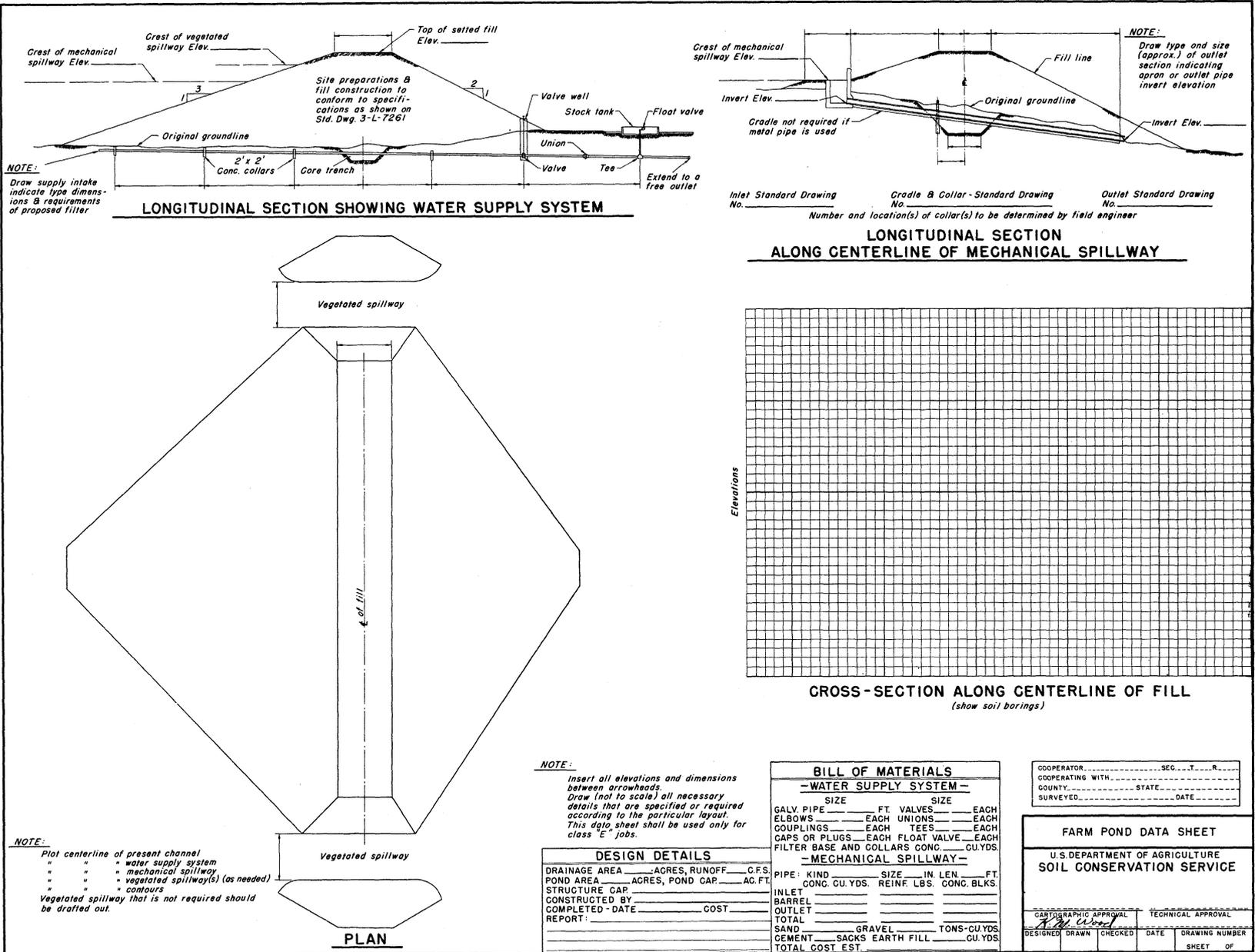


FIGURE 4.13 FARM POND DATA SHEET

DESIGN DETAILS

DRAINAGE AREA _____ ACRES, RUNOFF _____ C.F.S.
 POND AREA _____ ACRES, POND CAP _____ AC.FT.
 STRUCTURE CAP _____
 CONSTRUCTED BY _____
 COMPLETED DATE _____ COST _____
 REPORT: _____

BILL OF MATERIALS
 - WATER SUPPLY SYSTEM -

SIZE	SIZE
GALV PIPE _____ FT.	VALVES _____ EACH
ELBOWS _____ EACH	UNIONS _____ EACH
COUPLINGS _____ EACH	TEES _____ EACH
GAPS OR PLUGS _____ EACH	FLOAT VALVE _____ EACH
FILTER BASE AND COLLARS CONC. _____ CU.YDS.	

- MECHANICAL SPILLWAY -

PIPE: KIND	SIZE	IN	LEN	FT.
CONC.	CU.YDS.	REINF.	LB.S.	CONC. BLKS.
INLET	_____	_____	_____	_____
BARREL	_____	_____	_____	_____
OUTLET	_____	_____	_____	_____
TOTAL	_____	_____	_____	_____
SAND _____	GRAVEL _____	TONS-CU.YDS.	_____	_____
CEMENT _____	SACKS	EARTH FILL _____	CU.YDS.	_____
TOTAL COST EST. _____				

OPERATOR _____ SEC. _____ T. _____ R. _____
 COOPERATING WITH _____ STATE _____
 SURVEYED _____ DATE _____

FARM POND DATA SHEET

U.S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
DESIGNED	DRAWN	CHECKED	DATE
DRAWING NUMBER		SHEET OF	

ORDER THIS BLANK DATA SHEET BY DRAWING NUMBER 3-N-12248

Be sure the side walls of the core trench are cut to slope no steeper than 1:1 to insure adequate bond with the foundation material. The core trench should be backfilled with the most impervious material available.

4.63 Mechanical Spillway and Water Supply Pipe

a. An inspection to insure proper construction should be made during the time that the mechanical spillway and the water supply pipe are being installed.

b. The water supply pipe should not be laid until the core trench is backfilled to the elevation of the pipe. It is important that the soil surrounding the entire length of the pipe and the anti-seep collars be well compacted with impervious material. The anti-seep collars should be plain concrete, 2 feet by 2 feet, and 4 to 6 inches thick.

c. The mechanical spillway should be constructed on undisturbed soil. Extreme care should be exercised in cradling in accordance with the details found on Figures 4.10 or 4.11. All joints must be completely watertight and the soil carefully backfilled and compacted along the entire length of the pipe, around the anti-seep collars and around the inlet and outlet.

d. A trash rack around the mechanical spillway must be constructed by setting four posts spaced eight feet apart about the axis of the inlet, on which woven wire is placed. The lower edge of the wire should be at least six inches below the normal water level and extend in height to the crest of the emergency spillway. See Figure 4.5 for details.

4.64 Fill

a. The most impervious fill material should be used in the core, the next best on the pond side of the fill, and the least impervious on the lower side of the fill. Fill material should be laid in thin, even layers, not over eight inches thick. Each lift shall extend over the full width of the dam. If a bulldozer is used to build the fill, frequent trips should be made lengthwise of the fill to even off the material and aid in compaction. Frozen material shall not be used nor shall the fill be placed on a frozen foundation. Do not use dry material. The moisture content of the fill material should be such that when it is kneaded in the hand it will just form a ball which does not readily separate. Further information on fill material is given in paragraph 4.22 e.

b. After the fill has been built to required height add an additional 5% of the height for settlement. The fill should be covered with the top soil removed in the scalping operation in Paragraph 4.61.

c. All of the fill except the upstream part below the water line should be limed if necessary, fertilized, seeded with a good grass mixture, and mulched with manure or straw. The borrow areas above the water line should be leveled and receive the same treatment.

d. The pond, fill, and a reasonable area adjacent should be fenced to exclude livestock. An entrance should be provided for mowing of the fill and other maintenance operations.

4.65 Planting

*a. The pond area should be planted with appropriate shrubs and trees. Wildlife packets may be used.

4.70 MAINTENANCE

4.71 Fill and Vegetative Area

a. The fill, the vegetative spillway, and, if possible, a strip 20 feet wide around the pond should be kept free from rank vegetation. Maintenance applications of lime, fertilizer, and seed should be made as needed to maintain a good vigorous sod.

b. Encourage the farmer to inspect the fill frequently and repair any rodent or erosion damage. If signs of excessive seepage are discovered the engineer should be consulted for recommendations.

4.72 Other Maintenance Requirements

a. Keep mechanical spillway and trash rack free from debris.

b. Replace dead trees or shrubs around the pond area with new planting stock.

c. Inspect and keep fence in repair.

**d. If pond is stocked, fish pond heavily.

e. Keep all trees and shrubs off the earth fill and remove any woody growth that takes root.

References:

*Biology Handbook and appropriate job sheets.

**Biology Handbook.

PART 5

SPRINGS* AND HYDRAULIC RAMS

5.10 GENERAL SPRINGS

5.11 Definition and Types of Springs

- a. Springs are places where, without the aid of man, water flows from rock or sand onto the land or into a body of surface water.
- b. That portion of precipitation which percolates into the ground is called ground water. Ground water may be divided into two zones - saturated and unsaturated. The surface of the saturated zone is known as the water table. Ground water in the unsaturated zone moves downward with a pull of gravity, but water in the saturated zone moves horizontally and down gradient with the water table. An outcrop of the saturated zone produces a spring.
- c. Different types of springs are illustrated in Figure 5.1. (See page 5-2.)

5.12 Dependability

- a. The perched or contact spring is frequently the least dependable because of limited storage that may be available, and the artesian type usually affords the most dependable supply. However, this does not always hold true. The dependability of springs is difficult to estimate because of the many variables that affect the source of supply. The type of spring, conditions found after an exploratory excavation, and local information as to the past behavior of the spring are all factors that should be considered. Sound judgment must be used to eliminate the expensive development of springs that may soon go dry. Where possible, the flow of springs should be measured to determine how nearly it will meet stock water or other requirements.

5.20 DEVELOPING A SPRING

5.21 Perched Depression Spring

- a. In the development of this type of spring it is often necessary to provide a means of picking up or collecting water from several outcrops and leading it to one central point of concentration to provide an adequate supply (Figure 5.2, page 5-3). This is especially true in developing hillside springs. The collection trench or gallery is usually dug just above the line of seepage and excavated to a depth that will intercept the

*Adapted from material given in Engineering Handbook, USDA-SCS, Region V.

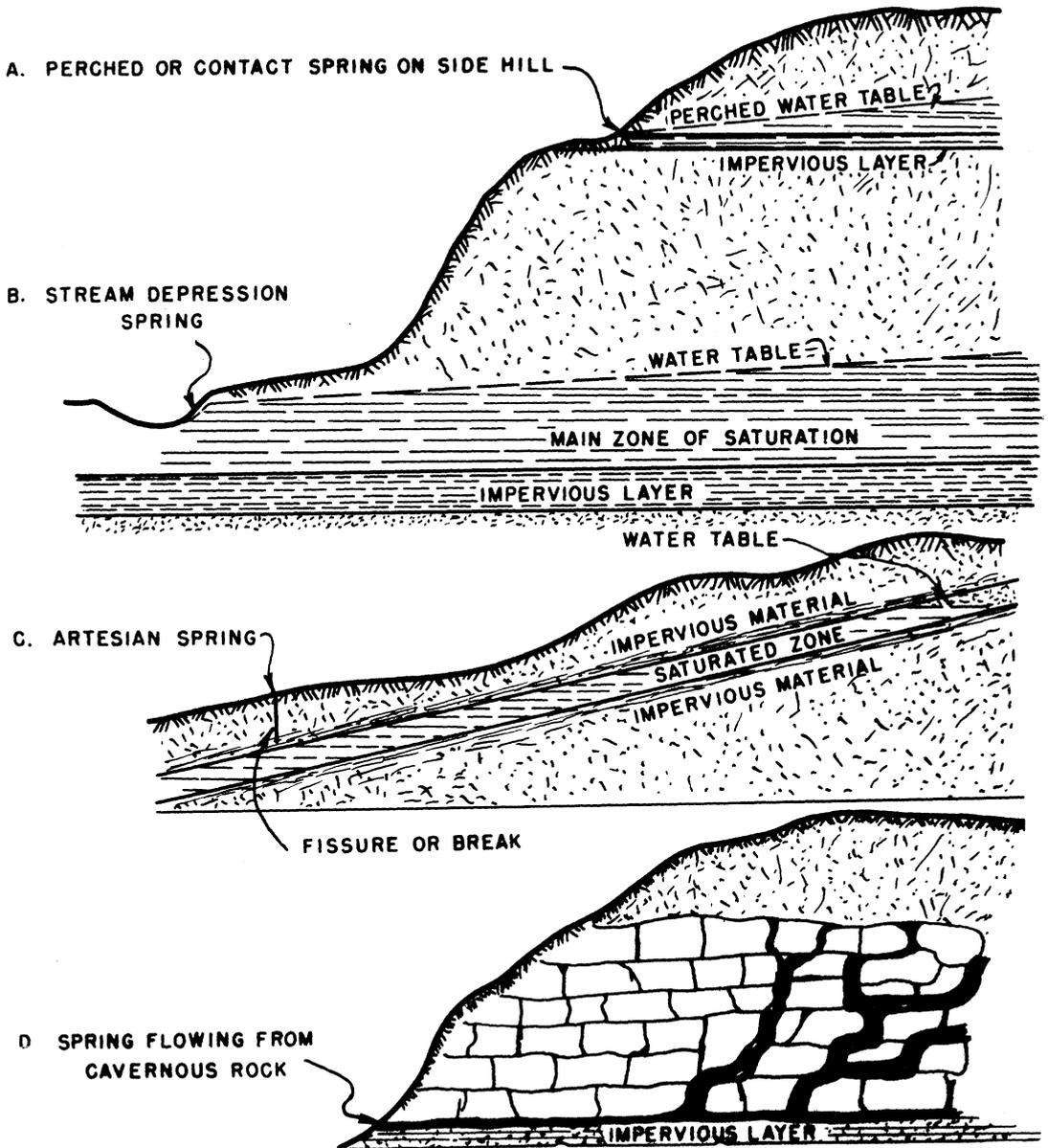


FIGURE 5.1 TYPICAL TYPES OF SPRINGS

water-bearing strata. In some cases it may be necessary to follow the sand veins into the bank a short distance to remove any obstructions so a sufficient flow is obtained. The trench is usually excavated about two feet wide to receive the collectors and for ease of digging.

b. The collector may consist of clay tile or perforated pipe laid in graded gravel and sand, or it may be simply a trench filled with graded gravel and sand. In the construction of the collector it is good practice to tamp impervious clay in the downstream side of the trench, as illustrated in the "Collector Detail" in Figure 5.2. The clay core is tied in with the impervious material below to intercept the water and cause it to flow

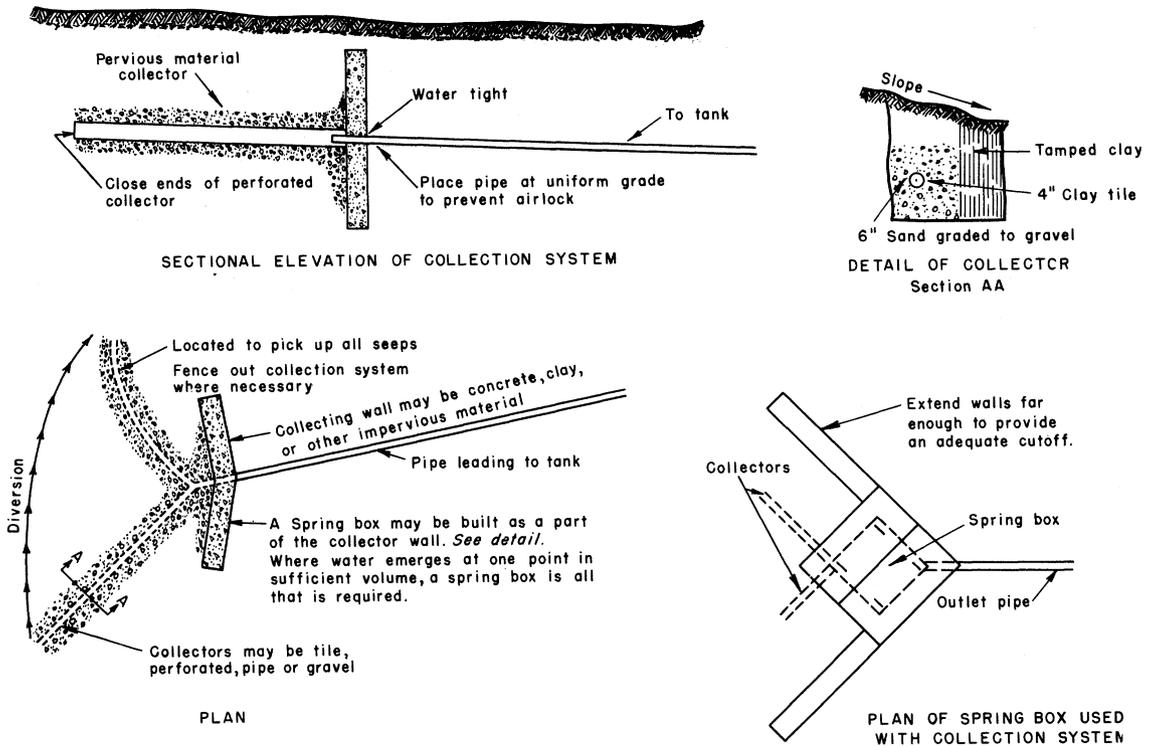


FIGURE 5.2 SPRING COLLECTION SYSTEM

laterally to the point of collection. Under some conditions sand points may be driven into the saturated vein to serve as collectors.

c. The head wall or cut-off is usually constructed in the shape of a large V with the apex at the lower side and the wall extending back into the banks to prevent the water from going around the ends (Figure 5.2). The wall should be at least six inches thick if concrete is used, and should be carried deep enough to prevent underflow. Rubble masonry, clay, or other impervious materials may also be used. Rock and graded gravel should be placed above the cut-off wall to collect what silt may be deposited and to direct the flow into the outlet pipe.

d. A spring box may be incorporated in the apex of the V-shaped wall. It has the advantage of making the spring more accessible, permitting maintenance without disturbing the system as a whole.

5.22 Artesian Spring

a. This is usually developed by enlarging the mouth by removing obstruction. The flow can then be collected by one of the various systems illustrated in Figures 5.2 and Figure 5.3 on page 5-4.

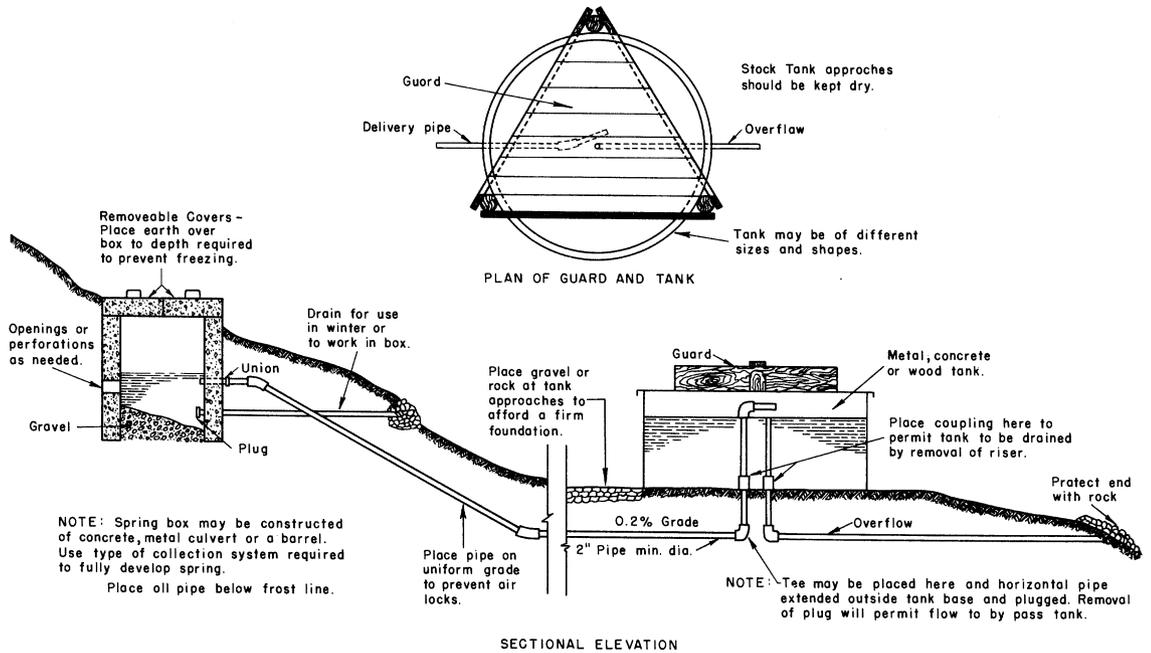


FIGURE 5.3 SPRING BOX AND PIPE ARRANGEMENT

5.23 Spring Flowing From Cavernous Rock

a. This type of spring is generally developed by constructing a spring box around the seep or opening in the rock where the water outcrops.

5.24 Spring Boxes

a. In the event that the spring box is used with a collector system, the upper wall should have openings or be constructed of some porous material so that all the water collected by the galleries can enter the box. Spring boxes for springs not requiring a collector system may or may not have a porous upper wall, depending upon the spring. In the case of springs coming out of a rock ledge, the sides of the spring box are frequently tied into the rock wall which serves as the upper side of the box.

b. Spring boxes may be constructed of monolithic or pre-cast concrete. Metal culvert sections or oil barrels may also be used. Wood spring boxes are not generally recommended, as their life is short. All spring boxes must be covered with a tight-fitting top to prevent any dirt or debris from getting inside. In case the spring is used for domestic water supply, the cover must be water-tight and the spring protected against any possible source of contamination. In cold weather the spring box and appurtenances should be covered with earth to a depth that will prevent freezing.

5.25 Delivery Pipes

a. An important part of the spring development is the arrangement of the delivery and overflow pipe layout (Figure 5.3).

Experience indicates that a minimum pipe diameter of $1\frac{1}{4}$ inches should be used where the grade is over one percent. Where the grade is between 0.5 percent and one percent, a $1\frac{1}{2}$ -inch minimum is recommended. Grades under 0.5 percent require a 2-inch minimum pipe. Grades less than 0.2 percent are not recommended. When pipe sizes smaller than those recommended are used, there is a tendency for them to become clogged with foreign matter, and they are difficult to clean.

b. The pipe should be laid carefully on a continuous uniform grade. Sags or high spots usually create air locks which may stop the flow. They also reduce the velocity of flow. Pipes should be laid below the frost line and covered to prevent freezing.

c. The pipe leaving the spring box should be placed at least six inches above the floor to provide a silt trap. A water-tight connection must be made where the pipe leaves the spring box or goes through a cut-off wall. A union should be placed on the pipe outside of the wall to permit easy removal of pipe sections.

d. Wherever possible, the outlet pipe should be placed at such an elevation that a head of water is not created on the spring. An increase in head will result in a corresponding decrease in the rate of flow, and in the case of a weak spring, may cause the seeps to change their path of flow.

e. The pipe connection with the water tank may be accomplished in a number of ways. The practice of bringing the pipe under the tank and vertically through the bottom is usually considered the most desirable where the tank is to be used during freezing weather. It has also been found beneficial to have the inlet and outlet pipes fairly close together, near the center of the tank. Even though the water freezes around the edge of the tank, it will tend to stay open at the center. Figure 5.3 illustrates a good method of bringing the delivery pipe into the tank as well as a method of bypassing the flow underneath the tank.

5.26 Protection

a. Springs frequently occur at points that are susceptible to flooding during periods of high run-off. Protection should be afforded to the spring and its appurtenant structures to permit use without continual maintenance. Diversions properly located will afford protection in many instances. The spring itself may be developed so that flood flows passing over the top will not cause damage. The tank should be set above the flood water level at a protected point by using a long delivery pipe placed at proper grade.

5.30 GENERAL, HYDRAULIC RAMS

5.31 Definition

a. The hydraulic ram is a simple mechanical device, automatic in operation, for raising water by water power.

b. The ram is suitable for supplying water for stock watering purposes and to meet other water supply needs about the farm.

It is to be noted that the ordinary hydraulic ram actually delivers only a small amount of the total water available from its supply.

c. It is not intended here to give sufficient information to enable one to work out all the design details of a particular site, but rather to arrive at the possibilities of using the hydraulic ram. Manufacturers of rams have information available on their respective products which will enable a definite choice of size of ram and price to be paid.

5.40 OPERATION

5.41 How the Hydraulic Ram Works (See Figure 5.4 and 5.5, page 5-7)

Briefly, this is how a hydraulic ram works. Water from the supply flows down the drive pipe to the ram, thus developing a certain power due to its weight and movement. It flows through the outside valve of the ram until it reaches a certain velocity, whereupon the valve closes. The column of water continues on through the inside valve into the air chamber. When the pressure in the air chamber equalizes and overcomes the power in the column of water a re-bounce takes place which closes the inside valve and opens the outside valve, allowing the water to start flowing again and the entire process is repeated. It is repeated from 25 to 100 times per minute, building up pressure in the air chamber, which in turn forces water through the delivery pipe to the place where it can be used.

5.50 DESIGN

5.51 Information Required

When the water supply is limited, a ram must be selected which will operate with the minimum quantity of water available; where there is an abundant water supply the size is governed by the quantity of water needed per day.

In deciding what size ram to use the following information must be obtained:

- (1) The number of gallons per minute which the spring, artesian well, or stream will deliver.

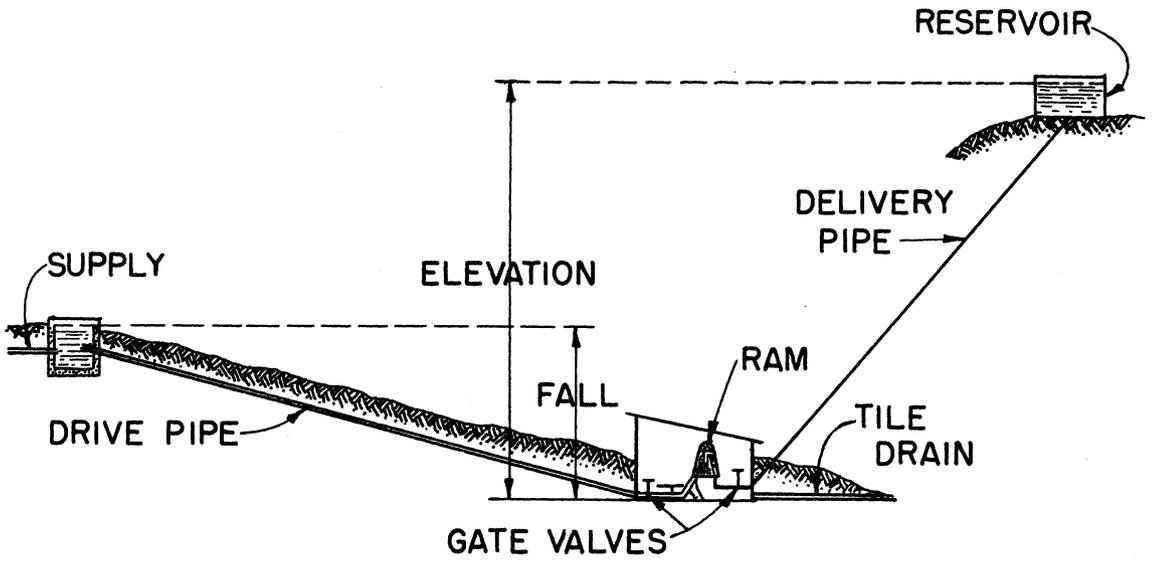


FIGURE 5.4 SKETCH OF TYPICAL RAM INSTALLATION

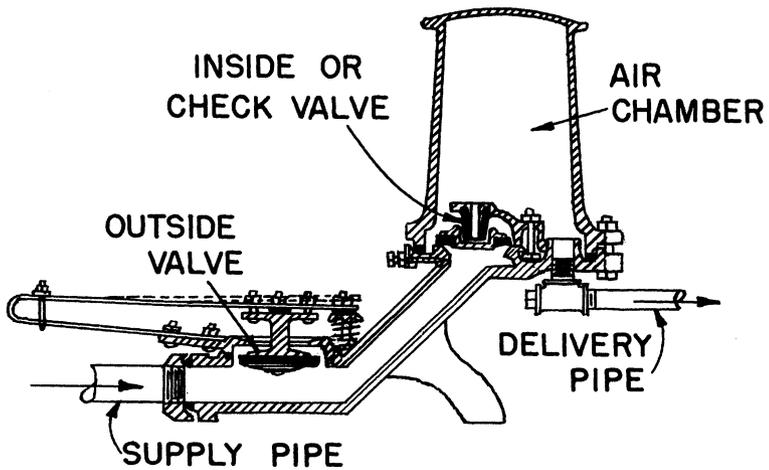


FIGURE 5.5 DIAGRAMMATIC SKETCH OF RAM

- (2) Number of gallons per 24-hour day desired from the ram.
- (3) Available fall in feet from the source of water to the ram.
- (4) Elevation to which water is to be raised above the ram.
- (5) Pipe line distance from ram to point of discharge.
- (6) Pipe line distance from the source of water to the ram.

This information will also be required by the company from whom the ram is purchased.

5.52 Determining Size of Rams

A formula for calculating the number of gallons of water delivered per hour to a given point is as follows:

$$D = \frac{V \times F \times 40}{E}$$

D = gallons per hour that the ram will deliver.

V = gallons per minute of supply water available.

F = fall in feet.

E = vertical elevation in feet that water is to be raised.

Similar information can be obtained by referring to the following table:

***GALLONS OF WATER LIFTED BY HYDRAULIC RAM PER GALLON RECEIVED FROM SOURCE**

Fall in Feet	Height Delivered (in feet)							
	12	18	24	30	36	48	60	72
2	0.1							
4	0.18	0.15	0.1					
6	0.33	0.2	0.17	0.13	0.1			
8	0.42	0.28	0.2	0.17	0.15	0.1		
10	0.54	0.36	0.27	0.22	0.18	0.14	0.1	
12	0.67	0.44	0.33	0.26	0.22	0.16	0.13	0.1

*From Farmers' Bulletin No. 1978 Safe Water For the Farm.

5.53 Length of Drive Pipe

The length of drive pipe to be used should be in direct relation to the vertical elevation. It is equal to the vertical elevation plus enough to overcome friction loss in the delivery pipe. For a good approximation use the vertical elevation plus 10% to 20% (to allow for this friction loss).

References:

- Rife Ram & Pump Works, Wayneboro, Virginia
- Gould Pump, Inc., Seneca Falls, New York
- Deming Co., Salem, Ohio
- Farmers' Bulletin No. 1978, Safe Water for the Farm

PART 6

WELLS*

6.10 GENERAL

6.11 Types of Wells

There are three general types of wells - dug, driven, and drilled. The method used in constructing a well depends largely on the depth to which it must be carried, the elevation of the ground water table, and the nature of the material encountered in the hole.

a. Dug wells are constructed by digging down to water-bearing strata. The open excavation is usually circular in shape and from three to five feet in diameter. Before modern well drilling equipment was available, the dug well had extensive use. However, under present-day methods, driven or drilled wells are in most cases far more satisfactory and economical.

b. A driven well is only adapted to relatively shallow depths. In sandy soils, wells have been driven to depths up to 60 feet. The three most common methods employed in sinking the well are:

(1) Attaching a sandpoint to the end of a pipe and driving it to the required depth.

(2) Forcing the pipe down by removal of material with a sandbucket or pump.

(3) By jetting the material away from the end of the pipe to permit it to penetrate to the desired depth.

c. A drilled well is suited to any type of material or depths. It is constructed by standard equipment which consists essentially of a derrick, a power plant, and special tools.

This type of well must be constructed by an experienced person who has the necessary equipment.

6.20 CONSTRUCTION OF WELL

6.21 Factors or Information to be Considered in Locating a Well

a. Locate the well so the natural drainage from barns, chicken houses, hog pens, feed lots, toilets, etc. are away from the well, never toward it, to eliminate danger of contamination.

b. Locate the well above floodwater elevation.

*Adapted from material given in Engineering Handbook, USDA - SCS, Region 5.

- c. If feasible, locate the well as near the point of use as possible. Windmill must be built so it will be 15 feet above all obstructions within 400 feet.
- d. Investigate existing supplies in proximity to well site as regards depth of hole, quality and quantity of water, and pumping head.
- e. Obtain information from local well drillers about wells drilled in the community.
- f. The following State offices are prepared to give information on ground water:

Illinois - Chief, State Geological Survey Division, Urbana

Indiana - Head of Ground Water Resources, Division of Water Resources, Indiana Department of Conservation, Indianapolis

Iowa - Director and State Geologist, Iowa City

Michigan - Geological Survey, Department of Conservation, Lansing

Minnesota - Division of Water Resources, St. Paul

Missouri - State Geologist, Rolla

Ohio - Chief Engineer, Ohio Resources Board, Columbus

Wisconsin - State Geologist, Madison

6.22 Casing

- a. The diameter of the well or casing is governed by the quantity of water required and by local custom. The exact size of the casing will be determined by conditions existing at the site.
- b. Practically all wells in this Region are cased the entire depth. The only exception is where the water-bearing stratum is composed of rock overlain with unconsolidated material. Under such circumstances the casing need only be extended to the rock and sealed.
- c. In most cases new casing should be used as the life of the well is dependent on the life of the casing. Second-hand casing is only used when the quality is equivalent to that of new pipe. The casing may be galvanized steel pipe or made of black iron. Second-hand pipe previously used in connection with gas or oil developments is not satisfactory, regardless of the condition of the metal itself. Such pipe may taint the water to a degree that it is not usable. Pertinent data in weights and diameter of types of pipe used for well casing is given in the following table:

WEIGHTS AND DIMENSIONS OF PIPE AND CASING						
Size	Diameters		Thick-ness	Weight Per Foot		Threads Per Inch
	External	Internal		Plain Ends	Threads & Couplings	
Standard Pipe - Black and Galvanized						
3/4	1.050	.824	.113	1.130	1.134	14
1	1.315	1.049	.133	1.678	1.684	11 $\frac{1}{2}$
1-1/4	1.660	1.380	.140	2.272	2.281	11 $\frac{1}{2}$
1-1/2	1.900	1.610	.145	2.717	2.731	11 $\frac{1}{2}$
2	2.375	2.067	.154	3.652	3.678	11 $\frac{1}{2}$
2-1/2	2.875	2.469	.203	5.793	5.819	8
3	3.500	3.068	.216	7.575	7.616	8
3-1/2	4.000	3.548	.226	9.109	9.202	8
4	4.500	4.026	.237	10.790	10.889	8
4-1/2	5.000	4.506	.247	12.538	12.642	8
Standard Black Well Casing						
2	2.250	2.050	.100	2.296	2.340	14
2-1/4	2.500	2.284	.108	2.759	2.820	14
2-1/2	2.750	2.524	.113	3.182	3.250	14
2-3/4	3.000	2.768	.116	3.572	3.650	14
3	3.250	3.010	.120	4.011	4.100	14
3-1/4	3.500	3.250	.125	4.505	4.600	14
3-1/2	3.750	3.492	.129	4.988	5.100	14
3-3/4	4.000	3.732	.134	5.532	5.650	14
4	4.250	3.974	.138	6.060	6.200	14
4-1/4	4.500	4.216	.142	6.609	6.750	14
4-1/2	4.750	4.460	.145	7.131	7.250	14

6.23 Well Cover

The top of the well should be sealed by means of a concrete slab (Figure 6.1, page 6-4). The slab is made large enough to serve as a base for the pumping equipment. The casing should extend about 12 inches above the normal ground surface and should make a watertight connection with the base which is usually made about six inches thick.

6.24 Drop Pipe

All drop pipe should be standard galvanized pipe. It is advisable to use a drop pipe having an internal diameter larger than that of the cylinder or working barrel to permit removal of the valves for repair without pulling the drop pipe. The drop pipe should extend far enough into or below the water-bearing strata to permit the well to be pumped continuously at capacity without danger of exposing the suction.

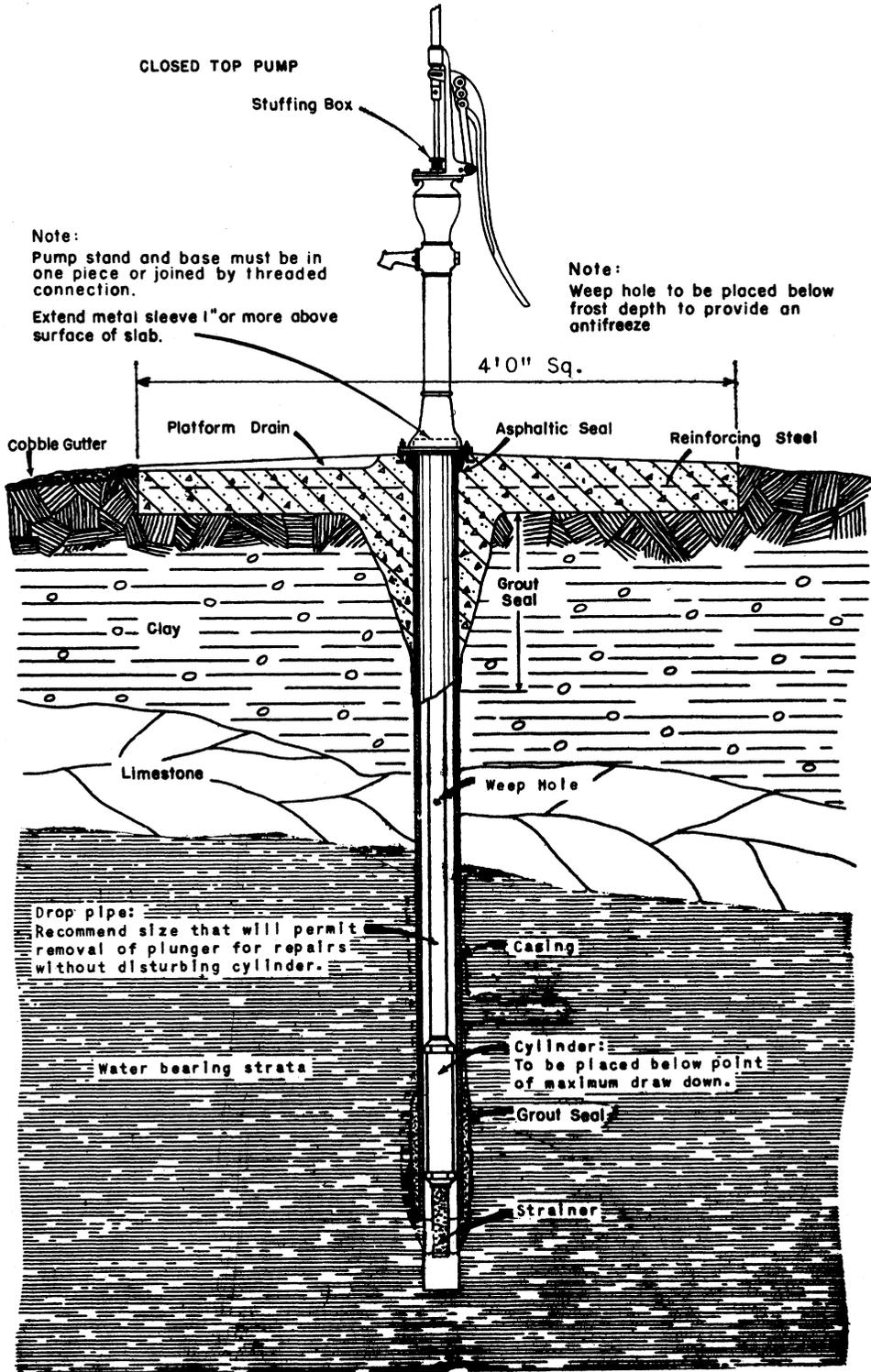


FIGURE 6.1 DRILLED WELL AND PUMP INSTALLATION

6.25 Cylinder

The size of the cylinder is determined by the diameter of the well, pumping rate, well depth, and size of wheel if a windmill is used. It is good policy to design the pumping unit to produce from two to three times the total daily requirements in 24 hours, particularly when wind is used as a source of power. Always select a cylinder having a capacity somewhat less than that of the well to permit continuous pumping without danger of lowering the water to the point where the suction is exposed. The two following tables can be used as a guide in selecting the size of cylinder for any particular well. When a hand pump is used, it is desirable to install as small a cylinder as possible, because the larger the cylinder the more power is required to operate the pump.

LARGEST SIZE CYLINDER THAT MAY BE USED IN VARIOUS SIZED WELL CASING

Size of Casing (Inches)	Largest Size of Cylinder and Type	
2	1-3/8"	Brass Body Flush Cap Cylinder
2-1/2	1-7/8"	Brass Body Flush Cap Cylinder
3	2-1/2"	Brass Body Flush Cap Cylinder
3-1/2	2-1/4"	Brass Lined Cylinder OR 3" Brass Body Flush Cap Cylinder
4	2-1/2"	Iron or Brass Lined Cylinder, 3-1/2" Brass Body Flush Cap Cylinder
4-1/2	3"	Iron or Brass Lined Cylinder, 4" Brass Body Flush Cap Cylinder

SIZES OF CYLINDER ADAPTED FOR DIFFERENT PUMPS ACCORDING TO DEPTH OF WELL

	Depth of Well - Feet						
	25	50	75	100	125	150	200
	Size of Cylinder - Inches						
1. Light hand top lift pump	3	2	-	-	-	-	-
2. Medium hand top lift pump	3 $\frac{1}{4}$	3	-	-	-	-	-
3. Heavy hand top lift pump	4	3 $\frac{1}{2}$	3 $\frac{1}{4}$	3	2 $\frac{1}{2}$	-	-
4. Light windmill top lift pump	3	2 $\frac{1}{2}$	-	-	-	-	-
5. Medium windmill top lift pump	3 $\frac{1}{2}$	3 $\frac{1}{4}$	3	2 $\frac{1}{2}$	2	-	-
6. Heavy windmill top lift pump	4	3 $\frac{1}{2}$	3 $\frac{1}{4}$	3	2 $\frac{1}{2}$	2 $\frac{1}{4}$	2

6.30 SELECTION OF PUMPS*

6.31 General

In selecting a pump consideration must be given to the capacity, location of the well, and type of power available. The four most common types of pumps are the plunger, centrifugal, turbine, and ejector pumps.

6.32 Plunger Type Pump

This type of pump is adapted to practically any depth of well and at depths exceeding 65 feet it is likely to be the most efficient type. It is positive in action and of relatively simple construction; and it is suitable for hand, windmill, or any other type of power operations. However, this type of pump must be set directly over the well, which may be objectionable, and it is subject to vibration and sometimes noisy.

6.33 Centrifugal Type Pump

Centrifugal pumps are efficient in the higher capacities but for small capacities 10 gallons per minute or less, their efficiency is not so high as that of the plunger pumps. It is usually not practical to adapt them to jobs requiring these small volumes of water. They are at their best when pumping for irrigation, city water systems, and other large volumes.

6.34 Turbine Type Pumps

Turbine pumps, as used in domestic water systems, are self-priming. Their smooth operation makes them suitable for installing where noise and vibration must be kept to a minimum. This type of pump requires a well of relatively large bore.

6.35 Ejector Pumps

Ejector pumps are of simple construction, quiet operation, and suitable either for deep or shallow wells. They are most efficient when the lift is between 25 to 65 feet, but it will operate with lifts of 120 feet. However, they are not usually recommended for wells where the depth to water is more than 85 feet. The pump need not be set directly over the well and it is especially suitable for use with pressure systems.

6.40 POWER REQUIREMENTS

6.41 Electric or Gasoline Engine

The following table gives the approximate H.P. required to pump a given quantity of water under a given head by electricity. Always select a motor that is overpowered. The capacity is based on 40 strokes per minute. To find the capacity of any size cylinder with less than 40 strokes per minute, deduct $1/40$ part of the capacity given for each stroke less than 40 strokes per minute.

*Adapted from Farmers' Bulletin 1978 "Safe Water For The Farm."

**CAPACITY OF DIFFERENT SIZED CYLINDERS AND HORSE POWER REQUIRED FOR
DIFFERENT TOTAL HEADS - SINGLE ACTING PUMP
(Assumed Efficiency Factor 0.33-1/3)**

Size Cylinder Inches	Length Stroke Inches	Stroke Per Minute	Gallons Per Hour	Horse Power Required for Total Head							
				25'	50'	75'	100'	125'	150'	200'	400'
2	6	40	196	.065	.13	.20	.25	.32	.38	.50	1.00
2	8	40	261	.08	.16	.24	.32	.40	.48	.64	1.28
2	10	40	326	.10	.20	.30	.40	.50	.60	.80	1.60
2-1/4	6	40	247	.075	.15	.23	.30	.38	.45	.60	1.20
2-1/4	8	40	330	.10	.20	.30	.40	.50	.60	.80	1.60
2-1/4	10	40	413	.13	.26	.39	.52	.65	.78	1.04	2.08
2-1/2	6	40	306	.095	.19	.29	.38	.48	.57	.76	1.52
2-1/2	8	40	408	.12	.24	.36	.48	.60	.72	.96	1.92
2-1/2	10	40	510	.16	.32	.48	.64	.80	.96	1.28	2.56
2-3/4	6	40	370	.115	.23	.35	.46	.58	.69	.92	1.84
2-3/4	8	40	493	.15	.30	.45	.60	.75	.90	1.20	2.40
2-3/4	10	40	617	.19	.38	.57	.76	.95	1.14	1.52	3.04
3	6	40	440	.14	.28	.42	.55	.69	.83	1.10	2.20
3	8	40	587	.185	.37	.56	.74	.93	1.11	1.48	2.96
3	10	40	734	.23	.46	.69	.92	1.15	1.38	1.84	3.68
3-1/4	6	40	517	.165	.33	.50	.65	.82	.98	1.30	2.60
3-1/4	8	40	690	.21	.42	.63	.86	1.07	1.28	1.72	3.44
3-1/4	10	40	862	.27	.54	.81	1.08	1.28	1.62	2.16	4.32

The material is given for general information only, as it is impractical to include enough data to cover all possible types of installations and determine all the loss of power that occurs from friction. Always check the motor size selected for a given installation with a reputable dealer to insure proper functioning of the unit. If a gasoline engine is used for power in place of a motor, add 50 percent to the H.P. required.

6.42 Windmill

The mill should have sufficient power to pump the quantity of water specified. The following table gives the approximate quantity of water delivered when the mill is operating in a wind strong enough to run at its maximum number of strokes. When the prevailing winds are light or variable, where the wind usually blows only a few hours each day, or where the exposure is poor, an oversized mill should be selected. Pumps and cylinders used with the various sizes of mills should be capable of giving a clear stroke equal in inches to the diameter of the windmill in feet; i.e., 8 inches for 8 feet, 10 inches for 10 feet, etc. The capacities shown in the table are based on the long stroke of the mills. When the short stroke is used, the capacity should be reduced about 25 percent. Use of the short stroke is not recommended except under conditions when it is required to fit an existing pump installation.

PUMPING CAPACITY OF MILLS

Size of Cylinder (Inches)	Capacity Per Hour (Gallons)		Elevation in Feet to Which Water Can Be Raised					
			Size of Mill					
	6'	8'-16'	6'	8'	10'	12'	14'	16'
1-3/4	105	150	130	185	280	420	600	1000
1-7/8	125	180	120	175	260	390	560	920
2	130	190	95	140	215	320	460	750
2-1/4	180	260	77	112	170	250	360	590
2-1/2	225	325	65	94	140	210	300	490
2-3/4	265	385	56	80	120	180	260	425
3	320	470	47	68	100	155	220	360
3-1/4	...	550	...	...	88	130	185	305
3-1/2	440	640	35	50	76	115	160	265
3-3/4	...	730	...	...	65	98	143	230
4	570	830	27	39	58	86	125	200
4-1/4	...	940	...	...	51	76	110	180
4-1/2	725	1050	21	30	46	68	98	160
4-3/4	...	1170	...	...	...	61	88	140

It should be noted that the pumping capacity of the mills in the table above, varying in diameter from 8 to 16 feet, is the same with cylinders of the same diameter. The length of stroke increases in proportion to the size of the wheel, but the number of strokes per minute decreases; consequently the discharge remains constant. With the 6-foot mill, which is back-gearred more than the other sizes and has a stroke of only $5\frac{1}{2}$ inches, the quantity of water delivered is about 30 percent less than for the other sizes. The reduction in capacity for any particular size of cylinder is compensated for in the ability of the 6-foot mill to raise water to a greater elevation than its true proportion.

Reference:

Farmers' Bulletin No. 1978 "Safe Water For The Farm"

PART 7

CONCRETE AND MASONRY STRUCTURES

7.10 GENERAL

7.11 General Functions of Concrete and Masonry Structures

a. Concrete and masonry structures are efficient supplemental control measures in soil and water conservation work. Good vegetative practices, together with proper land use, are indispensable in a sound soil and water management program. But there are many instances where vegetative measures and simple practices alone are inadequate to handle a concentration of water. In such a case permanent structures of masonry and concrete play an important part in reinforcing or supplementing the other practices.

b. There are also instances where a high degree of safety and permanence are desirable. Conservation measures may be required which will be good insurance against loss of life or destruction of property. Vegetative control measures are subject to the influences of such uncertain factors as climate, insects, etc., and therefore are not too dependable. On the other hand, properly designed and installed structures, of material such as concrete and masonry, are of long life and dependability.

7.12 Information Essential to the Farm Planner

a. The principal component parts of common structures.

b. Common types of permanent structures, their adaptability, advantages, and limitations, relative costs, etc.

c. An appreciation of field survey information incidental to the design of permanent structures, as well as the manner in which this information is developed on structure data sheets.

d. How to make preliminary rough cost estimates of structures.

e. Means of insuring the installation of structures of good quality and workmanship.

f. Structure maintenance practices.

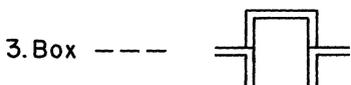
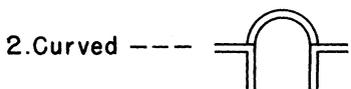
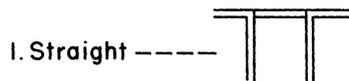
7.20 COMPONENT PARTS OF STRUCTURES (Figure 7.1, page 7-2)

7.21 Inlet

Water enters the structure through the inlet, which may be in the form of a box or a weir in a wall. The box may be straight or flared, while the wall may be straight, flared, or curved. Vertical walls extending down into the soil foundations under the

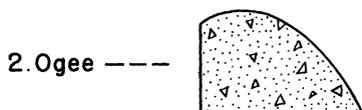
I. DROP SPILLWAY

A. INLET



B. CONDUIT

1. None

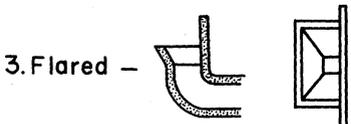


C. OUTLET

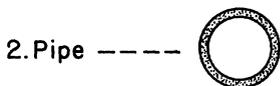
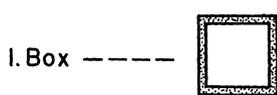


II. DROP INLET SPILLWAY

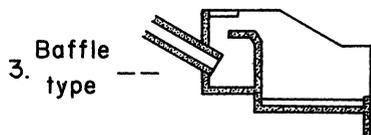
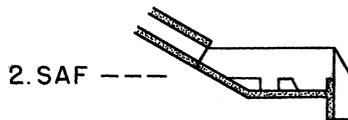
A. INLET



B. CONDUIT

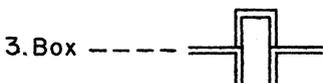
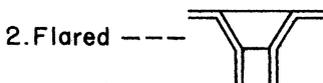
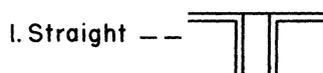


C. OUTLET

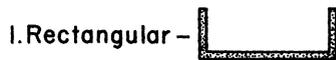


III. CHUTE SPILLWAY

A. INLET



B. CONDUIT



C. OUTLET



FIGURE 7.1 SPILLWAY NOMENCLATURE

inlet are known as cut-off walls. Their main purpose is to prevent water seepage under the structure. Similar walls, extending from the inlet to prevent seepage around the ends of the structure, are called headwall extensions. These walls also protect against burrowing rodents.

7.22 Conduit

The conduit receives the water from the inlet and conducts it through the structure. It restricts the water within a definite channel. The conduit may be closed in the form of a box or pipe, or it may be open as in a rectangular channel or ogee section. Cut-off walls or anti-seep collars are usually constructed as an appurtenance of the conduit to prevent seepage adjacent to it. This insures greater structure stability.

7.23 Outlet

The water leaves the structure through the outlet. Its function is to discharge the water into the channel below at a safe velocity. The outlet may be of the cantilever (projecting) type, a simple apron outlet, or an apron with any variation of an energy dissipator to minimize the erosive effect of the water. Cantilever outlets are necessary in locations where the channel grade below the structure is unstable.

Vertical walls known as toe walls are built around the apron to prevent undercutting. They are similar in construction to cut-off walls under the inlet. "Wing walls" or vertical walls, extending from the outlet back into the channel banks, protect against the swirling effect of the turbulent water as it enters the channel.

7.30 COMMON TYPES OF STRUCTURES

7.31 General Nomenclature (See Figure 7.1)

a. The three principal types of structures are known as drop spillways, drop inlets, and chutes. These are further described with respect to their inlet, conduit, and outlet. Any combination of inlet, conduit, and outlet may be used for each general type of structure. A spillway for an earth dam consisting of a straight box inlet, pipe conduit, and cantilever outlet would be known as a straight pipe drop inlet spillway with cantilever outlet, Figure 7.3, page 7-4.

7.32 Drop Spillways

a. Adaptability - An efficient structure (Figure 7.2, page 7-4) for the control of relatively low heads, normally up to eight feet.

It can be used effectively for the following purposes:

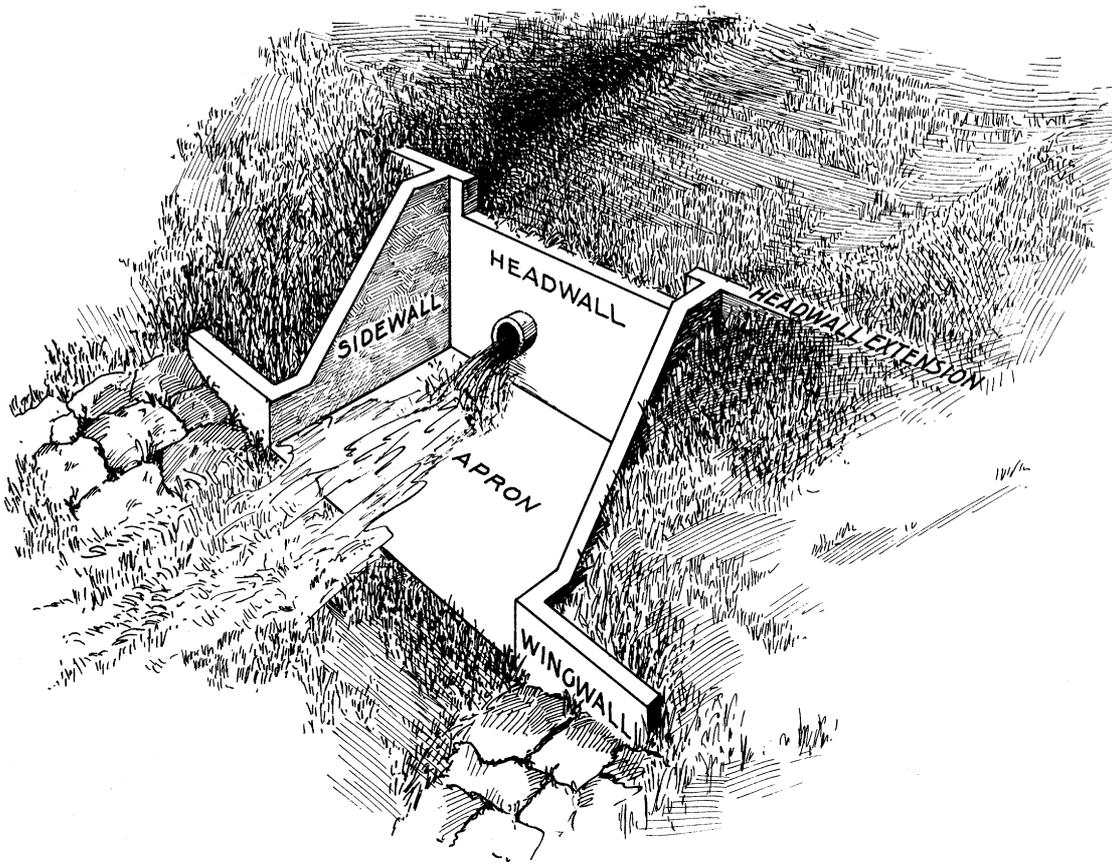


FIGURE 7.2 STRAIGHT DROP SPILLWAY

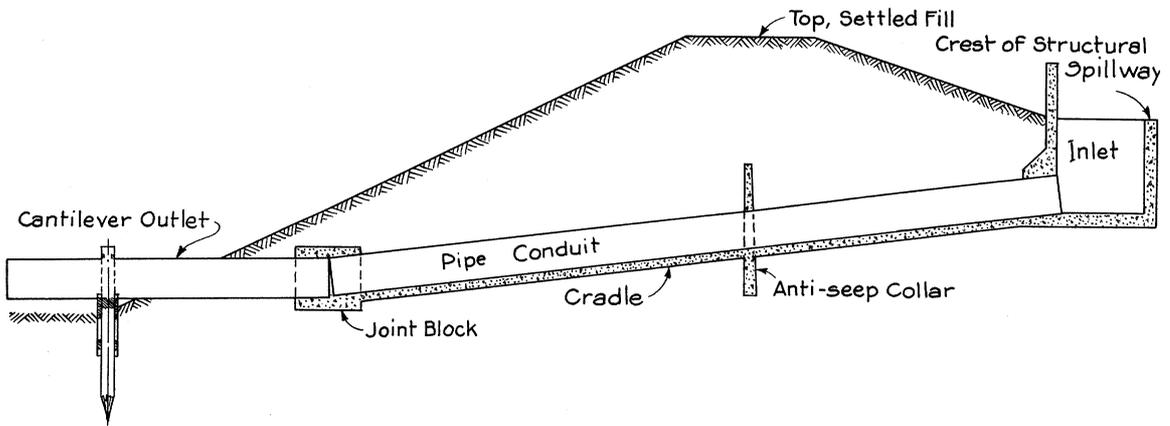


FIGURE 7.3 PIPE DROP INLET

Outlets for tile and surface water at upper ends of drainage ditches. Where the channel width below the proposed structure site is limited, the box type inlet is most effective.

Reservoir Outlets

Grade stabilization structures in lower reaches of water disposal systems; i.e., terrace and diversion outlets.

Erosion control structures, for protection of roads, buildings, and other improvements against encroaching gullies.

b. Advantages - This is a stable type of structure. The concrete block type structure can easily be built with farm labor, while the reinforced concrete type usually requires the services of a contractor.

c. Limitations - The life of many drop spillways is often shortened by undercutting of the apron and adjacent foundation. A stable grade below the structure is, therefore, essential to its stability.

d. Relative Costs - For control of relatively low heads, it is one of the more efficient types of structures when considered on a "cubic yard of concrete or masonry in place" basis. For discharges less than 250 c.f.s. the straight drop spillway is generally more economical, while above this capacity the box inlet type will be more economical.

7.33 Drop Inlet Spillway

a. Adaptability - A very efficient structure (Figure 7.3) in the control of relatively high heads, usually above ten feet. This structure type is well adapted to sites providing an appreciable amount of temporary storage above the inlet. It may be used in connection with relatively low heads, as in the case of a drop inlet on a road culvert.

Among its uses may be listed:

Outlets for farm ponds or reservoirs.

Erosion control structures in arresting gully heads.

At lower end of water disposal systems.

Outlets for silt detention reservoirs or settling basins.

Roadway structures.

Flood control structures.

b. Advantages - For high heads it requires less material than a drop spillway under similar circumstances or capacity requirements. It is relatively simple to build.

Where an appreciable amount of temporary storage is available above the inlet, the design discharge capacity of the structure can be materially reduced. Besides effecting a reduction in costs, this reduction of discharge results in a lower peak channel flow below, and consequently it can be a favorable factor in problems involving channel grade stabilization.

c. Limitations - Small drop inlets are subject to stoppage by debris. Effectiveness of this type of structure depends as much on the supporting earth fill material as on the structure itself.

d. Relative Costs - It is a cheaper structure than a drop spillway under high heads. The relatively low quantity of masonry or concrete material required in the structure is often offset by the need for large earth fills.

7.34 Formless Chutes

a. Adaptability - This type of structure (Figure 7.8, page 7-12 and 7-13) is used where low head control and the low range of spillway capacities (20 to 120 c.f.s.) are required. Its use has been limited to the southern part of the region because of the extreme variations in temperature in the northern part. It has particular adaptability to the control of overfalls at the end of terrace outlets.

b. Advantages - The spillway is easy to construct. The earth forming and concrete work can be handled by a small farm group. An inexperienced group can be trained to install this structure in a relatively short time. Maintenance and major repair work is more easily accomplished than on other spillways.

c. Limitations - The use of this structure is limited to sites that have good, natural underdrainage. It must not be used as a water impounding structure. The life expectancy is not as long as the other spillways covered in this "Part." Because of the ease of construction it is often placed at sites for which it is not adapted.

d. Relative Costs - This structure has the cheapest total installation costs for comparative discharge and head control. Inexperienced labor is usually all that is needed for the job. The elimination of wall forming is another major saving.

7.35 Formed Chutes

a. Adaptability - This type of structure (Figure 7.4, page 7-7) is generally adapted to the control of high heads where high discharge capacities are required.

b. Advantages - Sites adaptable to this type of structure usually present favorable construction conditions, since such sites are normally dry. It is not as susceptible to stoppage by debris as the drop inlet spillway. The discharge capacity of the spillway is not affected by high tailwater or silting below the apron.

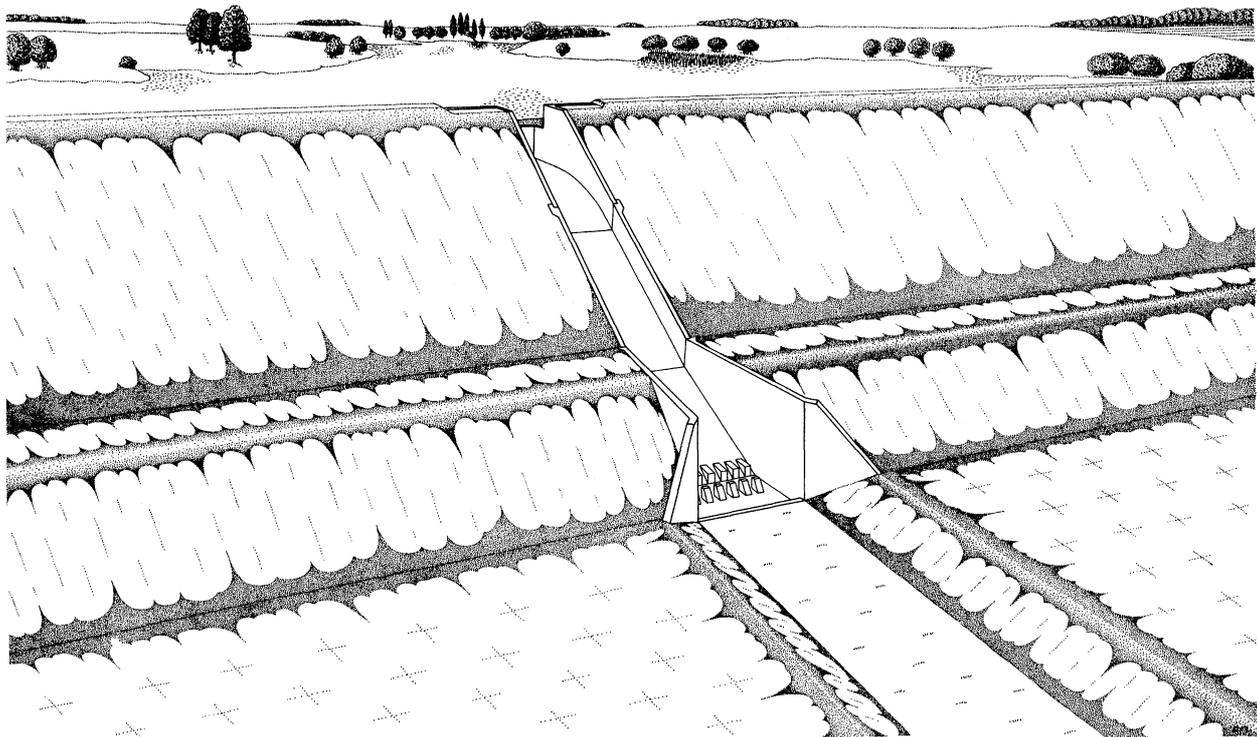


FIGURE 7.4 REINFORCED CONCRETE CHUTE

c. Limitations - For control of heads under ten feet this type will usually require more material than the drop spillways. Chutes should be restricted to site having favorable foundation conditions. Unstable soils and seepy banks require expensive under-drainage systems.

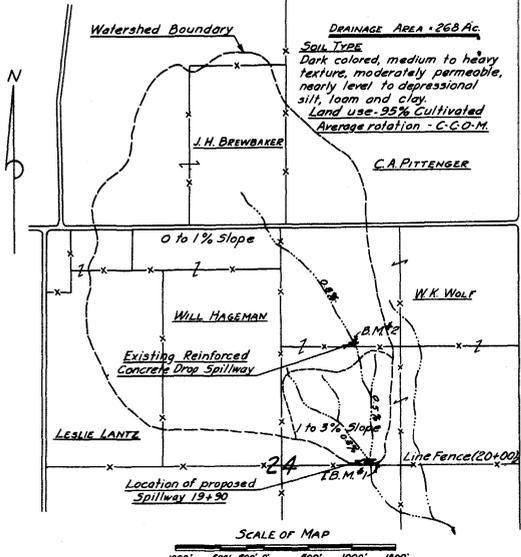
d. Relative Costs - Chutes with comparable discharge capacities normally require more material than drop spillways under low heads. For high heads and large discharges the chute is usually more economical.

7.40 STRUCTURE DATA SHEETS AND DESIGNS

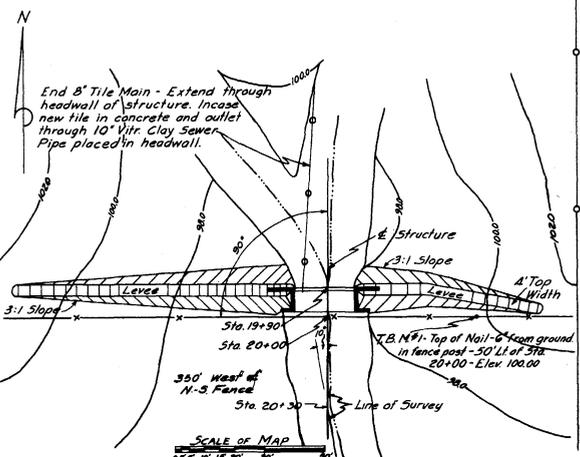
7.41 Preparation of Structure Data Sheets (Figures 7.5 and 7.6, pages 7-8 and 7-9) (See Part 2)

a. Gully or Channel Profile - This shows the bottom of the gully or channel, and top of the banks for a distance of at least 600

WATERSHED MAP



LOCATION PLAN OF STRUCTURE



HYDROLOGIC AND HYDRAULIC DATA

ESTIMATED RUNOFF RATE

RELIEF	4	Drainage Area - 268 Ac.	
SOIL INFILTRATION	10	PEAK FLOW	- 230 C.F.S.
VEGETAL COVER	12	ESTIMATED RUNOFF RATE $Q_p = P \cdot R \cdot E$	
SURFACE STORAGE	12	$Q_p = 230 \times 9 \times 10 = 225 \text{ C.F.S.}$	
	38		

USE REINFORCED CONCRETE DROP SPILLWAY

2.5' x 18.0' NOTCH AND A 3.0' HEADWALL
 SEE STANDARD DRAWING No. 3-P-136 FOR STRUCTURAL DETAILS OF SPILLWAY
 DISCHARGE CAPACITY Q = 230 C.F.S.

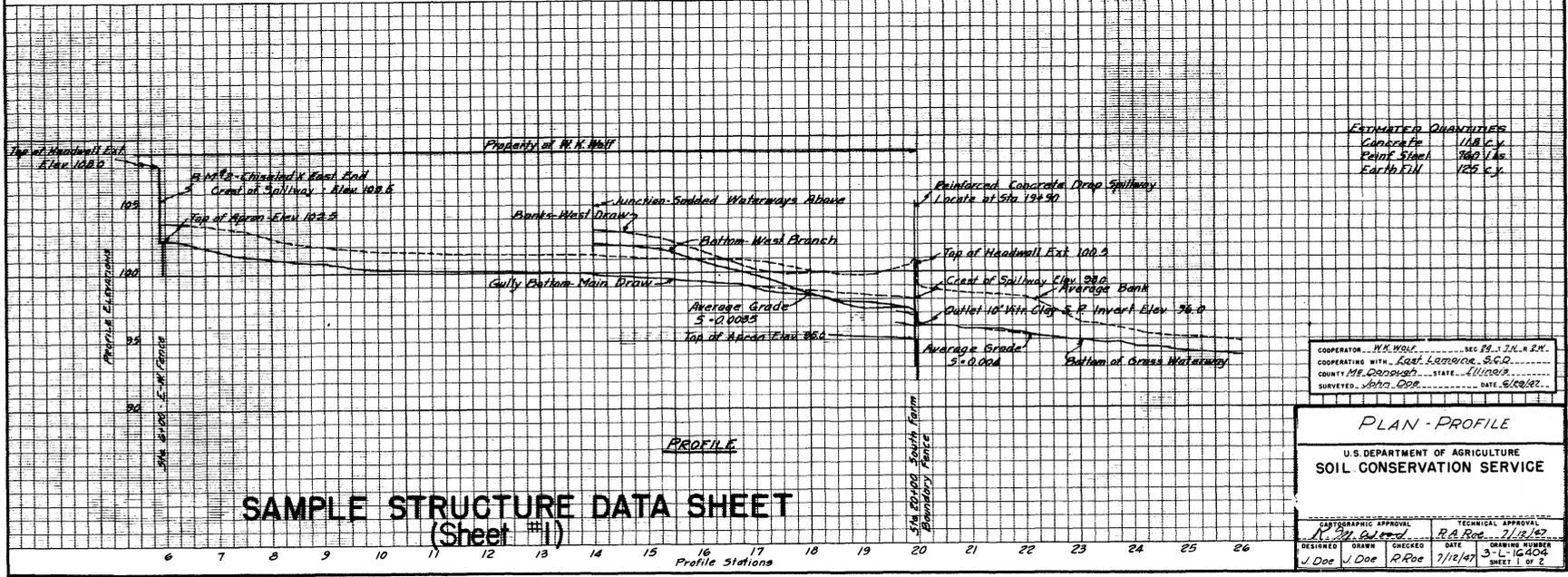
CHECK VELOCITY BELOW STRUCTURE

USE SECTION AT STA. 22+00 AS AN AVERAGE SECTION
 ASSUME HYDRAULIC GRADE LINE AT ELEV. 97.5 D=20'
 $A = 83.0' \text{ WP} \cdot 75.0' \text{ r} \cdot 1.13 \text{ n} = 0.04 \text{ s} = 0.0004 \frac{1}{2} \text{ v} = 2.55 \frac{1}{2} \text{ sec.}$
 $Q = 217.0 \text{ C.F.S.}$

CHECK VELOCITY ABOVE STRUCTURE

USE SECTION AT STA. 17+00 AS AN AVERAGE SECTION
 ASSUME HYDRAULIC GRADE LINE AT ELEV. 101.0 D=20'
 $A = 110' \text{ WP} \cdot 100.0' \text{ r} \cdot 1.1 \text{ n} = 0.04 \text{ s} = 0.0035 \frac{1}{2} \text{ v} = 2.34 \frac{1}{2} \text{ sec.}$
 $Q = 257 \text{ C.F.S.}$

FIGURE 75 SAMPLE STRUCTURE DATA SHEET (SHEET NO. 1)

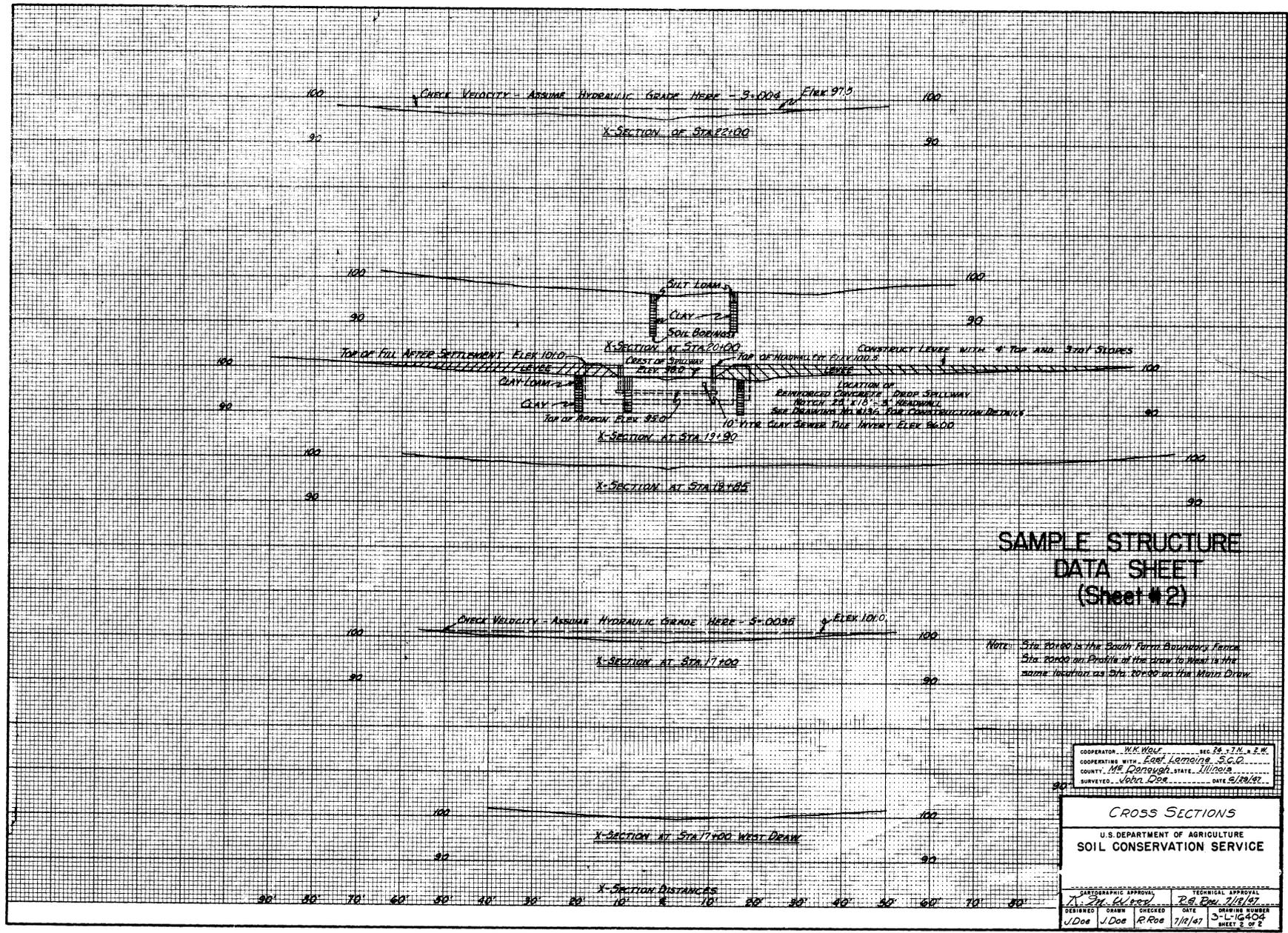


COOPERATOR	W.K. WOLF	SEC. BY	J.N. R.Z.M.
COOPERATING WITH	State Engineer, S.C.	DATE	1/22/42
COUNTY	ME. DOUGHERT	STATE	1/1/1933
SURVEYED BY	John Doe	DATE	6/18/42

PLAN - PROFILE
 U.S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL	TECHNICAL APPROVAL
J. Doe	R. Roe
DATE	DATE
7/12/47	1/22/42
SHEET	1 OF 2

FIGURE 76 SAMPLE STRUCTURE DATA SHEET (SHEET NO. 2)



**SAMPLE STRUCTURE
DATA SHEET
(Sheet #2)**

Note: Sta 20+00 is the South Farm Boundary Fence
Sta 2000 on Profile of the draw to meet in the
same location as Sta 20+00 on the Main Draw

COOPERATOR - W.K. Wolf	SEC 36 - 7N - 2W
COOPERATING WITH - Earl Leeming	56.02
COUNTY - Mc Donough	STATE - MISSISSIPPI
SURVEYED - John Doe	DATE 8/28/47

CROSS SECTIONS
U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
DESIGNED - J.Doe	DRAWN - J.Doe	DATE - 7/18/47	DATE - 7/18/47
CHECKED - J.Doe	APPROVED - R.Poe	DATE - 7/18/47	DATE - 7/18/47
J.Doe		R.Poe	
5-L-16404		SHEET 2 OF 2	

feet, both above and below the proposed structure site. In any event, the profile must be extended at least far enough below the structure site to be certain that a stable grade exists. The structure site, location of cross fences, location and size of tile lines, high water marks, and other pertinent data influencing the structure design are indicated on the profile. This information is used by the designer in establishing such relative elevations as top of spillway apron, crest of spillway weir, extreme top of dam, etc.

b. Watershed Map - See Part 2.50, page 2-12

c. Cross Sections - These are taken at the structure site, and at regular intervals of approximately 100 feet both above and below the site for a distance of 400-500 feet. These cross sections guide in locating the structure with respect to the center of the channel or gully, establish the relative elevations of the component parts of the structure, and are a basis for predicting the stability of the channel below the structure. Soil borings are normally plotted on the respective cross sections as an indication of channel or structure foundation stability.

d. Location Plan - See Part 2.60, page 2-14

e. Hydraulic and Hydrologic Calculations - These include calculations of runoff from the watershed, discharge capacities of the proposed structure and of other existing structures affecting the design.

7.42 Standard Structure Data Sheets

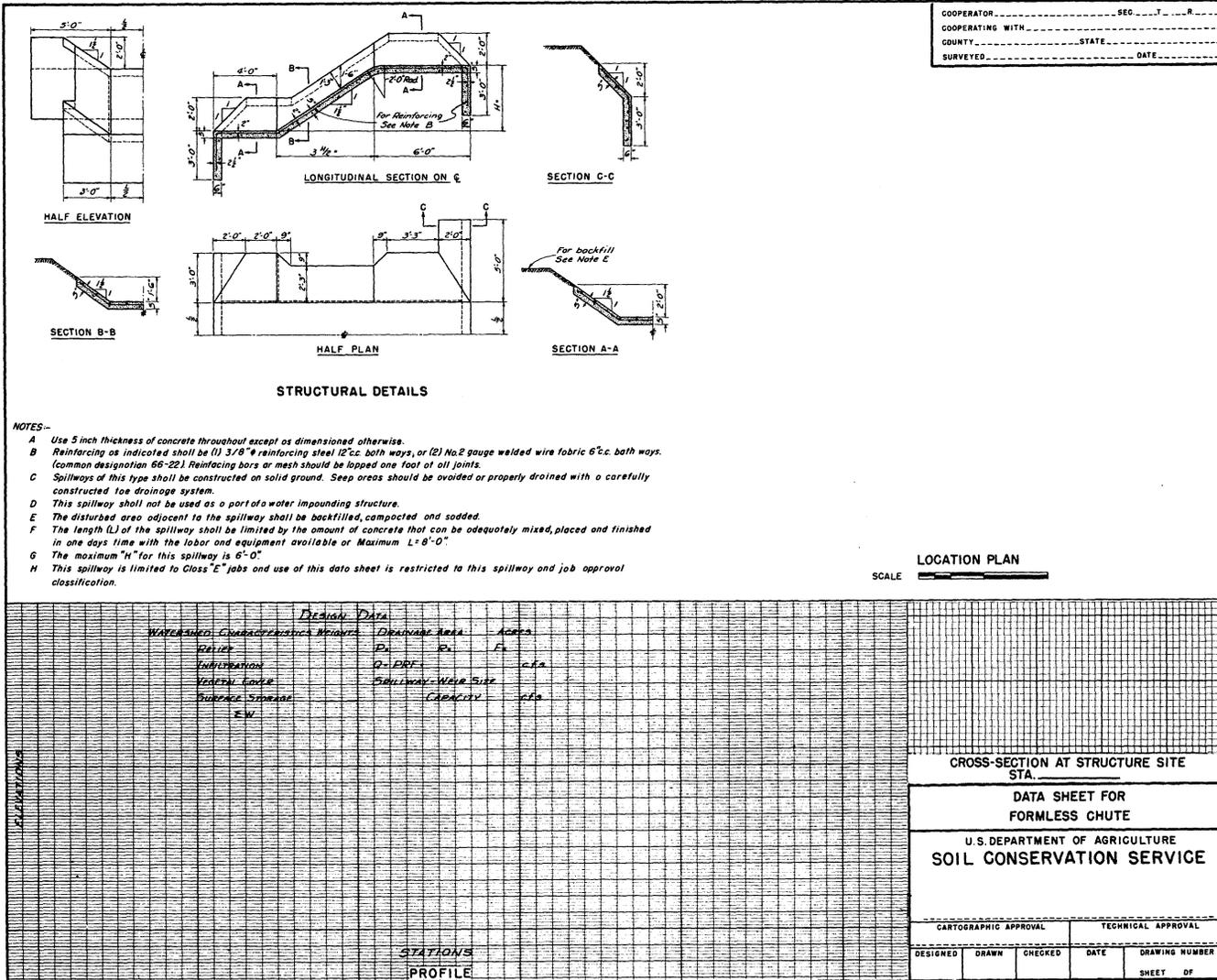
Standard "Data Sheet for Formless Chute" Figure 7.7, page 7-11, and "Data Sheet for Toe Walls" (Drawing #3-0-26750) can be used for these Class E structures. They can be obtained from the cartographic division. Information concerning material quantities and discharge capacities, which are needed in the planning and design of each structure, are given on Figure 7.8 pages 7-12 and 7-13, "Formless Chute (Class E Structure)"; Figure 7.12, page 7-20, "Index Sheet for R/C Straight Drop Spillways" and Figure 7.10, page 7-16, "Index Sheet for Concrete Block Straight Drop Spillways." Standard data sheets have design guides listed on the drawings and these standards should be used when available.

7.43 Structure Design

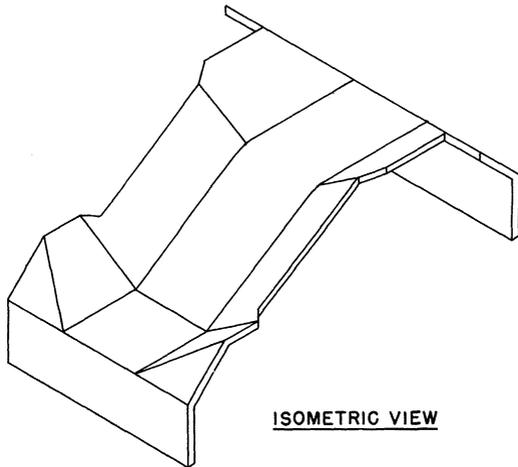
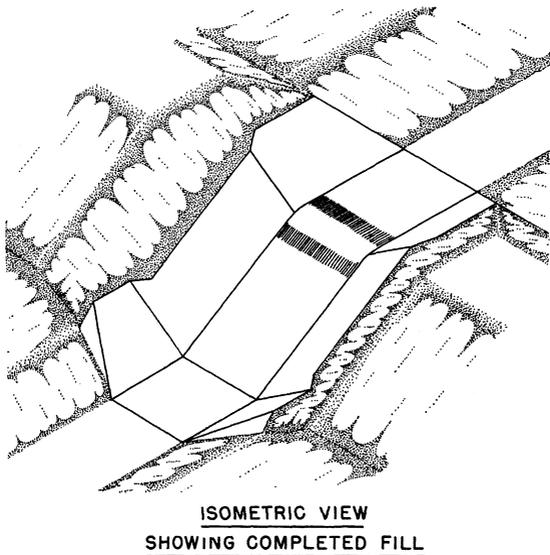
a. Purpose of Detailed Design - The detailed structure design develops in detail the over-all plan for the structure as indicated on the structure data sheet. Such items as detailed dimensions of the various parts of the structure, spacing of steel reinforcing bars in reinforced concrete, and location of construction joints are a few examples of detail.

b. Responsibility for Detailed Designs - Except in rare cases the responsibility for developing detailed designs rests with the engineer.

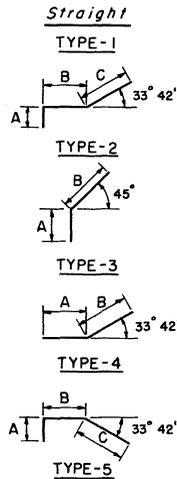
FIGURE 7.7 DATA SHEET FOR FORMLESS CHUTE (CLASS "E")



ORDER THESE BLANK DATA SHEETS BY DRAWING NUMBER 3-0-18798



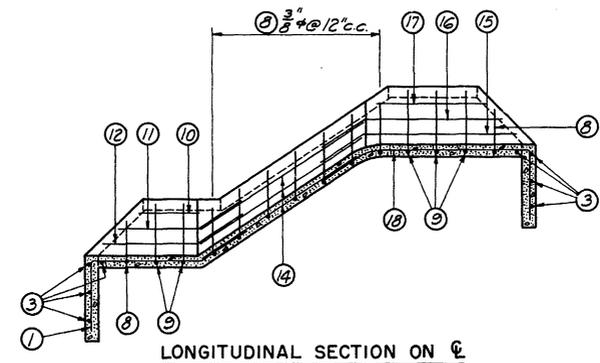
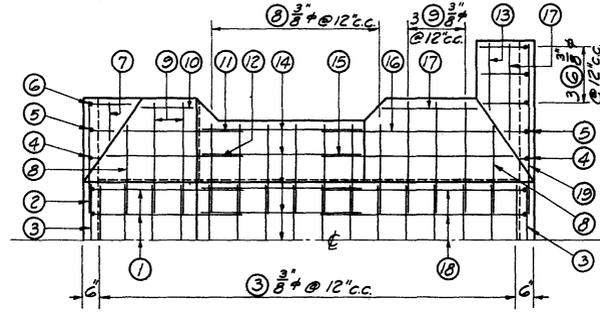
BAR TYPE DETAILS



QUANTITIES

3/8" STEEL = FEET = POUNDS
VOLUME OF CONCRETE = CU. YDS.

STEEL SCHEDULE								
MARK	QUAN	SIZE	LENGTH	TYPE	A	B	C	TOTAL FT.
1		3/8" #	7'-6"	2	2'-3"	4'-0"	1'-3"	
2	6	"	4'-0"	1	-	-	-	24'-0"
3	"	"	1	1	-	-	-	
4	4	"	3'-0"	3	2'-3"	0'-9"	-	12'-0"
5	4	"	3'-6"	3	2'-3"	1'-3"	-	14'-0"
6	8	"	4'-3"	3	2'-3"	2'-0"	-	34'-0"
7	2	"	1'-3"	1	-	-	-	2'-6"
8	"	"	3'-3"	4	2'-3"	1'-0"	-	12'-0"
9	10	"	4'-0"	4	3'-0"	1'-0"	-	40'-0"
10	2	"	2'-0"	1	-	-	-	4'-0"
11	2	"	4'-0"	4	2'-9"	1'-3"	-	8'-0"
12	2	"	4'-6"	4	3'-3"	1'-3"	-	9'-0"
13	2	"	2'-3"	1	-	-	-	4'-6"
14		"	1	1	-	-	-	
15	2	"	6'-0"	4	5'-0"	1'-0"	-	12'-0"
16	2	"	5'-6"	4	4'-6"	1'-0"	-	11'-0"
17	4	"	3'-6"	1	-	-	-	14'-0"
18	"	"	9'-6"	5	2'-3"	5'-9"	1'-6"	36'-0"
19	6	"	6'-0"	1	-	-	-	36'-0"



ALL STEEL @ 12" C.C. UNLESS NOTED

SCALE 1/4" = 1'-0"

FORMLESS CHUTE
(CLASS "E" STRUCTURE)

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL: *R. M. Wood*
TECHNICAL APPROVAL: *Adwin Freyburger*

COMPILED: A. Moroff
TRACED: D. F. L.
CHECKED: D. Polzin
DATE: 8-6-51

DRAWING NO. 3-N-22845

c. Types of Detailed Designs

Standard designs - These are designs prepared in advance to fit various combinations of conditions. An example of this is the set of standard designs for reinforced concrete drop spillways. Standard designs for this type and concrete block drop spillways are designated by drawing numbers on Index Sheets, Figures 7.9 and 7.10, pages 7-15 and 7-16. Standard designs are also available for pipe drop inlets, toe walls, and formless chutes.

After information incidental to a structure design has been secured by a field survey, it and all other pertinent information should be recorded on a structure data sheet. This information is then used to develop the structure design. All recorded information, calculations, and design data should be checked for accuracy, and the data sheet approved by a qualified individual before detailed design drawings for the structure can be ordered from the regional cartographic division. See Regional Memorandum #60 and Cartographic Handbook for necessary procedure.

Special designs - These are prepared to fit each individual case when standard designs are not applicable. They are "tailor-made" designs, and are made only after properly prepared and approved data sheets have been submitted.

7.50 PRELIMINARY COST ESTIMATES

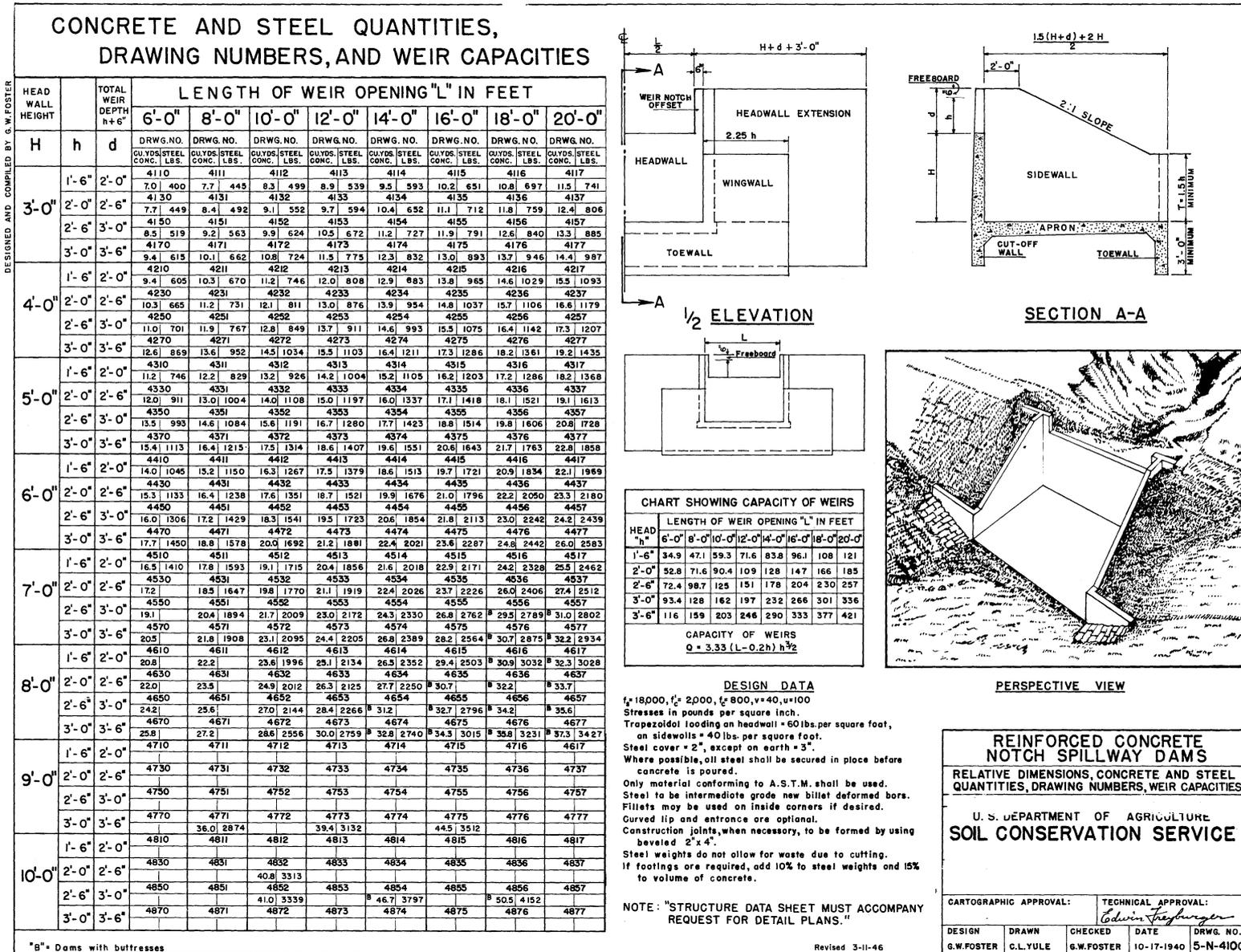
7.51 Useful Hints in Cost Estimating

- a. Use standard index sheets to estimate quantities of material in structures. These are given in Figures 7.8, 7.9, 7.10, and 7.11 (pages 7-12 and 7-13, 7-15, 7-16, and 7-17).
- b. Estimate the total costs of a structure on a "unit cost of material in place" basis; i.e., cost per cubic yard of reinforced concrete or cubic yard of earth fill in place.
- c. Become familiar with your local material, labor, and equipment costs and rates, or contact work group engineer.
- d. It is better to over-estimate costs than to under-estimate. Allow for waste or loss of material.

7.52 Example of Cost Estimating - In going over a farm with the owner, a farm planner is asked to estimate the cost of a needed structure at the lower end of a vegetated terrace outlet at a point where the outlet enters an open ditch. The following is a procedure:

Step 1 - Determine the extent and nature of the contributing watershed, preferably with aid of aerial photo and casual inspection. The watershed is estimated at 40 acres with normal runoff

FIGURE 79 REINFORCED CONCRETE STRAIGHT DROP SPILLWAY



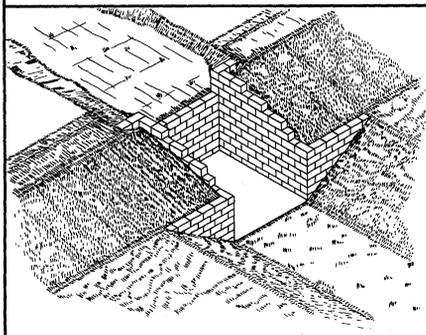
DRAWING NUMBERS AND MATERIAL QUANTITIES

Height of Overfall	Depth of Weir	LENGTH OF WEIR OPENING														
		4'-0"			8'-0"			12'-0"			16'-0"			20'-0"		
		DRAWING NO.			DRAWING NO.			DRAWING NO.			DRAWING NO.			DRAWING NO.		
H	d	CONC. CU. YDS.	STEEL LBS.	BLOCKS NO.	CONC. CU. YDS.	STEEL LBS.	BLOCKS NO.	CONC. CU. YDS.	STEEL LBS.	BLOCKS NO.	CONC. CU. YDS.	STEEL LBS.	BLOCKS NO.	CONC. CU. YDS.	STEEL LBS.	BLOCKS NO.
1'-8"	1'-4"	2.7	17.4	88	3.8	33.4	97	4.8	54.8	106	5.7	70.78	115	6.7	90.21	124
	2'-0"	3.2	17.0	116	4.3	38.5	125	5.4	60.0	134	6.4	82	143	7.5	104	152
	2'-8"		15242			15244			15246			15248			15250	
	3'-4"		15262			15264			15266			15268			15270	
	4'-0"		15282			15284			15286			15288			15290	
2'-4"	1'-4"	3.3	14	123	4.4	34	135	5.4	50	147	6.3	68	159	7.6	85.5	171
	2'-0"	4.6	329	162	6.0	384	174	7.3	447	186	8.7	510	198	10.1	573	210
	2'-8"	5.2	359	212	7.6	421	224	8.0	480	236	9.3	540	248	10.7	599	260
	3'-4"		15362			15364			15366			15368			15370	
	4'-0"	6.7	606	315	8.2	684	327	9.7	746	339	10.2	808	351	12.7	870	363
3'-0"	1'-4"	4.6	310	160	6.0	376	175	7.3	440	190	8.6	505	205	10.0	570	220
	2'-0"	5.3	316	215	6.7	451	230	8.1	514	245	9.3	577	260	10.6	640	275
	2'-8"	5.7	551	248	7.2	649	263	8.7	732	278	10.3	816	293	11.7	899	308
	3'-4"	6.9	722	335	8.3	852	350	10.1	947	365	11.7	1042	380	13.3	1137	395
	4'-0"		15482			15484			15486			15488				
3'-8"	1'-4"	5.4	372	208	6.7	439	226	8.0	508	244	9.7	576	262	11.1	644.2	280
	2'-0"	6.0	445	260	7.5	513	278	9.0	581	296	10.5	650	314	12.1	717	332
	2'-8"	6.9	719	326	8.3	834	344	10.1	930	362	11.7	1041	380	13.3	1123	398
	3'-4"	7.4	772	364	9.1	893	382	9.9	995	400	12.6	1096	418			
	4'-0"	7.7	889	418	9.5	1005	436	11.2	1106.3	454						
4'-4"	1'-4"	5.4	500	257	7.1	616	278	8.8	711	299	10.6	807	320	12.3	902	341
	2'-0"	6.5	684	315	8.1	803	336	9.8	904	357	11.5	1005	378	13.1	1107	399
	2'-8"	7.5	807	381	9.2	922	402	11.0	1026	423	12.7	1130	444			
	3'-4"	7.8	1288	417	9.5	1476	438	11.4	1640	459						
	4'-0"		15682			15684										
5'-0"	1'-4"	6.2	663	298	8.0	788	322	9.8	896	346	11.6	1004	370	13.4	1112	394
	2'-0"	7.6	826	393	9.3	956	417	11.1	1060	441	12.8	1168	465	14.6	1283	489
	2'-8"	7.7	1389	424	9.4	1593	448	11.2	1760	472						
	3'-4"		15762			15764										
	4'-0"		15782													

DISCHARGE CAPACITY OF SPILLWAY IN C.F.S.

HEAD h'	LENGTH OF WEIR OPENING "L" IN FEET				
	4	8	12	16	20
1'-4"	19	39	60	80	100
2'-0"	34	71	109	147	185
2'-8"	50	103	166	225	283
3'-4"	68	148	230	311	391
4'-0"	86	193	299	406	515

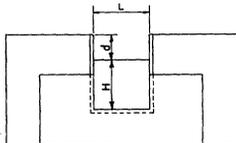
$Q = 3.33 (L - 0.2h) h^{3/2}$



NOTE:

The general use of this spillway is limited to grade stabilization and as toe walls for the protection of the outlet of sod flumes or channels. It is not recommended as a water impounding structure.

The discharge capacities given do not include freeboard within the spillway. The earth fill berms shall be constructed to a minimum settled fill height of 1'-0" above the top of the headwall extensions. On special design spillways allow 0'-6" (minimum) freeboard.



ELEVATION

NOTE: "STRUCTURE DATA SHEETS MUST ACCOMPANY REQUEST FOR DETAIL PLANS"

Revised 1-13-53

INDEX SHEET FOR CONCRETE BLOCK STRAIGHT SPILLWAY

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

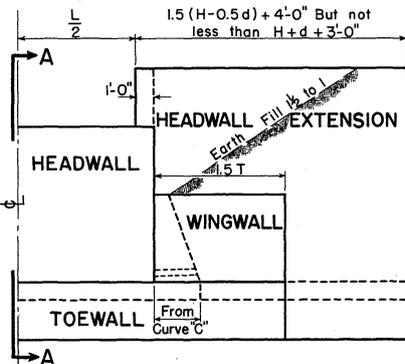
REFERENCE:

CARTOGRAPHIC APPROVAL			TECHNICAL APPROVAL		
DESIGNED	DRAWN	CHECKED	DATE	DRAWING NUMBER	
A.F. MORATZ	C. YURK	A.F. MORATZ	11-5-52	3-L-22853	
				SHEET OF	

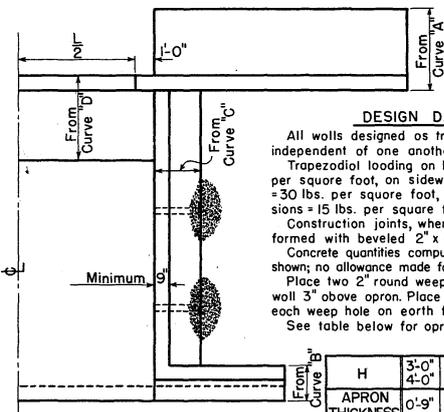
FIGURE 7.10 CONCRETE BLOCK STRAIGHT SPILLWAY

FIGURE 7.11 PLAIN CONCRETE STRAIGHT DROP SPILLWAY

CONCRETE QUANTITIES IN CUBIC YARDS										ADDITIONAL VOLUME IN CUBIC FEET FOR EACH ADDITIONAL FOOT IN WEIR LENGTH
HEAD WALL HEIGHT H	TOTAL WEIR DEPTH d	LENGTH OF WEIR OPENING "L" IN FEET								
		6'-0"	8'-0"	10'-0"	12'-0"	14'-0"	16'-0"	18'-0"	20'-0"	
3'-0"	1'-0"	9.0	10.0	10.9	11.9	12.8	13.8	14.7	15.7	12.8
	1'-6"	10.6	11.6	12.6	13.5	14.5	15.5	16.4	17.4	13.0
	2'-0"	12.6	13.7	14.7	15.8	16.8	17.8	18.9	19.9	13.3
	2'-6"	15.7	16.7	17.7	18.7	19.8	20.8	21.8	22.8	13.6
	3'-0"	19.7	20.7	21.7	22.7	23.8	24.8	25.8	26.9	13.9
4'-0"	3'-6"	24.8	25.8	26.8	27.9	28.9	30.0	31.0	32.0	14.1
	4'-0"	29.8	30.8	31.9	33.0	34.0	35.1	36.2	37.3	14.4
	1'-0"	13.0	14.2	15.5	16.7	18.0	19.2	20.5	21.7	16.5
	1'-6"	14.1	15.3	16.6	17.8	19.0	20.3	21.5	22.8	16.8
	2'-0"	16.9	18.1	19.4	20.6	21.9	23.2	24.4	25.7	17.1
5'-0"	2'-6"	20.6	21.9	23.2	24.4	25.7	27.0	28.3	29.6	17.4
	3'-0"	25.2	26.5	27.8	29.1	30.4	31.7	33.0	34.3	17.6
	3'-6"	30.6	31.9	33.2	34.7	35.9	37.2	38.6	39.9	17.9
	4'-0"	36.6	38.0	39.3	40.7	42.0	43.4	44.7	46.1	18.2
	1'-0"	19.1	20.7	22.3	23.9	25.5	27.1	28.7	30.2	21.6
6'-0"	1'-6"	20.2	21.8	23.2	25.0	26.6	28.3	29.9	31.6	22.0
	2'-0"	22.2	23.8	25.5	27.2	28.8	30.4	32.1	33.8	22.3
	2'-6"	26.7	28.4	30.1	31.7	33.4	35.1	36.7	38.4	22.6
	3'-0"	32.0	33.6	35.3	37.0	38.6	40.3	42.0	43.6	22.9
	3'-6"	36.6	38.3	40.0	41.7	43.4	45.1	46.8	48.5	23.2
7'-0"	4'-0"	45.3	47.0	48.8	50.5	52.2	54.0	55.7	57.5	23.5
	1'-0"	26.3	28.2	30.2	32.1	34.1	36.0	38.0	40.0	26.3
	1'-6"	28.1	30.1	32.1	34.0	36.0	38.0	40.0	42.0	26.6
	2'-0"	29.1	31.1	33.0	35.0	37.0	38.9	40.9	42.8	26.9
	2'-6"	33.0	35.0	37.1	39.1	41.1	43.1	45.1	47.1	27.2
8'-0"	3'-0"	39.1	41.1	43.1	45.2	47.3	49.3	51.3	53.4	27.5
	3'-6"	46.2	48.3	50.3	52.4	54.4	56.5	58.6	60.7	27.9
	4'-0"	53.1	55.3	57.5	59.8	62.0	64.2	66.5	68.7	28.2
	1'-0"	36.4	38.8	41.3	43.8	46.2	48.7	51.1	53.6	33.2
	1'-6"	37.9	40.4	42.9	45.4	47.9	50.4	52.9	55.4	33.6
9'-0"	2'-0"	39.4	41.9	44.4	46.9	49.4	51.9	54.4	57.0	33.9
	2'-6"	42.4	44.9	47.4	50.0	52.5	55.0	57.6	60.1	34.3
	3'-0"	48.2	50.8	53.4	56.0	58.6	61.2	63.8	66.5	34.6
	3'-6"	56.4	59.0	61.6	64.2	66.8	69.4	72.0	74.5	34.9
	4'-0"	65.4	68.0	70.6	73.2	75.8	78.4	81.0	83.7	35.3
10'-0"	1'-0"	47.6	50.5	53.5	56.4	59.4	62.3	65.3	68.3	39.9
	1'-6"	50.5	53.5	56.4	59.4	62.4	65.3	68.3	71.3	40.2
	2'-0"	51.4	54.4	57.4	60.4	63.4	66.4	69.4	72.4	40.5
	2'-6"	53.2	56.2	59.3	62.3	65.3	68.4	71.4	74.4	40.9
	3'-0"	58.4	61.4	64.5	67.5	70.6	73.6	76.7	79.7	41.2
3'-6"	67.0	70.1	73.2	76.4	79.5	82.6	85.8	89.0	41.6	
	4'-0"	77.0	80.1	83.2	86.4	89.5	92.6	95.7	98.8	41.9
	1'-0"	62.4	65.7	69.3	72.7	76.1	79.6	83.0	86.4	48.4
	1'-6"	65.1	68.7	72.3	75.9	79.5	83.1	86.7	90.3	48.8
	2'-0"	66.7	70.3	74.0	77.6	81.3	84.9	88.6	92.2	49.1
2'-6"	69.0	72.6	76.3	80.0	83.6	87.3	91.0	94.7	49.5	
	3'-0"	71.2	74.9	78.6	82.3	86.0	89.7	93.4	97.1	49.9
	3'-6"	80.5	84.2	87.9	91.6	95.3	99.0	102.7	106.5	50.3
	4'-0"	91.5	95.2	99.0	102.7	106.5	110.2	114.0	117.7	50.6
	1'-0"	78.6	82.7	86.8	90.9	95.1	99.3	103.5	107.6	56.5
1'-6"	80.9	85.1	89.4	93.6	97.9	102.1	106.4	110.6	56.9	
	2'-0"	83.8	88.1	92.3	96.6	100.8	105.1	109.4	113.6	57.3
	2'-6"	86.6	90.9	95.1	99.4	103.6	107.9	112.2	116.4	57.6
	3'-0"	89.3	93.5	97.8	102.1	106.4	110.7	115.0	119.3	58.0
	3'-6"	94.0	98.3	102.6	106.9	111.2	115.5	119.8	124.2	58.4
4'-0"	105.9	110.2	114.6	118.9	123.3	127.6	131.9	136.3	58.8	



HALF ELEVATION



HALF PLAN

DESIGN DATA

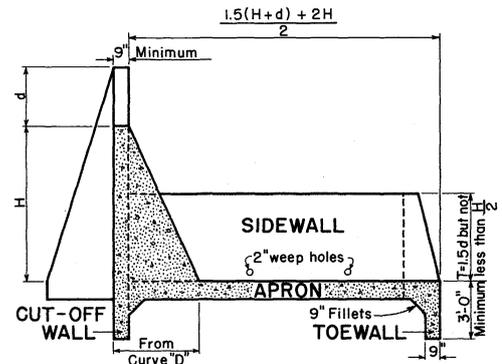
All walls designed as true gravity section, independent of one another.
 Trapezoidal loading on headwall = 62.5 lbs. per square foot, on sidewalls and wingwalls = 30 lbs. per square foot, on headwall extensions = 15 lbs. per square foot.
 Construction joints, when necessary, to be formed with beveled 2" x 4".
 Concrete quantities computed on structure as shown; no allowance made for waste or overrun.
 Place two 2" round weep holes in each sidewall 3" above apron. Place gravel drain around each weep hole on earth fill side of wall.
 See table below for apron thickness.

H	3'-0"	5'-0"	7'-0"	9'-0"
4'-0"	0'-9"	0'-10"	0'-11"	1'-0"

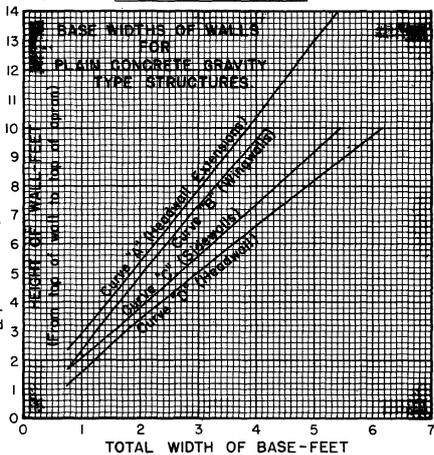
APRON THICKNESS

TABLE SHOWING CAPACITY OF WEIRS								
d	LENGTH OF WEIR OPENING "L" IN FEET							
	6'-0"	8'-0"	10'-0"	12'-0"	14'-0"	16'-0"	18'-0"	20'-0"
1'-0"	17.4	23.4	29.4	35.4	41.4	47.4	53.4	59.4
1'-6"	31.4	42.4	53.5	64.5	75.5	86.5	97.5	109.
2'-0"	47.5	64.5	81.4	98.4	115.	132.	149.	166.
2'-6"	65.2	88.9	113.	136.	160.	184.	208.	231.
3'-0"	84.2	115.	147.	178.	209.	240.	271.	302.
3'-6"	104.	143.	183.	222.	261.	301.	340.	379.
4'-0"	125.	173.	221.	269.	317.	365.	413.	461.

CAPACITY OF WEIRS = $Q = 3.0(L - 0.2d) d^{3/2} = C.F.S.$



SECTION A-A



PLAIN CONCRETE NOTCH SPILLWAY DAMS
 RELATIVE DIMENSIONS, CONCRETE QUANTITIES, BASE WIDTH OF WALLS, WEIR CAPACITIES.

U.S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL:	TECHNICAL APPROVAL:
DESIGN: G. A. REISE M. M. CULP	DRAWN: M. BERNSTEIN CHECKED: M. M. CULP DATE: 3-17-43 DRAWING NO.: 3-N-7236

characteristics and rainfall factor of 1.0.

Step 2 - For estimating purposes, calculate the runoff from the watershed on a 50-year frequency basis for all structures. Refer to Part 3.10, page 3-1. The runoff is estimated at 100 c.f.s.

Step 3 - Estimate head to be controlled (overfall into ditch) by use of hand level. Head to be controlled is determined as five feet.

Step 4 - Decide on type of structure to be used as influenced by site characteristics. Reinforced concrete drop spillway is selected.

Step 5 - By referring to Figure 7.9 select dimensions of weir notch to provide proper capacity.

$$h = 2'6'' \quad L = 8'$$

Also determine drawing number and quantity of material from table.

$$\text{For } (h = 2'6'' \quad H = 5')$$

$$(d = 3' \quad L = 8')$$

(Use Drawing No. 4351

(14.6 cubic yards of reinforced concrete required

Step 6 - Estimate cost on "material in place" basis.

15 cubic yards at \$40.00 per cubic yard in place (contractor's price)	\$600
400 cubic yards of earth wing levees at \$0.20 per cubic yard	80
Add 10 percent for contingencies	<u>70</u>
* Estimated net cost	\$750

Note: This figure is only a preliminary estimate. See Part 7, Paragraph 7.43c for procedure in securing detailed plans.

Similar cost estimates should be made for other adaptable structures for the site in question. Comparative costs should be considered in making a final selection.

7.60 HOW TO PROMOTE GOOD QUALITY IN CONSTRUCTION

7.61 Lay the "groundwork" with the farmer by:

- a. Emphasizing the need for using construction material of acceptable quality.
- b. Emphasizing the importance of building the structure as planned and designed. Regional Memorandum #60 requires withdrawal of Service assistance whenever the cooperator refuses to follow approved plans.

7.62 Give timely, adequate technical assistance both before and during the actual construction by:

- a. Providing sufficient stakes for construction purposes. "Double-check" your staking.
- b. Explaining the stakes to the farmer or the contractor, making sure he understands.
- c. Explaining the construction details to the farmer or contractor.
- d. Providing timely supervision and checking during the construction period.

7.63 Acquaint yourself with competent, reliable contractors in your locality. The farmer will appreciate a list of reliable contractors, should he not be able to do the work himself.

7.70 STRUCTURE MAINTENANCE

7.71 Important - Regardless of how well designed or constructed a permanent structure may be, its continued effective operation depends on how well it is maintained. Emphasize to the farmer the need for a sound maintenance program.

7.72 Essentials of Sound Maintenance Program

- a. The farmer should inspect the structure regularly for:
 1. Debris or obstructions at inlets or outlets of structures.
 2. Destructive action of burrowing rodents under structure proper or through adjacent earth fills.
- b. The farmer should make necessary repairs or remove debris immediately after inspection.
- c. Protect structures from livestock.
- d. Maintain all earth fills in good sod by mowing, re-seeding, and fertilizing.

DRAWING NUMBERS AND MATERIAL QUANTITIES																	
HEIGHT OF HEADWALL	DEPTH OF WEIR	LENGTH OF WEIR OPENING															
		6'-0"		8'-0"		10'-0"		12'-0"		14'-0"		16'-0"		18'-0"		20'-0"	
H	h	DRAWING NO.		DRAWING NO.		DRAWING NO.		DRAWING NO.		DRAWING NO.		DRAWING NO.		DRAWING NO.		DRAWING NO.	
		CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.	CONC. CU. YDS.	STEEL LBS.
1'-0"	1'-0"	7406		7408		7410		7412		7414		7416		7418		7420	
	1'-6"	2.3	99.0	2.6	112.0	2.9	130.0	3.2	137.0	3.5	150.0	3.8	163.0	4.1	176.0	4.4	189.0
	2'-0"	7426		7428		7430		7432		7434		7436		7438		7440	
	2'-6"	2.6	109.5	3.0	123.8	3.4	138.1	3.8	152.4	4.2	166.7	4.6	181.0	5.0	195.2	5.4	209.5
	3'-0"	7446		7448		7450		7452		7454		7456		7458		7460	
	3'-6"	1.8	139.3	2.0	156.0	2.3	173.0	2.5	190.0	2.7	207.0	3.0	224.0	3.2	241.0	3.4	258.0
1'-6"	1'-0"	7466		7468		7470		7472		7474		7476		7478		7480	
	1'-6"	4.0	180.0	4.4	196.0	4.8	212.0	5.2	228.0	5.6	244.0	6.0	260.0	6.4	276.0	6.8	292.0
	2'-0"	7486		7488		7490		7492		7494		7496		7498		7500	
	2'-6"	4.5	291.0	4.9	308.8	5.3	326.8	5.7	344.9	6.1	362.9	6.5	380.4	6.9	398.8	7.3	417.0
	3'-0"	7606		7608		7610		7612		7614		7616		7618		7620	
	3'-6"	2.9	129.0	3.3	147.0	3.7	164.0	4.1	182.0	4.5	200.0	4.9	217.0	5.3	231.0	5.7	252.0
2'-0"	1'-0"	7626		7628		7630		7632		7634		7636		7638		7640	
	1'-6"	3.3	165.0	3.7	184.0	4.1	203.0	4.5	222.0	5.0	240.0	5.4	260.0	5.8	278.0	6.2	297.0
	2'-0"	7646		7648		7650		7652		7654		7656		7658		7660	
	2'-6"	3.7	147.0	4.1	160.0	4.6	173.0	4.9	185.0	5.3	198.0	5.7	211.0	6.1	223.0	6.5	236.0
	3'-0"	7666		7668		7670		7672		7674		7676		7678		7680	
	3'-6"	4.8	370.0	5.3	401.0	5.8	433.0	6.3	465.0	6.8	497.0	7.3	528.9	7.8	561.0	8.3	593.0
2'-6"	1'-0"	7686		7688		7690		7692		7694		7696		7698		7700	
	1'-6"	5.2	390.0	5.7	414.0	6.2	448.0	6.7	468.6	7.2	495.9	7.7	523.2	8.2	551.2	8.7	577.8
	2'-0"	7806		7808		7810		7812		7814		7816		7818		7820	
	2'-6"	3.8	314.0	4.3	349.0	4.8	384.0	5.3	429.0	5.8	454.0	6.3	489.0	6.8	524.0	7.3	559.0
	3'-0"	7826		7828		7830		7832		7834		7836		7838		7840	
	3'-6"	4.0	313.0	4.5	348.0	5.0	383.0	5.5	419.0	6.0	454.0	6.5	489.0	7.0	524.0	7.5	559.0
2'-0"	1'-0"	7846		7848		7850		7852		7854		7856		7858		7860	
	1'-6"	4.2	336.0	4.7	372.0	5.2	407.0	5.7	443.0	6.2	478.0	6.7	515.0	7.2	550.0	7.7	586.0
	2'-0"	7866		7868		7870		7872		7874		7876		7878		7880	
	2'-6"	5.6	474.0	6.1	511.0	6.6	549.0	7.1	586.0	7.6	623.0	8.1	660.0	8.6	697.0	9.1	734.0
	3'-0"	7886		7888		7890		7892		7894		7896		7898		7900	
	3'-6"	6.1	549.0	6.6	586.0	7.1	623.0	7.6	661.0	8.1	699.0	8.6	736.0	9.1	773.0	9.6	811.0
2'-6"	1'-0"	7906		7908		7910		7912		7914		7916		7918		7920	
	1'-6"	4.3	343.0	4.8	380.0	5.3	417.0	5.8	454.0	6.3	491.0	6.8	528.0	7.3	565.0	7.8	602.0
	2'-0"	7926		7928		7930		7932		7934		7936		7938		7940	
	2'-6"	4.6	362.0	5.1	399.0	5.6	435.0	6.1	473.0	6.6	510.0	7.1	546.0	7.6	584.0	8.1	619.0
	3'-0"	7946		7948		7950		7952		7954		7956		7958		7960	
	3'-6"	5.0	384.0	5.6	421.0	6.1	459.0	6.7	496.0	7.3	534.0	7.8	572.0	8.4	609.0	9.0	647.0
3'-0"	1'-0"	7966		7968		7970		7972		7974		7976		7978		7980	
	1'-6"	5.9	459.0	6.5	494.3	6.9	532.4	7.5	569.1	8.1	605.9	8.7	642.6	9.3	679.4	9.9	716.1
	2'-0"	7986		7988		7990		7992		7994		7996		7998		8000	
	2'-6"	6.3	535.0	6.9	574.0	7.5	616.0	8.1	662.0	8.7	703.0	9.3	744.0	9.9	786.0	10.5	825.0

DISCHARGE CAPACITY OF SPILLWAY IN C.F.S.

"h" HEAD OVER CREST	LENGTH OF WEIR OPENING "L" IN FEET							
	6'-0"	8'-0"	10'-0"	12'-0"	14'-0"	16'-0"	18'-0"	20'-0"
0'-6"	7.0	9.0	12	14	16	19	21	23
1'-0"	19	26	33	39	46	53	59	66
1'-6"	35	47	59	72	84	96	108	121
2'-0"	53	72	90	109	128	147	166	185
2'-6"	72	99	125	151	178	204	230	257
3'-0"	93	128	162	197	232	266	301	336

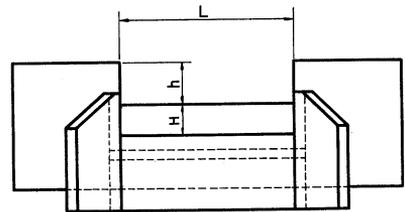
NOTE:

The spillway discharge capacities are computed from the formula $Q = 3.33 (L - 0.2h) h^{3/2}$

When the crest is submerged by high tailwater in the downstream channel, the formula $Q = 3.33 (L - 0.2h)(Nh)^{3/2}$ should be used to determine spillway capacities. The value of the coefficient "N" is given in the table on drawing No. 5-L-7285.

Where weirs of greater length than 20'-0" are required the apron and headwall can be expanded using the same detailing and cross-section dimensions. For expanded headwalls, buttresses (counterforts) should be added at approximately 12'-0" on centers.

This spillway should be used primarily as a toe-wall for sod flumes and at critical sections in constructed waterways.



ELEVATION

**INDEX SHEET FOR
R/C STRAIGHT DROP SPILLWAY**

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL <i>A. M. Wood</i>			TECHNICAL APPROVAL <i>Edwin Graybeaver</i>		
DESIGNED A.F. MORAZZ	DRAWN C. YURK	CHECKED R. MICHAUD	DATE 11-16-50	DRAWING NUMBER 3-L-7400	
				SHEET OF	

FIGURE 7.12 INDEX SHEET FOR R/C STRAIGHT DROP SPILLWAY

PART 8

TERRACING

8.10 GENERAL

8.11 Definition

A terrace is a constructed channel across a field slope built to standard specifications. It may be constructed either with a grade or with the channel and ridge of the terrace being level.

a. A graded terrace is one constructed so that it will have a grade, either variable or uniform, leading to a suitable outlet, designed for a safe and non-erosive velocity.

b. A level terrace is one constructed on a true contour where the channel becomes the impounding reservoir. The water is permitted to seep into the soil.

8.12 Uses and Limitations

a. Advantages of Terraces

Reduces length of slope

Reduces soil losses

Permits the use of more intensive rotations

Provides larger fields not broken by strips which can be more readily pastured as a unit.

Terraces, when properly used and constructed, are the most effective supporting conservation practice.

b. Limitation of Terraces*

They will not replace the need for good rotations in maintaining soil structure and fertility.

They will not replace the need for contouring.

Generally, terraces are not recommended on cropland slopes steeper than 10 percent.

c. Level Terraces

Level terraces should not be used except where all of the following conditions exist:

*Reference

Light textured or medium textured soils of high organic content where a good soil management system is followed so that the surface soil will not seal.

Where there is at least five feet of moderately or moderately rapid, permeable soil with less than 35 percent clay content.

d. Graded Terraces

Graded terraces should never be used unless there is a suitable outlet such as:

A natural outlet consisting of a waterway or a slope having sufficient cover and adequate width to prevent erosion.

A constructed and vegetated outlet along a fence or at some other suitable location.

8.20 PLANNING THE TERRACE SYSTEM

8.21 Preliminary Field Surveys

The farm planner should make sufficient surveys which will enable him to properly plan the terrace system. Sometimes merely a contour line will be sufficient. In more complex layouts it may be necessary to have a complete topographic survey made or to make a preliminary layout of the system in the field.

8.22 Correlate the Terrace System With the Farm Plan

A terrace system properly planned and integrated with the general farm plan becomes a very valuable improvement. However, a system poorly planned and poorly laid out can, and generally does, become a source of difficulty in operating the farm.

8.23 Roads and Lanes

Plan the location of roads and lanes carefully. The system can often be so planned that the roads may be placed on the field ridges providing easy access to the area between each terrace. The road may also be placed on or just below a terrace ridge. This permits easy travel and will prevent erosion of the traveled way. The ease with which crops can be removed from terraced fields is important.

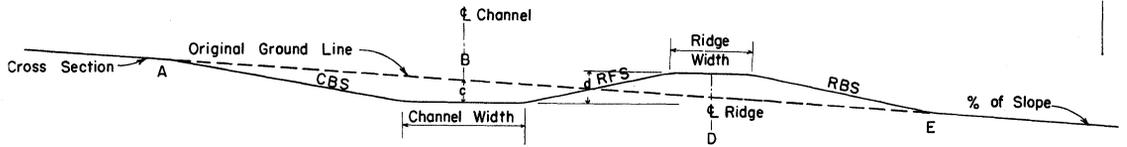
8.24 Outlets

Refer to Part 10 on Vegetated Outlets and Watercourses.

8.25 Terrace Specifications (Figure 8.1, page 8-3)

The terrace should be constructed according to specification regardless what type of equipment is being used. Copies of

TERRACE CHART



GRADED TERRACE CHANNEL DIMENSIONS								
Length Ft. Field Slope	Needed Terrace Ridge Height in Feet					Approximate Slope Ratio		
	200	400	600	800	1000	CBS	RFS	RBS
1	0.8	0.9	1.0	1.2	1.2	10:1	10:1	10:1
2	0.8	0.9	1.0	1.2	1.2	10:1	10:1	10:1
3	0.7	0.9	1.0	1.1	1.2	6:1	8:1	8:1
4	0.7	0.9	1.0	1.1	1.1	6:1	8:1	8:1
5	0.7	0.9	1.0	1.1	1.1	6:1	8:1	8:1
6	0.7	0.8	0.9	1.0	1.0	6:1	8:1	8:1
7	0.7	0.8	0.9	1.0	1.0	4:1	6:1	6:1
8	0.7	0.8	0.9	1.0	1.0	4:1	6:1	6:1
9	0.7	0.8	0.9	1.0	1.0	4:1	6:1	6:1
10	0.6	0.8	0.9	1.0	1.0	4:1	6:1	6:1
11	0.6	0.8	0.9	1.0	1.0	4:1	4:1	5:1
12	0.6	0.8	0.9	1.0	1.0	4:1	4:1	4:1
13	0.6	0.8	0.9	1.0	1.0	4:1	4:1	4:1
14	0.6	0.8	0.9	1.0	1.0	4:1	4:1	3:1
15	0.6	0.7	0.9	1.0	1.0	4:1	4:1	2½:1

NOTE: Above figures are settled ridge height and are based on 10yr. runoff and a channel with 6' bottom, 0.4 percent grade. The same height should be used for 0.6 percent grade. The height should be increased 0.1' for a grade of 0.2 percent. A top width of at least 2' should be provided.

TERRACE VELOCITY CHECK CHART							
Depth of water in feet required for various amounts of runoff and related grades in channel							
Terrace channel grade (per cent)							
0.2 0.4 0.6 0.8 1.0 1.5 2.0							
Depth of water (feet)							
Runoff c.f.s.							
2	0.4	0.3	0.3	0.3	0.2	0.2	0.1
3	0.5	0.4	0.4	0.3	0.3	0.3	0.2
5	0.6	0.5	0.5	0.5	0.4	0.4	0.4
10	0.9	0.8	0.7	0.6	0.6	0.6	0.5
1 ft/sec. — Velocity — 2 ft/sec.							

The figures to the left of the first stepped line represent velocities of less than one foot/second. Those between the lines represent velocities of one to two feet/second and those to the right represent velocities over two feet/second.

NOTE: For short distances terrace grades can be increased to improve alignment. The above velocity chart permits a check of channel velocity. Safe velocities for bare soils are: Sandy Soils 1.5' per second. Other Soils 2.0' per second. Chart is based on 6' bottom, 4 to 1 side slopes and a roughness coefficient "n" of 0.04. Runoff can be figured by multiplying area drained in acres by 4 c.f.s.

LEVEL TERRACE-CHANNEL CAPACITY-BASED ON RETAINING 2" RUNOFF

Field Slope %	Distance (feet) From A to:			Depth(feet)		Cross-Section End Area sq.ft.		Approximate Slope Ratio			Width(feet)	
	B	D	E	Ridge Heights d	Cut c	Excav.	Fill	CBS	RFS	RBS	Channel	Ridge
2	7.0	17.5	24	1.2	0.6	5.0	5.4	6:1	6:1	6:1	8	3
4	8.2	20.0	28	1.2	0.8	7.4	7.4	5:1	6:1	6:1	8	3
6	9.5	21	30	1.3	0.8	8.7	9.4	5:1	6:1	5:1	8	3
8	11.0	21.5	32	1.2	0.9	9.2	8.9	5:1	6:1	5:1	6	3
10	13	22	32	1.2	1.0	10.1	9.9	5:1	5:1	4:1	6	3
12	12	20	31	1.3	1.1	10.9	10.2	4:1	4:1	4:1	6	3
* 14	13	21	30	1.3	0.9	10.2	11.0	4:1	4:1	3½:1	6	3
* 15	12	20	28	1.3	1.0	10.8	10.6	3½:1	3½:1	2½:1	6	3

*Note: Terrace ridge and RBS to be kept in sod.

SPACING FORMULA ($\frac{S}{2} + 2$)

Field Slope %	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Vertical Interval	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5
Horizontal Interval	250	150	117	100	90	83	79	75	72	70	68	67	66	64	63
Feet per Acre	174	291	373	436	485	525	552	581	605	623	642	650	660	682	692
Acre per 1000 ft.	5.74	3.45	2.68	2.30	2.06	1.91	1.82	1.72	1.65	1.61	1.56	1.54	1.52	1.47	1.45

LEGEND

CBS-Channel back slope
 RFS-Ridge fore slope
 RBS-Ridge back slope
 S-Slope of land

GENERAL RECOMMENDATIONS

1. Provide uniform grades ranging from .3' to .6' per 100 feet of terrace length.
2. Grades can be varied to provide alignment of terraces as nearly parallel as topography will permit.
3. Convey runoff at non-erosive velocities.
4. Leave no depressions in channel over 0.2' deep.
5. Usually the top terrace should be located one interval below top of slope.
6. Terraces must discharge into natural or constructed vegetative areas or outlets where cross section assures safe velocities.
7. All planting and tillage operations shall be done parallel to the terraces.
8. Spacings may be increased or decreased 10% to suit local conditions.
9. No secondary channel shall be left below the terrace ridge.

NOTE: For more detailed information use local technical guide or consult qualified technicians.

Figure 8.1 can be secured from the Regional Supply Center. Order by Drawing No. 3-L-26266.

a. Spacing

In very tight soils where high runoff may cause rilling and erosion between the terraces, the spacing should be somewhat less than shown in the table. However, in porous soils high in organic matter the spacing may be increased. Consult local technical operation plan for local deviations from the standard specifications.

b. Grade

Either variable or uniform grades may be used. The use of a variable grade often permits better alignment of the terrace and to better fit the terrace to the field. In some localities with uniform field slopes, terraces may be staked parallel. This will require some adjustment of the grades. It may also require some cutting and filling.

When terraces are used for drainage purposes on wet land or passing through seep areas, the terrace grade may be increased materially (25-50 percent).

If erosion should develop at end of terrace, keep that portion in sod.

c. Length

The maximum length will generally be about 1600 feet. If longer terrace is desired, check the runoff and design, using diversion design chart for the necessary capacity to handle the extra runoff at non-erosive velocities.

8.26 Location of Top Terrace

The location of the top terrace is very important. If the top terrace fails, it often causes the failure of the lower terraces. Before locating the top terrace, inexperienced personnel should consult someone who has considerable experience in terrace layout.

Some general rules for location of the top terrace are:

If the top of the hill comes to a point, the interval may be increased to one and one-half times the regular terrace interval.

On long ridges, where the terrace approximately parallels the ridge, the regular interval should be used.

The watershed area above the top terrace should not exceed four acres.

8.30 STAKING TERRACES

8.31 Starting Point

a. After the vertical interval has been determined for graded terraces, staking of the terrace line may begin either at the outlet or some other point in the field. The first stake 50 feet from the outlet should be set .3 foot to .5 foot plus the cut "C" shown in the table above the terrace outlet. (See Figure 8.1.) This is to allow for the channel cut made in construction and the possible silting in the terrace outlet.

b. Rod readings by stations and suitable notes should be kept to facilitate layout, construction, and checking.

8.32 Location of the Stake Line in Relation to Completed Terrace

The channel of the completed terrace should coincide with the stake line. Offset lines for starting terrace construction may be made as indicated on Figures 8.2, page 8-6; 8.3, page 8-7; and 8.4, page 8-8 so that this will be achieved. (The ridge of level terraces should coincide with the stake line.)

8.33 Adjustment to Improve Sharp Bends

After the line has been staked it is well to check and arbitrarily move some stakes if necessary to ease sharp turns.

Ordinarily, limit such adjustments so that not more than six inches of extra cut or fill will be made. With a little experience, stakes can be moved up or down the slope to compensate for the equipment "creeping" while going around sharp bends.

8.40 CONSTRUCTION OF TERRACES

8.41 Methods

a. Preparation of Field

All dead furrows or ditches to be crossed should be filled in before the construction begins to prevent seepage through terrace ridge and to facilitate construction.

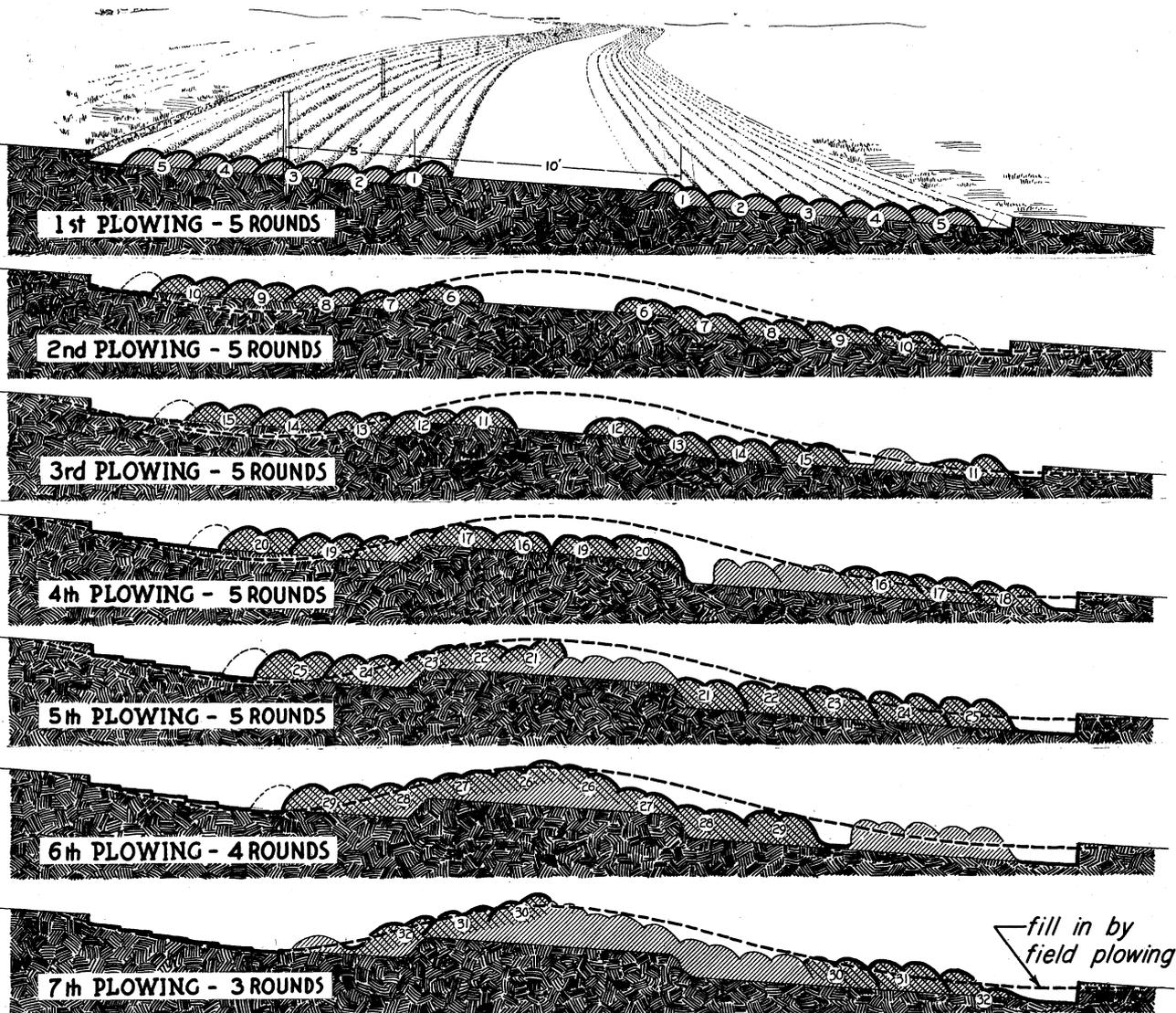
All old fencerows should be leveled off.

Surplus vegetation should be removed if the terrace is to be constructed with a plow or a whirlwind terracer.

Heavy sod should be thoroughly disked.

b. Moldboard Plow - From Both Sides

In starting the construction, the operator either leaves an island or he may start by backfurrowing. This is a matter for

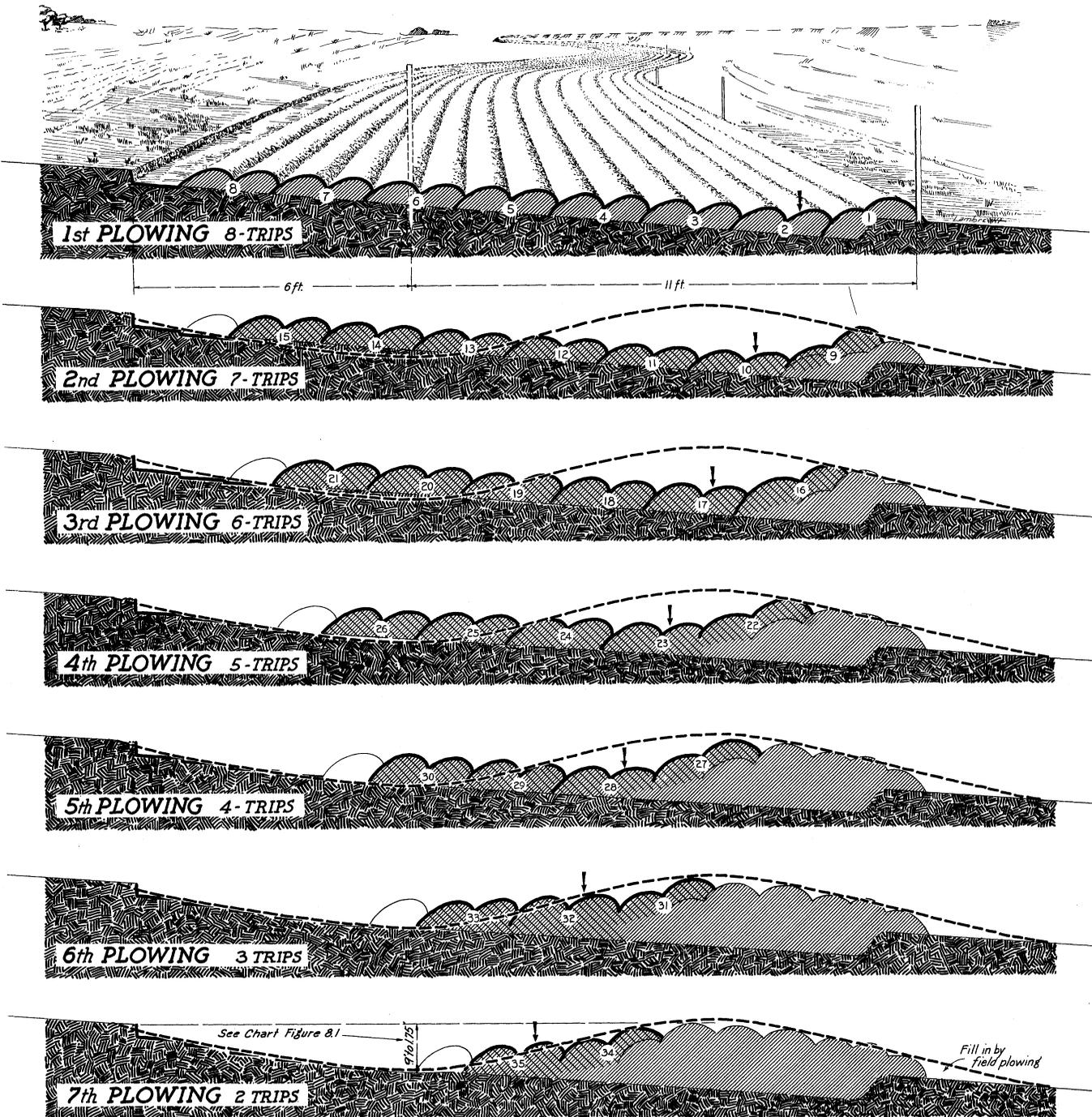


Method after setting channel stakes. Plow first furrow 5 ft down hill from channel stakes and return furrow 15 ft down hill from channel stake as indicated. Locate 1st furrow and return furrow by staking; or, by two men with a rod held between them. One of these men walks the channel stakes, the other walks ahead of the plow. When the first five rounds are completed, start successive plowings by numbered rounds. Note irregularity in return trip of round 11.

This drawing is based on use of a two-bottom, 14, or 16-inch plow. Remove jointers. Coulter may be left on. Use sharp shares. Maintain enough speed to turn furrow slice completely over. Remove crop residues and disk heavy sod well before plowing.

If terrace ridge is not the desired height, additional plowing may be necessary. To increase the size and width, additional rounds per plowing may be necessary.

FIGURE 8.2 A METHOD FOR TERRACE CONSTRUCTION PLOWING FROM BOTH SIDES



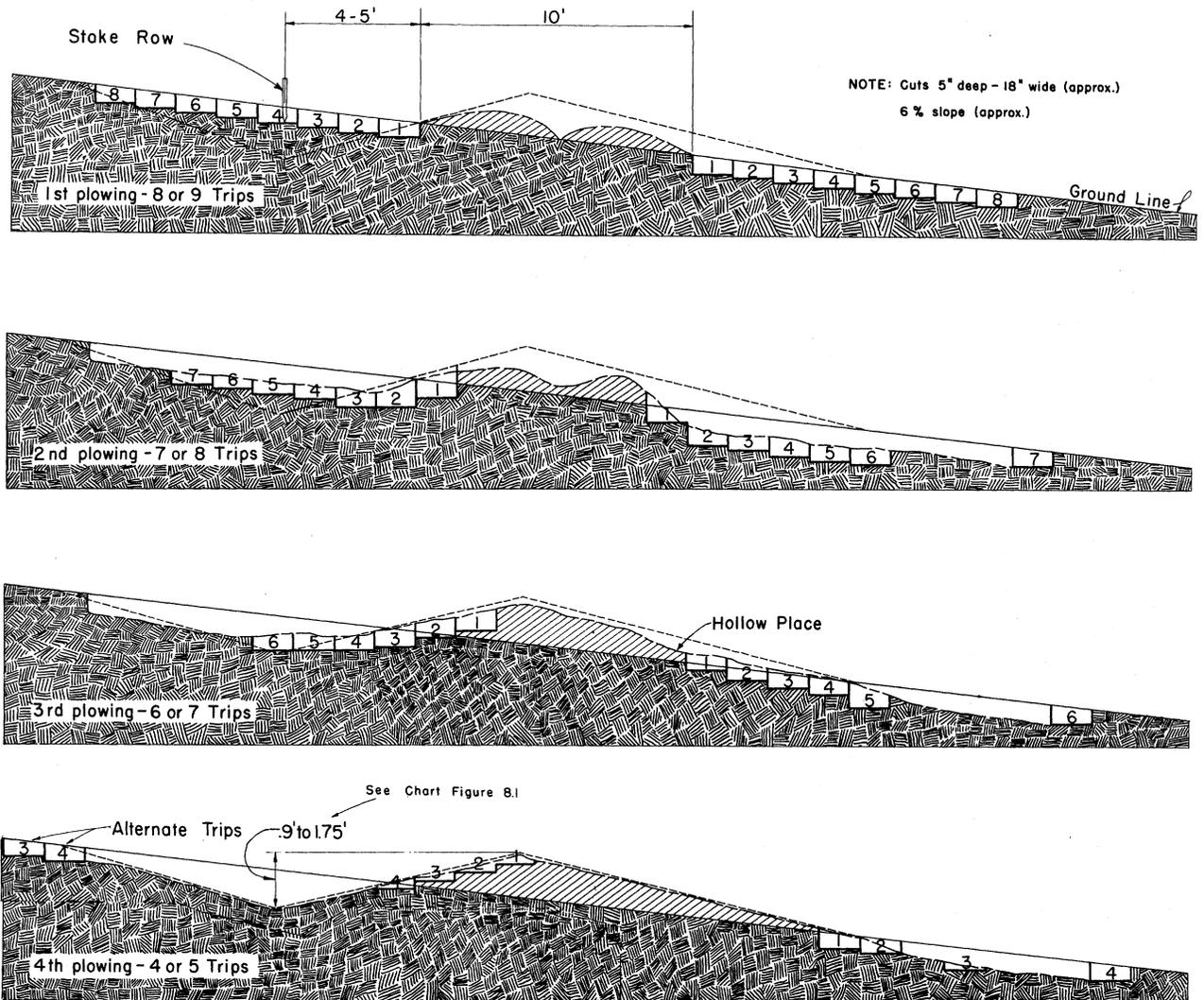
Method after setting channel stakes. Set a second row of stakes at 50-foot intervals (closer on sharp curves) 11 feet below channel stakes. This row marks first plowing.

This drawing is based on use of a two-bottom, 14, or 16-inch plow. Remove jointers. Coulter may be left on. Use sharp shares. Maintain enough speed to turn furrow slice completely over. Remove crop residues and disk heavy sod well before plowing.

Start first plowing by throwing furrow slice against lower stake line. Return empty, packing terrace, unless adjoining land is to be plowed. Start each successive plowing with the front bottom picking up the third furrow slice (marked with arrow) of the previous plowing. Crowd over if necessary, so as to form a smooth backslope.

If terrace ridge is not the desired height additional plowings may be necessary. To increase the size or width, additional rounds per plowing may be necessary.

FIGURE 8.3 A METHOD FOR TERRACE CONSTRUCTION PLOWING FROM THE UPPER SIDE ONLY



SUGGESTED PROCEDURE

Run the rotor in the gear which will throw the main stream of dirt into the center of the terrace ridge.

1st Plowing

After setting channel stakes, plow the first trip 4 to 5' downhill from the stake row and the return furrow 14 to 15' downhill from the stake row. The first trip and return can be located by staking or by two men walking with a rod held between them. One of these men walks on the stake row and the other man walks ahead of the plow.

2nd Plowing

The 2nd plowing starts with the plow being one furrow closer to the center of the island as indicated.

3rd Plowing

In the 3rd plowing the upper side of the ridge should be started with the plow just below the ridge top as shown. On the lower side, plowing should start just below the point where a hollow exists as indicated on the drawing.

4th Plowing

This plowing may not be needed. Often times if soil conditions are right, the first three plowings as indicated will build an adequate terrace. If the 4th plowing is needed it should be started near the top of the ridge on the upper side. Furrows should ordinarily be shallow. On the lower side they should start just below the toe of the slope. If the operator decides trips 3 & 4 are not needed to alleviate the channel on the lower side they may be made as indicated "Alternate Trips" on the upper side, throwing the soil either away from the channel with the rotor in high speed or scotter on the channel and ridge.

General

The plow should be set at a depth which will permit maximum tractor motor speed. This speed can be determined by the operating sound of the tractor motor. The speed of the rotor should be maintained at maximum speed for the gear setting.

Variations from the above procedure may be desirable to get on adequate terrace. This will depend on the soil conditions and the tractor power.

FIGURE 8.4 A METHOD FOR TERRACE CONSTRUCTION WITH WHIRLWIND

each one to decide and to develop a good technique. The island method with a moldboard plow is so widely used that it is further explained. It will require about 32 to 40 rounds to construct a standard terrace, about 45-50 rounds for level terraces. Figure 8.2 shows a method for sequence of rounds. Experience has shown that after the fifth series of rounds, or after 20 to 30 rounds, some deviations may be desirable due to the condition of the soil, how the plow operates, and the experience of the operator. The main thing is to keep the plow as level as possible. Drive at a rate of speed so that the furrows will be turned over by the moldboard. Start out by plowing the first series of rounds shallow. Then plow the next series about one inch deeper so as to reach undisturbed soil. If the soil is "powder dry" or too wet, it is advisable to delay construction until a favorable moisture condition exists. If level terraces are to be constructed, set offset stakes so that the ridge of the completed terrace will fall on the original staked line. (See Part 8.32.)

c. Moldboard Plow - From Upper Side Only

In using this method all of the soil is moved from the upper side. This method puts the channel somewhat deeper into the original soil. On soil where the highly pervious covering is thin and drainage is needed, this is a desirable feature, as the deeper channel tends to intercept horizontal movement of water. On steep slopes this method has considerable merit. Figure 8.3 shows a method for sequence of rounds.

d. Disk Plow or Disk Tiller

With the exception of not removing surplus vegetation follow the same procedure as with the moldboard plow. (See Figures 8.2 and 8.3.)

e. Whirlwind Terracer

The whirlwind terracer will not work satisfactorily in rocky or stony soil; neither will it work well in heavy sod. All heavy vegetation should be removed. Heavy sod should be thoroughly disked before starting the construction. To operate a whirlwind terracer satisfactorily, a tractor that can handle a three- or four-bottom plow is required. The plow should not cut deeper than the tractor can pull without reducing the motor speed. This will maintain the speed of the rotor necessary to throw the soil on the ridge. The terracer should be kept level so that the rotor can effectively throw the soil. It generally requires 30 to 35 rounds to complete a graded terrace, depending on the condition of the soil and size of tractor used.

A 10- or 12-foot island is recommended on the average fields, (Figure 8.4). Here, again, local methods are different and some operators start by throwing the soil together the first round. The method illustrated, therefore, is merely a guide. A method adapted to local conditions and the operator should be developed.

f. Bulldozer

The bulldozer has an advantage in many respects. It can be used on very rough, stony, and eroded soils. The ditches can be filled as part of the terrace construction operation. The bulldozer will operate under conditions in which other types of equipment cannot efficiently function, such as in extremely dried-out soils. Two methods have been used (Figure 8.5, page 8-11). The area should be plowed before starting construction. This will insure a more uniform terrace and will save time.

The roughing-in is accomplished by making three "cuts" and "bucks." After the roughing-in is completed, two rounds or more are made lengthwise to shape the slopes and sometimes one in the channel is necessary to give the terrace its final shape and cross section.

g. Motor-Patrol Type Grader

For heavy work this type of equipment does an excellent job. Where a contractor has enough work for a machine of this type, it is very effective and efficient. A skilled operator can cut a channel true to grade and very little follow-up will be required to remove high and low spots in the channel. See Figure 8.6, page 8-12, for a suggested sequence of trips.

h. Elevating Graders

Several types of elevating graders are being used with good success. The number of rounds and sequences depends upon size of machine and condition of the soil. The speed of the belt on several machines can be varied to place the soil where needed to bring the terrace to the required cross section.

This type of equipment will usually be used only by contractors. Methods will vary; however, the cross section of the terraces should conform to the standard.

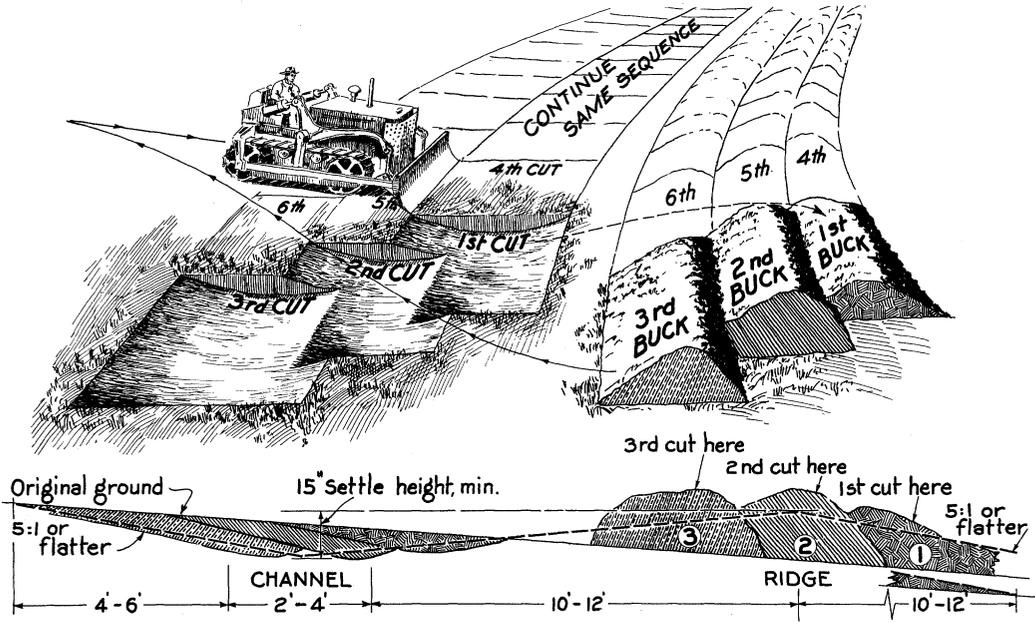
8.42 Time Required

Figure 8.7, page 8-12, gives the average time required for constructing terraces. Comparison between terraces built with a motor patrol or bulldozer and other types is not possible. This table includes time required for making cuts and fills for the motor patrol and bulldozer but does not for other types of equipment.

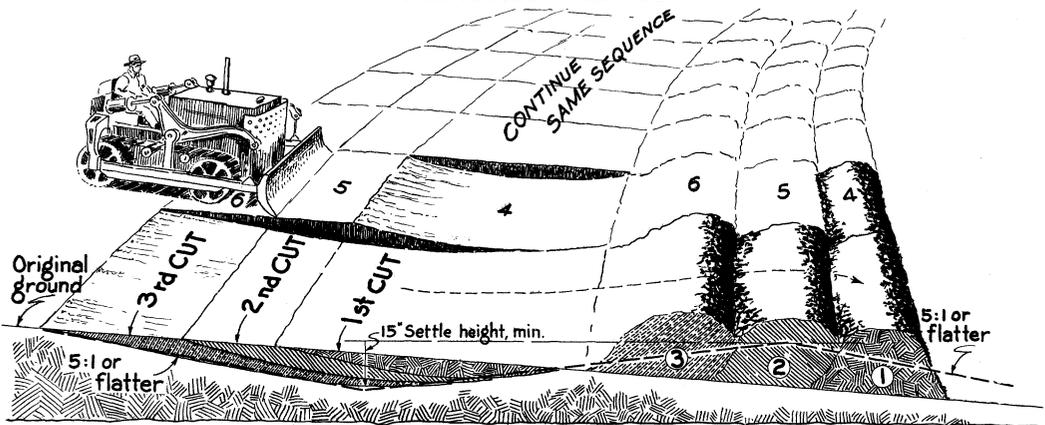
8.50 CHECKING FINISHED TERRACE

8.51 Method of Checking

The high and low points should be marked so that the necessary corrections can be made. Prevent ponding in graded terraces over 0.1 foot deep. This is always a hindrance to operation of farm equipment and it causes crop loss.

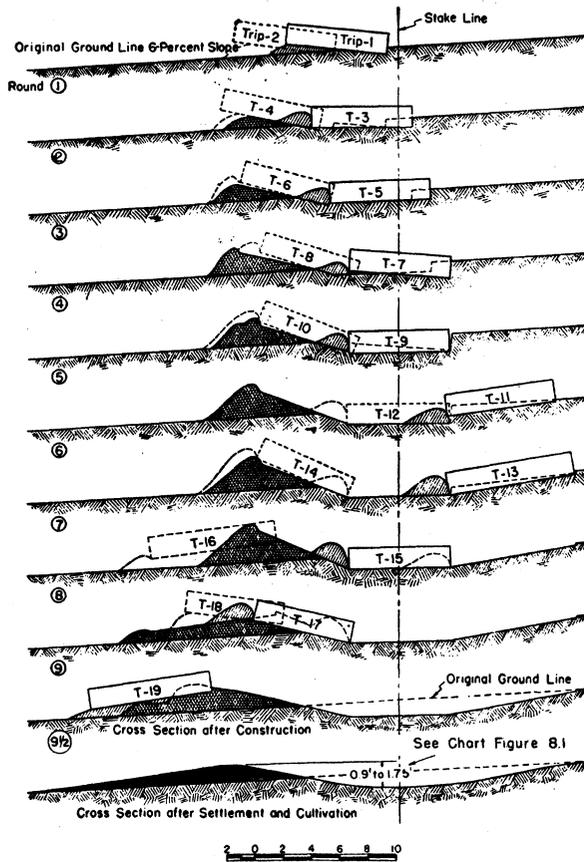


**Cross Section of Terrace
STAGGERED CUT METHOD**



STRAIGHT CUT METHOD

FIGURE 8.5 A METHOD FOR TERRACE CONSTRUCTION WITH BULLDOZER



Progressive steps in constructing a channel terrace in the Midwest with a 10-foot blade terracer. The terrace is constructed from the upper side only.

FIGURE 8.6 A METHOD FOR TERRACE CONSTRUCTION WITH MOTOR PATROL

Type of Equipment	Feet Per Hour	Hours Per Mile
Moldboard plow - 2 bottom	125 - 190	28 - 41
Disk tiller	170 - 190	28 - 31
Whirlwind	170 - 200	26 - 31
Motor patrol grader	180 - 220	24 - 29
Bulldozer	180 - 220	24 - 29
Elevating grader, small	180 - 220	24 - 29
Elevating grader, large	200 - 250	21 - 26

FIGURE 8.7 TIME REQUIREMENTS FOR TERRACING

When checking level terraces the ridge height should be checked for proper elevations. The terrace checking is as important as the laying out of a terrace. No terrace job should be considered completed until it has been checked.

8.60 TERRACE MAINTENANCE

8.61 The farmer should be encouraged to make an inspection periodically and after each heavy rain. Any breaks should be repaired and the channel and ridge brought to grade.

a. Repairs in fills should be higher and broader than the old portion to prevent over-topping or seepage.

8.62 It is essential that a good rotation be maintained, thus materially reducing the silting of the terrace channel. In fields low in organic matter, terraces may require special maintenance.

8.70 PLOWING TERRACED FIELDS

In many areas research and observation indicate that plowing with the conventional one-way plow, over a period of years, will eventually bench a terraced field. The profile between terraces eventually becomes hollowed out and a bench effect is developed. This difficulty can be overcome by using the two-way plow. The small amount of erosion between the terraces can be removed from the terrace channel and a constant profile, without benching, can be maintained.

Farmers should be encouraged to use the two-way plow.

8.71 How to Use the Two-Way Plow (See Figure 8.8, pages 8-15 and 8-16.)

Start the first step in this method of plowing by throwing the first furrow on the ridge of the top terrace from the back-slope side. The area below the top terrace is then plowed by turning all the furrows uphill. (See Step No. 1.)

When the narrowest place is within about 15 or 20 feet of the channel of the next terrace, the wide areas should be plowed out leaving a strip of unplowed land of even width through the field.

After all the wide areas are plowed, a land 15 or 20 feet wide will be left above the terrace channel. This should be plowed out by turning the furrows uphill as shown in Step No. 3.

The last step (Step No. 4) consists of plowing the area between the top of the ridge and the low point of the channel. This is done by throwing the first furrow toward the top of the ridge and continue throwing furrows in the same direction until this land is plowed out. This method will result in one dead furrow which occurs in the bottom of the terrace channel and one back-furrow which will occur on the ridge.

The area above terrace number one and the area between other terraces should be plowed using the same sequence.

After several plowings, using a two-way plow, the ridge may become too high. This can be prevented and the terrace broadened by leaving the backfurrow to one side or the other of the extreme peak.

8.72 How to Use the Conventional One-Way Plow

a. Method 1 - Dead Furrow Between Terraces (See Figure 8.9, page 8-20.)

The first step in this method is to backfurrow to each terrace ridge. If the terrace has lost some of its height, throw the furrows together at the top just like a land would be started anywhere. If the terrace ridge is already high enough, keep the plow below the ridge so that the disturbed soil from the first round just meets at the top. This helps to broaden the top of the terraces and makes them easier to farm.

Continue plowing on the land started with the backfurrow until an area about 20 feet above and 20 feet below the terrace ridge is plowed. When this has been done on each terrace, plow the remaining areas between the terraces as separate lands.

Continue to plow these lands until the unplowed strip narrows down to about 20 feet wide at the narrowest part (Step 2). This unplowed area will be irregular in width.

Plow extra furrows on the wide portions of the remaining area until a turnland 20 feet wide extends through the entire length of the field (Step 3). This permits irregular areas to be plowed out without turning on plowed ground.

This uniform width turnland can then be plowed as a regular land and will leave the dead furrow about halfway between terraces (Step 4). The turnland can be narrower than 20 feet if small equipment is used and should probably be wider if large plows and tractors are used.

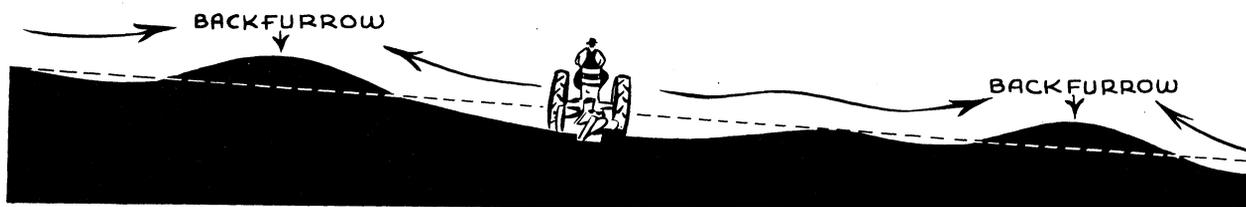
With this method of plowing, as illustrated, the furrow will be thrown into the terrace channel and the dead furrow will occur in the same place every time the field is plowed. Since that is not desirable, this method of plowing should be alternated with Method 2.

b. Method 2 - Dead Furrow in Terrace Channel (See Figure 8.10, page 8-21.)

Every other time the terraced area is plowed it is important to throw the furrow away from, rather than into the terrace channel. This is done by backfurrowing from the terrace ridge to the center of the terrace channel on each terrace (Step 1).

The best way to plow terraced land is with a two-way plow - a plow that has two sets of moldboards and permits throwing the dirt either to the right or to the left. Continuous plowing with the conventional plow will eventually bench a field. The drawing below, exaggerated for clarity, shows what happens to a terraced field after a number of plowings with conventional plows. Even though the dead furrows are shifted from one place to another you can't avoid throwing soil both downhill and uphill which is what causes benching of the field.

ONE-WAY PLOW METHOD



IN USING A ONE-WAY PLOW THE PROFILE BECOMES DISHED AND AFTER A NUMBER OF PLOWINGS THE TERRACES BECOME 'BENCHED'. - - - ARROWS INDICATE DIRECTION DIRT IS THROWN - - - DOTTED LINE INDICATES NATURAL GROUND LEVEL -

The two-way plow makes it possible to keep the terraces about as you built them as shown by the drawing below. Soil is thrown toward the terrace ridge and the dead furrow is always left in the terrace channel. This can be done only with the two-way plow.

Farmers who have terraces or plan to terrace should give serious consideration to the effect that plowing has on a terraced field. When the old plow wears out they should buy the two-way plow.

See the drawings on the back for steps in plowing terraced land with the two-way plow.

TWO-WAY PLOW METHOD

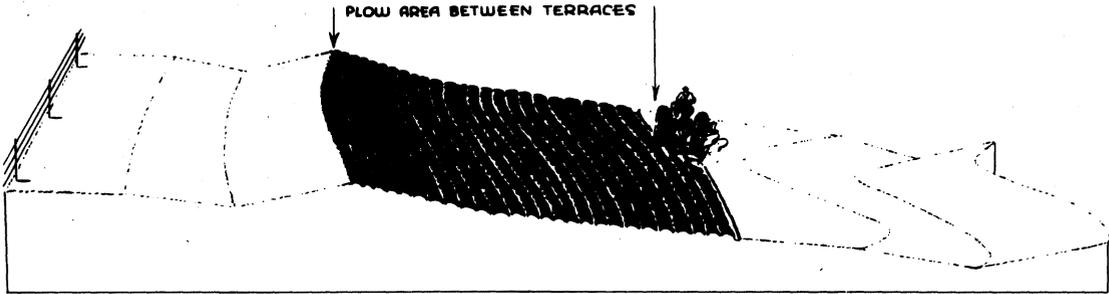


BY USING A TWO-WAY PLOW THE PROFILE REMAINS ALMOST CONSTANT - - - ARROWS INDICATE DIRECTION DIRT IS THROWN - - - DOTTED LINE INDICATES NATURAL GROUND LEVEL -

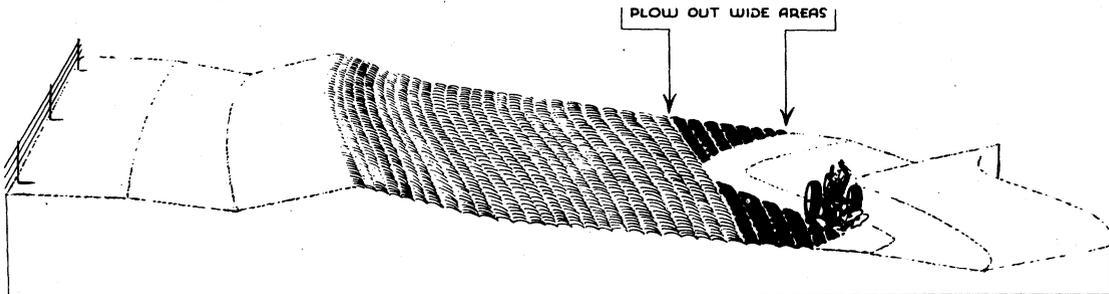
FIGURE 8.8 A METHOD: HOW TO PLOW TERRACED LAND WITH THE TWO-WAY PLOW

HOW TO PLOW TERRACED LAND WITH THE TWO-WAY PLOW.

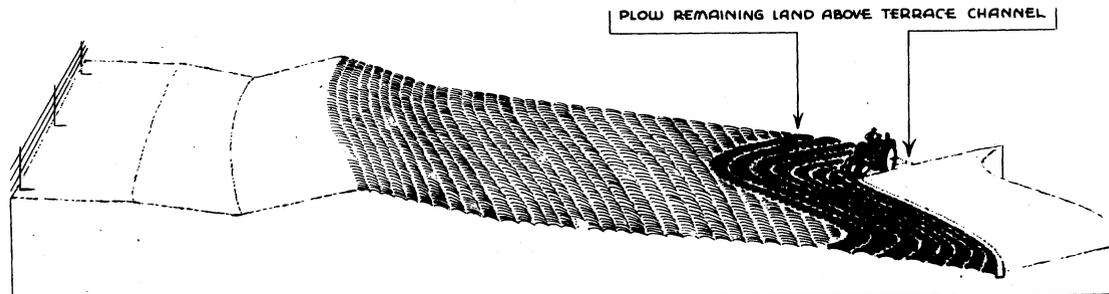
STEP NO. 1



STEP NO. 2



STEP NO. 3



STEP NO. 4

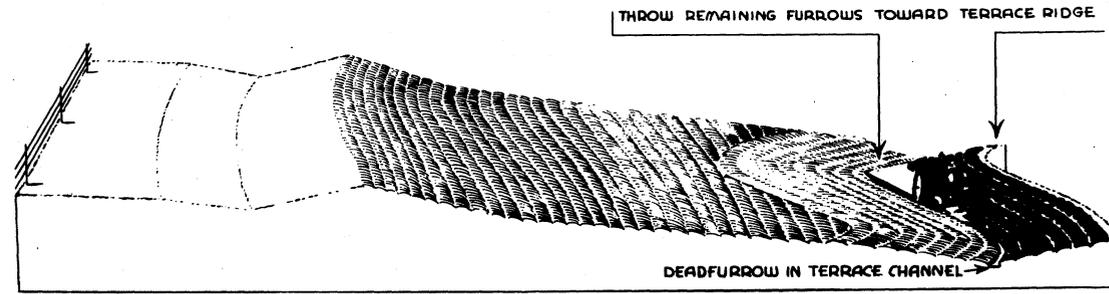


FIGURE 8.8 A METHOD: HOW TO PLOW TERRACED LAND WITH THE TWO-WAY PLOW

Then move up the slope 15 or 20 feet from the terrace channel and start another backfurrow parallel to the terrace channel (Step 2). The line to follow in laying this backfurrow can be done by eye after a little experience. It may be desirable to set a line of stakes the first time a farmer tries it, but after experience this will not be necessary. Continue to backfurrow this land until the dead furrow is reached in the terrace channel. The dead furrows formed there will materially increase the capacity of the terraces.

There is an unplowed area below each terrace which can be plowed as outlined in Method 1, Figure 8.9. Work the remaining land down to an even width strip and plow out as illustrated on the right in Steps 3 and 4. The same procedure is followed on all the terraces.

It is important to see that the dead furrows fall in a different place each time the field is plowed. The easiest and best way to do this is by alternating plowing Methods 1 and 2 and by varying the width of the plowed strip between the terraces. Plowing according to Method 2 throws the furrows out of the terrace channel.

Always plow out point or irregular-shaped areas before plowing all of the long ones. This gives solid or undisturbed ground to turn on, resulting in less wear and tear on equipment.

8.80 PREPARING SEEDBED AND PLANTING CROPS ON TERRACED LAND

8.81 All seedbed preparation should be carried out by using the terrace as a guide line for starting operations.

8.82 Planting Row Crops on Terraced Land

a. Method 1 (See Figure 8.11, page 8-22.)

When planting row crops such as corn or beans, start planting on the uphill side of the top terrace (Step 1). Don't straddle the terrace with the planter. Put the first row just off the terrace ridge on the uphill side. Continue planting to the top of the slope. Straddling the terrace ridge with the planter will cause trouble later in cultivating - the front shovels will be buried while the rear ones are dangling in the air.

After planting above the top terrace to the edge of the field, continue the planting by starting on the ridge back slope of the top terrace and plant down the slope about one-third of the distance between the first and second terrace (Step 2).

Then go to the channel side of ridge of the second terrace and plant up, just as with the first one, until a strip of land eight rows wide at the narrowest part is left unplanted (Step 3). This remaining area yet to be planted will almost certainly be irregular in width.

Now plant extra (shorter) rows on the wide portion of this remaining area until the eight-row width of turnland extends through the entire length of the field (Step 4). This permits planting the irregular areas without turning on planted ground. This procedure is necessary when planting is done with a hard- or loose-ground lister.

The eight-row width turnland is planted last, giving eight rows that go through the entire length of the field (Step 5). The width of this turnland may vary but eight rows are enough for either a two-row or a four-row planter.

Many prefer this method because no turning is done on planted ground, and a better contour is maintained. In harvesting pick the eight-turn rows and disk them down. This leaves a turning area for picking the point rows.

b. Method 2 (See Figure 8.12, page 8-23.)

Another method is to start planting on the channel back slope of the top terrace and continuing to the top of the slope or field boundary (Step 1).

Then start planting on the channel side of the ridge of the second terrace. Plant uphill until a land eight rows wide at the narrowest portion is left unplanted on the back slope of the next terrace above (Step 2).

The remaining area yet to be planted will be irregular in width. Next, plant extra (shorter) rows on the wide portions of the remaining area. This will leave an eight-row width of turnland extending through the entire length of the field (Step 3). Here again this permits the irregular areas to be planted without turning on the planted ground.

The final operation is that of planting the turnland. To do this start near the top of the ridge back slope of the top terrace and plant down eight rows (Step 4). The only difference between this method and the first is in location of turnland. In this method the eight-row turnland is left just below each terrace instead of halfway between terraces.

Many farmers prefer this method because:

- (1) It can be carried out without turning the equipment on planted ground. This is of considerable importance if you plant your corn with a hard ground or a loose ground lister.
- (2) Many farmers find this method of planting easier to explain and more easily understood by the hired man.
- (3) With the eight-row turnland area located on the back slope of the terrace it is easier to start picking on rows that extend the entire length of the field.

The establishing of the eight-row turnland area in both Methods 1 and 2 of planting is easily done by eye after a little experience in doing it. Here, as in plowing, it may be desirable to set two lines of stakes the first time the farmer tries it - one line of stakes in the upper side and the other line on the lower side of turnland. With added experience this will not be necessary.

c. Method 3 (See Figure 8.13, page 8-24.)

A third way to put in row crops is to start planting (Step 1) on the inside slope of the top terrace and planting to the top of the slope or field boundary just as in the other methods. Then start on the back slope (Step 2) of the top terrace and plant down to a point approximately one-half the distance to the second terrace.

Next (Step 3), start planting near the top of the channel back slope of the second terrace, planting uphill until the rows join those already planted. This will leave point rows near the center between terraces. (An alternate method of planting point rows is to plant from both sides rather than from one side as shown.) Continue this procedure with the remaining terraces. When planting is completed to the last terrace, use it as a guide line and plant to the bottom of the field. Where loose or hard ground listing is done Method 3 is not recommended because of turning on planted ground.

d. Method 4 (See Figure 8.14, page 8-24.)

Another method that could be used is identical to Method 3, except that the uneven area occurring near the center between terraces is not plowed but is left in sod crops. A temporary crop which can be harvested for hay can be used in the uneven area if it is plowed with the rest of the area. This procedure will work all right, but it is very seldom used or recommended. NOTE: Any method whereby point rows occur in the terrace channel should be avoided and certainly not recommended.

METHOD 1 - LEAVING DEAD FURROW BETWEEN TERRACES.

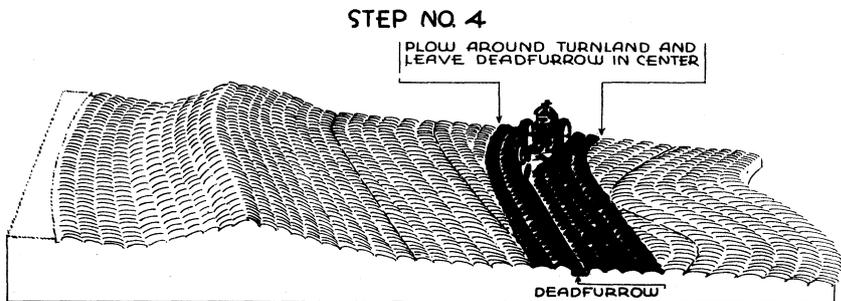
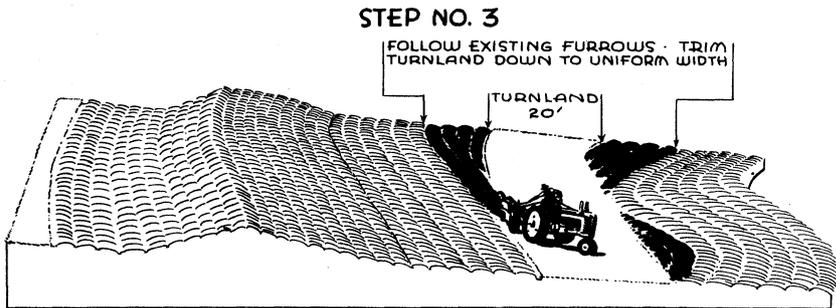
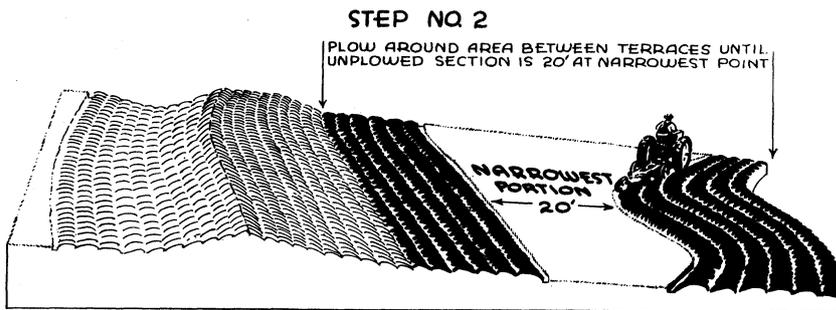
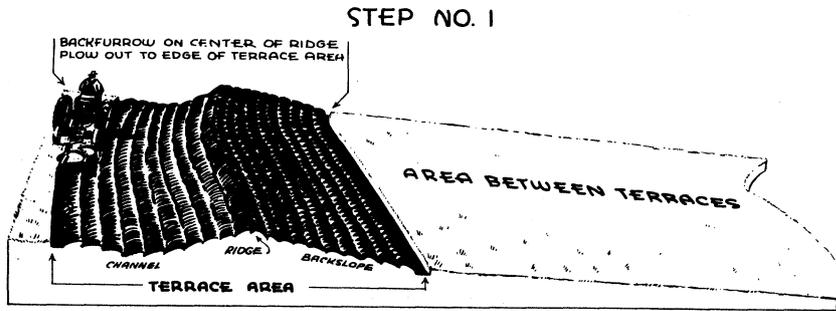
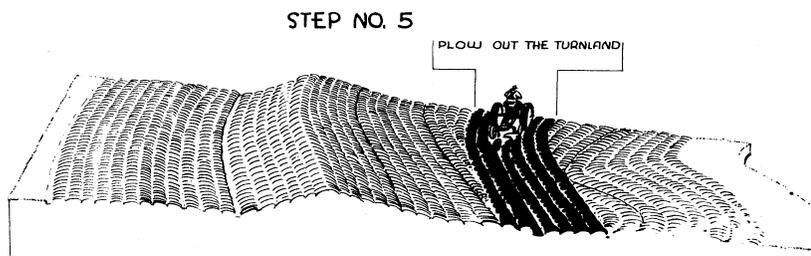
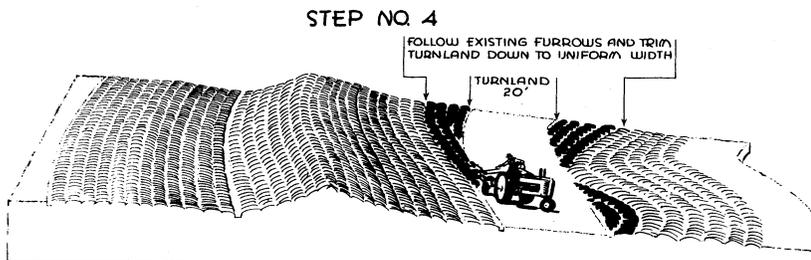
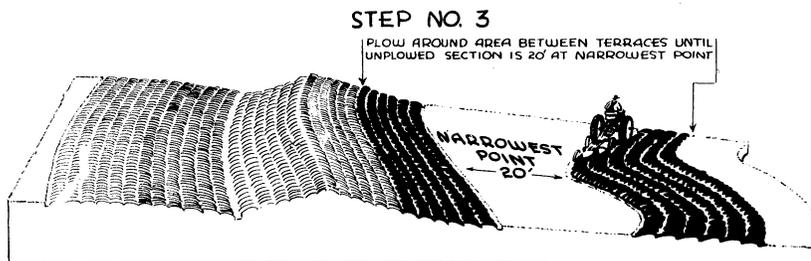
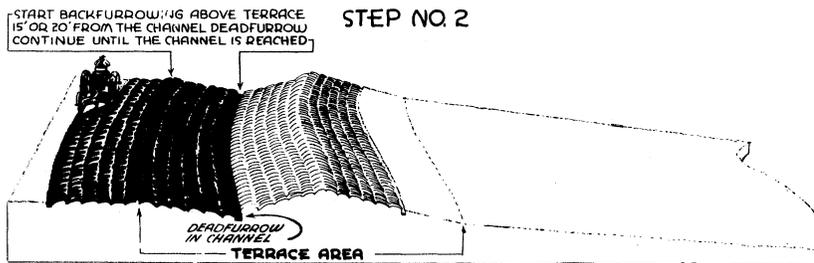
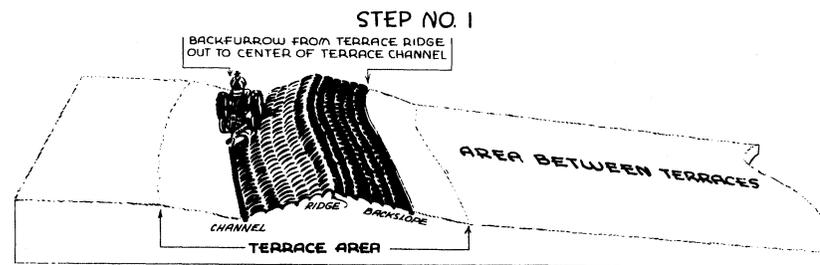


FIGURE 8.9 A METHOD: HOW TO PLOW TERRACED LAND WITH THE CONVENTIONAL ONE-WAY PLOW



It is advisable to alternate this method with the first method described on the opposite page.

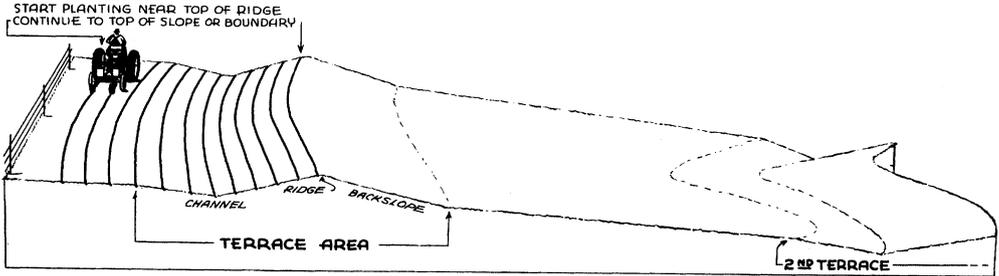
FIGURE 8.10 ANOTHER METHOD: HOW TO PLOW TERRACED LAND WITH THE CONVENTIONAL ONE-WAY PLOW

HERE'S

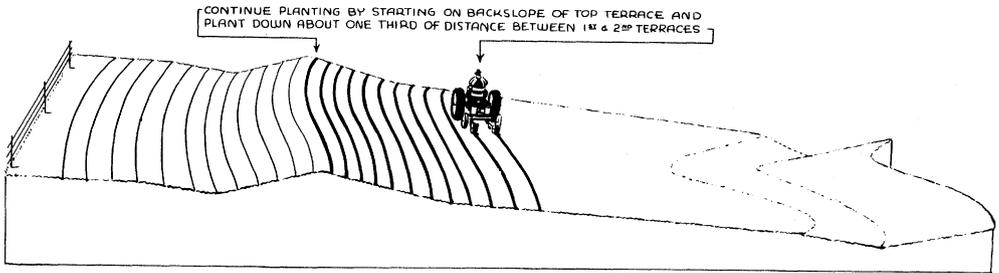
ONE

WAY

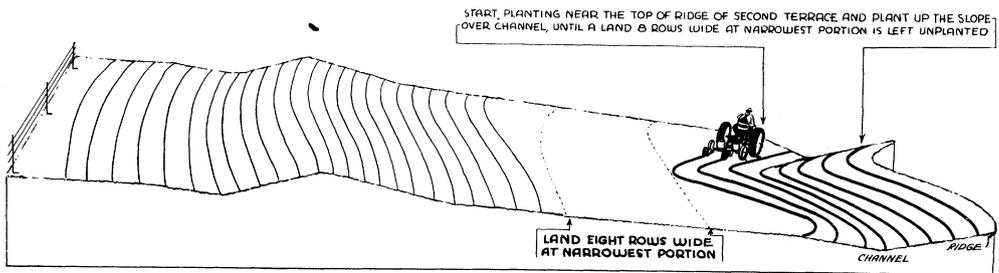
STEP NO. 1



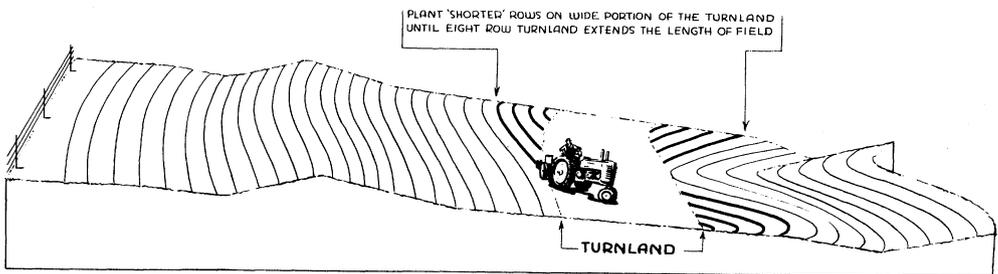
STEP NO. 2



STEP NO. 3



STEP NO. 4



STEP NO. 5

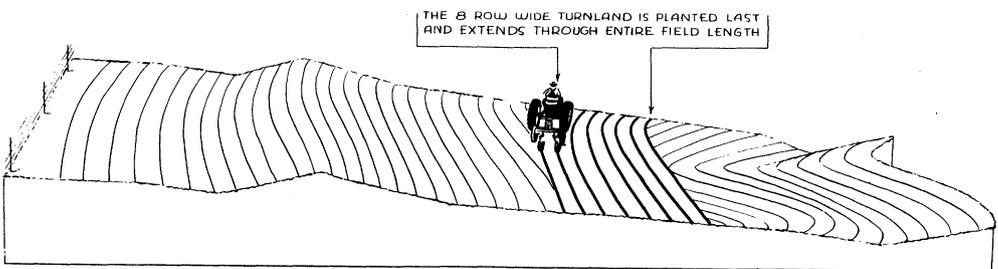
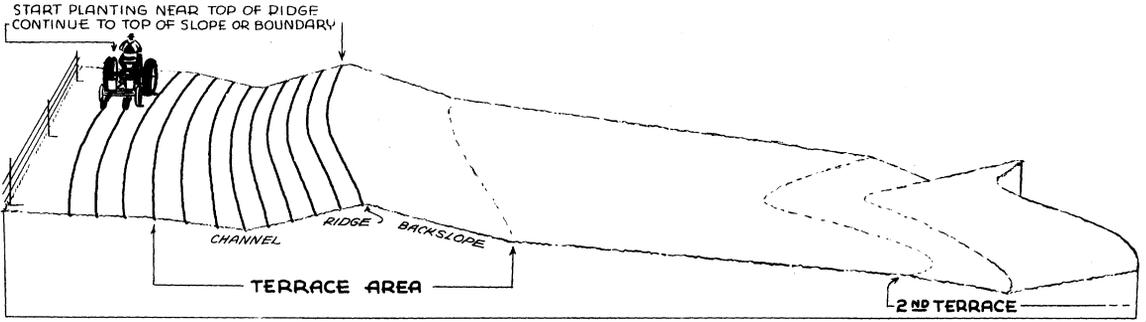
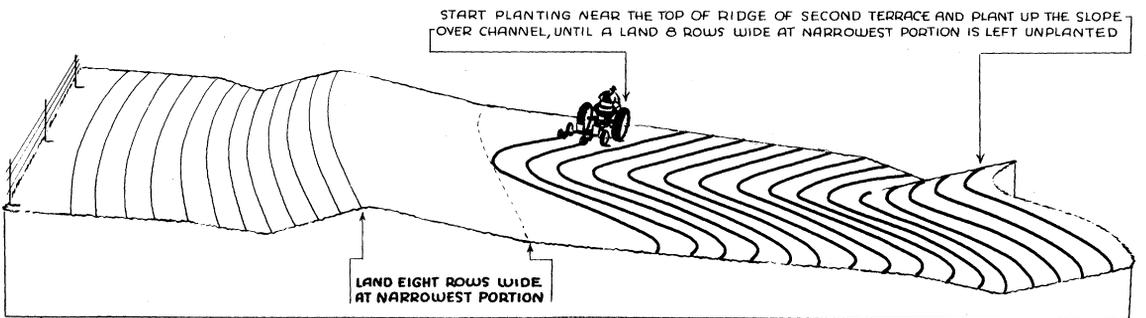


FIGURE 8.II A METHOD FOR: PLANTING ROW CROPS ON TERRACED LAND

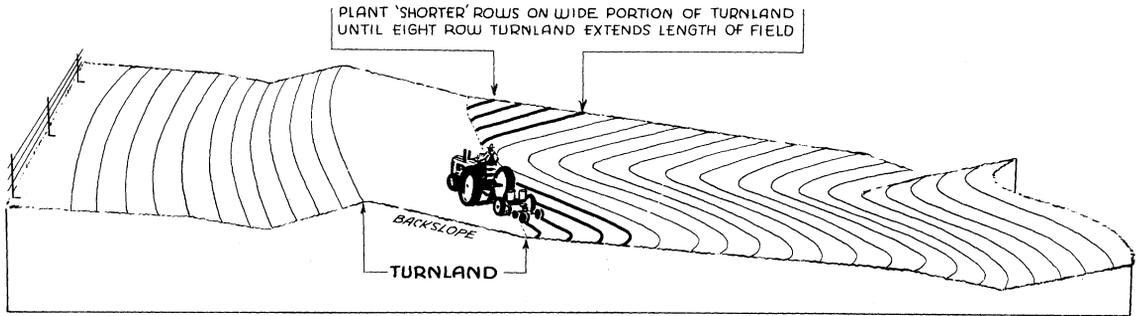
STEP NO. 1



STEP NO 2



STEP NO 3



STEP NO. 4

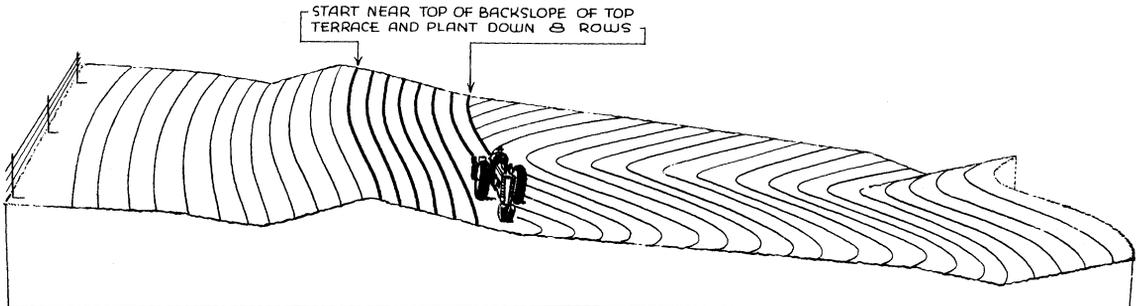
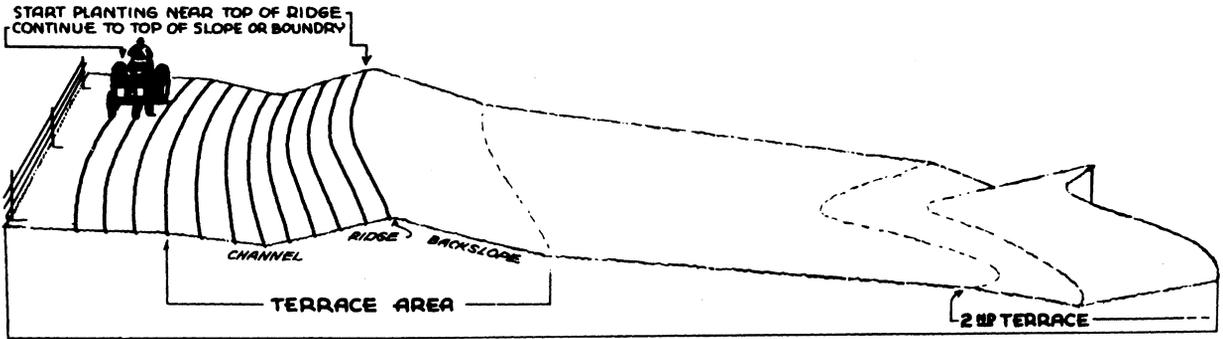
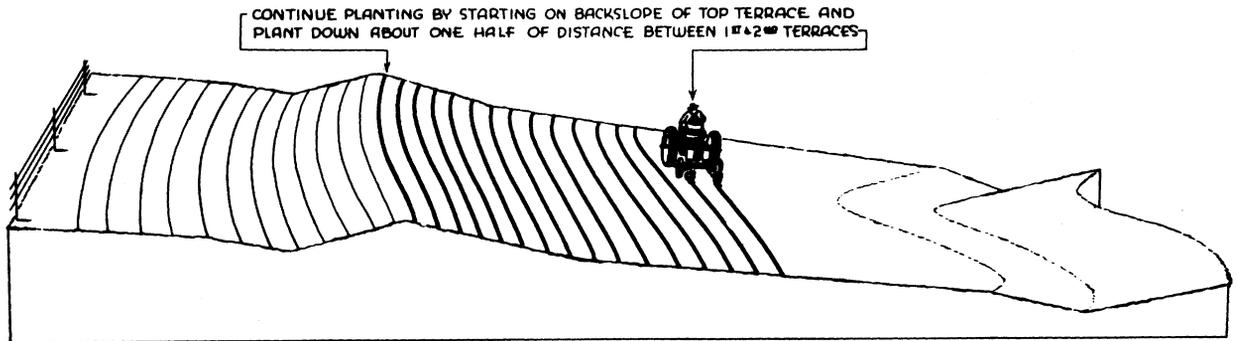


FIGURE 8.12 ANOTHER METHOD FOR PLANTING ROW CROPS ON TERRACED LAND

STEP NO. 1



STEP NO 2



STEP NO 3

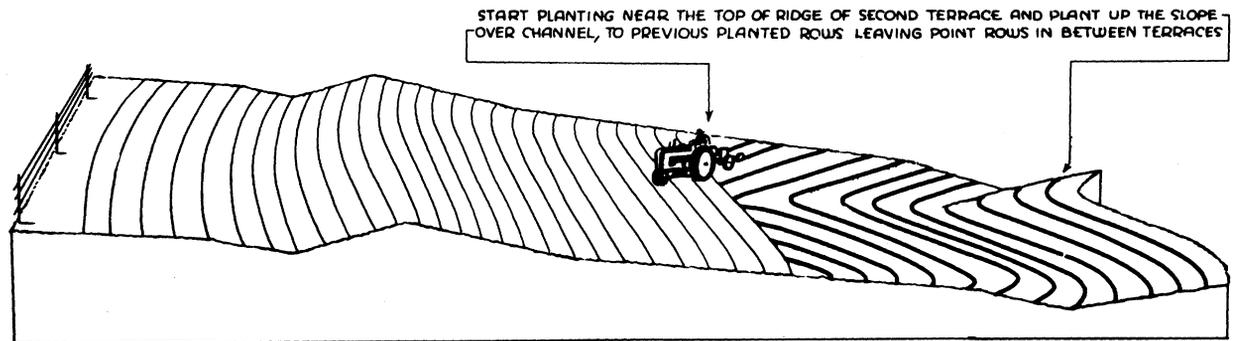
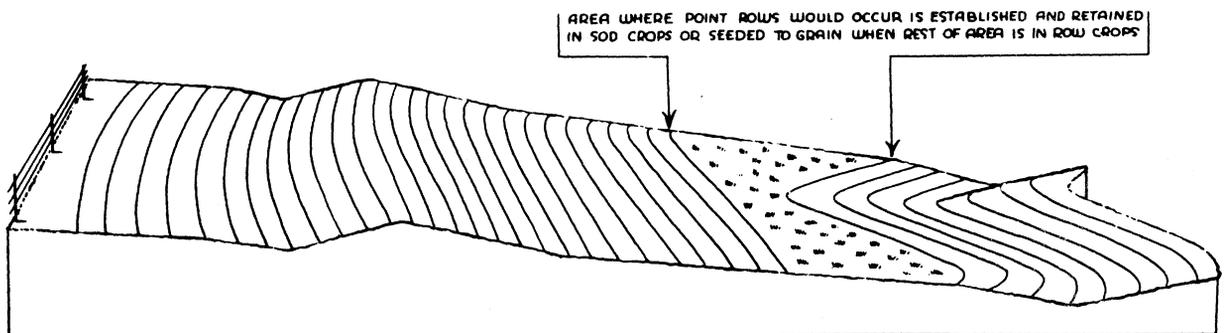


FIGURE 8.13 A THIRD METHOD FOR: PLANTING ROW CROPS ON TERRACED LAND



If you dont want to bother with point rows you can just leave the uneven area in meadow or small grain

FIGURE 8.14 A FOURTH METHOD FOR: PLANTING ROW CROPS ON TERRACED LAND

8.90 HARVESTING CROPS ON TERRACED LAND

8.91 Harvesting Grain (See Figure 8.15, page 8-26.)

Grain crops will either be harvested with a binder, a windrower, or cut direct with a combine. All of these operations present the same general problems. On land that slopes 6 percent or less, standard terraces built according to specifications (see Figure 8.1, page 8-3) can be crossed with machinery at almost any angle. The easiest way to harvest grain on such terraces is simply to cut around the field, as would be done if the terraces were not there. On the steeper slopes, where terraces cannot be built wide, it is probably better to harvest the grain with the terraces. This will cause some waste where the tractor and bull wheel knock down the grain. If terraces are nearly parallel it would be well to select one key terrace - usually near the center terrace. A land can then be opened on this terrace. With a binder or combine this will simply mean back cutting on the terrace ridge selected for a key terrace. With either of these machines it is best to put the grain wheel on the terrace ridge and make a complete round.

If a windrower, which delivers the grain to the center, is available the job is easy since only one back-cut through the field with the windrower is necessary. It is probably better to make this cut with the grain wheel running on the top of the terrace ridge. When using an old converted binder for a windrower, the better plan is to cut a strip through the field on the key terrace with a mower and use it for hay, or put it into a windrow with a side delivery rake after the first cut is made. The remainder of the terraces can be cut with the machine running parallel. By planning ahead, wide cuts can be made on the areas which have wide horizontal interval and narrow cuts made on the narrow interval. In this way the cut will approach the next terrace with the cut parallel to the ridge.

8.92 Harvesting Corn (See Figure 8.16, page 8-27.)

The method of picking corn on terraced land depends largely on how the field was planted. It will be the reverse, so to speak, of the corn planting procedure. Only one method is shown in detail which is for picking corn planted according to Method 1, Figure 8.11, page 8-22. Others will be very similar and, in any event, will be the reverse of the planting process.

First open up a land by picking the rows in the eight-row turnland. With a two-row mounted picker this is very simple. With other pickers it will be necessary to contend with down rows.

The short or point rows should be picked next (Step 2). They can be picked very easily by using the eight-row turnland to provide a place to turn equipment.

Next, as illustrated in Step 3, harvest all the long rows between the turnland and terrace number 2. As in the harvesting of the short rows, the eight-row turnland will furnish an adequate turnland for harvesting these rows.

SMALL GRAIN

On land that slopes less than about 6 percent terraces are built wide enough to let you cross them with machinery at almost any angle you choose. Thus you can cut such fields by going 'round and 'round them just as you always do. On steeper slopes, where terraces can't be built wide, it is probably better to harvest the grain with the terraces. The three drawings below showing a windrower in operation illustrate how this may be done.

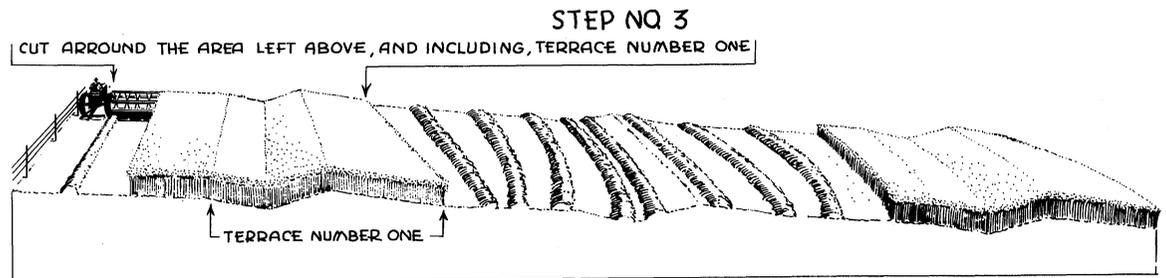
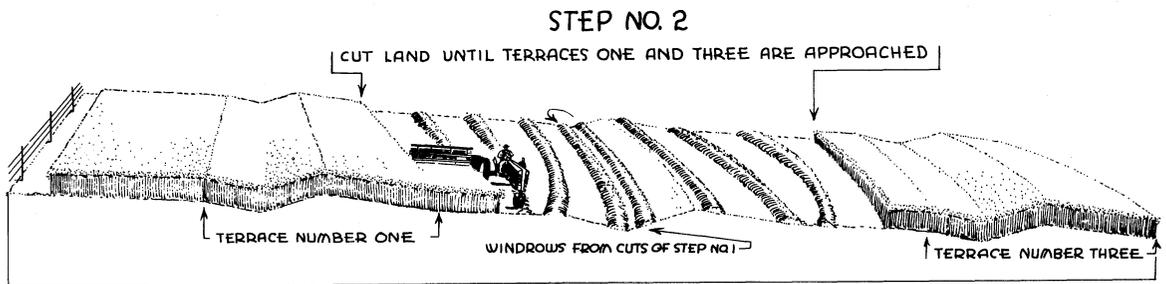
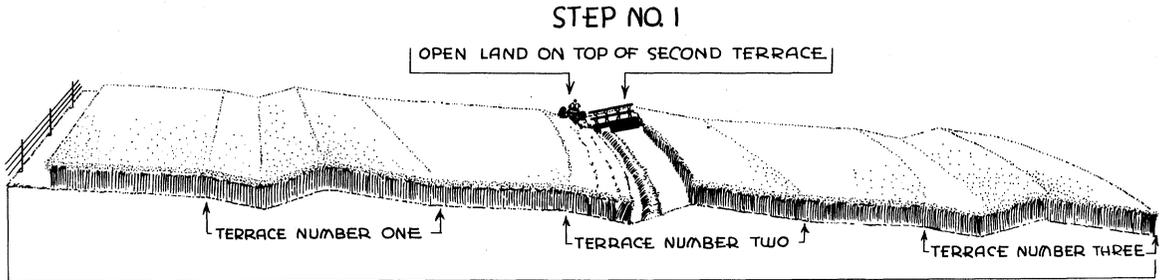
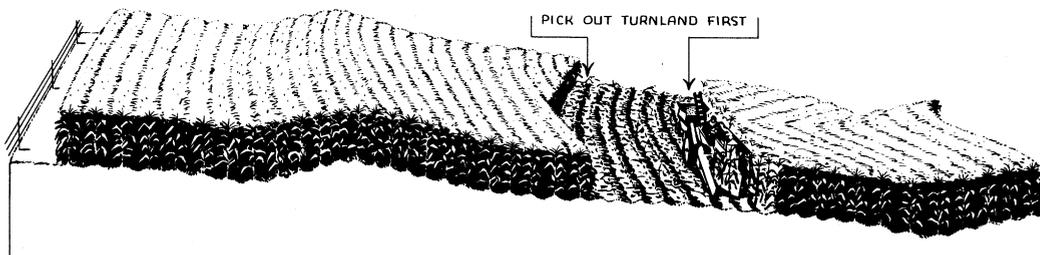


FIGURE 8.15 A METHOD FOR: HARVESTING CROPS ON TERRACED LAND (SMALL GRAIN)

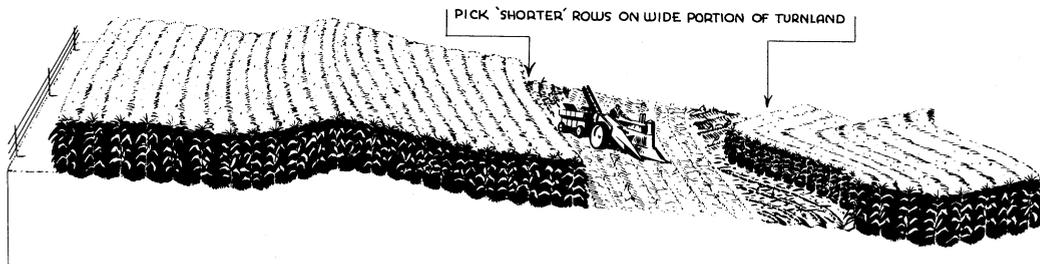
CORN

Harvest row crops in reverse of the way the field was planted. The illustrations below show how to harvest corn where the turnland was planted between the terraces.

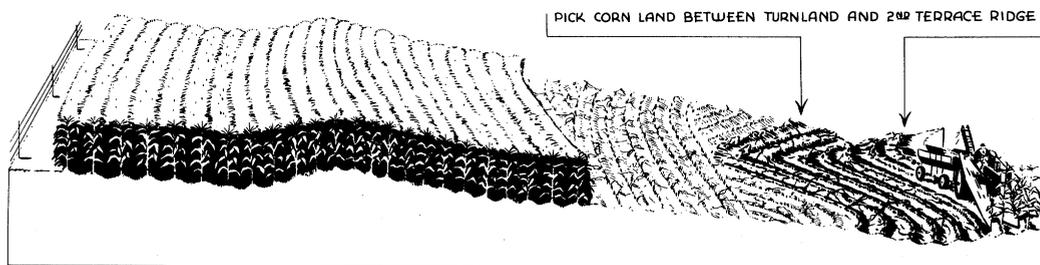
STEP NO. 1



STEP NO. 2



STEP NO. 3



STEP NO. 4

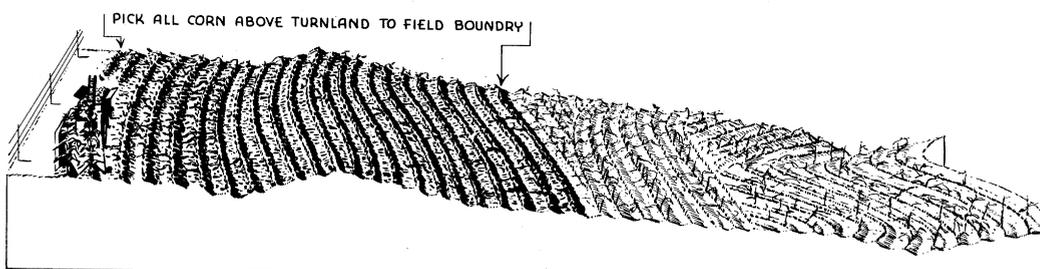


FIGURE 8.16 A METHOD FOR: HARVESTING CROPS ON TERRACED LAND (CORN)

The last step illustrated will be to harvest the rows up to and above the top terrace. Usually it is better to open a land in this area by picking around the area containing the long rows. This is illustrated in Step 4. After the long rows are harvested any short rows that remain along the field boundary can be harvested as a land by working around the remaining corn. By harvesting the long rows first, adequate turning area is provided for picking these short rows.

The remainder of the terraces are harvested as indicated in Steps 1, 2, and 3, and the area below the last terrace can be harvested by lands as is done in picking an ordinary field. It is well here, as in picking out the top terrace, to pick the long rows first, so that adequate turnlands are provided for harvesting the short rows.

Some details which apply to corn harvest in terraced fields in general are:

- (1) The method of adapting picking to the various planting methods is to study the charts for planting and use the reverse order.
- (2) On all methods of planting, harvest the long rows first. This leaves a good-sized area of picked corn to turn on in harvesting the short rows.
- (3) Where a mounted picker is used and the wagon is pulled behind the tractor, wide sideboards will be needed so that corn will not fall on the ground.
- (4) On the mounted type picker a shut-off of the elevator should be provided for short curves.
- (5) The procedures for harvesting corn for silage can follow the same steps as for picking corn.

8.93 Harvesting Hay

Techniques used in cutting hay are similar to those used with grain. On land sloping up to about 6 percent, hay should be cut just as though the field were not terraced. On steeper land it will be better to open up lands on the terraces and work each terrace as an individual unit. Using a side delivery rake presents the most difficult problem. The best starting position is to work the hay down from the top of the terrace ridge. This will leave one windrow in the bottom of the terrace channel and one on the ridge back slope. Both of these are easily picked up with a hay loader. If the short windrows are made and picked up in connection with the last long windrow, much excess driving in the field will be avoided.

PART 9

DIVERSIONS

9.10 GENERAL

9.11 Definition and Purpose

A diversion is an individually designed channel constructed across the slope for the purpose of intercepting surface runoff and conducting it to a safe outlet.

9.12 Diversions are used:

- a. To reduce the length of slope.
- b. To divert water out of active gully overfalls.
- c. To divert water away from farm buildings.
- d. To protect bottomland from overflow.
- e. To cut off headwater from the top terrace where the land above is not terraceable because of topography or land ownership.

9.13 Some points of importance to consider in use of diversions are:

- a. Drainage areas must be in grass, adequately supported by a rotation, strip cropped, or terraced, otherwise large soil losses will fill the channel. Filling of channels is the reason for most failures.
- b. Diversions should ordinarily not be of a greater spacing on strip-cropped fields than the width of three strips.
- c. Diversions and outlets must be designed so that velocities of the water will not exceed that allowable for the type of vegetation present.
- d. Diversions should not be used as a permanent control on fields which can be terraced.

9.14 Location and Spacing

- a. Where diversions are used with strip cropping to reduce the length of slope, the spacing as set up in the technical operations plan should be used. The spacing will vary according to soil type, location, width of strips, and the rotation used.
- b. In the control of gullies and diverting water from farm buildings two factors are important in the location of diversions:

- (1) Locate far enough above the lip of the gully overfall so that stable slopes will exist after sloughing has taken place.
- (2) Locate so that outlet water will be spread and velocities will be kept low enough for a safe outlet or construct an outlet in accordance with specifications for grassed waterways (see Part 10) or use a permanent structure for the outlet.

c. Where diversions are used to protect bottomland from overflow, the diversion should generally be located just above the cropland area. The principle for the outlet design is the same as above.

9.20 DESIGN OF DIVERSIONS

9.21 Diversions should ordinarily be designed to keep velocities as high as will be safe for the type of vegetation which will be present in the channel. Ordinarily safe velocities are:

Bare channel

Sand - 1.5 feet per second

Other - 2.0 feet per second

Poor channel vegetation - 3 feet per second

Fair channel vegetation - 4 feet per second

Good channel vegetation - 5 feet per second

9.22 Steps in Design of Diversion

- a. Determine the watershed area at the outlet of the diversion and at such other points where it is desired to change the grade or cross section.
- b. Obtain the maximum rate of runoff for 10-year frequency. (Refer to Figure 3.1.)
- c. Determine the channel size and grade (Figure 9.1). From the chart select bottom width, depth, and grade for the required runoff, based on safe velocity for the type of vegetation planned for the diversion. One important item to consider is that velocities should be based on channel vegetation. In most cases this will mean that you will either design for a low velocity based on bare channel or a high velocity based on degree of vegetation. Usually poor vegetation will not be a permanent condition and therefore channels should not be designed on this basis.
- d. For designs not covered in Figure 9.1, an engineering technician should be consulted.

FIGURE 91 DIVERSION DESIGN CHART

DEPTH IN FEET REQUIRED FOR DIVERSIONS WITH 4 TO 1 SIDE SLOPES

ΣW	ΣW	BOTTOM WIDTH	4'								6'								8'								10'							
			0.2	0.4	0.6	0.8	1.0	1.5	2.0	0.2	0.4	0.6	0.8	1.0	1.5	2.0	0.2	0.4	0.6	0.8	1.0	1.5	2.0	0.2	0.4	0.6	0.8	1.0	1.5	2.0				
ACRES	ACRES	$\frac{Q}{\Sigma W}$ SLOPE % CU FT.																																
		5	0.8	0.6	0.6	0.5	0.5	0.4	0.4	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.6	0.5	0.4	0.4	0.4	0.3	0.3	0.5	0.4	0.4	0.4	0.3	0.3	0.3				
		10	1.0	0.9	0.8	0.8	0.7	0.6	0.6	0.9	0.8	0.7	0.6	0.6	0.6	0.5	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.7	0.6	0.5	0.5	0.5	0.4	0.4				
		15	1.2	1.1	1.0	0.9	0.9	0.8	0.7	1.1	0.9	0.8	0.8	0.7	0.7	0.6	1.0	0.8	0.7	0.7	0.7	0.6	0.6	0.9	0.8	0.7	0.6	0.6	0.5	0.5				
		20	1.4	1.2	1.1	1.0	1.0	0.9	0.8	1.3	1.1	1.0	0.9	0.9	0.8	0.7	1.1	1.0	0.9	0.8	0.8	0.7	0.6	1.1	0.9	0.8	0.7	0.7	0.6	0.6				
		25	1.6	1.4	1.2	1.2	1.1	1.0	0.9	1.4	1.2	1.1	1.0	1.0	0.9	0.8	1.3	1.1	1.0	0.9	0.9	0.8	0.7	1.2	1.0	0.9	0.8	0.8	0.7	0.6				
		30	1.7	1.5	1.3	1.3	1.2	1.1	1.0	1.5	1.3	1.2	1.1	1.0	0.9	0.9	1.4	1.2	1.1	1.0	0.9	0.8	0.8	1.3	1.1	1.0	0.9	0.9	0.8	0.7				
		35	1.8	1.6	1.4	1.4	1.3	1.2	1.1	1.7	1.4	1.3	1.2	1.1	1.0	1.0	1.5	1.3	1.2	1.1	1.0	0.9	0.8	1.4	1.2	1.1	1.0	0.9	0.8	0.8				
		40	1.9	1.7	1.5	1.4	1.4	1.2	1.2	1.8	1.5	1.4	1.3	1.2	1.1	1.0	1.6	1.4	1.2	1.2	1.1	1.0	0.9	1.5	1.3	1.1	1.1	1.0	0.9	0.8				
		45	2.0	1.8	1.6	1.5	1.4	1.3	1.2	1.9	1.6	1.4	1.4	1.3	1.2	1.1	1.7	1.5	1.3	1.2	1.2	1.1	1.0	1.6	1.3	1.2	1.1	1.1	1.0	0.9				
		50		1.8	1.7	1.6	1.5	1.4	1.3	2.0	1.7	1.5	1.4	1.4	1.2	1.1	1.8	1.5	1.4	1.3	1.2	1.1	1.0	1.7	1.4	1.3	1.2	1.1	1.0	0.9				
		60		2.0	1.8	1.7	1.6	1.5	1.4		1.9	1.7	1.6	1.5	1.3	1.3	2.0	1.7	1.5	1.4	1.3	1.2	1.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0				
		70			2.0	1.8	1.7	1.6	1.5		2.0	1.8	1.7	1.6	1.4	1.3		1.8	1.6	1.5	1.4	1.3	1.2	2.0	1.7	1.5	1.4	1.3	1.2	1.1				
		80				2.0	1.9	1.7	1.6			1.9	1.8	1.7	1.5	1.4		1.9	1.8	1.6	1.5	1.4	1.3		1.8	1.6	1.5	1.4	1.3	1.2				
		90					2.0	1.8	1.7			2.0	1.9	1.8	1.6	1.5		2.0	1.9	1.7	1.6	1.5	1.4		1.9	1.7	1.6	1.5	1.4	1.3				
		100						1.9	1.8				2.0	1.9	1.7	1.6			2.0	1.8	1.7	1.6	1.5		2.0	1.8	1.7	1.6	1.4	1.3				
		120							2.0	1.9					2.0	1.9	1.7				2.0	1.9	1.7	1.6			2.0	1.8	1.7	1.6	1.5			
		140								2.0												2.0	1.9	1.7					2.0	1.9	1.7	1.6		
		160																						2.0	1.8					2.0	1.8	1.7		
		180																							1.9						1.9	1.8		
		200																							2.0						2.0	1.9		

NOTE: DARK LINES ACROSS CHART INDICATE VELOCITIES. FIGURE IN LINE GIVES VELOCITY. ALL DEPTHS ABOVE OR TO LEFT OF LINE WILL BE OF LESS VELOCITY.

THE ABOVE ARE MINIMUM DEPTHS. ON LOCATIONS WHERE SILTING WILL OCCUR 0.3' TO 0.5' FREEBOARD SHOULD BE PROVIDED DEPENDING ON THE SEVERITY OF THE SILTING.

DESIGN DATA: n=0.04 MAXIMUM DEPTH 2.0'

EXAMPLE: FROM CHART 3-L-14054 Q=53 CU. FT./SEC. - USE Q=50

MAXIMUM VELOCITY BASED ON VEGETATION 3'/SEC.

DEPTH REQUIRED FOR 6' BOTTOM CHANNEL=1.5' WITH 0.6% SLOPE IN CHANNEL *

*OTHER BOTTOM WIDTHS COULD HAVE BEEN USED.

9.30 LAYOUT AND CONSTRUCTION OF DIVERSION CHANNELS

9.31 When to Construct

The best time to build diversions is when the watershed area is mainly in grass so that channel silting and runoff will be at a minimum.

9.32 Layout

Use the same general procedure in laying out diversions as is used in terraces. A uniform grade may be used throughout length or the grade may be changed as you go upstream. If the latter is done, the size should be determined at each point the grade is changed.

9.33 Keeping Notes of Layout

The notes should be kept in a standard field book and should show the watershed area and estimated runoff in cubic feet per second; also, the recommended channel size and slope should be shown.

9.34 Method of Construction

After the diversion is staked it can be constructed similar to a terrace. (Part 8.4)

9.35 Checking Construction

Level shots should be taken on the channel and ridge to check on the finished grade and ridge height. Checking is important to determine the adequacy of the completed job. Keeping notes of level readings serves as a permanent record in case there are future questions. (Refer to instructions, Part 8.5.)

9.40 MAINTENANCE OF DIVERSION CHANNELS

9.41 Vegetate Channel and Upper Back Slope

Use the method outlined in detail under vegetated outlets and watercourse (Part 10) for establishing vegetation. Establishment of good channel vegetation is essential unless the channel was designed for bare channel conditions.

9.42 Annual Mowing of Channel

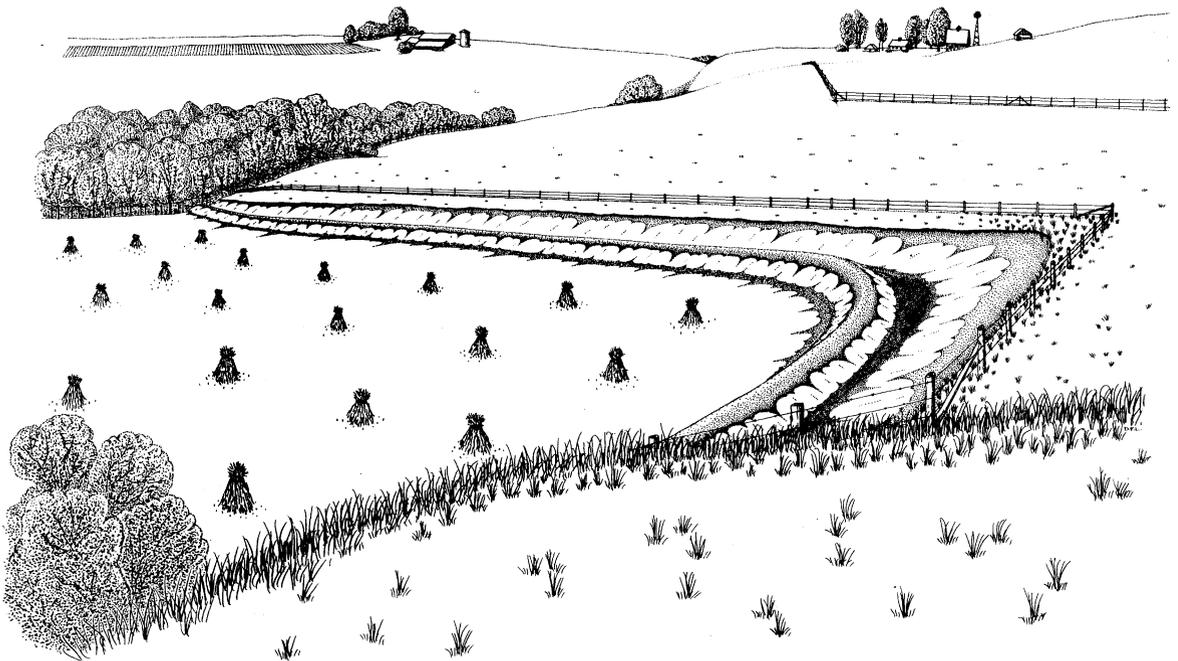
Mowing of the diversion channel is essential, otherwise briars and other brushy growth may obstruct flow. When woody growth gets too large, mowing is impossible and the diversion channel gradually becomes ineffective and generally results in failure.

9.43 Removal of Silt

The channel may require maintenance due to silt accumulations. Small silt deposits may be removed with a shovel or slip scraper. However, if the silt deposit extends for the full length of the diversions, the channel should be plowed out as in terrace maintenance plowing. Excessive channel silting generally indicates inadequate supporting vegetative practices.

9.44 Repair Rodent Holes and Breaks

Diversions left in permanent vegetation sometimes attract rodents, particularly ground hogs. The ridge should be examined at the time of mowing and if any breaks or holes are observed, these can be repaired with a shovel. A rodent hole is easy to repair if it is done immediately. However, if the water breaks through, it may erode to such an extent that considerable effort and time are necessary to make the repair.



PART 10

VEGETATED OUTLETS AND WATERCOURSES

10.10 WATER DISPOSAL

10.11 Vegetated Watercourse

a. The grassed watercourse is one of the most common and basic conservation practices generally recognized, accepted, and practiced by the farmer. Wherever there is rainfall, there are conditions under which a surplus of water will pass over the land in the form of runoff. The success of any soil conservation program depends on the removal of this surplus water without damage to the land.

b. The safe removal of surplus water is a problem common to every farm. The accumulated flow from only a few acres is sufficient to cause movement of soil to the extent that a gully is started. The need for a lined channel to transport concentrated runoff without damage to the land is obvious.

c. The success of a vegetated watercourse will depend on the proper shaping and preparation to produce conditions favorable to vegetative growth. Since vegetation is subject to deterioration through abuse and unfavorable seasons, it is also necessary to provide maintenance. Between the time of seeding and actual establishment, a watercourse is unprotected and subject to considerable damage unless special protection is provided. Therefore, it is important to meet the required dimensions within a reasonable degree.

d. Vegetated watercourses are of several shapes or cross sections - trapezoidal (flat bottom), parabolic (saucer or dish-shaped bottom), or "V" shaped. In general, the saucer-shaped watercourses are the most common in the region. Most of those constructed with the trapezoidal section end up as parabolic after a period of years. The "V" type is used in special situations.

e. Also of major importance for the successful establishment and maintenance of a vegetated watercourse is the conservation treatment in the watershed. The better the erosion control effected in the watershed the less the silting problem in the watercourse.

10.12 Watershed, Sketch Map

a. Terraces or diversions will normally change the surface drainage pattern. For this reason it is necessary to know approximately the final layout before estimating the amount of runoff the outlet will be required to handle. Since the outlet will be constructed previous to the terraces or diversions, it is essential that a determination of additional area, which will be

diverted into a waterway, be made before trying to estimate the runoff. (See Part 8.20.)

b. The watershed map can be completed after changes in normal surface watershed pattern are determined. Usually the natural watershed divides can be determined by field inspection and sketched on the aerial photo map.

10.20 WATERCOURSE LOCATION

10.21 Natural Draws

a. In general, the most satisfactory location is in a natural watercourse. Here the slope of the channel is usually the flattest in the watershed. Natural land slope confines the flow; is in effect like sideboards, and eliminates the need for free-board. Soil and moisture are usually most favorable to vegetative growth. This location interferes less with operations when it is necessary to cross the outlet.

b. Because of natural shape, these watercourses are the parabolic type of cross section.

10.22 Fence Row and Ridge Lines

a. This location usually is parallel to a fence line or following a ridge. This makes it necessary to construct an artificial channel. This location is sometimes used to eliminate an outlet in the central part of a field:

(1) To outlet terraces or diversions that cannot be extended to a natural draw.

(2) To provide an outlet away from buildings or other critical areas.

(3) To avoid using a natural draw which has a gully that would be expensive or impractical to control.

b. The constructed watercourse shape will generally depend on the type of equipment used to build them. While the chart used for design is based on the parabolic cross section, the watercourse may be built to trapezoidal or flat "V" section, depending on conditions, and using the dimensions from the design chart. Side slopes of 4:1 should be used for the trapezoidal shape in construction, with a flat bottom width to "fit" the over-all top width from the chart.

10.30 DESIGN

10.31 Velocity of Flow Is the Basis of Design

a. The design of a watercourse is the determination of channel dimensions so that the estimated flow will be discharged without

damage to the channel or the lining. The lining here considered is vegetation which can vary as to type and density. The speed (velocity) at which water can flow safely over each condition is then a matter of test and experience.

b. The prevailing range of velocity in use for design over the region is from three to eight feet per second. Range of permissible velocity will be determined by individual areas.

(1) A velocity of three feet per second will apply to a poor type of sod where, because of climate or soil, only a sparse cover can be expected.

(2) A velocity of four feet per second should be used under normal conditions where the watercourse is to be established by seeding.

(3) A velocity of five feet per second should only be used in areas where vigorous sod is quickly obtained or where water can be diverted out of watercourse while seeding is being established.

(4) Velocities of six feet per second will be used only when vegetation of good quality is already established, or where water can be diverted out of watercourse while seeding is being established.

(5) Velocities of seven to eight feet per second will be used only on established sod of excellent quality, and only under special circumstances which cannot be handled at a lower velocity. This condition will require special maintenance.

10.32 Shape of Watercourses

a. The parabolic cross section is best suited for general purposes because:

It is easily shaped.

Small flows are better confined to prevent meandering.

It is the most common shape found in nature.

b. The trapezoidal cross section is not a natural shape and is limited in its application. The design chart is developed for the parabolic section, but the same dimensions can be used for the trapezoidal section. (See Part 10.22b.) Tendency of meandering on a wide level bottom can be reduced by using a slightly dished section or flat "V" section (0.2 to 0.3 foot).

10.33 Watercourse Dimensions

Required data:

a. Watershed area, acres, soil characteristics, crops, and

topography. This information is used to estimate runoff, using the 10-year frequency chart, Figure 3.1, page 3-2.

b. Slope (grade) of watercourse in percent. (This is the fall per 100-foot length.)

c. Estimate of permissible velocity as listed in Part 10.31b.

d. The table of watercourse dimensions (Figure 10.1, page 10-5) has been prepared from basic hydraulic data to eliminate time-consuming steps and calculations by field men. You will note the table can be used for the design of either the parabolic (saucer) or trapezoidal cross section.

10.34 Example - Watercourse Design

a. Given:

(1) Watershed area - 20 acres

Watershed characteristics $\Sigma W = 50$

(2) Slope of watercourse - 5%

(3) Permissible velocity - (To be seeded) Select three feet per second.

(4) Rainfall factor $R = 0.8$ (determined by location)

Solution:

(1) From runoff chart, Figure 3.1

$Q = 38 \times 0.8 = 30.4$, use 30 c.f.s. for design

(2) Enter chart (Figure 10.1) on line reading 30 c.f.s. in left-hand column, follow to the right and under columns headed 5% slope, reading under velocity of three feet per second find the reading of "45," which is width in feet. In the same column at top under the three feet per second velocity read the depth of 0.4 feet. This results in a top width at water surface of 45 feet and flow depth of 0.4 foot to handle the discharge of 30 c.f.s. at velocity of three feet per second. If site conditions require freeboard, add four feet to width and 0.5 foot to depth. Under these conditions it is well to consider the possibility of diverting as much of the flow of water as possible by use of diversion(s) until construction and vegetation is accomplished. Also, these conditions will require special maintenance for best results.

If, in consideration of site conditions, the above watercourse is too wide, the alternative is to use a higher velocity for design, which results in narrower width. In this example, using a velocity of four feet per second for design,

GRASS WATERCOURSE DIMENSION CHART

Σ W	Σ W	Slope	0.5% Slope			1% Slope			2% Slope			3% Slope			4% Slope			5% Slope			6% Slope			8% Slope			10% Slope			12% Slope			14% Slope								
			2	3	4	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5	3	4	5						
Ac	Ac	VEL DEPTH C.F.S.	1.0'	1.8'	2.7'	1.1'	1.8'	2.4'	0.7'	1.0'	1.4'	0.5'	0.8'	1.0'	0.4'	0.6'	0.8'	0.4'	0.5'	0.7'	0.3'	0.5'	0.6'	0.3'	0.4'	0.5'	0.2'	0.3'	0.5'	0.2'	0.3'	0.4'	0.1'	0.3'	0.3'						
		10												10			13			15			18	10			22	10		26	12		30	15	10	39	17	10			
		15												16			20	10		23	12			27	13		33	16	10	41	19	10	44	22	12	60	25	14			
		20												21	10		26	13		30	15			35	17	10	44	22	12	54	25	14	60	29	16	80	36	19			
		25												26	13		32	16		37	19	11		44	22	12	55	28	15	67	31	18	75	36	20	100	41	24			
		30												31	16		39	19	11	45	23	13		53	26	15	66	34	18	80	38	22	90	43	25	120	49	28			
		35												27	13		36	18		45	22	13		52	27	15	62	30	17	77	40	21	93	44	25	105	50	29	57	33	
		40												31	15		41	21	12	51	25	15		60	31	17	71	35	19	88	44	24	106	50	29	121	57	33	64	37	
		45												35	17		47	23	13	58	28	16		68	35	18	80	39	22	100	48	27	120	56	32	64	37				
		50												39	19		52	26	15	65	31	18		76	39	22	89	43	25	112	52	30	62	35		71	41				
		60												46	22		62	31	17	78	37	22		92	46	27	107	52	30	65	36		75	42		87	49				
		70												54	26	15	72	36	20	91	44	25		108	53	31	126	60	35	75	43		87	50		102	58		115	66	
		80												62	30	17	83	42	23	104	50	29		123	60	35	70	40		87	49		100	57		116	66		75		
		90												70	34	19	94	47	26	118	57	33		67	39		78	45		97	56		112	64		128	74		85		
		100												78	38	22	105	53	30	64	37			74	44		88	50		108	62		125	71		83			94		
		120												94	45	26	126	61	36	76	44			90	52		105	60		125	74		87			100			113		
		140												109	53	30	72	41		90	51			106	61		120	70		87			103			117					
		160												125	60	34	83	47		102	58			120	69		80			100			118								
		180												67	38		92	52		114	65			78			90			112											
		200												74	43		103	58		72				87			100														
		220												82	47		112	64		79				95			110														
		240												90	51		70			86				104																	
		260												98	55		75			93				112																	
		280												106	59		80			100																					
		300												112	64		86			107																					
		320												120	68		92			114																					
		340												72			98																								
		360												76			104																								
		380												81			110																								
		400												86			115																								
		420												90																											
		440												95																											
		460												99																											
		480												103																											
		500												108																											

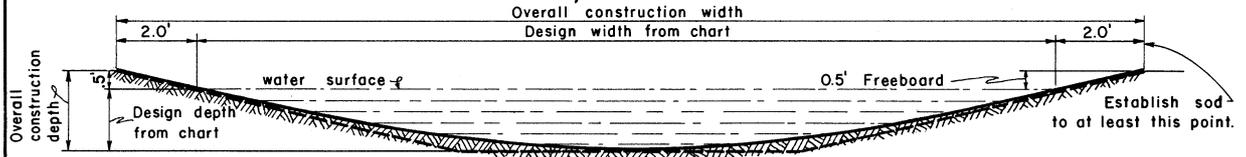
EXPLANATIONS

The first column on the left is the runoff in cubic feet per second. The top line across the page shows the percent slope of the watercourse. The second line gives a choice of three different design velocities—3 s.f., 4 s.f. and 5 s.f. The third line gives the depth in feet at center of the watercourse and is read under desired velocity. The figures in the body of the chart are top width in feet.

NOTE

For slopes less than 0.5 percent use size shown for 0.5 percent slope, or use diversion design chart. Special designs may be requested from Engineer.

For construction dimensions add .5' to depths from chart and add 4' to widths shown in chart.



EXAMPLE

Determine size of watercourse.
 Given: Q = 100 c.f.s. Slope = 3%
 Design velocity = 4 s.f.
 Solution: In left column under "c.f.s." find 100. Follow the 100 line right to the 3% slope columns and under the "4 s.f." column read the top width of 53 ft. In the third line from the top under the 3% slope and 4 s.f. you will find the depth to be 0.8 ft. — Construction Dimensions then are:
 Depth = .8' + .5' freeboard = 1.3 feet
 Width = 53' + 4' = 57' feet

GRASS WATERCOURSE DIMENSION CHART

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

REFERENCE: TECHNICAL NOTE - T-8-R-3
THE DESIGN OF GRASSED WATERCOURSE

CARTOGRAPHIC APPROVAL: *R. M. Wood* TECHNICAL APPROVAL: *Edna Hegerlinger*

DRAWN BEAU- CHAMP	TRACED BEAU- CHAMP	CHECKED KEAIRNS	DATE 9-16-46	DRAWING NO. 3-L-14010
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FIGURE 10.1 GRASS WATERCOURSE DIMENSION CHART

and allowing for freeboard, the constructed and vegetated width would be $23 + 4$, or 27 feet, with over-all depth of $0.5 + 0.5$, or 1.0 foot.

b. Given:

(1) Watershed area - 30 acres

Watershed characteristics $\Sigma W = 45$

(2) Slope of watercourse - 0.4% (Use 0.5% in Figure 10.1)

(3) Permissible velocity - 2 feet per second

(4) Rainfall Factor $R = 0.7$ (Determined by location)

Solution:

(1) From runoff chart, Figure 3.1, page 3-2

$$Q = 42 \times .7 = 29.4 \text{ use } 30 \text{ c.f.s.}$$

(2) Enter chart (Figure 10.1) on the line reading 30 c.f.s. in the left-hand column, follow to the right and under columns headed 0.5% slope, reading under velocity of two feet per second, find the reading of 23 feet width, and at top read depth of 1.0 foot. If site conditions require freeboard, add four feet to width and 0.5 foot to depth. Under these conditions it is well to consider the possibility of diverting as much of the flow of water as possible by use of diversion(s) until construction and vegetation is accomplished. Also, these conditions will require special maintenance for best results.

If the above dimensions are impractical for any reason, design will have to be at a higher velocity - say three feet per second.

Then from chart, Figure 10.1, find on the line for 30 c.f.s. and under three foot per second velocity, no dimension is given. However, note the general remark which applies reading "As widths are impractical for depths shown, use first width shown in column as practical for crossing with farm machinery; otherwise, design from Technical Note 8." Therefore, in this example dimensions will be width of 11 feet, and depth of 1.8 feet. If site conditions require freeboard, add four feet to width and 0.5 foot to depth. Under these conditions it is well to consider the possibility of diverting as much of the flow of water as possible by use of diversion(s) until construction and vegetation is accomplished. Also, these conditions will require special maintenance for best results.

or

(3) Using Diversion Design Chart, Figure 9.1 (page 9-3), (remember a diversion is in effect a watercourse across the slope and is on flatter grade or slope than most watercourses). Enter on the line reading 30 c.f.s. in the left-hand column, follow to the right, and under 4-foot bottom width and slope of 0.4% read depth of 1.5 feet. Note now that this reading is to the right of the 2-foot-per-second velocity line, which means that by using those dimensions velocity will be slightly over 2 feet per second, probably not enough to worry about. Then with design depth of 1.5 feet, allowing for freeboard, the constructed depth would be 2.0 feet. Constructed and vegetated width would be the width of both side slopes plus the bottom width, which in this case is $2 \times 4 \times 2 + 4$ or 20 feet.

If a shallower watercourse is needed for some reason, using Figure 9.1, again, move farther to the right on line 30 c.f.s., say to 10-foot bottom width, and slope of 0.4%. Now read depth of 1.1 feet. Velocity here is still slightly over 2 feet per second. Then with design depth of 1.1 feet, allowing for freeboard, the constructed depth would be 1.6 feet. Constructed and vegetated width would be the width of both side slopes plus the bottom width, which in this case is $2 \times 1.6 \times 4 + 10$ or 23 feet.

10.35 Design and Dimension Form

The examples above are illustrated on the form Figure 10.2 (pages 10-9 and 10-10), which is provided for the use of personnel in recording the design data and construction dimensions. They are stocked in the Regional Supply Center and are ordered by Drawing No. 3-L-17372.

10.36 Specifications

One of the examples above is illustrated on the form Figure 10.3 (pages 10-11 and 10-12), which is provided as a job sheet for the use of the farmer in construction and establishment of the vegetative lining of the watercourse. One should be prepared for each major watercourse to be constructed and vegetated. They are stocked in the Regional Supply Center, and are ordered by Drawing No. 3-L-23571.

10.40 CONSTRUCTION OF WATERCOURSES

10.41 Requirements

*a. Success of a vegetated watercourse will depend on obtaining physical conditions favorable to growth and maintenance of the vegetative cover. All agronomy practices that apply in establishing vegetation on a field need special emphasis when applied to the watercourse because the sod must withstand the additional hazard of flowing water. The determination of watercourse dimensions based on proper design will reduce this hazard to an economical minimum.

*Reference:

Agronomy Handbook and Technical Operations Plan.

b. Tile drainage of watercourses is essential where waterways tend to be wet and in areas where tile is generally recommended. Tile drainage may also be needed in some well-drained soils where seepage occurs in the waterway. A well-drained waterway is essential to permit the most economical operation of the field and to prevent damage to the waterway when crossing it with equipment. Broken tile in waterways must be repaired. In some cases it may be necessary to abandon old tile because of poor conditions or because of inadequate depth. New tile should be laid immediately following grading of the watercourse. Tile lines should be laid to one side of the watercourse at sufficient depth so that any laterals will have a minimum cover of 2.5 feet at the low point in the watercourse. Tile lines should outlet at a permanent structure or by use of corrugated pipe as illustrated by drawing No. 3-L-16564 in Figure 11.33. This should be provided where the water disposal system changes from tile and broad shallow vegetated watercourse to an open drainage ditch.

c. When plans for sub-drainage are completed, actual work on grading of the watercourse is ready to start.

10.42 Equipment

a. Many excellent watercourses have been prepared using only a plow, disk, and harrow. These tools work best when it is possible to drive a tractor anywhere over the watercourse area without danger of overturning the tractor.

b. As the size of the watercourse increases, the greater is the advantage of additional tools and equipment. A manure loader may be used to advantage to slope steep banks by pushing in dirt from the top. When sloping is done from the top, care must be taken to secure compaction of the loose fill material. Not more than 8-12 inches of loose material should be allowed to accumulate before compaction can be accomplished. Then sloping can be resumed and the process repeated until completed. It is also desirable to fill some low places and cut into banks and ridges to improve both grade and alignment; the Fresno or roll-over scraper and manure loader all can be used to advantage.

c. Small graders with a blade length not to exceed six feet can be used to supplement the plow in working-in and completing the grading. The highway auto patrol grader is excellent equipment for all kinds of watercourse work. On large, deep, and irregular watercourses, the track tractor with bulldozer can be the most economical type of equipment.

10.43 Procedure

a. In extreme cases of poor and infertile soil areas, it may be desirable first to remove the remaining topsoil and work it away from the watercourse area, then grade-in the watercourse, and later bring back the topsoil as a covering for the waterway. This is difficult and expensive but may be necessary to establish vegetation.

GRASS WATERWAY DESIGN AND DIMENSIONS

John Roe

456

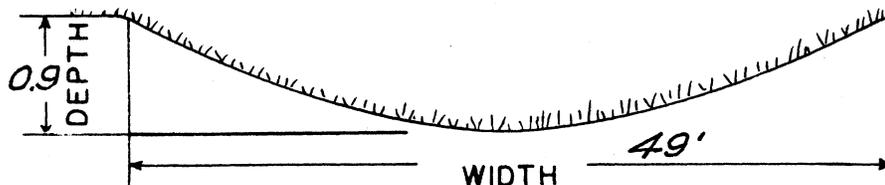
Utopia

CO-OPERATOR

PLAN NO

SOIL CONSERVATION DISTRICT

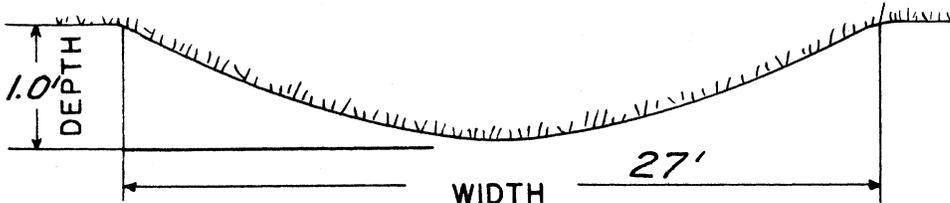
Location on farm (*)) *Example* Part *10.34a*
1st Solution



R	16
SI	10
VC	10
SS	15
ΣW	51

Drainage Area= 20 Slope= 5 % Design V= 3 fs. $Q = 30$ c.f.s.

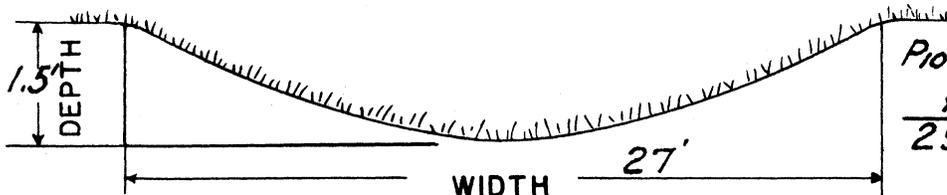
Location on farm (*)) *Example* Part *10.34a*
2nd Solution



R	16
SI	10
VC	10
SS	15
ΣW	51

Drainage Area= 20 Slope= 5 % Design V= 4 fs. $Q = 30$ c.f.s.

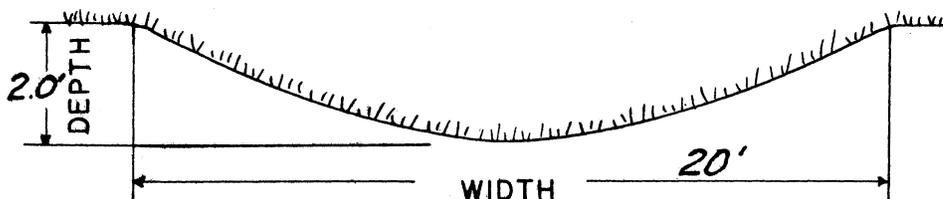
Location on farm (*)) *Example* Part *10.34b*
1st Solution



R	8
SI	14
VC	12
SS	10
ΣW	44

Drainage Area= 30 Slope= 0.4 % Design V= 2+ fs. $Q = 30$ c.f.s.

Location on farm (*)) *Example* Part *10.34b*
Solution based on Diversion Chart



R	
SI	
VC	
SS	
ΣW	44

Drainage Area= 30 Slope= 0.4 % Design V= 2+ fs. $Q = 30$ c.f.s.

* Waterway number - see land use map

FIGURE 10.2 GRASS WATERWAY DESIGN AND DIMENSIONS

SPECIFICATIONS FOR GRASS WATERWAY ESTABLISHMENTS

John Roe

Cooperator

456

Plan No.

Utopia

Soil Conservation District

Waterway 1st Example

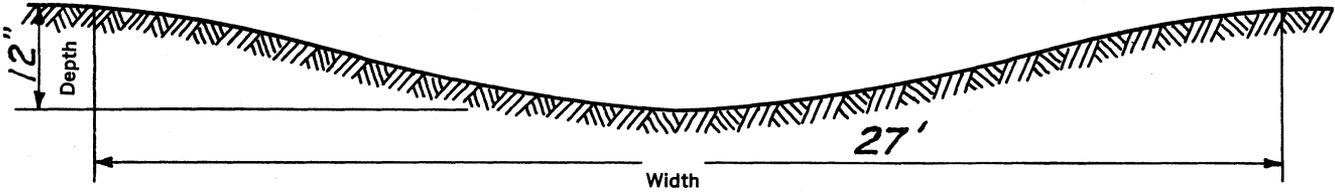
Field No. Second Solution

DIMENSIONS

Width 27 Ft.

Depth 12 Inches

Length 600 Ft.



SOIL TREATMENT

TO BE PLOWED UNDER

TOTAL

Manure 1 loads per 100 ft.

6 loads

Fertilizer: 0-20-20 analysis 50 lbs. per 100 ft.

300 lbs.

Fertilizer: _____ analysis _____ lbs. per 100 ft.

_____ lbs.

Fertilizer: _____ analysis _____ lbs. per 100 ft.

_____ lbs.

TO BE WORKED IN THE SURFACE

TOTAL

Manure _____ loads per 100 ft.

_____ loads

Mixed Fertilizer: _____ analysis _____ lbs. per 100 ft.

_____ lbs.

STABILIZING CROP

TOTAL

Corn (broadcast) _____ Pecks per 100 ft.

_____ bushels

SEEDING GRASS

Preparation:

- ~~1. Clip grass high with a mower (cut 10 inches) on August 15.~~
2. Rake and remove all clippings.
3. Broadcast ammonium nitrate at 25 lbs. per 100 ft. 150 total lbs.

Seeding Mixture: 8# Brome plus suitable companion crop
 Seeding Rate of Mixture 10 lbs. per 100 ft. of waterway 60 total

Suggested Method of Seeding: Broadcast or drill seed August 15 to October 1. Broadcast seed can be covered by LIGHT disking (disk set almost straight), or a cultipacker or a rotary hoe.

SOIL CONSERVATION SERVICE
 Drawing No. 3-L-23571

GPO—SCS 559

FIGURE 10.3 SPECIFICATIONS FOR GRASS WATERWAY ESTABLISHMENTS

MAINTENANCE

1. Repair damaged areas promptly.
2. Mow 6 inches high and rake twice a year.
Dates_____

3. Apply 100 lbs. ammonium nitrate per acre annually, preferably in early fall; and a complete fertilizer in the spring.
4. An application of trash-free manure each year such as chicken manure, could replace the ammonium nitrate.
5. When plowing the field adjoining the waterway
 - a. Plow right angle to waterway.
 - b. Leave border irregular to prevent cutting along the edge.
6. Do not use for a driveway or lane.

b. The grading procedure for plow and grader equipment is to drive up and down the watercourse adjacent to the low ground or ditch and move earth into the low part. Sections not requiring much work will be rough-finished first so that the watercourse can be crossed with the equipment. This leaves the deeper, more difficult areas isolated, but makes it possible to work equipment from all sides. These areas are then worked individually until filled and rough finished.

c. Methods used in constructing terraces with a plow can also be applied to filling a ditch. That is, essentially, to begin plowing next to the ditch, throwing dirt into the ditch on the first round, then plow several more rounds as in plowing a land. This step is repeated until the ditch is sufficiently filled to permit crossing. The desired cross section is then obtained by backfurfrowing at the low point and plowing lands as required.

d. When it is necessary to construct an outlet or watercourse along a fencerow, ridge line, or across a level portion of a bottom field, it is usually necessary to move earth out of the proposed watercourse. For this procedure the same method as is used for the construction of a drainage ditch can be used. Reference is made to Part 11.

10.44 Specifications

Clear trees and brush from area.

Correct drainage problem.

Construct according to design dimensions.

Secure a compacted fill free of any organic material.

Provide stabilized outlet by previously establishing watercourse, sod chutes, and permanent structures.

To establish seeding, apply mulch, increase rate of seeding, fertilizers, and manure in accordance with specifications in local Technical Guides. Provide protection from grasshoppers, by poisoning.

Maintain by mowing, controlled grazing; re-establish vegetation as necessary; and fertilize along with adjacent field.

10.50 SOD CHUTE

10.51 Definition and Use

a. A sod chute may be defined as a steep-sodded section of a watercourse constructed to conduct the design flow of water through it in the shortest distance at a safe velocity. The required vegetation may be established by transplanting sod, or if the water can be diverted around the section for sufficient time, it may be established by seeding.

- b. A sod chute may be used:

At overfalls or abrupt changes in the slope of a natural waterway.

At the lower end of watercourses to conduct water into a natural channel.

To conduct water from the flat area next to a drainage ditch to the bottom of the ditch.

10.52 Limitation of Use Will Ordinarily Be Indicated in Design Tables

- a. The required dimensions obtained from the chart may limit use on the basis that required width or total length is impractical for the site under consideration.

10.53 Design of Sod Chutes

- a. Figure 10.4 gives the design nomenclature.

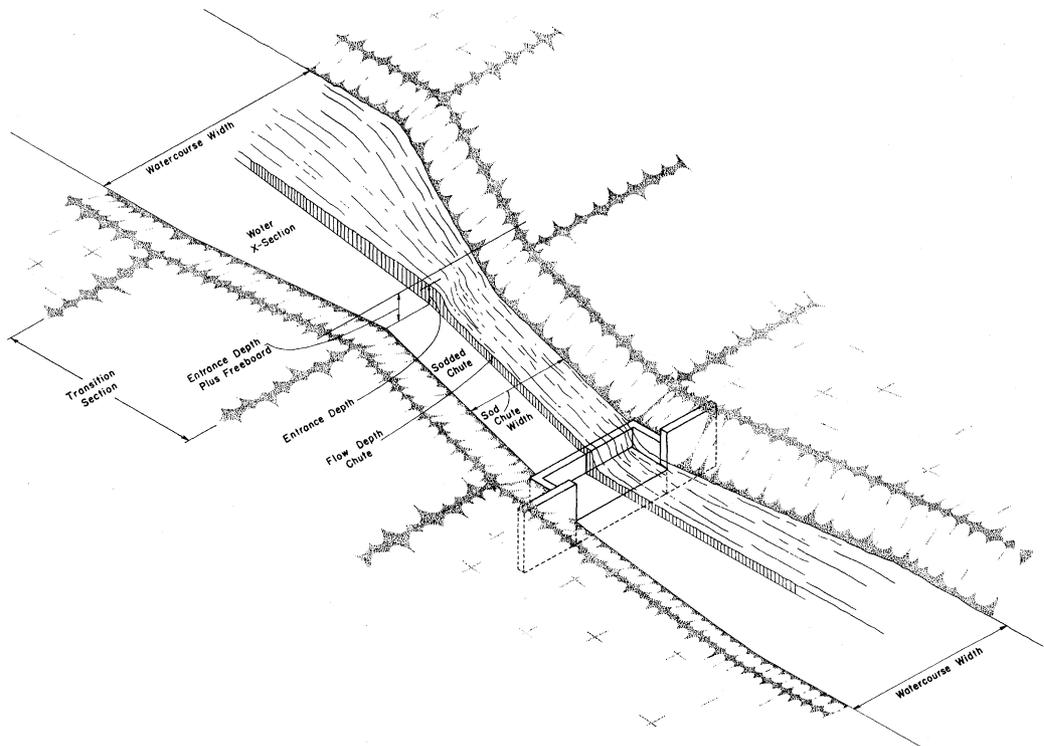


FIGURE 10.4 SOD CHUTE AND TOE WALL

Basically, the consideration for design of a sod chute is the same as for a vegetated watercourse. Since sod chutes are generally constructed by transplanting sod or protected by a diversion until seeding is established, the range in permissible velocities is higher when compared with watercourses where vegetation is established from seed. Velocities considered safe are given in Part 10.3lb.

b. When water flows from a watercourse to a chute with a steeper grade, a transition in flow takes place - that is, a decrease in depth of flow with an increase in velocity. Chute widths will usually be less than watercourse widths with a tendency toward restriction of flow at the entrance.

c. To assure adequate entrance capacity, the sod chute table includes required entrance depths. Levees may be constructed to the chute entrance if necessary to provide the required depth.

10.54 Example

Given: $Q = 140$ c.f.s., estimated runoff from watershed.

Height to control - 4 feet.

Try 10% slope of chute or 10:1. Length - $4 \times 10 = 40$ feet.

Excellent sod available and good soil; exposure is southwest - may be hot and dry.

Select 7 feet per second velocity.

Solution: Sod chute dimensions (Figure 10.5, page 10-16).

In the left-hand column under "Required Capacity," find 140 c.f.s. Follow this line to the right and under column 10 percent slope and 7 feet per second velocity, find 39 foot bottom width.

In the same column on line "Chute Depth" find 0.6 foot.

In the same column on line "Entrance Depth" find 1.2 feet.

Construction Dimensions:

Slope - 10% or 10:1.

Height = 4 feet.

Length - $4 \times 10 = 40$ feet plus.

Bottom width - 39 feet.

Total depth - 1.2 feet (entrance depth) + 0.5 foot (freeboard) = 1.7 feet.

Chute depth - 0.6 foot.

SOD CHUTE — DIMENSION TABLE TRAPEZOIDAL CROSS SECTION

CHUTE SLOPE	2% SLOPE RATIO 50:1					4% SLOPE RATIO 25:1					6% SLOPE RATIO 16 1/4:1					8% SLOPE RATIO 12:1					10% SLOPE RATIO 10:1					14% SLOPE RATIO 7:1									
	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8					
PERMISSIBLE VELOCITY, FT./SEC.	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8
REQUIRED CAPACITY Q. - C.F.S.	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD	FAIR SOD	GOOD SOD	EXCELLENT SOD					
ENTRANCE DEPTH FT.	0.8	1.1	1.5	1.9	2.4	0.8	1.1	1.5	1.9	2.3	0.7	1.0	1.4	1.8	2.2	0.5	0.7	1.0	1.3	1.6	0.5	0.7	0.9	1.2	1.5	0.4	0.5	0.8	1.0	1.2	0.2	0.3	0.3	0.4	0.5
CHUTE DEPTH FT.	0.6	0.8	1.0	1.2	1.4	0.5	0.7	0.9	1.1	1.3	0.4	0.6	0.8	1.0	1.2	0.3	0.4	0.5	0.7	0.9	0.2	0.3	0.4	0.6	0.7	0.2	0.3	0.3	0.4	0.5	0.2	0.3	0.3	0.4	0.5
ACRES																																			
	10										10					10					12					15	10				18	10			
	15					10					14					19	10				24	12				32	16	10			40	20	13		
	20					15					18					24	12				30	15				40	20	13			49	25	16	10	
	25					21					27	12				35	18	10			42	22	12			48	26	14			59	35	21	13	
	30					25	10				31	15				40	20	10			48	22	12			54	30	17	10		60	34	19	10	
	35					28	12				36	17				45	25	14			52	27	16			58	32	18	10		66	38	21	13	
	40	10				34	16				40	20	10			50	28	16			58	32	18			64	36	20	10		72	40	24	14	10
	45	12				40	20	10			48	25	12			58	32	18			66	36	20			72	40	24	14	10	80	44	28	16	10
	50	14				46	23	11			54	29	15			64	34	19	10		72	40	24	14	10	78	44	28	16	10	84	48	32	18	10
	60	18				53	27	13			60	34	18	10		70	40	24	14	10	78	44	28	16	10	84	48	32	18	10	90	54	36	24	14
	70	21	10			59	31	15			67	37	17	10		78	44	28	16	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	80	25	11			61	33	16			70	40	24	14	10	80	48	32	18	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	90	29	13			63	35	17			72	42	26	14	10	82	50	34	18	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	100	33	15			65	37	18			74	44	28	16	10	84	52	36	20	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	120	40	19	10		67	39	19			76	46	30	17	10	86	54	38	21	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	140	48	24	11		69	41	20			78	48	32	18	10	88	56	40	22	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	160	55	28	14		71	43	21			80	50	34	18	10	90	58	42	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	180		33	16		73	45	22			82	52	36	19	10	92	60	44	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	200		37	19		75	47	23			84	54	38	20	10	94	62	46	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	220		41	22	10	77	49	24			86	56	40	21	10	96	64	48	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	240		45	25	12	79	51	25			88	58	42	22	10	98	66	50	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	260		50	27	14	81	53	26			90	60	44	23	10	100	68	52	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	280		54	30	16	83	55	27			92	62	46	24	10	102	70	54	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14
	300		58	33	18	85	57	28			94	64	48	25	10	104	72	56	24	10	84	48	32	18	10	90	54	36	24	14	96	60	40	24	14

EXAMPLE

Given: Q = 90 c.f.s. Estimated runoff from watershed.
 Height to control: 2.5 feet.
 Try 8% slope of chute or 12:1, Chute length = 2.5 X 12 = 30 ft. (length is O.K. for site)
 Good sod available and good soil.
 Select velocity: 6 feet per second.

SOLUTION

In the left hand column under "REQUIRED CAPACITY" c.f.s. find "90" c.f.s. Follow this to right and under column "8%" slope and "6" ft. per second velocity find "31" feet bottom width. In some column on line "CHUTE DEPTH" find "0.5" foot. In some column on line "ENTRANCE DEPTH" find "1.0" foot.

CONSTRUCTION DIMENSIONS

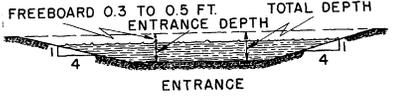
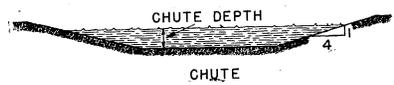
Slope: 8% or 12:1 slope.
 Bottom width: 31 feet.
 Total depth: 1.0' (entrance depth) + 0.4' (freeboard) = 1.4 feet.
 Chute depth: 0.5 feet. (Normal excavation and shoring will provide required depth plus additional depth for freeboard.)

NOTE: Minimum bottom width 10 feet.

BASIS OF DESIGN

$$V = \frac{1.486}{n} R^{2/3} S^{1/2} \quad n = .040$$

4:1 SIDE SLOPES



**SOD CHUTE - DIMENSION TABLE
TRAPEZOIDAL CROSS SECTION**

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL TECHNICAL APPROVAL

DESIGNED <i>T. R. Wire</i>	DRAWN <i>C. York M. E. W.</i>	CHECKED	DATE <i>8-21-51</i>
			DRAWING NUMBER 3-L-16240 SHEET OF

10.56 Construction of Sod Chutes

- a. Sod chutes may be subjected to relatively high velocities; it is recognized that the maintenance of vegetation is somewhat difficult and hazardous. Particular care must be taken in design, layout, and construction.
- b. If a dumpy level is available, it should be used to set final grade stakes before laying the sod or seeding. The chute should be level across the width, on a line at a right angle with the direction of flow. (Grade stakes will assure a level cross section and a uniform grade.) Construction of level cross section can be made with carpenter's level, tape, and straight edge.
- c. To determine a satisfactory location to end a watercourse, or a sod chute presents many varied and difficult problems. The objective is to terminate a location so that the watercourse below is stable. The most common problem is that the channel below the chute is narrow. Another problem is that conditions at the bottom may not be favorable to establish and maintain vegetation because of poor soil or rocky condition or siltation from adjacent ditches or streams.
- d. All of the stated problems are commonly corrected by use of a notch spillway dam or a toe wall (Figures 10.6 and 10.7, page 10-18). All the necessary information set up in Part 7 should be followed in designing this type of structure.
- e. The same specifications for construction of a watercourse apply to the construction of a sod chute as set up in Part 10.44.
- f. In addition to the above specifications, the following apply if chute is to be sodded:

Finish final grade with not less than three inches of top-soil.

Leave surface in a condition similar to a firm seedbed.

Cut sod thin.

Lay sod in strips across the chute.

Start laying sod at the bottom.

Stagger joints of the sod strips.

Lay sod two feet up side slopes.

Fill any open joints with loose soil.

Tamp or roll all laid sod.

Rubber-tired farm tractor is a good roller.

Sod should be pinned down in some manner. Wire (No. 9) staples, or chicken wire pegged down, are some successful methods used in the field.

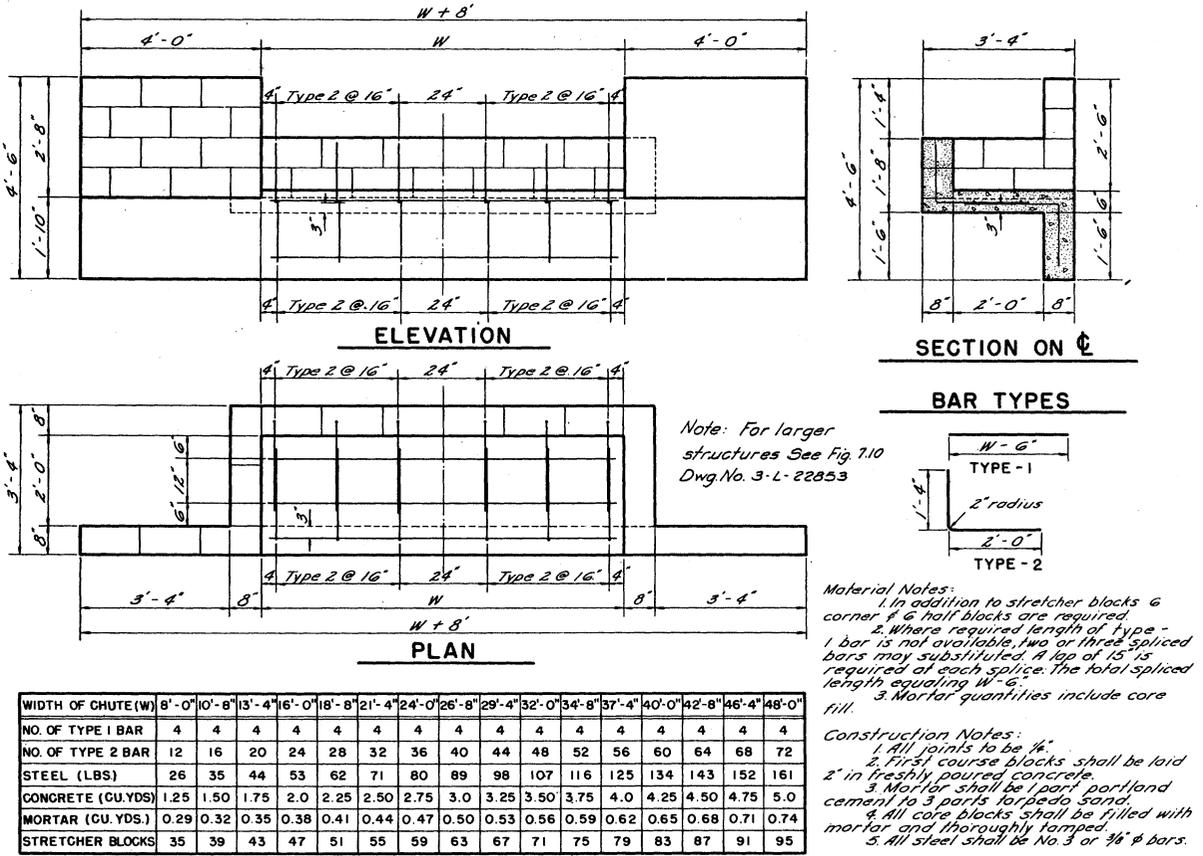


FIGURE 10.6 STANDARD DESIGN-CONCRETE BLOCK TOE WALL

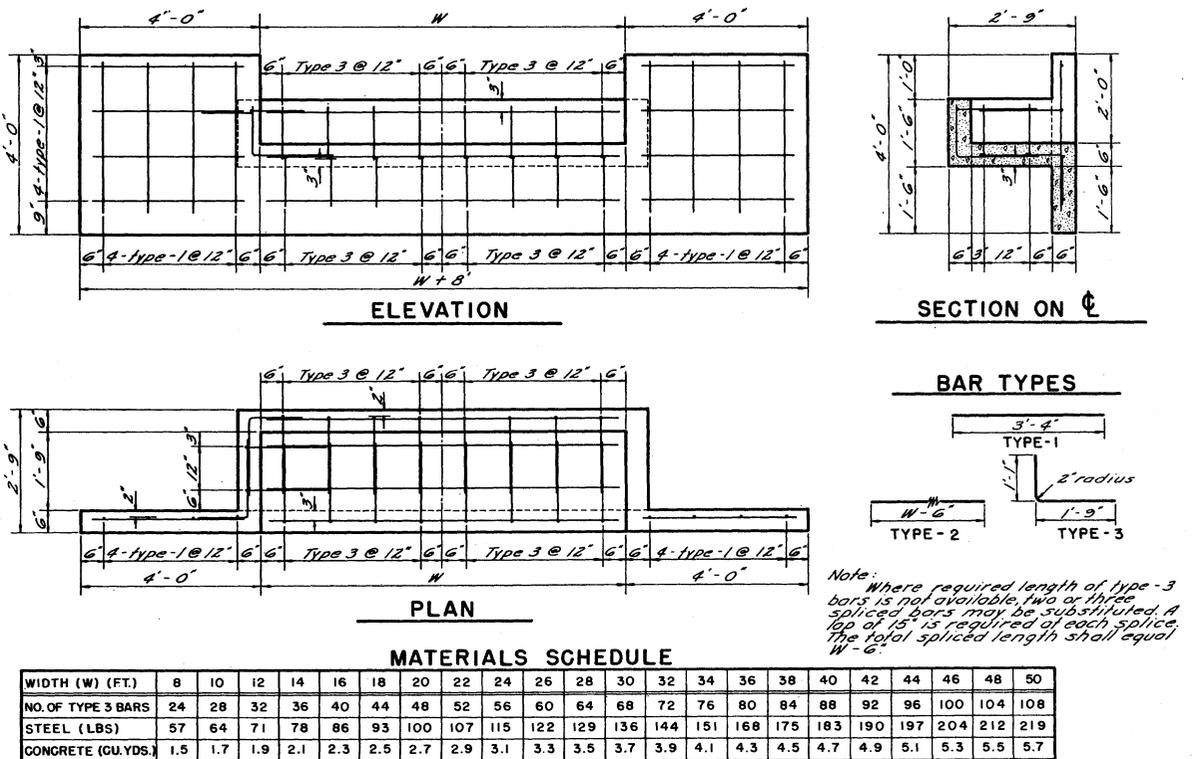


FIGURE 10.7 STANDARD DESIGN-REINFORCED CONCRETE TOE WALL

Protect from livestock during critical seasons.
 Mowing or grazing is a necessity for maintenance.

g. A suggested type of sod cutter is illustrated. (Farmers' Bull. 1814)

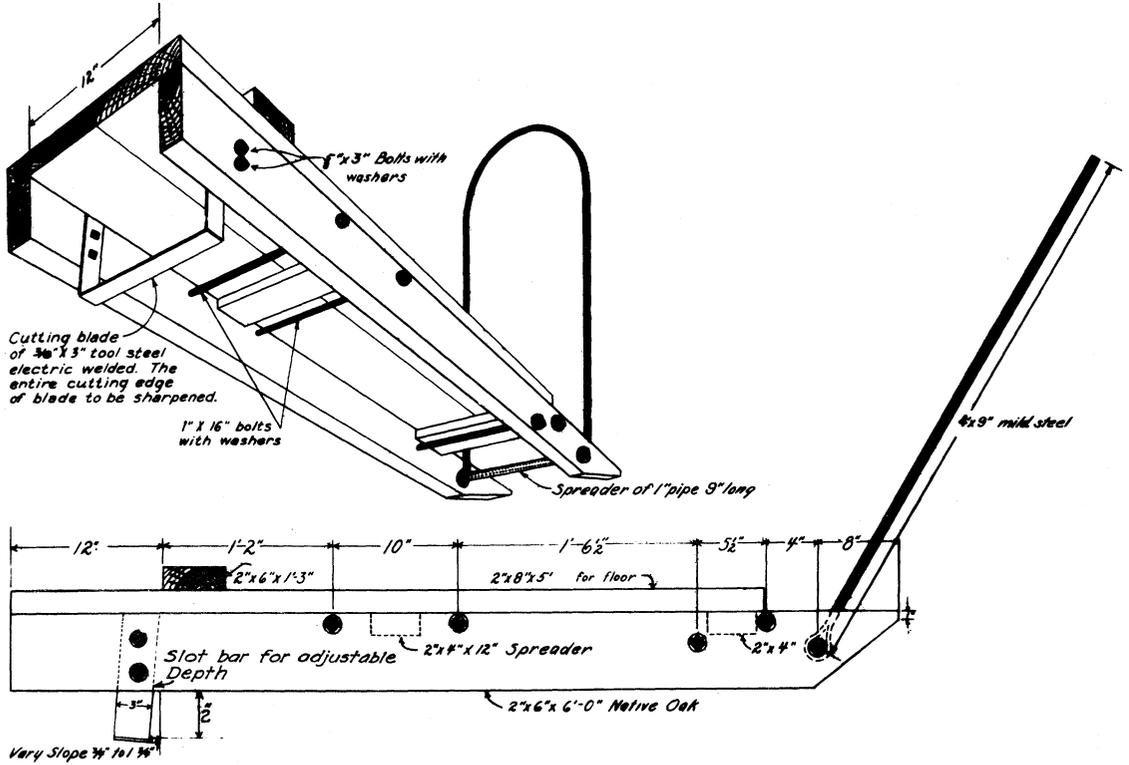


FIGURE 10.8 A HOME-MADE SLED-TYPE SOD CUTTER

PART 11

LAND DRAINAGE

11.10 INTRODUCTION

11.11 Purpose and Scope

The information on land drainage in this handbook is written as a field guide for farm conservation planners and conservation aids. It is intended for their use in the solution of relatively simple drainage problems on small areas of agricultural land. No attempt has been made to cover the entire field of land drainage as it applies to the larger, more complicated problems.

11.20 EFFECTS AND BENEFITS OF LAND DRAINAGE

11.21 Drainage Defined

Drainage is the removal of surplus water, known as free water or gravitational water, from the surface or below the surface of farm land in order to create favorable soil conditions for plant growth. The process of removing free water from the surface is referred to as surface drainage and the removal of free water from the subsoil is known as subsurface drainage. Sometimes free water in the soil is called internal water and the process of removal is termed internal drainage.

11.22 Kinds of Water in the Soil

a. Hygroscopic moisture is the thin film of moisture retained by each soil particle after it has been air dried; or, in other words, it is the moisture that is absorbed by the soil particles from the atmosphere. The hygroscopic moisture film is extremely thin and it is held so firmly by adhesion to the soil particles that it cannot be used by the roots of plants. There is no movement of hygroscopic water from one soil particle to another, Figure 11.1, page 11-2.

b. Capillary Water

(1) When a soil has the maximum amount of hygroscopic water and additional small amounts of moisture are added, the thickness of the moisture film is increased. When a continuous film of water develops between soil particles it is known as capillary water. Figure 11.1. Small amounts of capillary water are not available for plant growth. The moisture content must be above the maximum hygroscopic level, a certain percentage (this varies with the soil), before there is sufficient moisture to prevent a plant from wilting or dying. This percentage of moisture is called the wilting coefficient.

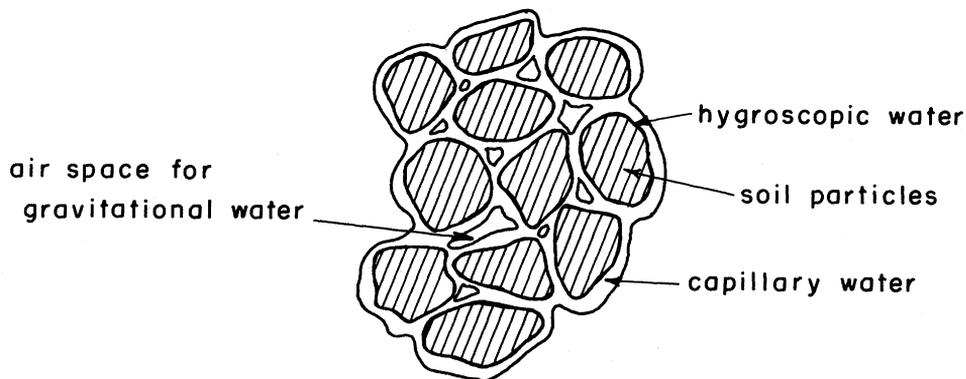


FIGURE 11.1 SOIL WATER IN RELATION TO SOIL PARTICLES

(2) As capillary water is added to the soil above the wilting point the soil moisture film around the soil particles increases and a portion of the pore space between the particles becomes filled with water. This is the water upon which the roots of plants mainly rely for plant growth.

(3) Capillary water is controlled by surface tension and the movement may be up or down. Capillary "pull" depends on the curvature of the moisture film around the soil particles; the smaller the radius of curvature the greater the pull. Thus capillary pull is greater in soils having small particles such as clay; and less on soils with relatively large particles such as sandy soils. As more and more water is added to a soil the moisture film around the soil particles becomes thicker and presently the point of maximum capillary capacity (moisture-holding capacity) is reached.

c. Free Water. If water is added above the capillary capacity it will slide off the moisture film and be acted upon by gravity. This water is called free water or gravitational water. See Figure 11.1. Sometimes free water below the surface is referred to as internal water. The presence of free water in the soil or on the ground surface for any period of time is detrimental to plant growth and this is the water that needs to be removed by drainage.

11.23 Benefits of Land Drainage

a. Removal of free water promotes soil bacterial action.

(1) Soil bacterial action is essential for the manufacture of plant food. Free water in the soil creates unfavorable conditions for plant growth because the pore space is filled

with water and air is excluded. The presence of air in the soil is essential for soil bacteria growth. These bacteria change organic matter into organic acids which in turn dissolve the elements in the soil that furnish plant food. After the elements of plant food have been changed into soluble salts through bacterial action they are taken into the capillary water and held in readiness for use by the plants.

(2) The roots of plants and the soil bacteria must have oxygen. Drainage accomplishes this by providing air space in the soil. Changes in atmospheric pressure assist in "ventilating" the soil. Also, through rainfall, water passes downward in the soil, carrying out carbon dioxide and permitting fresh air to be drawn in. Thus drainage provides soil aeration.

b. Drained soils warm up more quickly.

(1) Soils that are too wet warm up very slowly. They are frequently referred to as cold soils. The removal of free water by drainage allows the soil to warm up more quickly because considerably more heat is required to raise the temperature of saturated soil as compared to well drained soil.

(2) Soil warmth promotes increased activity of bacteria. This in turn affects the rate of release of plant food and the growth of plants.

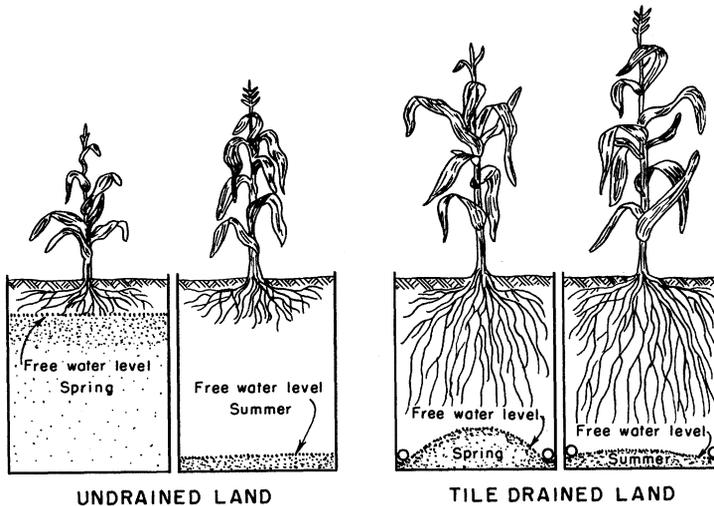
(3) Soils that warm up sooner in the spring can be planted to crops earlier and better germination conditions for seed are provided. These factors result in a longer growing season.

c. Drainage increases the root zone area.

(1) The removal of free water in the subsurface increases the amount of capillary moisture available to the plant. For example, if the free water is removed only from the top foot of soil the roots will be confined to this area for obtaining plant nutrients; but if the free water is removed from the top three or four feet this entire depth of soil is available as a root zone upon which plant nutrients and moisture can be obtained. Figure 11.2, page 11-4.

d. Most soils cannot be over-drained.

The removal of free water in the soil simply removes moisture in excess of the maximum capillary capacity. Drainage does not remove the capillary water and there is no danger of over-draining a soil by placing the drains too close together. The depth of the drains does control the height of the water table however, and if the water table is too low in soils with a low capillary "pull" the moisture may not move upward into the root zone. On most soils there is no danger of over-drainage, but on



ROOT GROWTH IS RESTRICTED TO THE SOIL AREA ABOVE THE "PERCHED" WATER TABLE. WHEN WATER RECEDES AFTER A LONG WET SPELL, ROOT EXTENSION IS USUALLY LIMITED.

Taken from "Farm Drainage—An Important Conservation Practice," by P.W. Manson and C. O. Rost, Agricultural Engineering, June 1951.

FIGURE II.2 ROOT DEVELOPMENT OF PLANTS GROWN ON DRAINED AND UNDRAINED SOILS

some extremely sandy soils and some peat and muck areas there is this possibility. On these soils there is a depth of water table which is best for plant growth and in the design of the drainage systems it is necessary to take this into consideration.

11.24 General Conditions Under Which Drainage is Applicable

Not all land can be drained economically, and it is well to keep in mind that there are limitations. The general conditions under which land drainage is applicable are the following:

a. Capability of the Land

The soils to be drained should be of such capability as to provide good permanent cropland or pasture after drainage.

b. Availability of Outlet

The land to be drained must have an adequate outlet that will provide sufficiently rapid removal of drainage waters.

c. Degree of Drainage Required

Drainage must be planned to provide the degree of drainage required by the crops to be grown.

d. Protection From Overflow

Lands subjected to frequent or prolonged overflow from streams must be protected by levees and floodgates or pumps before the drainage operation is undertaken.

11.30 PRELIMINARY INVESTIGATION OF DRAINAGE JOBS

11.31 General

a. When the drainage of any tract of land is contemplated, whether by open ditches or tile drains, a certain amount of preliminary investigation is necessary in order to get a clear understanding of the nature of the problem, the amount of work that will be required, the approximate costs, and the benefits that will accrue. This is true whatever may be the size of the tract to be drained, but the larger the area the more time should be given to preliminary work. The conducting of a preliminary analysis may be divided into the following steps:

- (1) Reconnaissance of the area.
- (2) Assembling maps and other pre-field data.
- (3) Preliminary instrument work.
- (4) Preliminary design, cost estimate, and appraisal of benefits of the proposed job.

On small jobs these steps may be accomplished at one time; but on larger jobs the steps generally are more or less separate operations. These are discussed in the following paragraphs.

11.32 Reconnaissance of the Area

a. Importance and General Nature of Reconnaissance

- (1) The first step in the preliminary analysis of any drainage project, whether large or small, is a reconnaissance of the area. This is of very great importance and it should never be omitted, for it is the beginning step in sizing up the job.

The reconnaissance is sometimes called "walking the area," for there is no substitute for thoroughly tramping over literally every acre to become acquainted with the problems, the general topographic conditions, and any unusual physical features.

- (2) For the reconnaissance a map of the area is very helpful for reference purposes. The only instrument needed is a hand level and a soil auger for making soil borings if drainage of the soils is questionable. Never attempt to make a preliminary instrument survey of the area until it has first been examined by a reconnaissance.

- (3) In this initial step available information from the landowner and others familiar with the area should be obtained. The technician should not attempt to give a solution to the problem but rather to seek information, and

make sufficient observations to ascertain the over-all feasibility of the job as indicated by the nature of the soils, the probable location of the outlet, the approximate area to be drained, and the general lay of the land. In short, the technician should acquire a mental picture of the problem and formulate his plan for gathering additional preliminary survey data and information needed to make an appraisal of the practicability and feasibility of the job.

b. Nature of the Soil

(1) The first thing that should be considered, both by the technician and the owner, is the inherent fertility of the land. Not all land that can be drained is worth the cost. The economic justification of the job will depend largely upon the value of the crops that can be grown on the drained land. Some wet land can be drained easily but the soil has definite plant food deficiencies; other soils of heavy clay are difficult and expensive to drain; still other soils have subsoil conditions that practically preclude the construction of drainage works. The soils should be carefully investigated both from the standpoint of physical feasibility of accomplishing drainage as well as the productiveness of the land. These factors should be carefully and thoroughly explored by the technicians in consultation with property owners and others who have had experience in draining similar land. Before proceeding further with the investigation a favorable decision should have been reached that the land can be drained and that the benefits derived are likely to justify the cost.

(2) In conducting the soils investigation all sources of information should be utilized. Where there are conservation surveys, these should be referred to, and if the nature of the soils make drainage doubtful an individual trained in soils should be consulted. Sufficient borings should be made with the soil auger to indicate whether or not drainage can be accomplished, and if there are physical soil conditions that need more careful exploration.

11.33 Assembling Maps and Other Pre-field Data

If the reconnaissance indicates the proposed job is feasible, steps should be taken to make more thorough preliminary observations. The technician will save considerable time if he assembles as much data as possible in the office prior to returning to the job. First and of foremost importance is a suitable map of the area. For small jobs this generally will be aerial photos, and conservation survey maps. For larger jobs, county or township maps may prove helpful. But in every case locate the best map available. An office study often will indicate physical features of the job that should be explored, and from information obtained in the reconnaissance it may be possible to delineate the benefited area and the watershed boundary. The

conservation survey map should be studied and the technician should familiarize himself with the soils of the area, particularly as they relate to the drainage problem.

11.34 Preliminary Instrument Survey

a. The nature of the drainage problem may be such that a reconnaissance is all that is needed to arrive at a preliminary determination of the feasibility and practicability of the job. This is more likely to be the case in small projects or where land drainage patterns are so pronounced that the physical lay of the land is obvious. But frequently some preliminary instrument work is needed in order to determine if the job can be done and the approximate cost.

b. Regardless of the size of the job, or the nature of the drainage problem, the first thing to establish is the location of the outlet and carefully investigate its adequacy. This may have been done approximately in the reconnaissance but it should now be more definitely determined. Such level readings should be taken and other measurements and estimates made to enable the technicians to reach a decision regarding the outlet because the functioning of the whole drainage system hinges on this point.

c. Preliminary Instrument Survey

The nature of the problem as well as the lay of the land will determine the amount of preliminary level shots that will be necessary. Some technicians gather such meager data that it is impossible to reach a preliminary decision on the job. Others gather so much detail that it virtually amounts to a detailed survey. The objective of the preliminary instrument survey is to obtain elevations, topography, and other field information necessary to definitely determine if the job is feasible, what it will cost, and the probable benefits. Only that field information should be gathered that is needed to determine these points. Some detailed suggestions for making preliminary level surveys follow:

(1) Establishing Bench Marks

Begin the preliminary level work by establishing a bench mark conveniently located, and as the survey progresses establish still other bench marks. If properly located and permanently established, these bench marks will be very helpful and time saving if a more detailed survey is made later.

(2) Preliminary Topographic Information

The purpose of preliminary topographic survey data is to determine the general lay of the land so that the approximate pattern of the drainage system can be tentatively planned. These topographic shots can be plotted on a small

sketch in the survey book, or they can be located approximately on an aerial photograph. Only critical points in topography should be taken, keeping in mind that the object is merely to ascertain the general plan of the drainage system.

(3) Preliminary Profiles

Preliminary profiles of existing or proposed ditch lines and tile mains frequently are necessary in order to establish the amount of grade available, estimate approximate yardage of earth that must be excavated, etc. The method of running preliminary profiles is similar to that used in detailed surveys described in Part 1, except that the readings are taken a greater distance apart and stations are not marked by stakes except at intervals of 500 to 1,000 feet. Distances along the profile can be determined by rough chain measurements, by means of stadia, or by accurate pacing. If an aerial photo of known scale is available the location of readings can be indicated on the photo and the distances scaled later in the office. Sufficient elevations of average ground, low spots, flow line, and cross section readings should be taken so that a preliminary profile can be plotted. This is necessary in order to determine the grade available, depth of channel or tile, and approximate yardage to be excavated from open ditches. The same accuracy should be exercised in obtaining preliminary profile elevations as in the final survey, the main difference being the frequency of the shots and a minimum of stationing along the profile.

11.35 Other Preliminary Field Information

At the time of the preliminary instrument survey, other pertinent field data should be gathered. This information, if accurately obtained, may be used later in final design.

- a. Soils information should have been determined during the reconnaissance but if some doubt exists regarding the soils these points should be cleared up at this time.
- b. The area in need of drainage should be delineated on an aerial photograph.
- c. The drainage area should also be outlined if it is a factor that will affect design of the system.
- d. Size and elevation of culverts, bridges, and other physical features affecting preliminary design should be obtained.
- e. Information regarding crops to be grown by the owner should be gathered, since this may affect the proposed design.

11.36 Preliminary Design, Cost Estimate, and Appraisal of Benefits

With the preliminary levels and other field information, a preliminary plan of the drainage system should be prepared. For simple small jobs this preliminary plan may be very simple (possibly nothing more than a sketch in a note book), but on larger jobs it may be necessary to plot up profiles, ditch cross sections, and topographic information to arrive at the preliminary design. This preliminary design is important because it is the final basis for determining the feasibility of the job, the approximate cost, and the probable benefits. Therefore the preliminary design needs to be done with a reasonable degree of accuracy, particularly as it affects these points.

11.37 Discussion of Proposed Plan With the Owner

The final step in the preliminary investigation is to present the findings to the owner. All facts, both favorable and unfavorable, should be discussed; the general plan, together with the estimated cost and the benefits that will be likely to result, should be explained. With all of this information the owner can intelligently reach a decision on whether he desires to proceed with the job. If the owner's decision is negative a large amount of time will not have been spent on unnecessary surveys and detailed designs. If he desires to proceed, then the preliminary information will be most helpful and time saving in making the detailed survey and final design of the job.

11.40 DRAINAGE OUTLETS

11.41 General

A drainage outlet receives the water from an individual field drainage system or from a series of field drainage systems. The importance and necessity of an adequate drainage outlet is obvious for there must be some method of disposal of field drainage water if the system is to function. An adequate outlet will remove the surplus water from the area drained before damage occurs to the crops.

11.42 Kinds of Drainage Outlets

a. There are four kinds of drainage outlets:

- (1) Open ditch outlets
- (2) Tile outlets
- (3) Combination tile outlet and relief ditches
- (4) Outlets by drainage pumping.

b. Open Ditch Outlets

(1) An open ditch outlet is an excavated open channel constructed to a predetermined size and grade for the purpose of disposing of drainage water from surface, or tile drainage system, or for disposal of flood water. Open ditch outlets vary in size from small individual lateral ditches to main outlet ditches.

(2) Open ditch outlets are commonly used because they are comparatively low in cost and surface water is rapidly and efficiently removed. However, they have some disadvantages. Open ditches occupy land area, make farming operations more difficult, the construction of bridges is necessary, regular cutting of vegetative growth, and clean-out at periodic intervals is required. Under certain conditions therefore, as described under tile outlets, this latter method may prove to be more satisfactory.

c. Tile Outlets

(1) A tile outlet is a covered drain of predetermined size laid beneath the ground surface at a specified grade and elevation. It generally serves for the disposal of water from tile drainage systems, but it may also be used to remove surface water from shallow depressional areas.

(2) Advantages to the uses of tile outlets are: low maintenance cost, no land area is taken up by the outlet, and no bridges or culverts are required. In the past, when installation costs were lower, there was a tendency to use large size tile outlets (up to 42 inches in diameter). But the present trend is toward the use of more open ditch outlets.

(3) The choice between open ditch and tile outlets is largely a matter of economics. Where land values are high, tile outlets may prove more practical than open ditches for the smaller drainage areas (under 300 acres). Generally an open ditch outlet is cheaper to construct and maintain than a tile outlet where the diameter of the tile exceeds 24 inches.

(4) Tile outlets do not, in many cases, eliminate damage by excessive flood waters. This runoff flows over the ground surface, creating a ditch or gully frequently washing out the tile. In many cases a surface relief ditch may be necessary.

(5) The design of tile outlets should be made by an engineer. Farm conservation planners, however, need to be sufficiently conversant with the general conditions under which this type of outlet is applicable.

d. Combination Tile Outlets and Surface Relief Ditches

(1) Where tile outlets are used in preference to open ditches and the capacity of the tile is not sufficient to remove storm waters, a surface relief ditch should be provided. They may be vegetated or bare channel, depending upon the channel velocities. The use of surface relief ditches to relieve flood waters may result in a more economic design for the tile outlet, since the tile would not be called upon to carry storm flow.

(2) The design of combined tile outlets and surface relief ditches will not be discussed in this handbook. The complexity of the problem generally is beyond the scope of drainage work undertaken by farm conservation planners and their aids.

e. Outlets by Drainage Pumping

(1) Where an outlet is not available to receive gravity flow from drainage systems the water may be discharged into natural streams or outlet ditches by pumping. This type of outlet is mainly applicable to large levee districts along main tributaries. However, drainage pumps can be used successfully as a means of outletting drainage water from relatively small individual field installations. This type of outlet has been especially successful in the drainage of peat and muck soils for truck crops, and it has also been used successfully as a means of outletting tile drainage water for regular field crops. Limiting factors that affect the installation of field drainage pumping systems are the initial installation costs, fixed pumping charges, and annual maintenance costs.

(2) The use of drainage pumping systems has limited application and the design should be done under the supervision of an engineer. Consequently this type of outlet is not discussed further in this handbook.

11.50 OPEN OUTLET DITCHES

11.51 General

a. Open outlet ditches are the only kind generally applicable to simple installations by farm conservation planners and aids. The following discussion, therefore, is limited to this type.

b. In design and construction of drainage outlets the steps or procedures generally used are the following:

- (1) Obtaining necessary information and surveys.
- (2) Plotting survey data and compiling the information on an appropriate data sheet.
- (3) Design of the outlet ditch.
- (4) Layout and construction.

11.52 Obtaining Necessary Information and Surveys

a. Profile Information

The obtaining of various elevations and other physical information along the course of the ditch and in the adjacent fields is referred to as profile information. Slightly different procedures and information are required where there is an existing ditch and where a new ditch is to be constructed. The information to be obtained in each case follows:

(1) Profiles where there is an existing ditch.

(a) At even 100 foot stations or at critical points between stations obtain elevations of the natural field level alongside the ditch, the old ditch bottoms, and the top of old spoil banks.

(b) On existing culverts and bridges along the ditch line obtain the following: location, size of opening, length, and kind of material (concrete, C.M.P., etc.). Also secure upstream and downstream elevation of the flow line, elevations of top of road crossing the structure, and the elevations of low points on the road in the vicinity.

(c) Where existing tile outlets empty into the ditch, obtain the location, size, and kind of outlet, and the elevation of the flow line.

(d) Where open ditches, laterals, or tributaries drain into the ditch, obtain the bottom elevation of the flow line at the point of entrance and any other pertinent data that would be useful in design.

(e) Locate, describe, and obtain elevations as required of any other physical features along the ditch that will affect the design such as: cattle ramps, fences, surface flow entering ditch, etc.

(2) Profiles on new ditch lines.

If a new ditch is to be constructed the centerline of the proposed ditch must be located first, then obtain the following:

(a) Natural ground elevation along the centerline of proposed ditch at even stations and at critical points between even stations. Obtain similar elevations of the natural ground alongside the ditch also if there is any appreciable variation.

(b) Information and elevations on culverts, bridges,

and roads, and other features along the ditch line as specified for profiles along existing ditches.

(c) The location, size, and flow line elevation of existing tile that will be intersected by the ditch.

b. Cross Sections

(1) On existing ditches take cross sections at intervals of 100 to 400 feet, depending on the irregularity of the topography and variation in the size of the ditch. These cross sections should extend out into the land adjoining the ditch so that any low points needing drainage will be picked up.

(2) Where there is no existing ditch, cross sections generally are not needed unless the ground level on either side of the ditch line is obviously at a different elevation.

c. Side Shots

If there is any evidence whatsoever of low points in the field to be drained, elevations of these low points should be obtained. Sometimes this can be done in connection with obtaining profiles or cross sections, but if this is not possible a line of levels should be run to the low point to obtain the elevation. The location of this point should be obtained and described in the field notes.

d. Soil Borings

Take as many borings as are needed to be sure of the kind of soil material to be encountered in the proposed ditch construction.

e. Watershed Information

Locate the watershed boundaries on a suitable map, preferably an aerial photo. Generally this can be done with the aid of a hand level or by observation of the direction of waterflow. Farmer information also is helpful.

f. High Water Marks

Obtain elevation and information of high water marks and flooding in previous years. Sometimes drift marks of previous high water is noticeable on trees, culverts, or posts. Often the only source of high water information is from the local people residing near the ditch. High water elevations should be obtained at 500 to 1,000 foot intervals along the ditch under design and the height of flow of the channel into which the ditch outlets should be definitely obtained.

11.53 Plotting Survey Data

The procedures and methods for plotting survey data described in Part 2 "Preparation of Engineering Data Sheets," should be followed. A sample open ditch data sheet is shown in Figure 11.3, page 11-15.

11.54 Designing the Outlet Ditch

Factors affecting the size of the ditch are the drainage runoff, required depth, grade of the ditch, the ditch side slopes, culverts, and other structures.

a. Determining Drainage Runoff

(1) Open drainage ditches generally are not designed to carry peak runoff resulting from a particular frequency rain. Ordinary field crop ditches are designed to remove excess surface water within a 24-hour period following an ordinary rain. Some surface flooding of the land during this period is permissible.

(2) Specialized crops such as truck crops, however, require design and construction of a ditch of such a size that overflow seldom results. For these crops, flooding cannot be permitted during the growing season except for two to four hours. The high crop value warrants this added drainage protection; and furthermore, most specialized crops such as carrots and onions are extremely sensitive to flooding.

(3) Drainage runoff is determined on the basis of the removal of a definite number of inches of rainfall over the entire drainage area in a 24-hour period. Design curves for the removal of various depth of water in 24 hours are given in Figure 11.4, page 11-16. Determine the drainage runoff to be used in open ditch design from these curves as follows: First determine the watershed area from the watershed map; then, select the curve on Figure 11.4 that is applicable to the condition and particular location and read the drainage runoff "total discharge" from that curve for the watershed area.

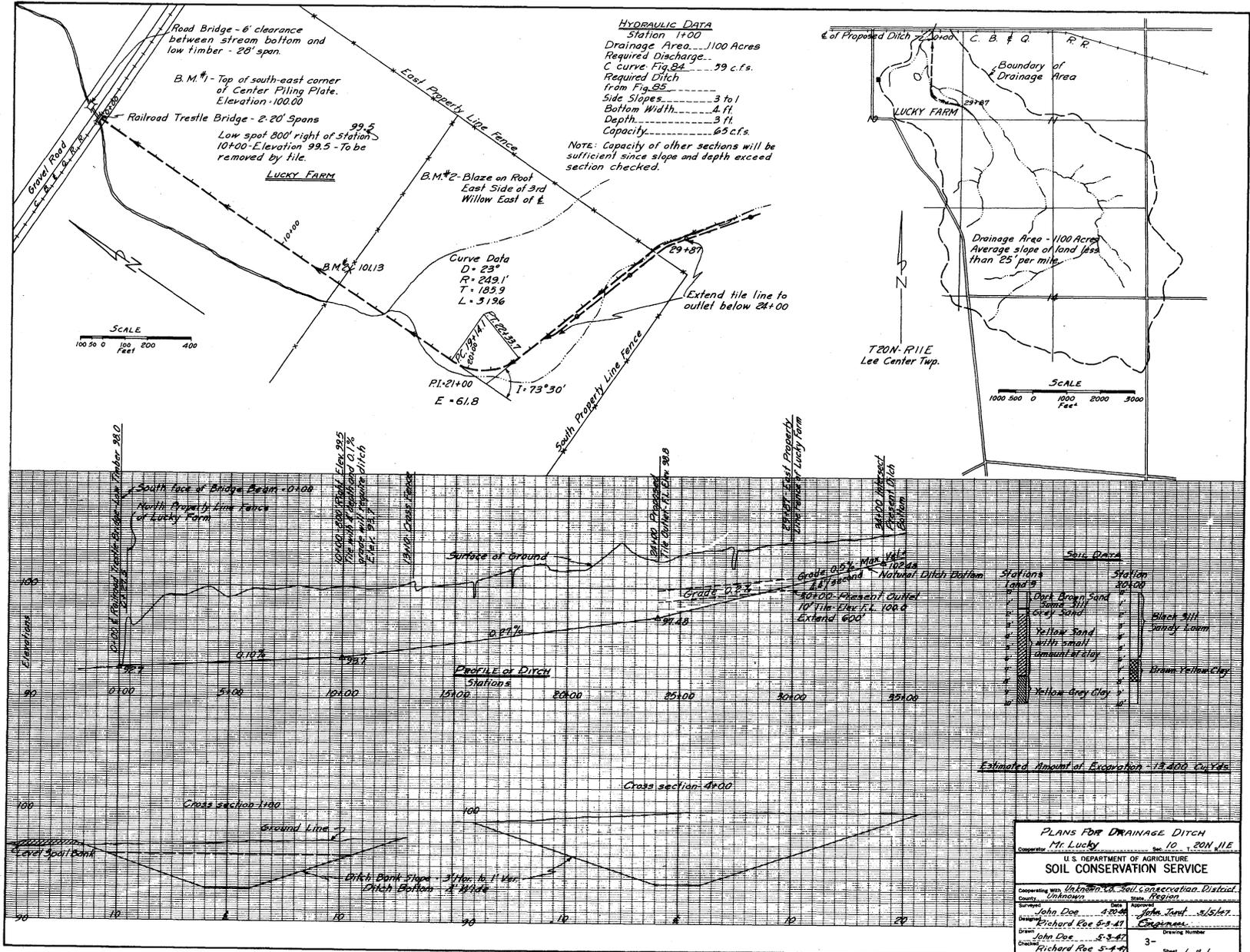
b. Depth of Ditch

Two factors affect the depth of outlet ditches; the depth required to remove surface runoff and the depth necessary to provide an outlet for tile drainage. Ditches should be checked for both of these factors to determine which one governs depth.

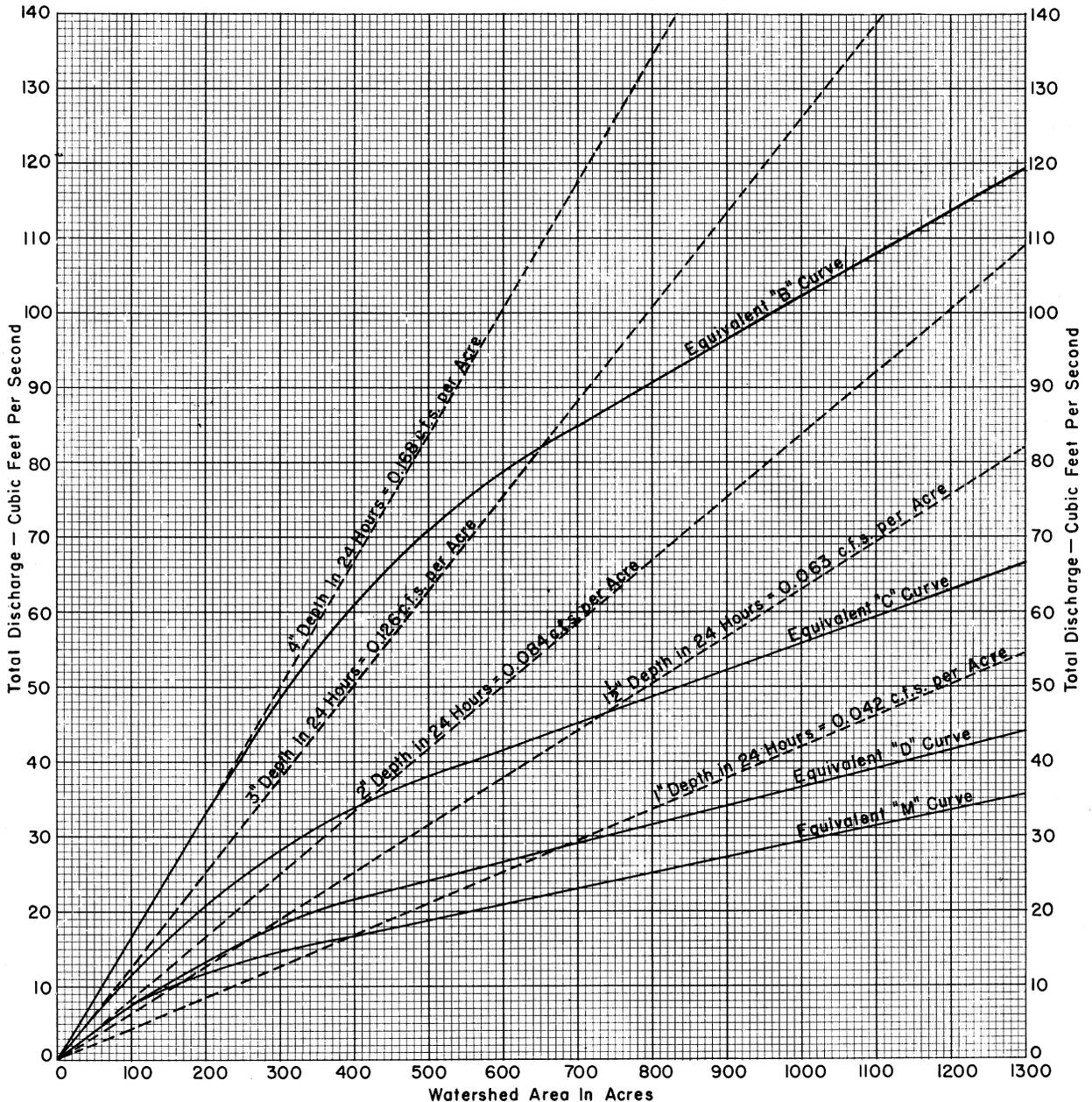
(1) Depth required to remove surface runoff.

In order for the surface water to flow into ditches freely the design ditch flow line should be below the ground surface. This is accomplished by giving ditches extra depth varying

FIGURE II.3 SAMPLE DRAINAGE DITCH DATA SHEET



DRAINAGE RUN-OFF CURVES FOR OPEN DITCH DESIGN IN FLAT WATERSHED AREAS OF LESS THAN 2 SQUARE MILES



Notes: Curves applicable only to flat watershed areas having average slope less than 25 feet per mile watershed area to be determined above each section of ditch for which capacity is to be computed.

For lands with steeper slopes than given above and ordinary valley drainage use next higher run-off curve to give equal protection.

Explanation of Curves: B - For excellent drainage except in Claypan soils in Southern part of Region 3. Very good drainage on these soils.

C - For excellent drainage in northern Minnesota, Wisconsin, Michigan. For very good agricultural drainage in Ohio, Indiana, Illinois, Iowa, northern Missouri, southern Minnesota, Wisconsin and Michigan. For good agricultural drainage in southern Missouri.

D - For good agricultural drainage in northern Minnesota, Wisconsin and Michigan. For fair agricultural drainage in Ohio, Indiana, Illinois, Iowa, northern Missouri, southern Minnesota, Wisconsin and Michigan.

M - For fair agricultural drainage in Red River Valley, Minnesota.

Reference "Drainage Specifications S-1"

FIGURE II.4 DRAINAGE RUNOFF CURVES FOR OPEN DITCH DESIGN

from 1.0 foot for main outlets to 0.5 foot for lateral outlets. For example, if the depth of lateral outlet ditch, as determined from Figure 11.6, pages 11-21 to 11-23a inclusive, is found to be 3.0 feet, then the actual constructed depth should be 3.5 feet.

(2) Depth required for tile drainage.

Outlet ditches should be deep enough to accommodate tile drainage systems. They should be deep enough to provide the minimum depth for tile mains and laterals with at least one foot of clearance between flow line of the tile at its outlet and the low water stage in the ditch. Assuming that tile are laid at 3.5 to 4.0 feet the minimum depth of the outlet ditch would be 5.0 to 5.5 feet. This added depth is necessary in order to allow for silting that normally occurs, and also provides a longer period for free outlet (unsubmerged) of the tile. However, if the outlet ditch is on such a grade that silting will not occur and there is no low water flow a few hours after a storm this clearance may be reduced.

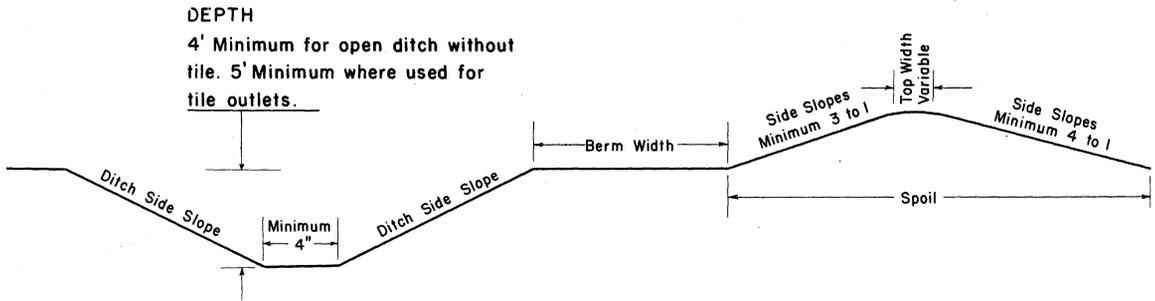
c. Determining Grade of Ditch Bottom

While there are a number of factors to be considered in arriving at the grade of the ditch, it is usually determined from the natural ground slope (in percent). This can be obtained by a study of the plotted profiles. When there is no natural ground slope in the direction of proposed ditch flow, use a minimum grade of 0.02%, or such other minimum grade as is specified in the local Technical Guide.

d. Determination of Ditch Side Slopes

(1) The side slopes affect the capacity of the ditch and therefore it is necessary to choose the appropriate side slopes before the ditch size can be determined. The soil borings show the kind of soil material that will be encountered. With the soil boring information and information from the farmer as to how maintenance is to be done the side slopes can be decided from the standards specified in Figure 11.5, page 11-18.

(2) In clay and clay loam soil it is considered the best practice to use 2:1 side slopes. However, in clay and heavy soil, side slopes of $1\frac{1}{2}$:1 may be adequate, or side slopes of 1:1 can be used on muck and peat soil since they tend to stabilize on a steeper slope. In deep sands where it is impossible to establish vegetation a 1:1 side slope may be used, but the ditch section must be enlarged and deepened over that required for design flow to allow for sloughing. The amount of enlargement should be determined by an engineer. Under normal conditions ditchbanks cannot be mowed safely on slopes much steeper than 3:1 or $3\frac{1}{2}$:1, depending on



DITCH SIDE SLOPE

Deep peats and mucks 1 to 1 side slopes may be used. Heavy clays 1 1/2 to 1 side slopes may be used but 2 to 1 preferable. If mowing is desired not less than 3 1/2 to 1 should be used.

BERM WIDTH

Minimum for shallow ditches (4 to 5' deep) 10 feet.

For deep ditches.

1 to 1 slope use 2 X depth.

2 to 1 slope use 1 X depth but never less than 10 feet.

FIGURE 11.5 TYPICAL DITCH CROSS-SECTION

the type of equipment. Unless the slopes are flat enough to mow, or if the banks are not to be maintained by mowing there is no particular advantage to a flat side slope. The minimum slope for clay and clay loam soils should be that required to establish a satisfactory cover.

e. Structures for Road Crossings

In addition to the design of the ditch cross section, attention must be given to the design of culverts and bridges. Public road culverts and bridges should be of sufficient size to pass flood flows without excessive damage to the structure, highway, and field crops. In addition, they should be of such a capacity to pass the designed drainage runoff with the headwater and tailwater carried below the ditchbanks.

Farm road crossings may be designed only for drainage design flow if the landowner accepts responsibility of all damage for loss of the structure or for overflow of adjacent land during floods.

Public road culverts and bridges should be designed by an engineer. The less complicated hydraulic designs for farm road crossings as described in Part 11.80 may be undertaken by work unit conservationists and conservation aids.

f. Erosion Control Structures

(1) Control of erosion is one of the major responsibilities of the Soil Conservation Service. Service personnel must not overlook this in the assistance they give in open ditch drainage.

(2) Provisions should always be made for lowering surface water from adjoining fields to the ditch. This may be accomplished by installing chutes, drop spillways, pipe drop inlet spillways, or other suitable structures.

(a) Vegetated chutes may be used where the volume of water is small. Vegetated chutes must be mowed frequently to maintain a good dense sod. If a vegetated chute is used on a ditch of constant flow, the toe must be raised above normal water level and protected with a toe wall to prevent unraveling of the sod. The toe of the chute should be recessed into the bank a distance of 10 feet from the edge of the ditch bottom and then raised on a slope not steeper than 8:1. Design of sod chutes is covered in Part 10.50.

(b) Pipe drop inlet spillways may be used advantageously to convey water from back of a levee or continuous spoil bank into a drainage ditch. Where a ditch passes through an area of flat land without definite concentration of surface flow into the ditch, lateral drainage from the adjacent land can usually be provided by standard pipe drop inlets with a pipe size of at least 12" in diameter placed at the low points but not to exceed 1,000 feet apart along the ditch with the inlet back of a levee or spoil bank.

(c) Where definite concentrations of surface flow into the drainage ditch are found to exist, special designs will need to be made.

(d) Where the volume of water to be handled is large, drop spillways of reinforced concrete, masonry, or concrete block should be used. Suitable inlet structures should be provided to protect the head end of the ditch from eroding.

g. Example of Ditch Design

With the above information the required cross section of the ditch can be determined from Figure 11.5, page 11-18, and Figure 11.6, pages 11-21 to 11-23a inclusive.

(1) Example:

300 acre watershed

Location - northern Iowa

Land slopes less than 25 ft./mile (1/2%)

Common field crops to be grown

Ditch to be used for tile outlet

Use "C" curve Figure 11.4

Required drainage design discharge $Q = 28$ c.f.s.

Borings show material to range from silty clay loam to clay loam down to 4 foot average depth, and grading from clay loam to clay from 4 foot to 6 foot depth. Cooperator prefers to control vegetation by chemical spray method. From Figure 11.5, side slopes not steeper than $1\frac{1}{2}:1$ are required. The minimum bottom width that can be dug with a dragline is 4.0 feet. Natural ground slope from profiles = 0.06%. From tables Figure 11.6, 4 foot bottom ditch, $1\frac{1}{2}:1$ side slopes, 3 feet deep will carry 33 c.f.s., but ditch is to be used for tile outlet and will require 5 foot minimum depth. Specify 4 foot bottom ditch, 5 foot depth, with $1\frac{1}{2}:1$ side slopes.

h. Completion of Ditch Plan

- (1) If the final designs and specifications are not within reasonable agreement with the preliminary investigation, a further contact should be made with the cooperator and an agreement reached before proceeding with the final detail plans. When a cooperator understands Service standards and the reasons for them he is more apt to follow plans and specifications.
- (2) After the cooperator has agreed to accept the designs and specifications, complete the plans by adding the following information:
 - (a) Record ditch design computations on plan profile sheet.
 - (b) Draw ditch bottom grade on profiles (generally parallel to natural ground slope).
 - (c) Record computed quantities (earth excavation and other). (See Part 1.53 for computation of yardage.)
 - (d) Draw up typical cross sections to show ditch bottom width, side slopes, berm width, and spoil leveling specifications.
 - (e) Record any other pertinent data and specifications. (See Figure 11.3 for typical data sheet of above example.)
 - (f) Design and complete structure data sheet or use standard designs. (See Figures 11.7 and 11.8, pages 11-24 and 11-25.)

OPEN DITCH DESIGN TABLE FOR DITCHES WITH 1 TO 1 SIDE SLOPES

DITCH SIZE				SLOPE																																		
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	.02 %				.04 %				.06 %				.08 %				.10 %				.15 %				.20 %										
				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES								
					B	C	D	M		B	C	D	M		B	C	D	M		B	C	D	M		B	C	D	M		B	C	D	M					
4	0.5	5.0	2.25	0.7	4	6	8	8	0.9	5	7	11	11	1.1	7	9	13	13	1.3	8	10	15	15	1.5	9	12	18	18	1.8	11	14	21	21	2.0	12	16	24	24
4	1.0	6.0	5.00	2.1	12	17	25	25	3.0	18	24	36	36	3.7	22	29	44	44	4.3	26	34	51	51	4.8	29	38	57	57	5.8	35	46	73	73	6.7	40	54	86	86
4	1.5	7.0	8.25	4.4	26	33	52	52	6.1	36	49	78	78	7.5	45	62	99	99	8.7	52	72	119	123	9.7	58	82	136	146	12.0	72	105	176	206	14.0	83	125	212	272
4	2.0	8.0	12.00	7.2	43	59	94	94	10.0	60	85	140	153	13.0	77	115	194	238	15.0	89	135	251	315	16.0	98	146	250	360	20.0	119	190	345	555	23.0	137	227	455	700
4	2.5	9.0	16.25	11.0	66	95	158	178	16.0	95	146	250	360	19.0	113	179	319	510	22.0	131	214	415	650	25.0	149	254	535	795	30.0	180	330	740	1035	35.0	213	430	940	1250
4	3.0	10.0	21.00	16.0	95	146	250	360	22.0	131	214	415	650	27.0	161	283	620	890	31.0	187	350	780	1080	35.0	213	430	940	1250	43.0	265	640	1260	1585	49.0	300	810	1445	1870
6	0.5	7.0	3.25	1.0	6	8	12	12	1.4	8	11	17	17	1.7	10	13	20	20	2.0	12	16	24	24	2.2	13	17	26	26	2.7	16	21	32	32	3.1	18	25	37	37
6	1.0	8.0	7.00	3.2	19	25	38	38	4.4	26	35	52	52	5.4	32	43	67	67	6.3	38	51	80	80	7.0	42	57	91	91	8.6	51	71	117	121	9.9	59	84	139	150
6	1.5	9.0	11.25	6.3	38	51	80	80	8.9	53	74	122	128	11.0	66	95	158	178	13.0	77	115	194	238	14.0	83	125	212	272	17.0	101	157	271	410	20.0	119	190	345	555
6	2.0	10.0	16.00	10.0	60	85	140	153	15.0	89	135	231	315	18.0	107	168	293	460	21.0	125	202	377	600	23.0	137	227	455	700	28.0	167	298	660	935	33.0	200	385	880	1180
6	2.5	11.0	21.25	16.0	95	146	250	360	22.0	131	214	415	650	27.0	161	283	620	890	31.0	187	350	780	1080	35.0	213	430	940	1250	42.0	260	610	1220	1540	49.0	300	810	1445	1870
6	3.0	12.0	27.00	22.0	131	214	415	650	30.0	180	330	740	1035	37.0	225	475	1015	1320	43.0	265	640	1260	1585	48.0	295	780	1410	1820	59.0	380	1090	1800	2320	68.0	470	1330	2140	2760
8	0.5	9.0	4.25	1.3	8	10	15	15	1.8	11	14	21	21	2.3	14	18	27	27	2.6	15	21	31	31	2.9	17	23	35	35	3.6	21	29	43	43	4.1	24	33	49	49
8	1.0	10.0	9.00	4.1	24	33	49	49	5.9	35	47	75	75	7.2	43	59	94	94	8.4	50	70	114	116	9.3	56	78	129	137	11.0	66	95	158	178	13.0	77	115	194	238
8	1.5	11.0	14.25	8.3	50	69	112	114	12.0	72	105	176	206	14.0	83	125	212	272	17.0	101	157	271	410	19.0	113	179	319	510	23.0	137	227	455	700	26.0	155	268	575	840
8	2.0	12.0	20.00	14.0	83	125	212	272	19.0	113	179	319	510	24.0	143	240	495	745	27.0	161	283	620	890	30.0	180	330	740	1035	37.0	225	475	1015	1320	43.0	265	640	1260	1585
8	2.5	13.0	26.25	20.0	119	190	345	555	28.0	167	298	660	935	35.0	213	430	940	1250	40.0	245	555	1140	1450	45.0	280	695	1320	1675	55.0	345	975	1650	2140	63.0	420	1200	1950	2520
8	3.0	14.0	33.00	27.0	161	283	620	890	39.0	240	530	1100	1405	48.0	295	780	1410	1820	55.0	345	975	1650	2140	61.0	400	1145	1880	2420	75.0	550	1490	2400	3110	92.0	820	1920	3090	4000
10	0.5	11.0	5.25	1.6	10	13	19	19	2.3	14	18	27	27	2.8	17	22	33	33	3.3	20	26	39	39	3.7	22	29	44	44	4.5	27	36	54	54	5.1	30	40	62	62
10	1.0	12.0	11.00	5.2	31	41	64	64	7.4	44	61	97	97	9.0	54	75	124	130	10.0	60	85	140	153	12.0	72	105	176	206	14.0	83	125	212	272	17.0	101	157	271	410
10	1.5	13.0	17.25	10.0	60	85	140	153	14.0	83	125	212	272	18.0	107	168	293	460	21.0	125	202	377	600	23.0	137	227	455	700	28.0	167	298	660	935	33.0	200	385	880	1180
10	2.0	14.0	24.00	17.0	101	157	271	410	24.0	143	240	495	745	29.0	173	314	700	985	33.0	200	385	880	1180	37.0	225	475	1015	1320	46.0	285	725	1340	1720	63.0	330	915	1580	2050
10	2.5	15.0	31.25	25.0	149	254	535	795	35.0	213	430	940	1250	43.0	265	640	1260	1585	49.0	300	810	1445	1870	55.0	345	975	1650	2140	68.0	470	1330	2140	2760	78.0	590	1570	2520	3260
10	3.0	16.0	39.00	34.0	206	405	900	1225	48.0	295	780	1410	1820	59.0	380	1090	1800	2320	67.0	460	1300	2100	2710	75.0	550	1490	2400	3110	92.0	820	1920	3090	4000					

FIGURE 11.6 DITCH DESIGN CHARTS (1:1 SIDE SLOPE)

DITCH SIZE				SLOPE																													
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	.25 %				.30 %				.35 %				.40 %				.45 %				.50 %									
				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES				"Q" c.f.s.	WATERSHED HANDED BY DRAINAGE CURVES			
					B	C	D	M		B	C	D	M		B	C	D	M		B	C	D	M		B	C	D	M		B	C	D	M
4	0.5	5.0	2.25	2.3	14	18	27	27	2.5	15	20	30	30	2.7	16	21	32	32	2.9	17	23	35	35	3.1	18	25	37	37	3.3	20	26	39	39
4	1.0	6.0	5.00	7.5	45	62	99	99	8.3	50	69	112	114	8.9	53	74	122	128	9.5	57	80	132	142	10.0	60	85	140	153	11.0	66	95	158	178
4	1.5	7.0	8.25	15.0	89	135	231	315	17.0	101	157	271	410	18.0	107	168	293	460	19.0	113	179	319	510	21.0	125	202	377	600					
4	2.0	8.0	12.00	26.0	155	268	575	840	28.0	167	298	660	935	30.0	180	330	740	1035	33.0	200	385	880	1180										
4	2.5	9.0	16.25	39.0	240	530	1100	1405																									
4	3.0	10.0	21.00																														
6	0.5	7.0	3.25	3.5	21	28	42	42	3.8	23	30	45	45	4.1	24	33	49	49	4.4	26	35	52	52	4.6	27	36	55	55	4.9	29	39	58	58
6	1.0	8.0	7.00	11.0	66	95	158	178	12.0	72	105	176	206	13.0	77	115	194	238	14.0	83	125	212	272	15.0	89	135	231	315	16.0	95	146	250	360
6	1.5	9.0	11.25	22.0	131	214	415	650	24.0	143	240	495	745	26.0	155	268	575	840	28.0	167	298	660	935										
6	2.0	10.0	16.00	37.0	225	475	1015	1320	40.0	245	555	1140	1450																				
6	2.5	11.0	21.25	55.0	345	975	1650	2140																									
6	3.0	12.0	27.00																														
8	0.5	9.0	4.25	4.6	27	36	55	55	5.0	30	40	61	61	5.4	32	43	67	67	5.9	35	47	75	75	6.2	37	50	79	79	6.5	38	52	84	84
8	1.0	10.0	9.00	15.0	89	135	231	315	16.0	95	146	250	360	17.0	101	157	271	410	19.0	113	179	319	510	20.0	119	190	345	555	21.0	125	202	377	600
8	1.5	11.0	14.25	29.0	173	314	700	985	32.0	193	365	820	1130	35.0	213	430	940	1250	37.0	225	475	1015	1320										
8	2.0	12.0	20.00	48.0	295	780	1410	1820																									
8	2.5	13.0	26.25																														
8	3.0	14.0	33.00																														
10	0.5	11.0	5.25	5.8	35	46	73	73	6.3	38	51	80	80	6.8	40	55	88	88	7.4	44	61	97	97	7.7	46	63	102	102	8.2	49	68	110	112
10	1.0	12.0	11.00	18.0	107	168	293	460	20.0	119	190	345	555	22.0	131	214	415	650	23.0	137	227												

OPEN DITCH DESIGN TABLE FOR DITCHES WITH 1 1/2 to 1 SIDE SLOPES

DITCH SIZE				.02%		.04%				.06%				.08%				.10%				.15%				.20%												
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES														
				c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M					
4	0.5	5.5	2.38	0.7	4	6	8	8	1.0	6	8	12	12	1.2	7	9	14	14	1.4	8	11	17	17	1.5	9	12	18	18	1.9	11	15	23	23	2.2	13	17	26	26
4	1.0	7.0	5.50	2.3	14	18	27	27	3.3	20	26	39	39	4.0	24	32	48	48	4.7	28	37	56	56	5.2	31	41	64	64	6.3	38	51	80	80	7.3	43	60	95	95
4	1.5	8.5	9.38	5.0	30	40	61	61	6.9	41	56	90	90	8.5	50	70	116	118	9.8	58	83	138	148	11.0	66	95	158	178	14.0	83	125	212	272	16.0	95	146	260	360
4	2.0	10.0	14.00	8.5	50	70	116	118	12.0	72	105	176	206	15.0	89	135	231	315	17.0	101	157	271	410	19.0	113	179	319	510	23.0	137	227	455	700	27.0	161	283	620	890
4	2.5	11.5	19.38	13.0	77	115	194	238	19.0	113	179	319	510	23.0	137	227	455	700	27.0	161	283	620	890	30.0	180	330	740	1035	36.0	220	450	975	1280	42.0	260	610	1220	1540
4	3.0	13.0	25.50	19.0	113	179	319	510	27.0	161	283	620	890	33.0	200	327	880	1180	39.0	240	530	1100	1405	43.0	265	640	1260	1585	53.0	330	915	1580	2050	61.0	400	1145	1880	2420
6	0.5	7.5	3.38	1.0	6	8	12	12	1.4	8	11	17	17	1.7	10	13	20	20	2.0	12	16	24	24	2.3	14	18	27	27	2.8	17	22	33	33	3.2	19	25	38	38
6	1.0	9.0	7.50	3.3	20	26	39	39	4.7	28	37	56	56	5.8	35	46	73	73	6.7	40	54	86	86	7.4	44	61	97	97	9.2	55	77	127	135	11.0	66	95	158	178
6	1.5	10.5	12.38	6.8	40	56	88	88	9.7	58	82	136	146	12.0	72	105	176	206	14.0	83	125	212	272	15.0	89	135	231	315	19.0	113	179	319	510	22.0	131	214	415	650
6	2.0	12.0	18.00	12.0	72	105	176	206	16.0	95	146	250	360	20.0	119	190	345	555	23.0	137	227	455	700	26.0	155	268	575	840	32.0	193	365	820	1130	37.0	225	475	1015	1320
6	2.5	13.5	24.38	17.0	101	157	271	410	25.0	149	254	535	795	30.0	180	330	740	1035	35.0	213	430	940	1250	39.0	240	530	1100	1405	49.0	300	810	1445	1870	56.0	355	1005	1690	2190
6	3.0	15.0	31.50	25.0	149	254	535	795	36.0	220	450	975	1280	43.0	265	640	1260	1585	50.0	310	835	1480	1920	56.0	355	1005	1690	2190	69.0	480	1350	2180	2820	79.0	605	1590	2570	3310
8	0.5	9.5	4.38	1.4	8	11	17	17	1.8	11	14	21	21	2.2	13	17	26	26	2.7	16	21	32	32	3.0	18	24	36	36	3.7	22	29	44	44	4.2	25	35	50	50
8	1.0	11.0	9.50	4.4	26	35	52	52	6.2	37	50	79	79	7.4	44	61	97	97	8.7	52	72	119	123	9.8	58	83	138	148	12.0	72	105	176	206	14.0	83	125	212	272
8	1.5	12.5	15.38	8.8	52	73	121	125	13.0	77	115	194	238	14.0	83	125	212	272	18.0	107	168	293	460	20.0	119	190	345	555	24.0	143	240	495	745	28.0	187	298	660	935
8	2.0	14.0	22.00	15.0	89	135	231	315	21.0	125	202	377	600	26.0	155	268	575	840	29.0	173	314	700	985	33.0	200	385	890	1180	40.0	245	555	1140	1450	47.0	290	755	1375	1770
8	2.5	15.5	29.38	22.0	131	214	415	650	31.0	187	350	780	1080	38.0	230	500	1055	1360	44.0	270	665	1300	1630	50.0	310	835	1480	1920	61.0	400	1145	1880	2420	70.0	490	1370	2220	2860
8	3.0	17.0	37.50	31.0	187	350	780	1080	44.0	270	665	1300	1630	54.0	335	940	1620	2100	62.0	410	1175	1920	2460	69.0	480	1350	2180	2820	86.0	720	1770	2850	3680					
10	0.5	11.5	6.38	1.7	10	13	20	20	2.4	14	19	29	29	2.7	16	21	32	32	3.3	20	26	39	39	3.8	23	30	45	45	4.6	27	36	55	55	5.3	32	42	66	66
10	1.0	13.0	11.50	5.4	32	43	67	67	7.6	45	62	101	101	9.3	56	78	129	137	11.0	66	95	158	178	12.0	72	105	176	206	15.0	89	135	231	315	17.0	101	157	271	410
10	1.5	14.5	18.38	11.0	66	95	158	178	15.0	89	135	231	315	19.0	113	179	319	510	22.0	131	214	415	650	24.0	143	240	495	745	30.0	180	330	740	1035	35.0	213	430	940	1250
10	2.0	16.0	26.00	18.0	107	168	293	460	25.0	149	254	535	795	31.0	187	350	780	1080	36.0	220	450	975	1280	40.0	245	555	1140	1450	49.0	300	810	1445	1870	57.0	365	1030	1730	2230
10	2.5	17.5	34.30	27.0	161	283	620	890	38.0	230	500	1055	1360	46.0	285	725	1340	1720	54.0	335	940	1620	2100	60.0	390	1120	1840	2370	74.0	535	1470	2370	3060	85.0	700	1740	2800	3630
10	3.0	19.0	43.50	37.0	225	475	1015	1320	53.0	330	915	1580	2050	65.0	440	1255	2030	2610	75.0	550	1490	2400	3110	84.0	685	1720	2760	3580	102.0	995	2180	3480	4550					

FIGURE 11-6 DITCH DESIGN CHARTS (1 1/2:1 SIDE SLOPE)

DITCH SIZE				.25%				.30%				.35%				.40%				.45%				.50%														
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES				"Q" WATERSHED HANDLED BY DRAINAGE CURVES														
				c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M					
4	0.5	5.5	2.38	2.5	15	20	30	30	2.7	16	21	32	32	2.9	17	23	35	35	3.1	18	25	37	37	3.3	20	26	39	39	3.5	21	28	42	42					
4	1.0	7.0	5.50	8.2	49	68	110	112	9.0	54	75	124	130	9.7	58	82	136	146	10.0	60	85	140	153	11.0	66	95	158	178	12.0	72	105	176	206					
4	1.5	8.5	9.38	17.0	101	157	271	410	19.0	113	179	319	510	21.0	125	202	377	600	22.0	131	214	415	650	23.0	137	227	455	700										
4	2.0	10.0	14.00	30.0	180	330	740	1035	33.0	200	385	880	1180	36.0	220	450	975	1280																				
4	2.5	11.5	19.38	47.0	290	755	1375	1770																														
4	3.0	13.0	25.50																																			
6	0.5	7.5	3.38	3.6	21	29	43	43	3.9	23	31	46	46	4.2	25	33	50	50	4.5	27	36	54	54	4.8	29	38	57	57	5.0	30	40	61	61					
6	1.0	9.0	7.50	12.0	72	105	176	206	13.0	77	115	194	238	14.0	83	125	212	272	15.0	89	135	231	315	16.0	95	146	250	360	17.0	101	157	271	410					
6	1.5	10.5	12.38	24.0	145	240	495	745	26.0	155	268	575	840	29.0	173	314	700	985	31.0	187	350	780	1080															
6	2.0	12.0	18.00	41.0	250	580	1180	1495	45.0	280	695	1320	1675																									
6	2.5	13.5	24.38	62.0	410	1175	1920	2460																														
6	3.0	15.0	31.50																																			
8	0.5	9.5	4.38	4.8	29	38	57	57	5.2	31	41	64	64	5.6	33	44	70	70	6.0	36	48	76	76	6.4	38	52	82	82	6.7	40	54	86	86					
8	1.0	11.0	9.50	15.0	89	135	231	315	17.0	101	157	271	410	18.0	107	168	293	460	19.0	113	179	319	510	21.0	125	202	377	600	22.0	131	214	415	650					
8	1.5	12.5	15																																			

OPEN DITCH DESIGN TABLE FOR DITCHES WITH 3 TO 1 SIDE SLOPES

DITCH SIZE				0.2%												0.4%												.06%												.08%												.10%												.15%												.20%											
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES																																							
				B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M																																												
4	0.5	7.0	2.75	0.8	5	6	10	10	1.1	7	9	13	13	1.3	8	10	15	15	1.5	9	12	18	18	1.7	10	13	20	20	2.1	12	17	25	25	2.4	14	19	29	29	2.9	17	23	35	35																																												
4	1.0	10.0	7.00	2.8	17	22	33	33	4.0	24	32	48	48	4.9	29	39	58	58	5.7	34	45	72	72	6.3	38	51	80	80	7.8	46	64	104	104	9.0	54	75	124	130																																																	
4	1.5	13.0	12.75	7.0	42	57	91	91	9.0	54	75	124	130	11.0	66	95	158	178	13.0	77	115	194	238	15.0	89	135	231	315	18.0	107	168	293	460	20.0	119	190	345	555																																																	
4	2.0	16.0	20.00	12.0	72	105	176	206	17.0	101	157	271	410	21.0	125	202	377	600	24.0	143	240	495	745	27.0	161	283	620	890	32.0	193	365	820	1130	38.0	230	500	1055	1360																																																	
4	2.5	19.0	28.75	19.0	113	179	319	510	27.0	161	283	620	890	33.0	200	385	880	1180	39.0	240	530	1100	1405	42.0	260	610	1220	1540	53.0	330	915	1580	2050	61.0	400	1145	1880	2410																																																	
4	3.0	22.0	39.00	29.0	173	314	700	985	41.0	250	580	1180	1495	51.0	315	865	1515	1960	59.0	380	1090	1800	2320	65.0	440	1255	2030	2610	80.0	620	1620	2600	3360	93.0	840	1950	3130	4050																																																	
6	0.5	9.0	3.75	1.1	7	9	13	13	1.5	9	12	18	18	1.9	11	15	23	23	2.2	13	17	26	26	2.4	14	19	29	29	3.0	18	24	36	36	3.4	20	27	40	40																																																	
6	1.0	12.0	9.00	3.8	23	30	45	45	5.4	32	43	67	67	6.7	40	54	86	86	7.6	45	62	101	101	8.5	50	70	116	118	10.0	60	85	140	153	12.0	72	105	176	206																																																	
6	1.5	15.0	15.75	8.0	48	66	107	107	12.0	72	105	176	206	15.0	89	135	231	315	17.0	101	157	271	410	19.0	113	179	319	510	23.0	137	227	455	700	26.0	155	268	575	840																																																	
6	2.0	18.0	24.00	15.0	89	135	231	315	21.0	125	202	377	600	26.0	155	268	575	840	30.0	180	330	740	1035	33.0	200	385	880	1180	41.0	250	580	1180	1495	47.0	290	755	1375	1770																																																	
6	2.5	21.0	33.75	24.0	143	240	495	745	33.0	200	385	880	1180	41.0	250	580	1180	1495	47.0	290	755	1375	1770	53.0	330	915	1580	2050	65.0	440	1255	2030	2610	75.0	550	1490	2400	3110																																																	
6	3.0	24.0	45.00	35.0	213	430	940	1250	50.0	310	835	1480	1920	61.0	400	1145	1880	2420	70.0	490	1370	2220	2860	78.0	590	1570	2520	3260	96.0	890	2020	3250	4220	111.0	1150	2410	3850	5030																																																	
8	0.5	11.0	4.75	1.4	8	11	17	17	2.0	12	16	24	24	2.4	14	19	29	29	2.9	17	23	35	35	3.2	19	25	38	38	3.9	23	31	46	46	4.5	27	36	54	54																																																	
8	1.0	14.0	11.00	4.8	29	38	57	57	6.8	40	55	88	88	8.4	50	70	114	116	9.8	58	83	138	148	11.0	66	95	158	178	13.0	77	115	194	238	15.0	89	135	231	315																																																	
8	1.5	17.0	18.75	10.0	60	85	140	153	15.0	89	135	231	315	18.0	107	168	293	460	20.0	119	190	345	555	23.0	137	227	455	700	28.0	167	298	660	935	35.0	200	385	880	1180																																																	
8	2.0	20.0	28.00	18.0	107	168	293	460	26.0	155	268	575	840	31.0	187	350	780	1080	36.0	220	450	975	1280	40.0	245	555	1140	1450	49.0	300	810	1445	1870	57.0	365	1030	1750	2230																																																	
8	2.5	23.0	38.75	28.0	167	298	660	935	46.0	245	555	1140	1450	49.0	300	810	1445	1870	56.0	355	1005	1690	2190	64.0	430	1225	2000	2560	77.0	575	1540	2490	3220	89.0	770	1850	2970	3840																																																	
8	3.0	26.0	51.00	41.0	250	580	1180	1495	58.0	375	1060	1770	2270	71.0	500	1400	2260	2920	82.0	650	1670	2680	3470	92.0	820	1920	3090	4000	112.0	1170	2430	3900	5080	130.0	1460	2910	4640	6020																																																	
10	0.5	13.0	5.75	1.8	11	14	21	21	2.5	15	20	30	30	3.0	18	24	36	36	3.5	21	28	42	42	3.9	23	31	46	46	4.8	29	38	57	57	5.5	33	44	68	68																																																	
10	1.0	16.0	13.00	5.9	35	47	75	75	8.3	50	69	112	114	10.0	60	85	140	153	12.0	72	105	176	206	13.0	77	115	194	238	16.0	95	146	250	360	19.0	113	179	319	510																																																	
10	1.5	19.0	21.75	12.0	72	105	176	206	17.0	101	157	271	410	21.0	125	202	377	600	25.0	149	254	535	795	27.0	161	283	620	890	34.0	206	405	900	1225	39.0	240	530	1100	1405																																																	
10	2.0	22.0	32.00	21.0	125	202	377	600	30.0	180	330	740	1035	37.0	225	475	1015	1320	42.0	260	610	1220	1540	47.0	290	755	1375	1770	58.0	375	1060	1770	2270	67.0	460	1300	2100	2710																																																	
10	2.5	25.0	43.75	33.0	200	385	880	1180	46.0	285	725	1340	1720	57.0	365	1030	1730	2230	66.0	450	1280	2060	2660	73.0	520	1450	2330	3010	90.0	790	1870	3000	3900	104.0	1030	2230	3570	4660																																																	
10	3.0	28.0	57.00	47.0	290	755	1375	1770	67.0	460	1300	2100	2710	82.0	650	1670	2680	3470	94.0	855	1970	3170	4110	105.0	1050	2250	3610	4710	122.0	1440	2890	4600	5960																																																						

FIGURE 11.6 DITCH DESIGN CHARTS (3:1 SIDE SLOPE)

DITCH SIZE				.25%												.30%												.35%												.40%												.45%												.50%											
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES				"Q" c.f.s.				WATERSHED HANDLED BY DRAINAGE CURVES																																			
				B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M																																								
4	0.5	7.0	2.75	2.7	16	21	32	32	3.0	18	24	36	36	3.2	19	25	38	38	3.4	20	27	40	40	3.7	22	29	44	44	3.9	23	31	46	46	4.3	25	33	50	50																																					
4	1.0	10.0	7.00	10.0	60	85	140	153	11.0	66	95	158	178	12.0	72	105	172	200	13.0	75	111	185	225	13.0	80	119	201	252	14.0	84	125	215	278	15.0	89	135	231	315																																					
4	1.5	13.0	12.75	23.0	137	227	455	700	25.0	149	254	535	795	27.0	161	283	620	890	29.0	173	314	700	985	31.0	187	350	780	1080	32.0	193	365	820	1130																																										
4	2.0	16.0	20.00	42.0	260	610	1220	1540	46.0	285	725	1340	1720	57.0	310	835	1480	1920																																																									
4	2.5	19.0	28.75	68.0	470	1330	2140	2760																																																																			
4	3.0	22.0	39.00																																																																								
6	0.5	9.0	3.75	3.9	23	31	46	46	4.2	25	33	50	50	4.5	27	36	54	54	4.8	29	38	57	57	5.1	30	40	62	62	5.4	32	43	67	67																																										
6	1.0	12.0	9.00	14.0	83	125	212	272	15.0	89	135	231	315	16.0	95	146	250	360	17.0	101	157	271	410	18.0	107	168	293	460	19.0	113	179	319	510																																										
6	1.5	15.0	15.75	30.0	180	330	740	1035	33.0	200	385	880	1180	35.0	213	430	940	1250	38.0	230	500	1055	1360	40.0	245	555	1140	1450																																															
6	2.0	18.0	24.00	53.0	330	915	1580	2050	58.0	375	1060	1770	2270																																																														
6	2.5	21.0	33.75	84.0	685	1720	2760	3580																																																																			
6	3.0	24.0	45.00																																																																								
8	0.5	11.0	4.75	5.0	30	40	61	61	5.5	33	44	68	68	5.9	35	47	75	75	6.4	38	52	82	82	6.7	40	54	86	86	7.1	42	58	92																																											

OPEN DITCH DESIGN TABLE FOR DITCHES WITH 4 TO 1 SIDE SLOPES

DITCH SIZE		SLOPE	02%				04%				06%				08%				10%				15%				20%						
Bottom Width Feet	Depth in Feet		Top Width Feet	Area Square Feet	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES					
				B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M		
0	0.5	4.0	1.00	0.2	1	2	2	0.3	2	2	4	4	0.3	2	2	4	4	0.4	2	3	5	5	0.4	2	3	5	5	0.6	4	5	7	7	
0	1.0	8.0	4.00	1.3	8	10	15	1.8	11	14	21	21	2.2	13	17	26	26	2.6	15	21	31	31	2.9	17	23	35	35	3.5	21	28	42	42	
0	1.5	12.0	9.00	4.0	24	32	48	4.8	30	40	61	61	7.0	42	57	91	91	8.0	48	66	107	107	9.0	54	75	124	130	10.0	60	86	140	153	
0	2.0	16.0	16.00	8.0	48	66	107	10.7	60	80	121	121	14.0	83	115	176	176	16.0	95	146	250	250	18.0	107	158	293	360	23.0	137	227	455	700	
0	2.5	20.0	25.00	15.0	89	135	231	315	21.0	125	202	377	377	26.0	155	268	575	840	30.0	180	330	740	1035	41.0	250	580	1180	41.0	250	580	1180	495	
0	3.0	24.0	36.00	24.0	143	240	495	745	34.0	206	405	900	1225	43.0	269	711	1222	1540	49.0	300	810	1445	1870	54.0	335	940	1620	2100	67.0	460	1300	2100	2710
2	0.5	6.0	2.00	0.5	3	4	6	0.7	4	5	7	7	0.8	23	30	45	45	4.4	26	35	52	52	5.0	30	40	61	61	6.1	36	49	78	78	
2	1.0	10.0	6.00	3.2	13	17	26	3.1	18	25	37	37	3.8	23	30	45	45	4.4	26	35	52	52	5.0	30	40	61	61	6.1	36	49	78	78	
2	1.5	14.0	12.00	5.6	33	44	70	7.0	29	47	65	106	97	5.8	32	136	146	11.0	66	95	158	178	12.0	72	105	176	206	15.0	89	135	231	315	
2	2.0	18.0	20.00	11.0	66	95	158	178	16.0	95	146	250	360	19.0	113	179	319	510	22.0	131	214	415	650	25.0	149	254	535	795	30.0	180	330	740	1035
2	2.5	22.0	30.00	19.0	113	179	319	510	27.0	161	283	620	890	33.0	200	385	880	1180	38.0	230	500	1055	1360	43.0	265	640	1280	1585	52.0	320	890	1550	2000
2	3.0	26.0	42.00	30.0	180	330	740	1035	42.0	260	610	1220	1540	52.0	320	890	1550	2000	60.0	390	1120	1840	2370	67.0	460	1300	2100	2710	82.0	650	1670	2680	3470
4	0.5	8.0	3.00	0.8	5	6	10	1.0	7	9	13	13	1.4	8	11	17	17	1.6	10	13	19	19	1.8	11	14	21	21	2.2	15	21	31	31	
4	1.0	12.0	8.00	3.1	18	25	37	3.7	13.8	23	30	45	45	5.4	32	43	67	67	6.3	38	51	90	90	7.0	42	57	91	91	9.1	61	86	140	153
4	1.5	16.0	15.00	7.0	42	57	91	91	11.0	66	95	158	178	13.0	77	115	194	238	15.0	89	135	231	315	17.0	101	157	271	410	20.0	119	190	345	555
4	2.0	20.0	24.00	10.0	66	95	158	178	20.0	119	190	345	555	24.0	143	240	495	745	28.0	167	298	660	935	31.0	187	350	780	1080	38.0	230	500	1055	1360
4	2.5	24.0	36.00	23.0	137	227	455	700	33.0	200	385	880	1180	40.0	245	555	1140	1450	47.0	290	755	1375	1770	52.0	320	890	1550	2000	64.0	430	1225	2000	2560
4	3.0	28.0	48.00	36.0	220	450	975	1280	50.0	310	835	1480	1920	61.0	400	1145	1880	2420	71.0	500	1400	2260	2920	79.0	605	1590	2570	3310	94.0	905	2050	3300	5890
6	0.5	10.0	4.00	1.1	7	9	13	1.3	15	16	10	13	19	2.0	12	16	24	24	2.2	13	17	26	26	2.5	15	20	30	30	3.1	18	25	37	37
6	1.0	14.0	10.00	4.1	24	33	49	4.9	5.8	35	46	73	73	7.2	43	59	94	94	8.3	50	69	112	114	9.3	56	78	129	137	11.0	66	95	158	178
6	1.5	18.0	18.00	9.0	54	75	124	130	13.0	77	115	194	238	16.0	95	146	250	360	19.0	113	179	319	510	22.0	125	202	377	600	26.0	155	268	575	840
6	2.0	22.0	28.00	17.0	101	157	271	410	24.0	143	240	495	745	29.0	173	314	700	985	34.0	206	405	900	1225	38.0	230	500	1055	1360	46.0	285	725	1340	1720
6	2.5	26.0	40.00	28.0	167	298	660	935	39.0	240	530	1100	1405	48.0	295	780	1410	1820	55.0	345	975	1650	2140	62.0	410	1175	1920	2460	76.0	560	1520	2460	3160
6	3.0	30.0	54.00	41.0	250	580	1180	1495	58.0	370	1060	1770	2270	72.0	510	1420	2290	2960	83.0	665	1690	2730	3530	92.0	820	1920	3080	4000	113.0	1180	2460	3940	5140
8	0.5	12.0	5.00	1.5	9	12	18	1.8	21	22	17	25	25	2.5	15	20	30	30	2.9	17	23	35	35	3.3	20	26	39	39	4.0	24	32	48	48
8	1.0	16.0	12.00	5.2	31	41	64	64	7.3	43	60	95	95	8.9	53	74	122	128	10.0	60	85	140	153	12.0	72	105	176	206	14.0	83	125	212	272
8	1.5	20.0	21.00	11.0	66	95	158	178	16.0	95	146	250	360	20.0	119	190	345	555	22.0	131	214	415	650	25.0	149	254	535	795	31.0	187	350	780	1080
8	2.0	24.0	32.00	20.0	119	190	345	555	28.0	167	298	660	935	35.0	213	430	940	1250	40.0	245	555	1140	1450	45.0	280	695	1320	1675	55.0	345	975	1650	2140
8	2.5	28.0	45.00	32.0	193	365	820	1130	45.0	280	695	1320	1675	55.0	345	975	1650	2140	64.0	430	1225	2000	2560	72.0	510	1420	2290	2960	87.0	735	1800	2890	3740
8	3.0	32.0	60.00	47.0	290	755	1375	1770	67.0	460	1300	2100	2710	82.0	650	1670	2680	3470	94.0	855	1970	3170	4110	106.0	1065	2280	3650	4760	129.0	1440	2890	4600	5980
10	0.5	14.0	6.00	1.8	11	14	21	21	2.5	15	20	30	30	3.1	18	25	37	37	3.6	21	29	43	43	4.0	24	32	48	48	4.9	29	39	58	58
10	1.0	18.0	14.00	6.2	37	50	79	79	8.7	52	72	119	123	11.0	66	95	158	178	12.0	72	105	176	206	14.0	83	125	212	272	16.0	101	157	271	410
10	1.5	22.0	24.00	13.0	77	115	194	238	19.0	113	179	319	510	23.0	137	227	455	700	26.0	155	268	575	840	30.0	180	330	740	1035	36.0	220	450	975	1280
10	2.0	26.0	36.00	23.0	137	227	455	700	33.0	200	385	880	1180	40.0	245	555	1140	1450	46.0	285	725	1340	1720	62.0	410	1175	1920	2460	76.0	560	1520	2460	3160
10	2.5	30.0	50.00	37.0	225	475	1015	1320	52.0	320	890	1550	2000	63.0	420	1120	1950	2520	73.0	520	1450	2330	3100	82.0	650	1670	2680	3470	100.0	960	2130	3400	4440
10	3.0	34.0	66.00	53.0	330	915	1580	2050	75.0	550	1490	2400	3110	92.0	820	1920	3090	4000	106.0	1065	2280	3650	4760	119.0	1290	2620	4180	5450	146.0	1730	3350	5300	6900

DITCH SIZE		SLOPE	25%				30%				35%				40%				45%				50%										
Bottom Width Feet	Depth in Feet		Top Width Feet	Area Square Feet	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	"Q" c.f.s.	WATERSHED HANDLED BY DRAINAGE CURVES	
				B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M	B	C	D	M		
0	0.5	4.0	1.00	0.8	5	6	10	10	0.8	5	6	10	10	0.9	5	7	11	11	1.0	6	8	12	12	1.0	6	8	12	12	1.0	6	8	12	12
0	1.0	8.0	4.00	4.6	27	36	55	55	5.0	30	40	61	61	5.4	32	43	67	67	5.8	35	46	73	73	6.2	37	50	79	79	6.5	38	52	84	84
0	1.5	12.0	9.00	14.0	83	125	212	272	15.0	89	135	231	315	16.0	95	146	250	360	17.0	101	157	271	410	18.0	107	168	293	460	19.0	113	179	319	510
0	2.0	16.0																															

OPEN DITCH DESIGN TABLE FOR DITCHES WITH 8 to 1 SIDE SLOPES

DITCH SIZE		SLOPE																																				
		0.2%					0.4%					0.6%					0.8%					1.0%					1.5%					2.0%						
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES									
				c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B	C	D	M					
0	0.5	8.0	2.00	0.4	2	3	5	5	0.6	3	3	3	3	0.7	4	6	8	8	0.8	5	6	10	10	0.9	5	7	11	11	1.1	7	9	13	13	1.3	8	10	15	15
0	1.0	16.0	8.00	2.6	15	21	31	31	3.8	23	30	45	45	4.6	27	36	55	55	5.3	32	42	66	66	5.9	35	47	75	75	7.3	43	60	95	95	8.4	50	70	114	114
0	1.5	24.0	18.00	7.8	46	64	104	104	11.0	66	95	158	178	13.0	77	115	194	238	16.0	95	146	250	360	17.0	101	157	271	410	21.0	125	202	377	600	250	149	254	535	795
0	2.0	32.0	32.00	17.0	101	157	271	410	24.0	143	240	495	745	29.0	173	314	700	985	33.0	200	388	880	1180	37.0	225	475	1015	1320	46.0	285	725	1340	1720	530	330	915	1580	2050
0	2.5	40.0	50.00	31.0	187	350	780	1080	43.0	265	640	1260	1585	53.0	330	915	1580	2050	61.0	400	1145	1880	2420	68.0	470	1330	2140	2760	63.0	665	1690	2730	3530	960	890	2020	3250	4220
0	3.0	48.0	72.00	50.0	310	835	1480	1920	70.0	490	1370	2220	2860	86.0	730	1770	2850	3680	99.0	940	2100	3370	4380	110.0	1135	2380	3810	4980	135.0	1540	3060	4840	6280	1660	1900	3620	5720	7450
2	0.5	10.0	3.00	0.7	4	6	8	8	1.0	6	8	12	12	1.2	7	9	14	14	1.4	8	11	17	17	1.6	10	13	19	19	1.9	11	15	23	23	2.2	13	17	26	26
2	1.0	18.0	10.00	3.5	21	28	42	42	5.0	30	40	61	61	6.1	36	49	78	78	7.0	42	57	91	91	7.9	47	65	106	106	9.7	58	82	136	146	11.0	66	95	155	178
2	1.5	26.0	21.00	9.5	57	80	132	142	13.0	77	115	194	238	16.0	95	146	250	360	19.0	113	179	319	510	21.0	125	202	377	600	26.0	155	268	575	840	300	180	330	740	1035
2	2.0	34.0	36.00	39.0	113	179	319	510	28.0	167	298	660	938	34.0	206	405	900	1225	39.0	240	530	1100	1405	44.0	270	665	1300	1630	54.0	335	940	1620	2100	62.0	410	1175	1920	2460
2	2.5	42.0	56.00	59.0	213	430	940	1260	49.0	295	786	1410	1920	59.0	380	1090	1800	2320	69.0	480	1350	2180	2820	77.0	575	1540	2490	3220	94.0	855	1970	3170	4110	109.0	1115	2350	3770	4920
2	3.0	50.0	78.00	55.0	345	975	1650	2140	77.0	575	1540	2490	3220	95.0	870	2000	3200	4170	110.0	1135	2380	3810	4980	122.0	1340	2700	4310	5600	161.0	1810	3490	5510	7180	1730	2210	4100	6490	8500
4	1.0	20.0	12.00	4.4	26	35	52	52	6.4	38	52	82	82	7.8	46	64	104	104	9.0	54	75	124	130	10.0	63	85	140	153	12.0	17	22	33	33	3.2	19	25	38	38
4	1.5	28.0	24.00	11.0	66	95	158	178	16.0	95	146	250	360	20.0	119	190	345	555	23.0	137	227	455	700	25.0	149	254	535	795	31.0	187	350	780	1080	36.0	220	450	975	1280
4	2.0	36.0	40.00	22.0	131	214	415	650	32.0	193	365	820	1130	39.0	240	530	1100	1405	45.0	280	695	1320	1675	50.0	310	835	1480	1920	62.0	410	1175	1920	2460	110.0	1260	2570	4100	5360
4	2.5	44.0	60.00	38.0	230	500	1055	1350	55.0	345	975	1650	2140	67.0	460	1300	2100	2710	77.0	575	1540	2490	3220	86.0	720	1770	2850	3680	106.0	1065	2280	3650	4760	122.0	1340	2700	4100	5360
4	3.0	52.0	84.00	60.0	390	1120	1840	2370	86.0	720	1770	2850	3680	104.0	1030	2230	3570	4660	121.0	1320	2680	4270	5560	135.0	1540	3050	4840	6290	165.0	2070	3880	6120	8000	191.0	2550	4600	7310	9600
6	1.0	22.0	14.00	5.5	33	44	61	61	7.7	46	65	102	102	9.4	56	79	131	139	11.0	66	95	158	178	12.0	72	105	176	206	15.0	89	135	231	231	17.0	101	157	271	410
6	1.5	30.0	27.00	13.0	77	115	194	238	19.0	113	179	319	510	23.0	137	227	455	700	26.0	155	268	575	840	29.0	173	314	700	985	36.0	220	450	975	1280	42.0	260	610	1220	1540
6	2.0	38.0	44.00	26.0	155	268	575	840	36.0	220	450	975	1280	44.0	270	665	1300	1630	51.0	315	965	1515	1950	57.0	365	1030	1730	2230	70.0	490	1370	2220	2860	80.0	620	1620	2600	3360
6	2.5	46.0	65.00	43.0	265	640	1260	1585	60.0	390	1120	1840	2370	74.0	535	1470	2450	3060	85.0	700	1740	2800	3630	96.0	890	2020	3250	4220	117.0	1260	2570	4100	5360	135.0	1540	3050	4840	6290
6	3.0	54.0	90.00	67.0	460	1300	2100	2710	94.0	855	1970	3170	4110	115.0	1190	2510	4020	5240	132.0	1490	3290	4720	6130	149.0	1780	3400	5430	7060	182.0	2380	4350	6900	9050	210.0	2920	5140	8160	10950
8	0.5	16.0	6.00	1.6	10	13	19	19	2.3	14	18	27	27	2.8	17	22	33	33	3.2	19	25	38	38	3.6	21	29	43	43	4.5	27	36	54	54	5.2	31	41	64	64
8	1.0	24.0	16.00	6.4	38	52	82	82	9.0	54	75	124	130	11.0	66	95	158	178	13.0	77	115	194	238	14.0	83	125	212	272	17.0	101	157	271	410	20.0	119	190	345	555
8	1.5	32.0	30.00	15.0	89	135	231	315	21.0	125	202	377	600	26.0	155	268	575	840	30.0	180	330	740	1035	34.0	206	405	900	1225	41.0	250	580	1180	1495	47.0	295	755	1375	1770
8	2.0	40.0	48.00	28.0	167	298	660	938	40.0	245	555	1140	1450	49.0	300	810	1445	1870	57.0	365	1030	1730	2230	63.0	420	1200	1950	2520	78.0	590	1570	2520	3260	90.0	790	1870	3000	3900
8	2.5	48.0	70.00	47.0	290	755	1375	1770	67.0	460	1300	2100	2710	85.0	650	1670	2680	3470	95.0	870	2000	3200	4170	105.0	1050	2250	3610	4710	129.0	1440	2890	4600	5980	149.0	1780	3430	5430	7060
8	3.0	56.0	96.00	72.0	510	1420	2290	2960	102.0	995	2160	3480	4550	125.0	1380	2780	4440	5760	144.0	1690	3290	5210	6790	160.0	1980	3740	5900	7680	197.0	2670	4770	7590	10000	2280	3290	5700	8970	11660
10	0.5	18.0	7.00	2.0	12	16	24	24	3.4	20	27	40	40	3.9	23	31	46	46	4.4	26	35	52	52	5.4	32	43	67	67	6.2	37	50	79	79	7.9	50	67	109	109
10	1.0	26.0	18.00	7.4	44	61	97	97	10.0	60	85	140	153	13.0	77	115	194	238	15.0	89	135	231	315	17.0	101	157	271	410	20.0	119	190	345	555	23.0	137	227	455	700
10	1.5	34.0	33.00	17.0	101	157	271	410	24.0	143	240	495	745	29.0	173	314	700	985	33.0	206	405	900	1225	39.0	240	530	1100	1405	45.0	280	695	1320	1675	50.0	310	835	1480	1920
10	2.0	42.0	52.00	31.0	187	350	780	1080	44.0	270	665	1300	1630	54.0	335	940	1620	2100	63.0	420	1200	1950	2520	70.0	490	1370	2220	2860	80.0	620	1620	2600	3360	90.0	940	2100	3370	4380
10	2.5	50.0	75.00	52.0	320	890	1550	2000	73.0	520	1450	2330	3010	89.0	770	1850	2970	3840	103.0	1010	2200	3500	4600	115.0	1220	2510	4020	5240	141.0	1640	3310	5090	6630	163.0	2030	3820	6050	7860
10	3.0	58.0	102.00	78.0	590	1570	2520	3260	110.0	1135	2380	3810	4980	135.0	1540	3060	4840	6290	156.0	1900	3620	5720	7450	174.0	2230	4130	6540	8560	213.0	2960	5240	8300	11020	246.0	3690	6240	9800	

11-238

FIGURE 11.6 DITCH DESIGN CHARTS (8:1 SIDE SLOPE)

DITCH SIZE		SLOPE																											
		.25%					.30%					.35%					.40%					.45%					.50%		
Bottom Width Feet	Depth in Feet	Top Width Feet	Area Square Feet	"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					"Q" WATERSHED HANDLED BY DRAINAGE CURVES					
				c.f.s.	B	C	D	M	c.f.s.	B	C	D	M	c.f.s.	B														

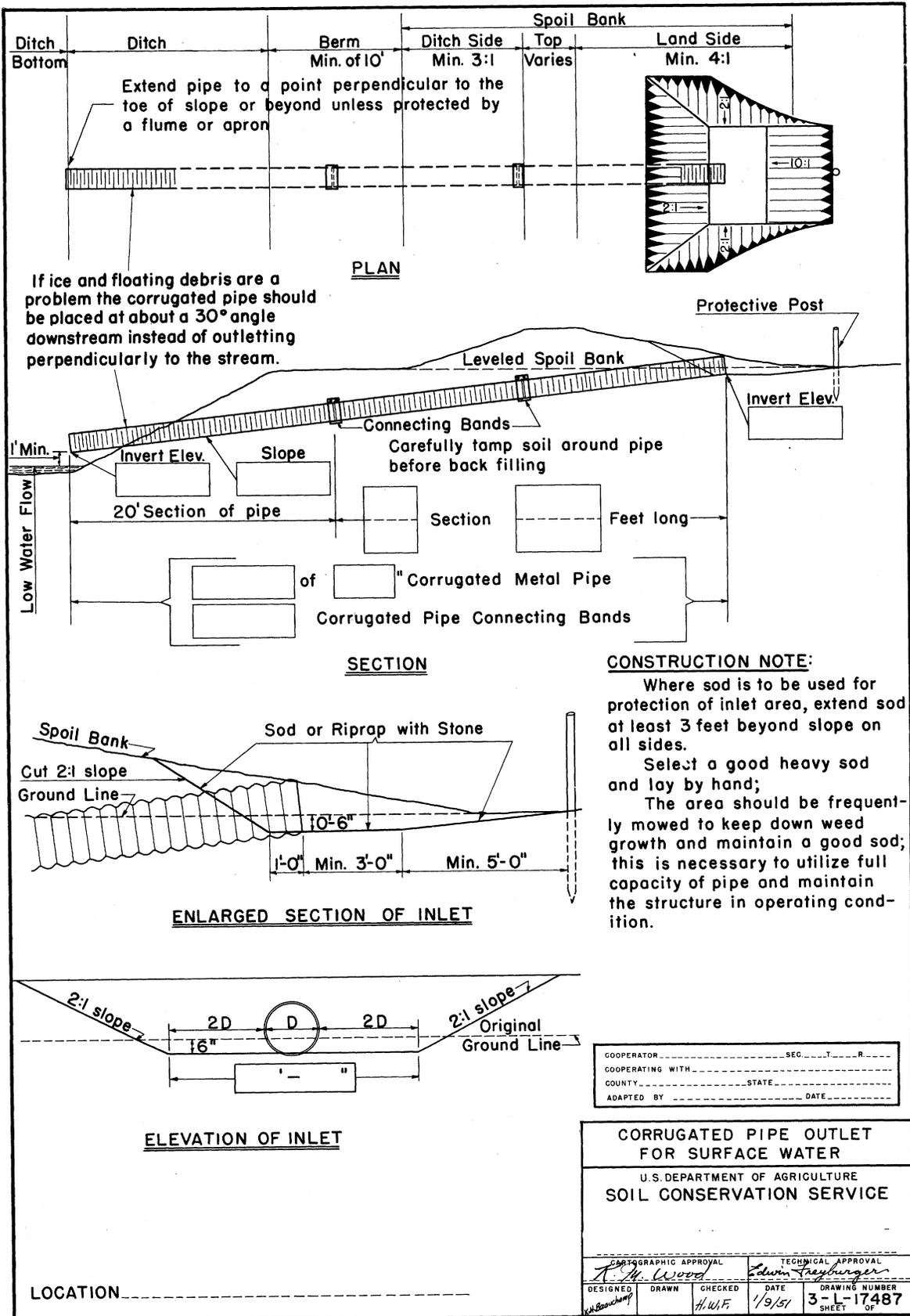
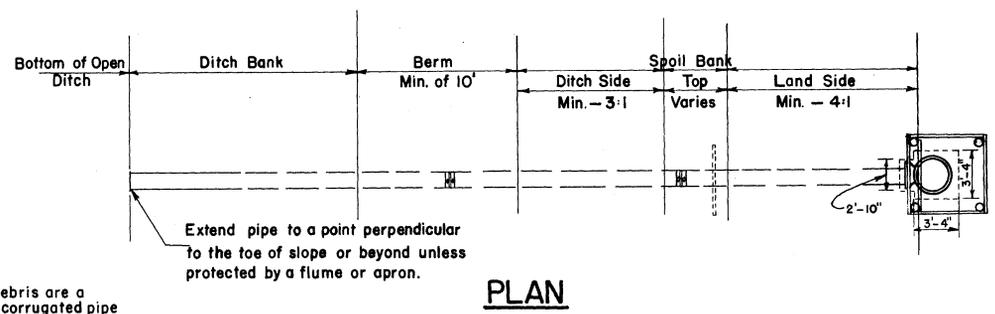


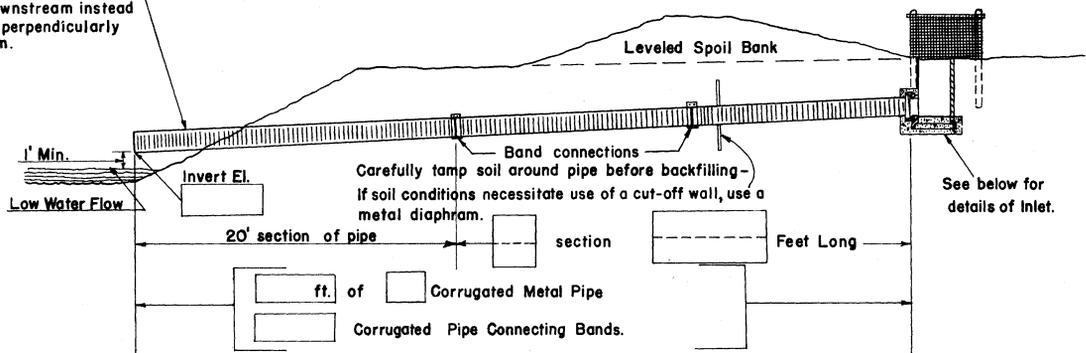
FIGURE 11.7 CORRUGATED PIPE OUTLET FOR SURFACE WATER



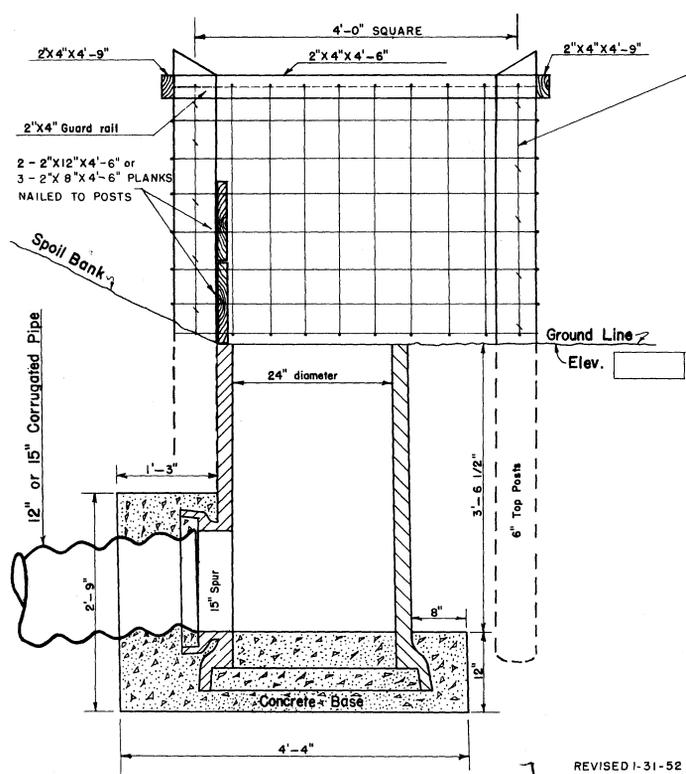
If ice and debris are a problem the corrugated pipe should be placed at about a 30° angle downstream instead of outletting perpendicularly to the stream.

Extend pipe to a point perpendicular to the toe of slope or beyond unless protected by a flume or apron.

PLAN



SECTION



NOTE:

Place 32" heavy woven wire fence on all four sides. Fasten 2" x 4" guard rail to posts over top strand of fence. Staple fence to guard rail between posts.

MATERIALS FOR INLET

- 1-24" T branch bell & spigot vitrified clay tile 4'-long with 15" spur
- 0.6 cu. yds. of concrete
- 4 bags of cement
- 0.6 yds. of gravel
- 0.3 yds. of sand
- 4-6" top post 6' long.
- 18'-32" heavy woven wire fence
- Lumber
 - 2-2" x 12" x 4'-6" planks
 - 2-2" x 4" x 4'-6"
 - 2-2" x 4" x 4'-9"
- Necessary staples and spikes or bolts.

COOPERATOR	SEC.	T.	R.
COOPERATING WITH			
COUNTY			
STATE			
ADAPTED BY			
DATE			

**PIPE OUTLET FOR SURFACE WATER
SEWER TILE INLET**

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

REVISED 1-31-52

DESIGNED		DRAWN		CHECKED		DATE		TECHNICAL APPROVAL			
A. W. F.		A. W. F.		A. W. F.		1/9/51		Edwin Freyburger			
DRAWING NUMBER				DRAWING NUMBER				DRAWING NUMBER			
3-L-17490				3-L-17490				3-L-17490			
SHEET				SHEET				SHEET			
OF				OF				OF			

Location

FIGURE 11.8

11.55 Ditch Layout and Construction

a. General

Construction should not be started, whether to be done by contractor or cooperator, until details of the plans and specifications are discussed and understood by both the cooperator and contractor. This is important. Generally the most economical and best adapted equipment for open ditch construction is a dragline. In the method of layout as described below it is assumed a dragline will be used.

b. Ditch Layout

Centerline stakes and slope stakes set at 100 foot intervals along the ditch are usually sufficient. Determine depth of cut from ground level at one of the slope stakes (at each station) and mark it on this slope stake. (See Part 1.52c for procedure in setting slope stakes.) Place a reference stake offset 4 to 6 feet outside of slope stake and on the opposite side from where spoil is to be placed. This stake is sometimes used to check grade and ditch alignment behind the dragline; when used, these are generally set at each station.

c. Checking Construction

All construction should be carefully checked as work progresses and faulty work or work that does not meet specifications should be corrected while the equipment is reasonably close. The final check and approval should be made before the equipment leaves the job. The work should be checked for the following, plus any other specification requirements:

- (1) Conformance of ditch grade to the designed grade.
- (2) Conformance of ditch bottom width to designed bottom width.
- (3) Conformance of side slopes and berms to designed side slopes and berms.
- (4) Conformance of spoil spreading to specifications.
- (5) Conformance of pipe outlet installations for tile drains to specifications.
- (6) Conformance of pipe inlet installations for surface water to specifications.
- (7) Conformance of open lateral surface drain installations to specifications.

11.56 Ditch Maintenance

a. Ditchbanks and channels should be kept clean of shrubs and trees. If silt bars or sand bars occur in the channel, they should be removed. Sod on ditchbanks is necessary for effective maintenance. It serves to control washing of the soil as well as to retard the growth of weeds and willows. Expensive seedbed preparation and seeding of ditchbanks are desirable but only insofar as the banks will retain and germinate the seed. The seeding should extend from the water level in the ditch to at least the ridge of the spoil bank. If there is no spoil bank the distance should be at least one rod from the top of the ditch. Little work may be possible on the ditchbanks, especially if they are steeper than 2:1, but the berm and spoil bank should be properly prepared for seeding. When well vegetated the seed from this area generally will spread to the ditchbanks. Seeding recommendations in local Technical Guides should be followed in establishing vegetation. Woody growth of various kinds usually sprout easily on new ditchbanks. It is a good idea to remove this young growth by spraying or hand cutting if necessary. After establishing a good sod it is necessary to control weeds and woody growth by pasturing, mowing, or spraying. Slopes 3:1 or flatter are considered necessary for successful use of mowing equipment. The pasturing of ditches is effective if properly controlled. Stock should be kept off ditchbanks following freezing spells or periods of heavy rainfall. Ditches must not be overgrazed. HOGS SHOULD BE KEPT OUT OF DITCHES AT ALL TIMES.

b. Ditch rights-of-way provide an ideal habitat for wildlife if properly managed. Mowing should not be done, nor pasturing allowed, until after grain harvest, so that ground-nesting birds will have a chance to get off the nest. (Refer to Regional Biology Handbook for "Wildlife Management of Ditches and Odd Areas.") An electric fence will facilitate control of pasturing.

11.60 SURFACE DRAINAGE

11.61 General

a. Surface Drainage Defined

Surface drainage, as the name implies, is the removal of surplus water from the surface of agricultural land. The purpose is to rid land quickly of its excess water and thereby prevent soil from becoming too wet.

b. Conditions Under Which Surface Drainage is Applicable

This system of drainage is applicable under certain soil and other conditions as follows:

- (1) Very slowly permeable soils such as heavy clay or gumbo.
- (2) Shallow soils (9-20 inches) with underlying very slowly permeable subsoils.

(3) Soils that need and are responsive to tile drainage but where no outlet for tile can be made available.

(4) Areas that are not economically feasible to tile drain.

(5) As a supplement to tile drainage.

c. Types of Surface Drainage Systems

(1) There are essentially five types of surface drainage systems in common usage.

(a) Bedding system.

(b) Random ditch system.

(c) Field ditch system for water table control and surface water removal.

(d) Cross slope ditch system (similar to drainage type terraces).

(e) Parallel ditch system.

(2) These various systems are described in detail in Part 11.65.

d. Procedure to follow in establishing surface drainage:

(1) The installation of surface drainage systems is similar to the execution of any other engineering project. The following essential steps are discussed in the paragraphs below:

(a) Gathering essential field information and making an engineering survey.

(b) Preparation of the topographic map.

(c) Arrangement and design of the system.

(d) Construction.

(e) Maintenance

11.62 Gathering Field Information and Survey Data Needed For Design of Surface Drainage Systems

a. General

Before starting to make a final survey the technician should have made a preliminary inspection of the area in accordance with the general procedures outlined in Part 11.30 above. As a result of this preliminary inspection a decision should have already been reached on the nature of the problem, the type of

surface drainage system to be used, and the availability and location of a suitable outlet. With these preliminary decisions already reached the next step is to gather the essential field information and survey data needed to plan the surface drainage system. The amount of information will vary with the individual field and the system to be used.

b. Topographic Information Required

Topographic information of the area to be drained is necessary except on fields with sufficient slope so that the general lay of the land is obvious by eye. This information especially is necessary for determining the direction of bedding furrows, the location of field surface ditches, and other details in planning. Mistakes in the layout are commonly found, especially in planning bedding systems, and many times the beds run the opposite direction to that required for best drainage. These mistakes can be avoided if proper topographic information is obtained. Some details to observe in obtaining topography are:

- (1) The grid system, described in Part 1.43 is the most simple method of obtaining topographic information. However, other methods may be used if suitable equipment is available which local technicians are trained to use.
- (2) On flat land, obtain elevations at 100 foot to 300 foot horizontal intervals depending on how nearly level the land is and whether or not the drainage pattern is apparent from inspection. Locate all low or depressional areas and take additional elevations of them as a part of the survey. The flatter the land the more important it is to take elevations at relatively close intervals.
- (3) On depressional type topography where random surface drains are to be used, vary the amount of survey data according to ground conditions. In cases where depressional areas are numerous, elevations at close intervals will be necessary, whereas in areas with few depressions a skeleton topographic map may suffice. In either case the survey should be in sufficient detail to locate and determine elevations of depressional areas and the low point of the divide between depressional areas.
- (4) Physical features of adjacent land affecting the surface drainage of the proposed area should be obtained. Especially obtain the location, elevations, and information of: all ditch bottoms or drainageways, size of opening and flow line elevations of culverts and bridges, or any other similar information necessary to plan the drainage system.
- (5) Unless the outlet ditch is obviously adequate it will be necessary to run a profile and cross section survey of the ditch line to determine if it has sufficient grade and capacity to serve as an outlet (see Part 1.37 for details of profile and cross section surveys).

11.63 Preparation of Topographic Map

General instructions for preparation of data sheets outlined in Part 2 should be followed in making the topographic map. The following suggestions are applicable especially to surface drainage systems.

a. Use standard size drawing paper, preferably plan-profile paper when available. When the area is too large to get the location plan on the unruled part of plan-profile paper at the proper scale, use standard plain drawing paper for the location plan. Then use full size profile paper for plotting profile.

b. The minimum scale of the topographic map will depend on the frequency of elevation shots. Some judgment should be exercised in choosing an appropriate scale. For most bedding furrow systems the minimum scale should be 200 feet per inch; but for a random surface drainage system with scattered depressional areas, a scale of 300 or 400 feet per inch may be satisfactory. It might even be possible to plot elevations on an aerial photo (660 feet = 1 inch, or 440 feet = 1 inch).

c. Show the location and elevation of bench marks, existing outlet ditches, survey base lines, field divisions, roads, and other physical information.

d. Contour lines are generally needed in planning the arrangement of surface drains, but many times on very flat land it is not practical to draw them in. In such cases it is better to plot the location and elevation of survey shots on the map and do the detail planning of the surface drainage system directly from the plotted elevations.

11.64 Basic Steps in Planning and Design of Surface Drainage Systems

The planning and design of surface drainage systems may be divided into the following basic steps:

a. Arrangements and Design of the Surface Drainage System

This involves a study of the topographic map and the development of a plan showing the arrangement of the surface drains and the location of the field ditches and the location of the outlet ditch. Detailed information on arrangement and design of various surface drainage systems is given in Part 11.65.

b. Design of Field Ditches

The field ditches that remove the water from the shallow field drains require individual and special design. A detailed discussion on the design of field ditches is given in Part 11.66.

c. Design of Outlet Ditches

The outlet ditch draining the entire system is essential for proper function of surface drainage. A suitable outlet either must be available or a special design must be prepared. Outlets for surface drainage are similar to all other open ditch design for drainage purposes. This subject is covered in detail in Part 11.40.

11.65 The Arrangement and Design of the Surface Drainage System

a. General

Brief descriptions and detailed specifications for the various types of surface drainage systems are given below. Using the topographic map (described in Part 11.63) as a base map, the system to be used should be planned in accordance with these specifications. It is recognized that the planning of surface drainage must be adapted to local conditions and, therefore, some deviation from specifications may be necessary.

b. Arrangement and Design of Bedding System

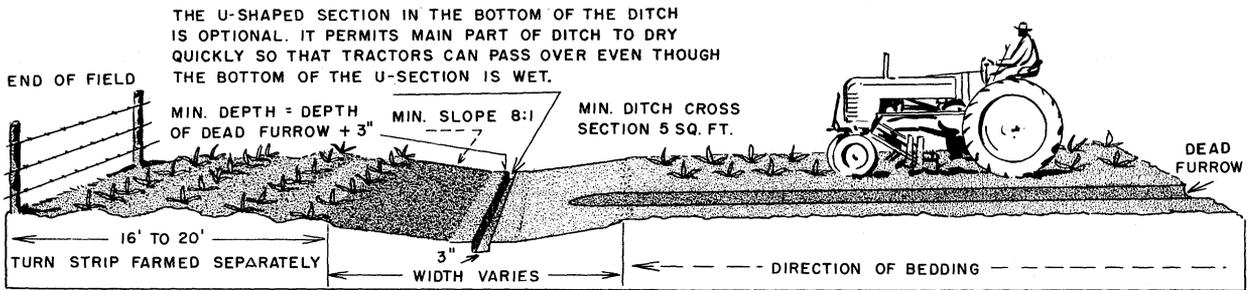
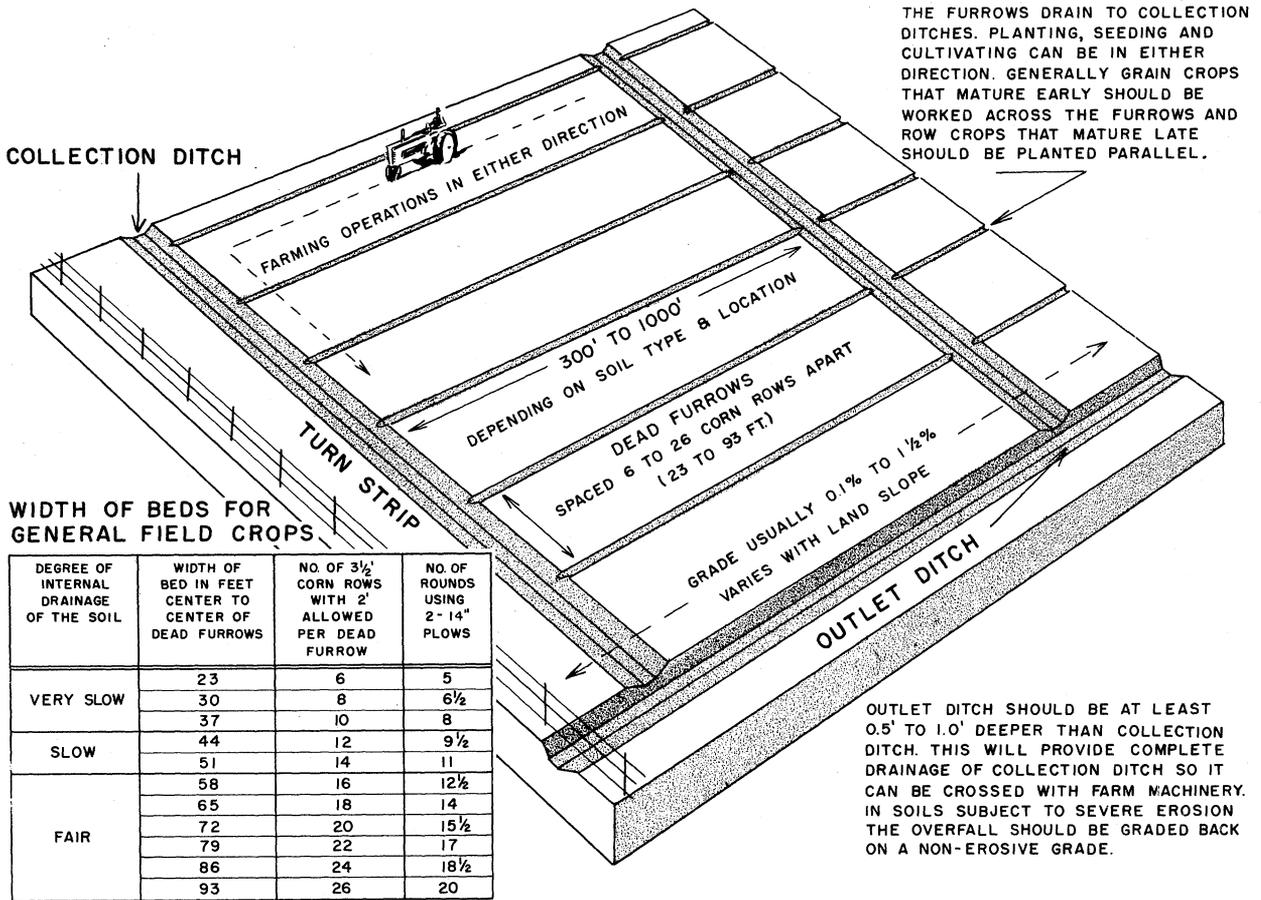
(1) Description and General Application

This system of surface drainage is generally used on land with flat slopes ($0-1\frac{1}{2}\%$) where the soils are slowly permeable and where tile drainage is not economically feasible. The system is designed, constructed, and maintained so that excess surface water drains laterally from beds similar to plow lands into the dead furrows, thence into the collection ditches and finally into an outlet ditch. Figure 11.9, page 11-32. The planning of the bedding system should be given careful consideration and an understanding reached with the cooperator on the layout to be used. Improper understanding of the layout by the farmer and lack of planning have been the major causes of failures. A typical plan of a bedding system is shown in Figure 11.10, page 11-33.

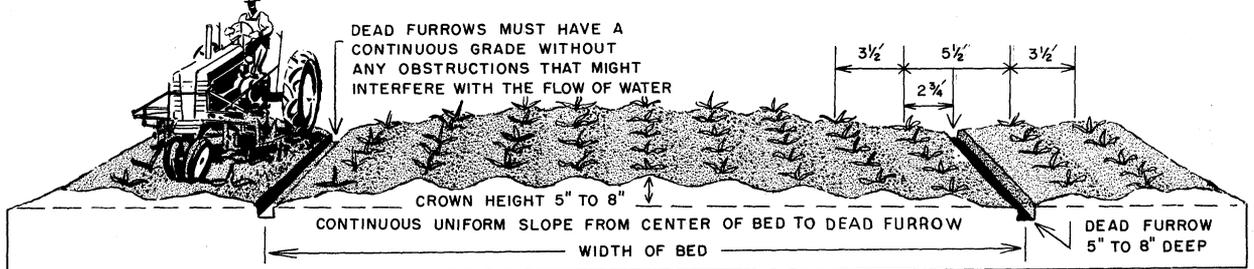
(2) Factors Affecting the Width of Beds

The following conditions should be considered in determining bed widths:

- (a) Kind of crops to be grown. Some permanent pasture or hay crops do not require as narrow beds as general rotation crops.
- (b) On land that has numerous shallow depressional areas land smoothing should be done before bed widths are considered.
- (c) Slope of field. Flatter fields require narrower beds.



CROSS SECTION AT END OF FIELD SHOWING COLLECTION DITCH AND TURN STRIP



CROSS SECTION OF BED SHOWING CROWN EFFECT AND PROPER SPACING OF CORN ROWS

FIGURE 11.9 SURFACE DRAINAGE BEDDING

(d) Drainage characteristics of the soil. Soils with low infiltration and permeability rates require closer bedding.

(3) Recommended Bed Widths

(a) The bed widths specified in Figure 11.9 may be used as a general guide. They should be supplemented by local experience, as reflected in local Technical Guides. When the bed width has been determined make minor adjustments so that the width is adaptable to farming operations. It is usually unprofitable to grow row crops in dead furrows, thus bed widths should be adjusted so that the rows will fit the beds without unnecessary waste of ground along dead furrows or crowding rows too close to dead furrows. See Figure 11.9, page 11-32 and Figure 11.22, page 11-59 for details of laying out beds. Bed widths should be adjusted so that the width is a multiple of one through or one round with the plow. Size of plow will govern. For example: a two-bottom 14-inch plow, when properly set and operated, will plow a width 28 inches per through and 13 throughs or $6\frac{1}{2}$ rounds will cover a 30-foot width. Likewise, 16 throughs or 8 rounds will cover a 37-foot width, etc. Time will be saved when beds are spaced to fit the plow.

(4) Direction of Beds

The beds should be laid out with the dead furrows running in the direction of greatest slope. Collection ditches are laid out in the direction of lessor slope because they can be graded. When land slopes are steeper than $1\frac{1}{2}\%$, drainage type terraces should be used, see Part 11.65e, page 11-42.

(5) Location of Collection Ditches

Collection ditches are the field drains that carry the surplus water from the bedding furrows. Some of the important features in location of these ditches are:

(a) The spacing of collection ditches should be at regular intervals depending upon land slope and imperviousness of the soil. On flat slopes (0.1%) with very slow permeability the spacing should be about 300 feet. This may be increased to 1,000 feet for more sloping land with fair permeability.

(b) Where collection ditches are placed at the end of fields allow a turn strip between the ditch and the end of the field as shown in Figure 11.9. This is necessary so that the dead furrow can be plowed out all the way to the collection ditch.

(c) Where there are natural low spots in the field that are not smoothed out, collection ditches should follow these depressions similar to that used in the random ditch system. See example Figure 11.11, page 11-36.

(d) Where it is necessary to drain water into collection ditches and the spoil cannot be disposed of without obstructing the drainage into the ditch, use a double ditch (commonly referred to as a "W" ditch). See Part 11.66e for further details on this type of ditch.

(6) Design of Collection Ditches

The design of collection ditches is essentially the same as for all field ditches for surface water removal. Refer to Part 11.66 for design details.

c. Arrangement and Design of Random Ditch System

(1) General Description

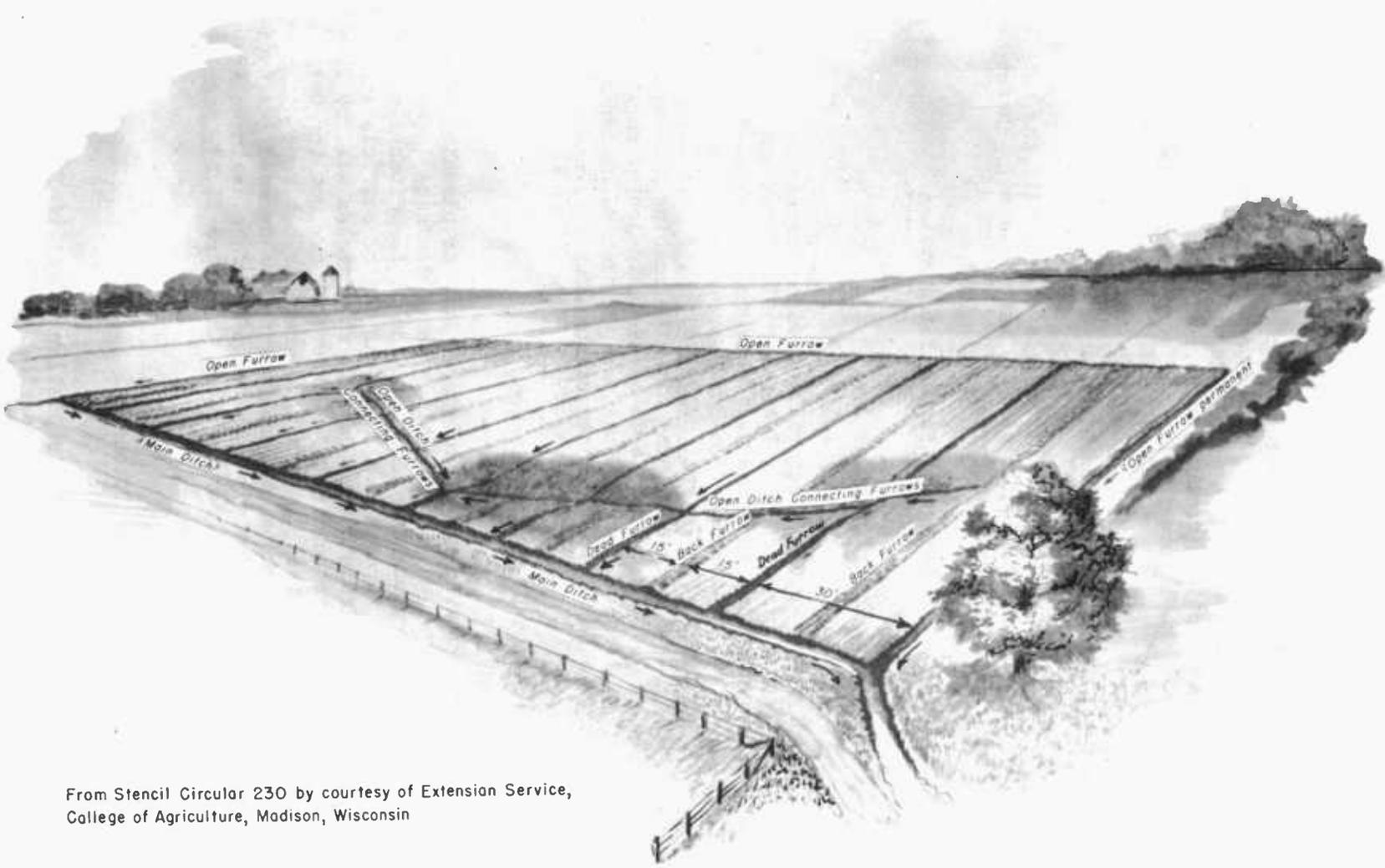
This system, which is generally used on depressional type topography, consists of a lateral outlet ditch and surface drains extending into the wet "pockets" or depressions. The surface drains meander from one depression to the other flowing toward the lateral outlet ditch, Figure 11.12, page 11-37. It is necessary many times to combine this system with the bedding system to do an adequate job of surface drainage, Figure 11.11. Sometimes on high value land, tile drainage also is used in conjunction with the random system.

(2) Location of Random Ditches

No exact criteria can be laid down for the planning of random ditch systems. Since this type of drainage is used on depressional topography the location of the ditches must be run at random through the low spots and of sufficient size and depth to drain them. Usually the ditches will be located in cultivated fields. Where they are not too deep they may be crossed in farming operations but some ditches draining deep pockets obviously cannot be crossed. A typical plan of a random ditch system of surface drainage drawn on a standard data sheet is shown in Figure 11.13, page 11-38 and 11-39.

(3) Design of Random Ditches

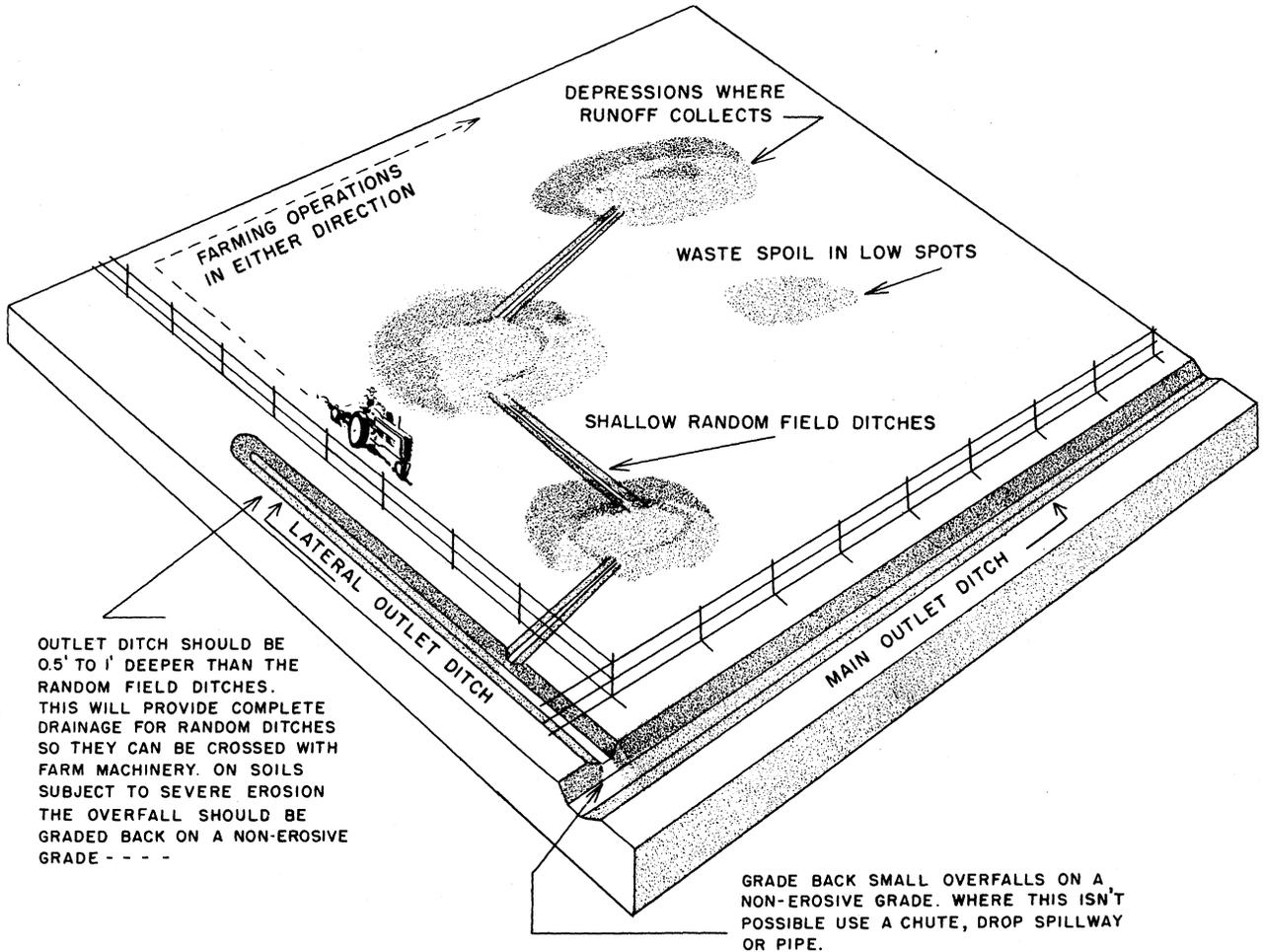
Design of random ditches is similar to all field ditches for surface water removal, as described in Part 11.66.



From Stencil Circular 230 by courtesy of Extension Service,
College of Agriculture, Madison, Wisconsin

FIGURE 11.11 COMBINED BEDDING AND RANDOM DITCH SYSTEM OF SURFACE DRAINAGE

REMOVE MINOR DEPRESSIONS BY LAND SMOOTHING WITH LAND PLANE OR LEVELER
SMOOTH AREA SO LAND WILL DRAIN TO THE LARGE DEPRESSIONS OR RANDOM DITCHES



CROSS SECTION OF RANDOM DITCH

CROSS-SECTIONAL AREA SHOULD BE DESIGNED FOR NOT LESS THAN APPLICABLE DRAINAGE RUNOFF & NEVER LESS THAN 5 SQ. FT.

MIN. SIDE SLOPE OF 4:1 WHERE FARMING OPERATIONS ARE PARALLEL TO DITCH AND 8:1 OR FLATTER WHERE THE FARMING OPERATIONS CROSS THE DITCH.

MOVE SPOIL TO DEPRESSIONS. IF THIS IS NOT POSSIBLE USE A DOUBLE DITCH WITH SPOIL PLACED BETWEEN DITCHES.

MIN. DEPTH 9"

FIGURE 11.12. RANDOM DITCH SYSTEM OF SURFACE DRAINAGE

FIGURE 11.13 STANDARD DATA SHEET FIELD DRAINAGE DITCH PLAN (1 OF 2)

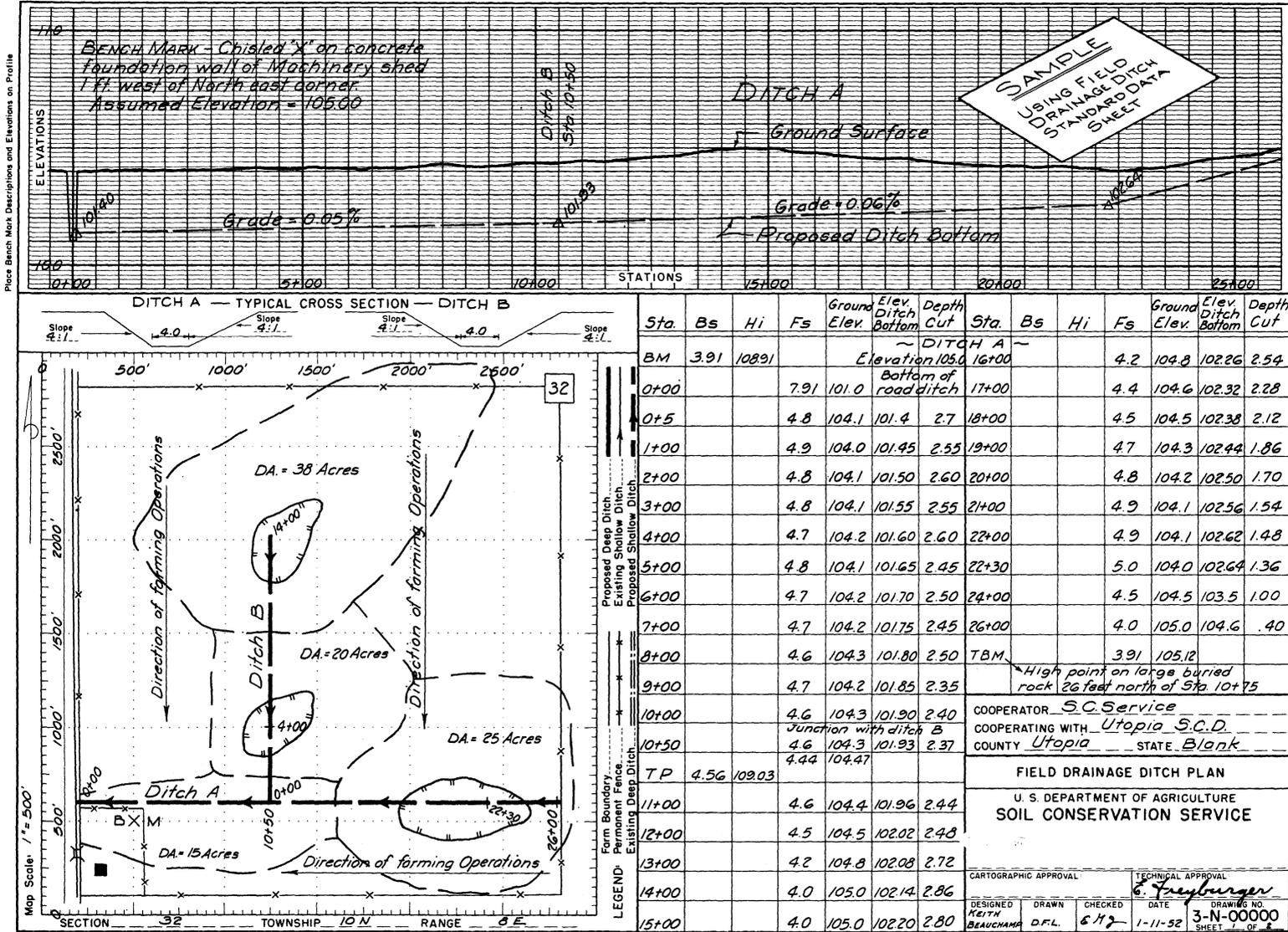
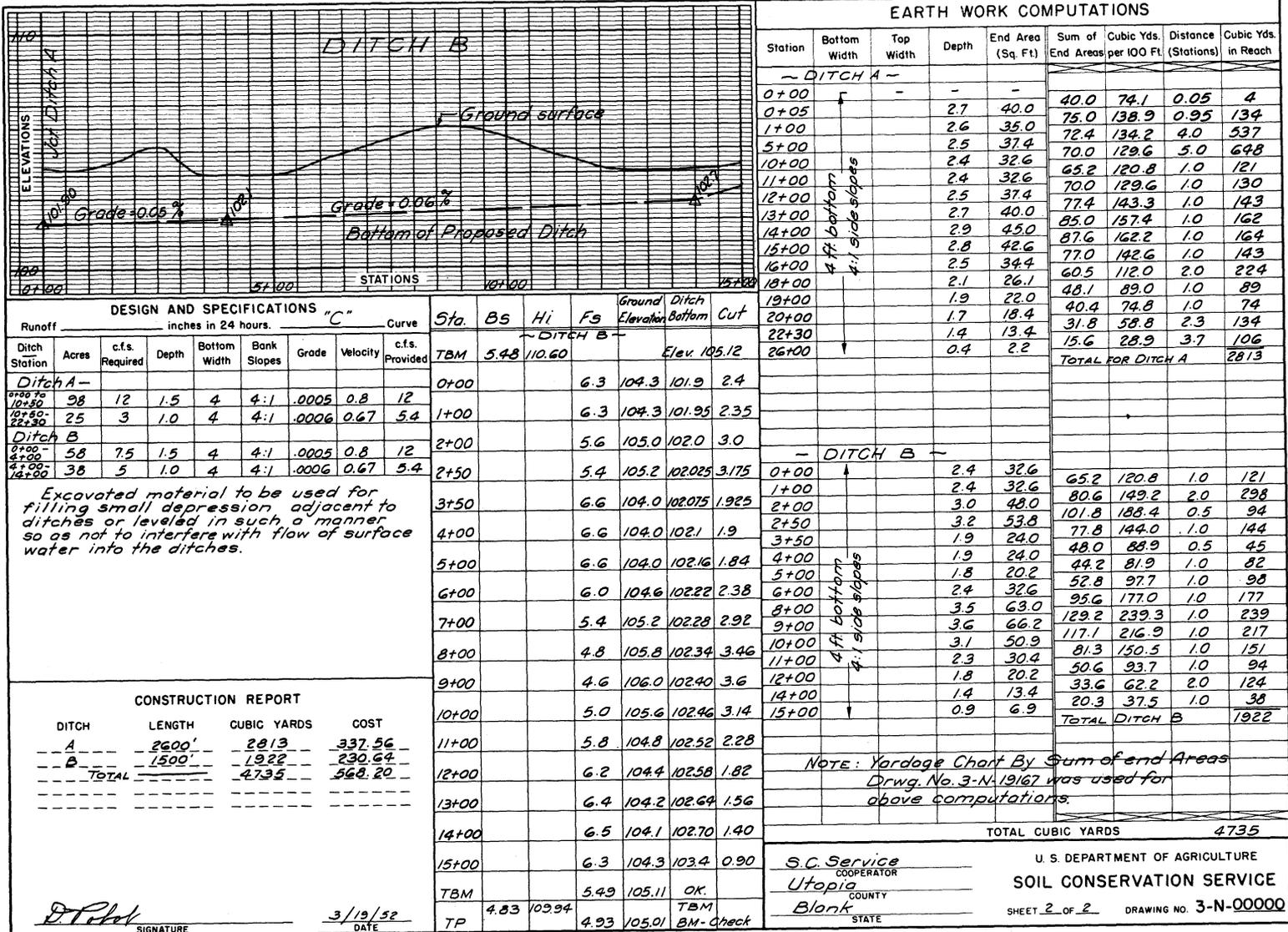


FIGURE 11.3 STANDARD DATA SHEET FIELD DRAINAGE DITCH PLAN (2 OF 2)



d. Arrangement and Design of Field Ditch System for Water Table Control and Surface Water Removal

(1) Description and general application:

This system of surface drainage consists of field ditches laid out in a regular parallel pattern across the field. The function of the ditches is to lower the water table sufficiently for crop production and to collect and remove surface water from the field, Figure 11.14, page 11-41. Ditches for this purpose are used under conditions where lowering of the water table is necessary but where the use of tile is not economically or physically feasible. The following are some typical soil conditions where these ditches are used:

- (a) On peat and muck soils where tiling is not applicable.
- (b) On sands with high water table.
- (c) On moderately or highly permeable mineral soils which have a high water table. Sometimes these soils are underlain with a water-bearing sand.

(2) Design specifications:

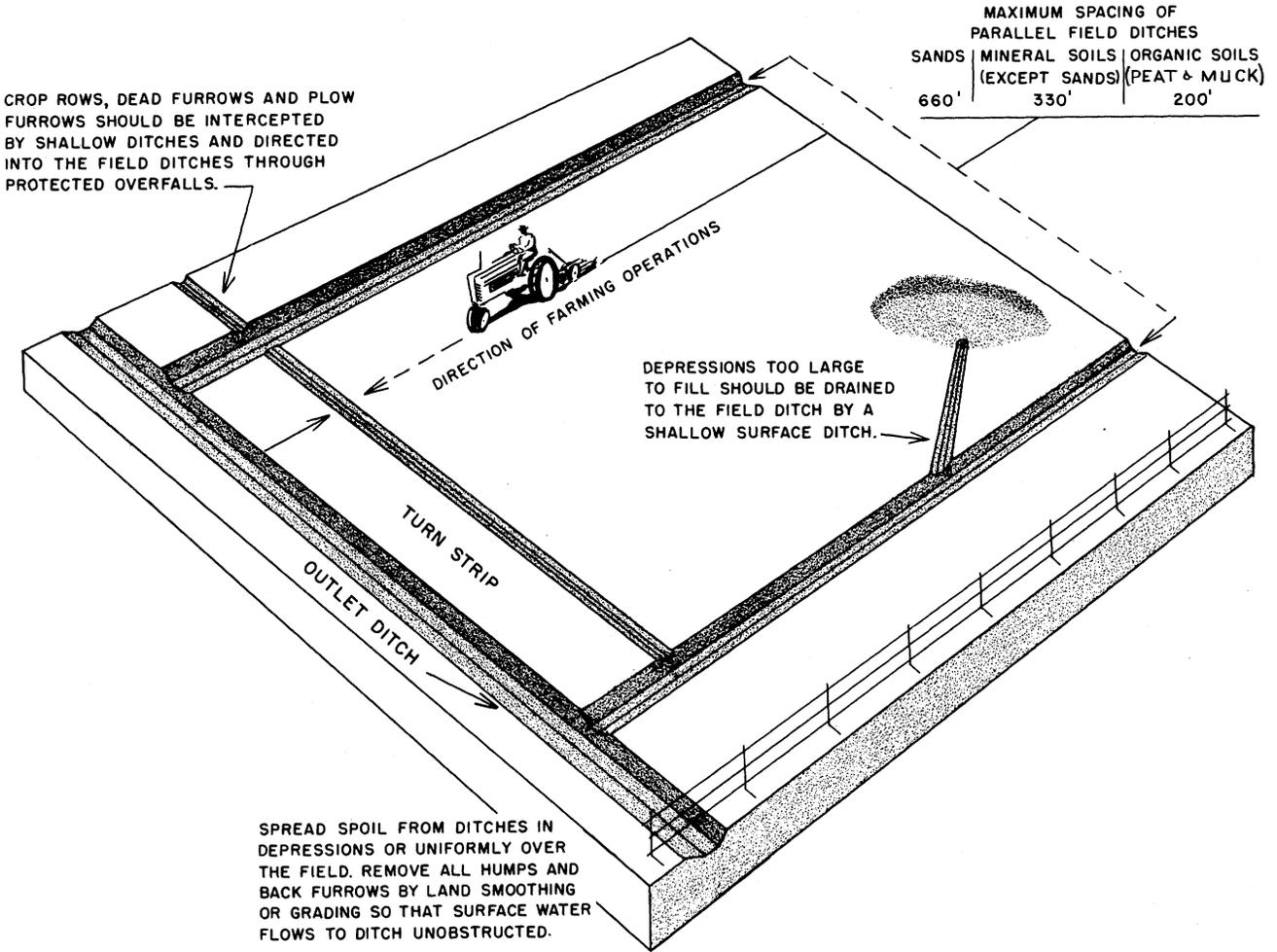
- (a) The ditches are laid out parallel, across the field at depth and spacings for various soil conditions as follows:

MINIMUM SPECIFICATIONS FOR FIELD DITCHES FOR WATER TABLE CONTROL UNDER VARYING SOIL CONDITIONS

Ditch Specifications	Sand	Mineral Soils Except Sand	Organic Soils
Depth	4 ft.	2.5 ft.	3.0 ft.
Bottom width	4 ft.	1 ft.	1 ft.
Side slopes	1:1	$1\frac{1}{2}$:1	Vertical
Max. spacing	660 ft.	330 ft.	200 ft.

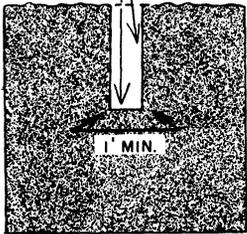
- (b) The spoil should be used to fill depressional areas between ditches or spread sufficiently to allow the area next to the ditch to be used for turn rows or permit cultivation.

- (c) Crop rows, dead furrows, and plow furrows should be intercepted in shallow ditches and directed into field ditches through protected overfalls.



MIN. SLOPE VERTICAL FOR RAW PEAT AND 1:1 FOR DECOMPOSED PEAT AND MUCK.

MIN. DEPTH 3.0'

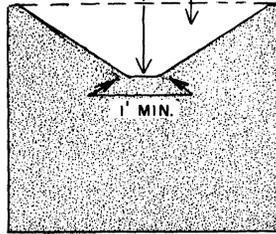


ORGANIC SOILS (PEAT & MUCK)

TYPICAL MINIMUM DITCH CROSS SECTIONS

MIN. SLOPE OF 1 1/2 : 1

2.5' MIN. DEPTH

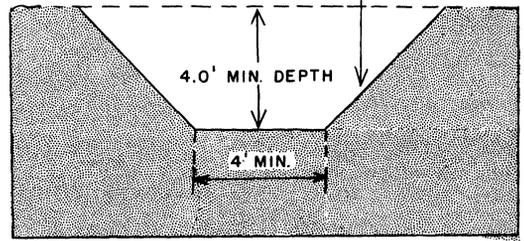


MINERAL SOILS EXCEPT SANDS

MIN. SLOPE OF 1:1

4.0' MIN. DEPTH

4' MIN.



SANDS

FIGURE 11.14 FIELD DITCH SYSTEM FOR WATER TABLE CONTROL AND SURFACE WATER REMOVAL

e. Arrangement and Design of Cross Slope Ditches (drainage type terrace)

(1) Description and Application

This type of surface drainage resembles terracing in that the drainage ditches follow around the slope on a uniform grade according to the lay of the land. For this reason they have been called cross-slope ditches. Figure 11.15, page 11-43. This method has application on sloping wet fields, four percent or less, where internal drainage is poor from the plow sole downward and where many shallow field depressions hold water after rains.

(2) Design Specifications

(a) Ditch alignment. Across slope as straight as topography permits and with limited cuttings through ridges and humps.

(b) Spacing. One hundred feet on 4 percent slope, increasing to 150 feet as the slope decreases to 0.5 percent.

(c) Depth and cross section. Design the channel to carry 10-year frequency rain but minimum cross section should be not less than 6 square feet. Minimum depth should be 6 inches for trapezoidal section with 6 feet bottom and 8:1 side slopes. For V section the minimum depth should be 9 inches with 10:1 side slopes.

(d) Spoil. Excavated material should be placed in depressional areas between ditches. Excess material shall be spread to a maximum height of 3 inches on the downhill side of the ditch.

(e) Land smoothing. Area between ditches should be smoothed or graded after depressions have been filled to eliminate all surface basins and humps that will obstruct the free flow of surface water.

f. Arrangement and Planning of Parallel Ditch System

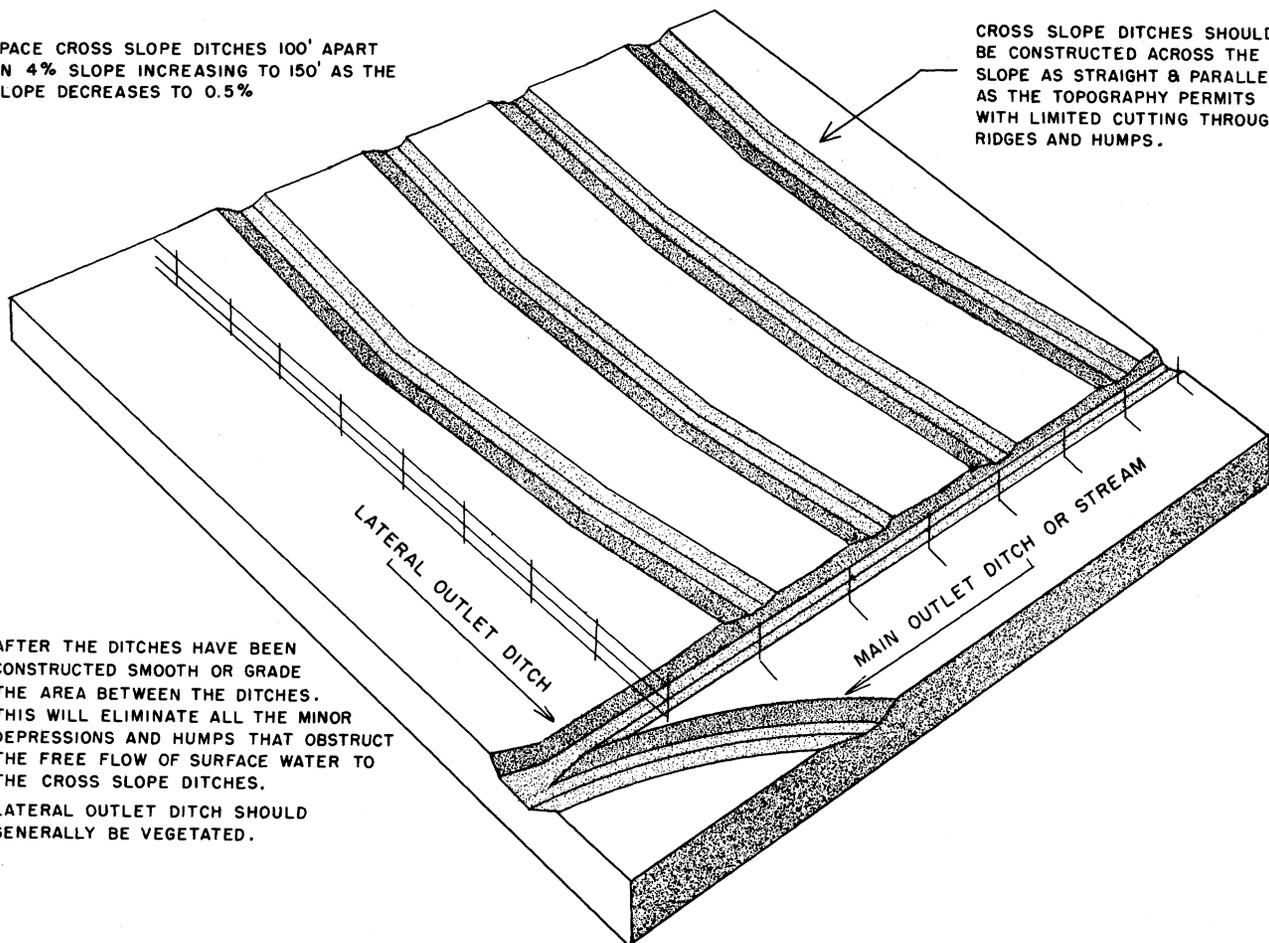
(1) Description and Application

The "parallel ditch system" is adapted to flat, poorly drained soils in which there are numerous shallow depressions. Quite often in the past bedding has been used under these conditions but this may be eliminated if the field is smoothed or graded so there is uninterrupted crop row drainage to the parallel field ditches.

The field ditches should be parallel but not necessarily equidistant. The success of the system depends largely upon

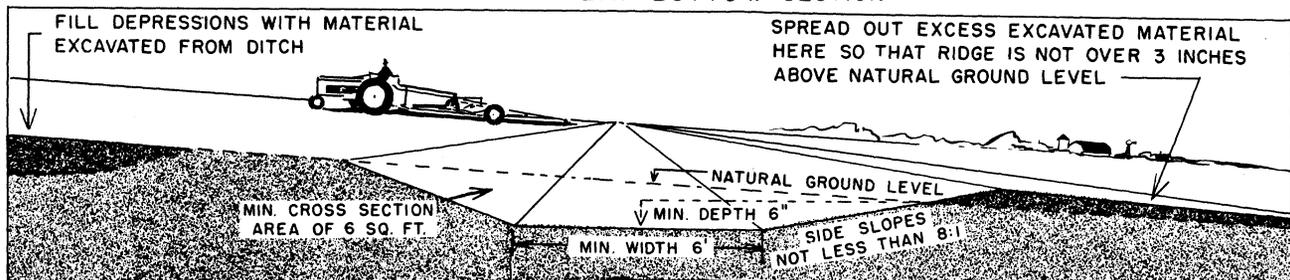
SPACE CROSS SLOPE DITCHES 100' APART ON 4% SLOPE INCREASING TO 150' AS THE SLOPE DECREASES TO 0.5%

CROSS SLOPE DITCHES SHOULD BE CONSTRUCTED ACROSS THE SLOPE AS STRAIGHT & PARALLEL AS THE TOPOGRAPHY PERMITS WITH LIMITED CUTTING THROUGH RIDGES AND HUMPS.



AFTER THE DITCHES HAVE BEEN CONSTRUCTED SMOOTH OR GRADE THE AREA BETWEEN THE DITCHES. THIS WILL ELIMINATE ALL THE MINOR DEPRESSIONS AND HUMPS THAT OBSTRUCT THE FREE FLOW OF SURFACE WATER TO THE CROSS SLOPE DITCHES. LATERAL OUTLET DITCH SHOULD GENERALLY BE VEGETATED.

TYPICAL FLAT BOTTOM SECTION



TYPICAL V-CANNEL SECTION

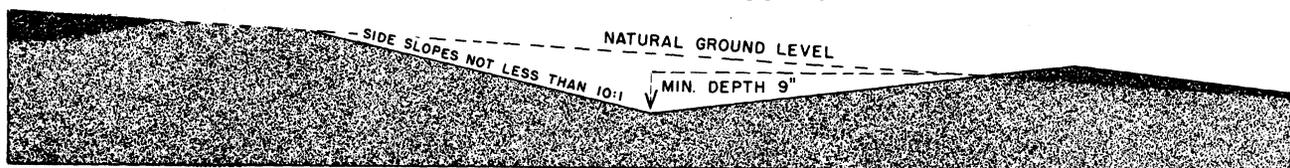


FIGURE 11.15 CROSS SLOPE DITCH SYSTEM OF SURFACE DRAINAGE-TERRACE TYPE DRAINAGE

the spacing of the parallel ditches and the smoothing or grading between ditches.

(2) Design Specifications

Design of this system must be adapted to the individual field using a few general principles. The ditches must be spaced so that the length of row drainage from a high point to a field ditch is such that the row can safely carry the runoff without much overflow or erosion in the row. Another factor influencing ditch spacing is the amount of earth and the distance it will have to be moved to provide complete row drainage. Figure 11.16, page 11-45.

Field experience indicates that the maximum length of grade draining to a given ditch should be about 600 feet. This maximum length of grade should be reduced on slowly permeable, highly erodible soils to about 300 feet. Therefore, the maximum spacing where the land drains in one direction should be about 600 feet. If the topography is such that the land will drain from a ridge located between the ditches, the maximum spacing could then be 1,200 feet.

When the ground surface has some general slope in one direction, the area between ditches can be smoothed, thus filling the depressions and removing barriers. It is not necessary that the slope be uniform between ditches. It can be broken according to the lay of the land.

On areas where the ground surface has little or no general slope, a grade must be established between ditches by cutting on one side of the field and filling on the other side. Minimum dimensions of the parallel ditches are given in Figure 11.16, page 11-45.

11.66 Design of Field Ditches

a. General

(1) The term "field ditches" is used to designate the part of the surface drainage system that collects surplus water from the field drain and conveys it to an outlet ditch. These ditches have been variously named collection ditches, interception ditches, and random ditches, depending on the type of surface drainage. However, the fundamentals of design and construction are the same.

(2) The location of the proposed field ditches was determined in planning the surface drainage system. Therefore, the remaining work to be done is to design the ditches for construction.

The purpose of this part of the handbook is to discuss design criteria of these various field ditches.

PARALLEL DITCHES TO INTERCEPT AND RAPIDLY REMOVE SURFACE WATER FROM THE FIELD AND REDUCE THE LENGTH OF ROW DRAINAGE

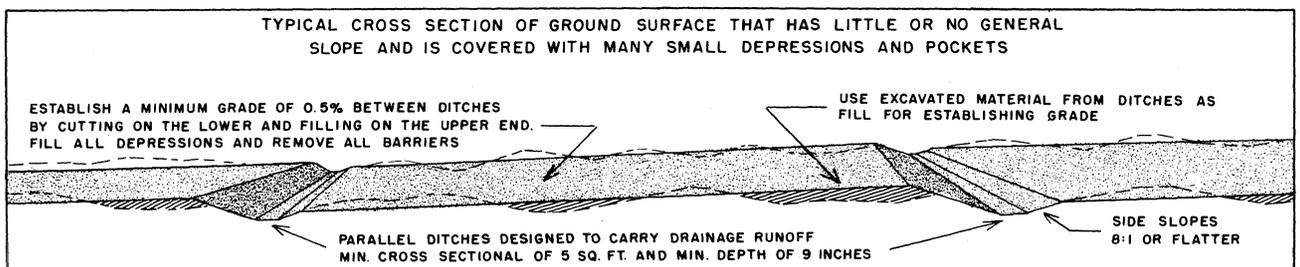
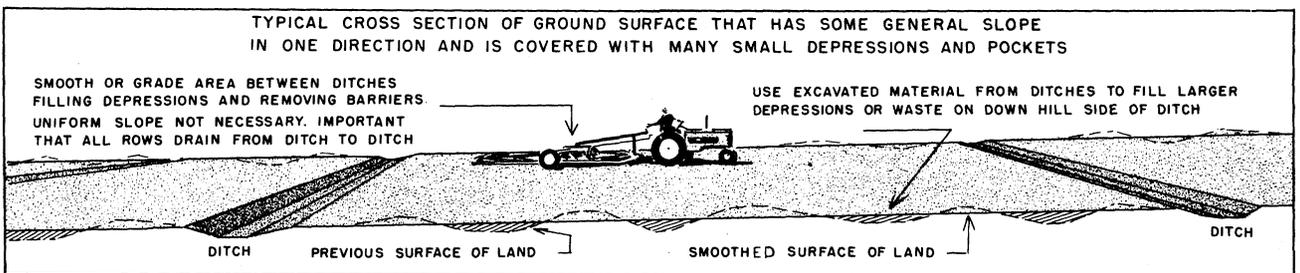
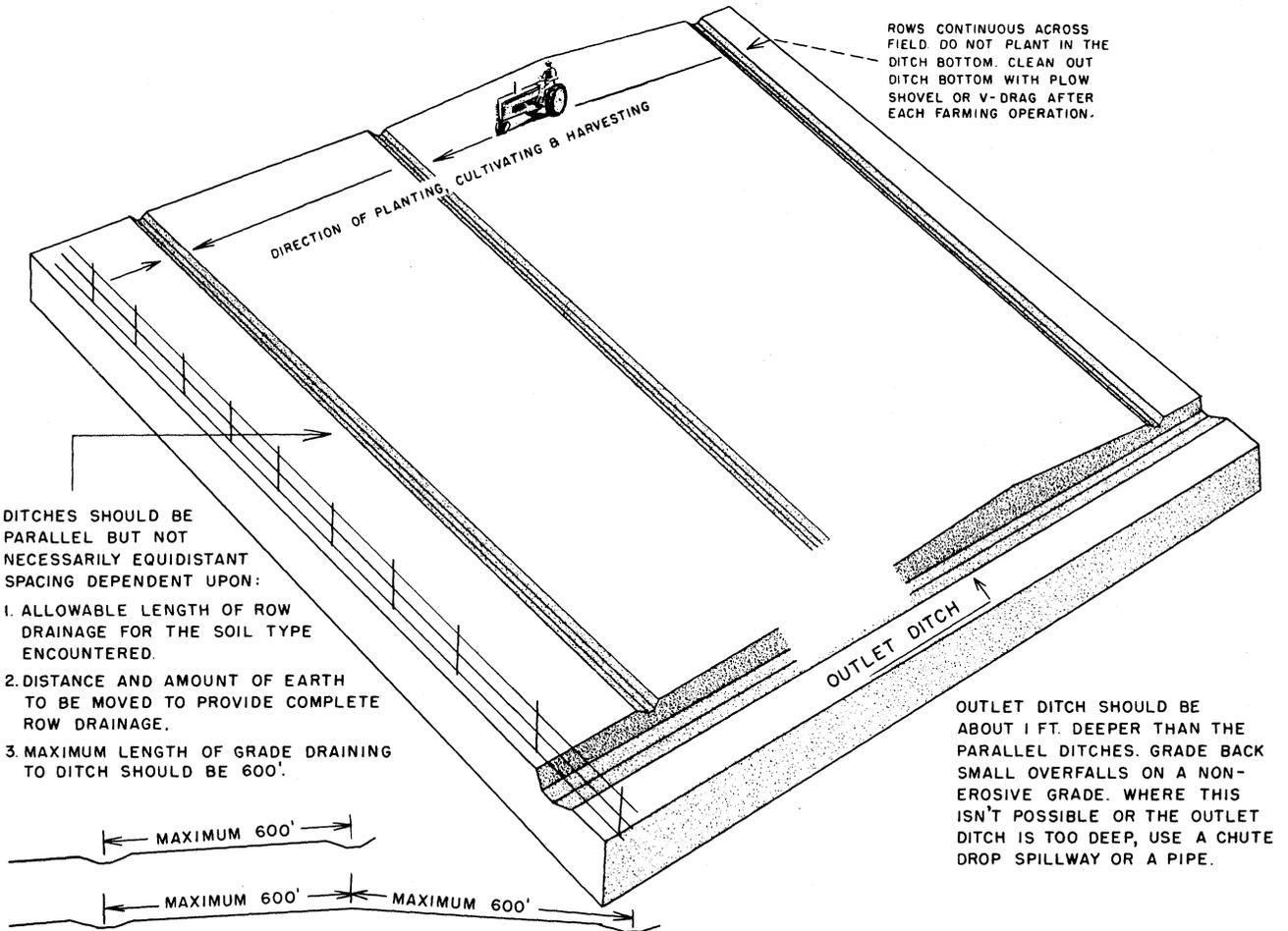


FIGURE 11.16 PARALLEL DITCH SYSTEM OF SURFACE DRAINAGE

b. Determining Runoff Into Field Ditches

(1) This is the first step in design. Generally the same criteria and process is applicable for computing runoff for surface ditches as outlined under Part 11.54a, "Determining Drainage Runoff." Use applicable curves, Figure 11.4, page 11-16 to determine the amount of runoff to be removed by the open field ditches. Judgment must be exercised in the selection of the proper curve. On soils having poor internal drainage use the next higher curve indicated for the locality.

(2) In determining runoff generally, start at the lower extremity of the improvement and work upstream and determine the c.f.s. (Q) for each reach (length) of ditch. In the sample Figure 11.10, page 11-33 on collection ditch "A" the reaches are broken down as follows: 1st reach Sta. 0+00 to Sta. 1+00; 2nd reach Sta. 1+00 to Sta. 7+00, 3rd reach Sta. 7+00 to Sta. 17+00, 4th reach Sta. 17+00 to Sta. 22+00. Reaches in this case were located between points where side drainage entered. In cases where no concentrated side drainage enters, the reaches should be broken down so that there are about 20 to 30 acres in each reach. It must be remembered that the c.f.s. (Q) required for each reach is considered constant.

c. Determining Ditch Slope

(1) Determine slope of ditch from plotted profiles of natural ground slope along ditch location.

(2) Where there is no natural ground slope, or a slope opposite to ditch flow, a graded ditch must be used with a minimum slope of 0.05% or the minimum specified in the local Technical Guide.

(3) In determining ditch grades the velocities should be checked and the maximum grade designed so that the following allowable velocities are not exceeded.

Bare channels or channels planted to field crops

Sand or silt	- 1.5 feet per second
Loams	- 2.0 feet per second
Clay	- 2.5 feet per second

Vegetated channels

Poor vegetation	- 3 feet per second
Fair vegetation	- 4 feet per second
Good vegetation	- 5 feet per second

d. Design Criteria for Single Ditches

(1) The term "single ditch" is used to differentiate from double ditch ("W" ditch) discussed in the next paragraph. Single ditches are used where the placement of spoil does not obstruct surface flow into the ditch.

(2) Depth and Capacity

The ditch capacity should be sufficient to remove the calculated runoff. The minimum depth of ditch should be 9 inches and minimum cross sectional area 5 square feet.

(3) Ditch Cross Section

Use 4:1 or flatter sideslopes where the ditch may be crossed by farm machinery but farming operations are parallel to the ditch, and 8:1 side slopes or flatter where farming operations are across the ditch. Where ditches are so located as not to be crossed with farm equipment, side slopes of 2:1 may be used.

(4) Spoil Placement

The spoil removed in ditch excavation should be leveled and so placed that there is no interference with flow of surface water into the ditch.

e. Design Criteria for "W" Ditches (double or twin ditches)

(1) This ditch has application where land drains toward the ditch from both directions, where land is very flat and row drainage enters from both sides, or where excavated material will not be used for filling depression. The "W" ditch actually consists of two parallel ditches, with the spoil from excavation placed between. In this way surface water can enter the ditch from each side unobstructed. Figure 11.17, page 11-48. It will be adapted to construction with the farm plow.

(2) The two ditches comprising the "W" should be parallel with a minimum of 30 feet between their centerlines.

(3) Depth and Cross Section

Adequate capacity to carry the calculated runoff with a minimum cross section area of 5 square feet and 9 inches minimum depth. Side slope not steeper than 8:1.

(4) Spoil Disposal

The spoil shall be spread in the center area between the two ditches and slightly crowned. Make the crowned section not less than 4 feet in width measured from the top inside slope of one ditch to the top inside slope of the other ditch.

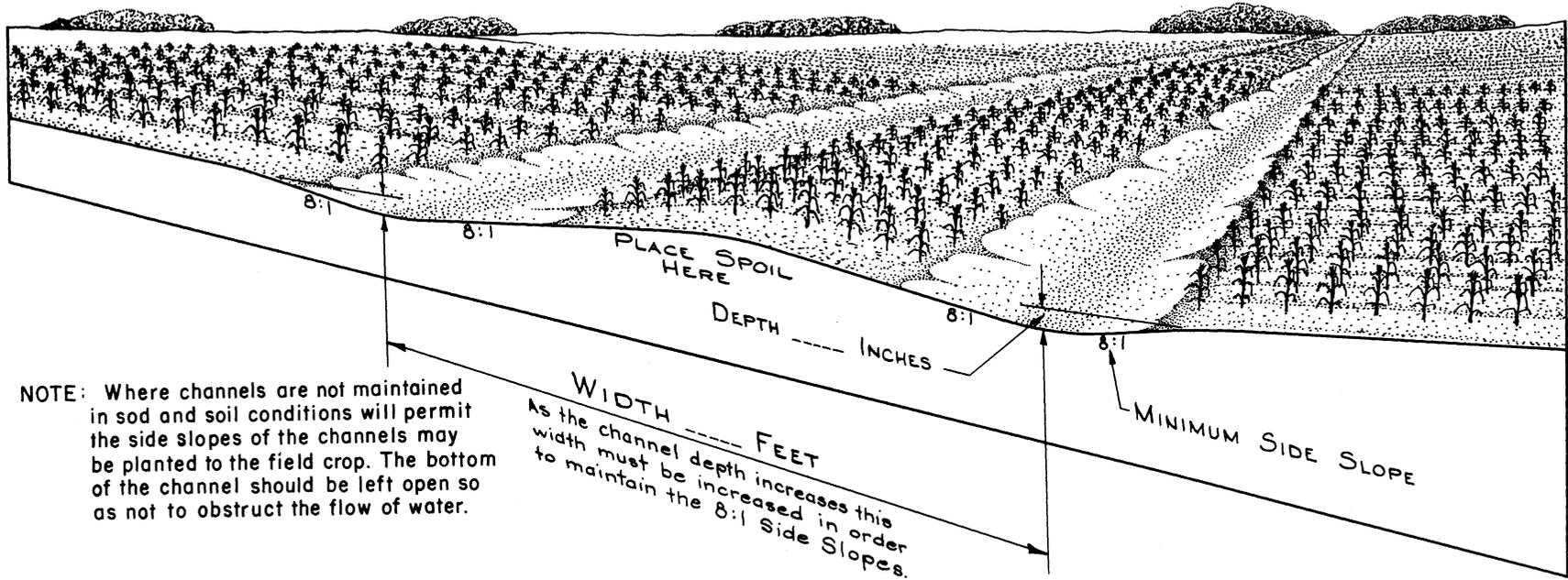


FIGURE 11.17 CROSS SECTION OF TWIN OR DOUBLE DITCH

NOTE: Where channels are not maintained in sod and soil conditions will permit the side slopes of the channels may be planted to the field crop. The bottom of the channel should be left open so as not to obstruct the flow of water.

f. Determining Ditch Size

Using runoff information and cross sections as outlined above determine the ditch size both for single and "W" ditches from tables Figure 11.6, pages 11-21 through 11-23a inclusive. In some cases it may be necessary to interpolate between depths shown in tables.

11.67 Layout and Construction of Surface Drainage Ditches

a. Layout

Layout for construction generally consists of setting centerline stakes and slope stakes on 100 foot intervals. Slope stakes usually serve only as a marker of construction limits of the ditch top width and they are lost or knocked down during early phases of construction. Under such construction circumstances it is better to mark cuts on centerline stakes and leave the stakes on a narrow strip of undisturbed earth until the remainder of the ditch is down to grade and approximately to final shape.

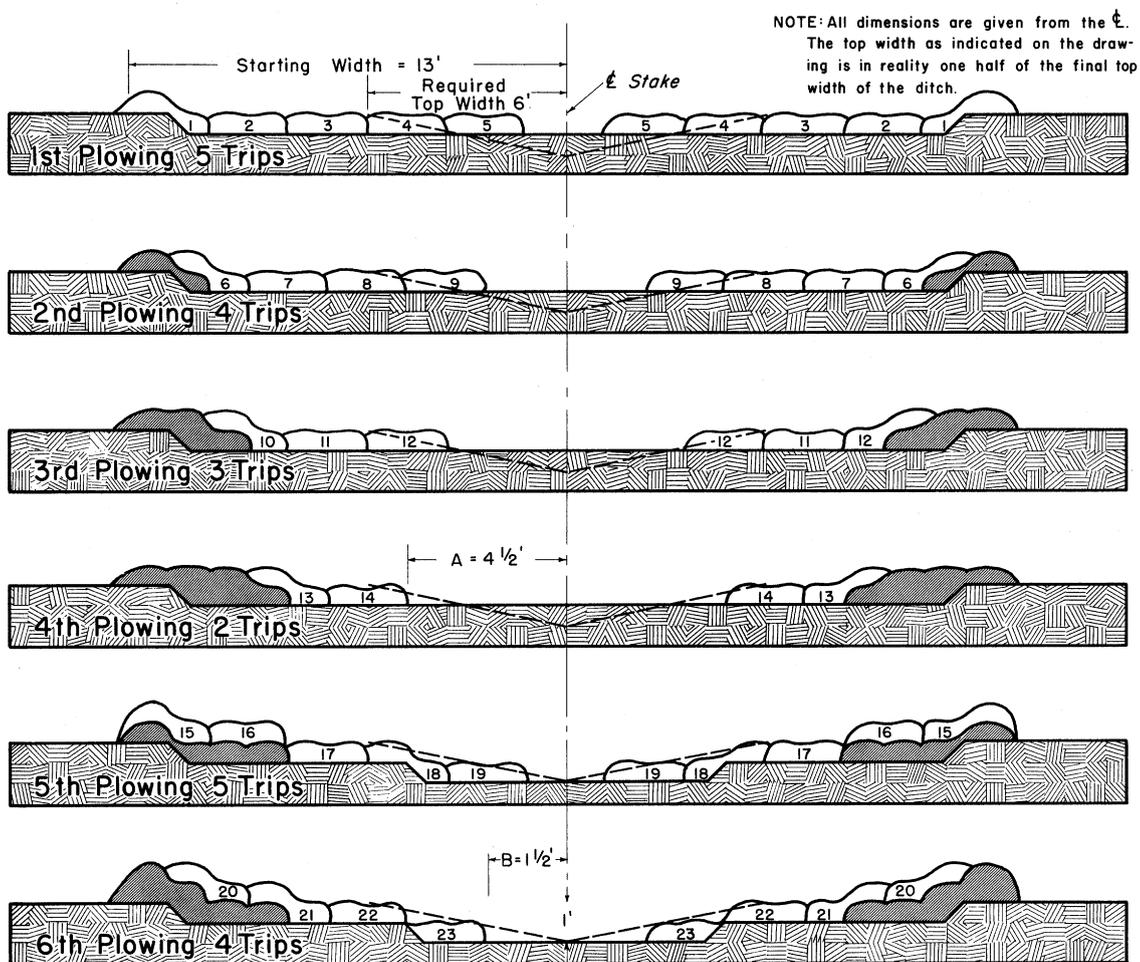
This method gives the equipment operator an opportunity to check for depth from time to time by using a rule or hand level. It is applicable when blade graders, motor patrols, plows, or whirlwind terracers are used to construct the ditch. When carry-all scrapers, rotary scrapers, small draglines, etc. are used, it is better to mark cuts on slope stakes and use them to check from during construction.

Another method commonly used to check construction consists of setting off-set stakes outside the working limits at a known elevation. Cuts to ditch bottom grade are determined and marked with reference to these off-set stakes.

b. Methods of Construction

(1) Construction may be done with a moldboard plow, blade grader, motor patrol grader, whirlwind terracer, carry-all scraper, rotary scraper, slip scraper, bulldozer, or a small dragline. While all of these have been used successfully, the depth and size ditch will generally determine the most economical type of equipment to use. If there is no problem of placing the spoil, the use of a moldboard plow or whirlwind terracer should not be overlooked for the construction of ditches up to 18 inches in depth. This equipment is especially well adapted to the construction of "W" ditches.

A whirlwind terracer has an advantage in construction of shallow ditches for it will spread the spoil over a larger area than some of the other types of equipment. It is generally more economical to construct ditches of 18 inches to 30 inches in depth with a blade grader, motor patrol, carry-all, rotary scraper, small dragline, or bulldozer. Refer to Figures 11.18, 11.19, and 11.20 on pages 11-50, 11-51, and 11-52. Economical construction with blade grader and motor patrol is limited to a maximum of about 30-inch depth.



This drawing is based on the use of a two-bottom 14 inch plow, plowing 6 inches deep. If other than a 14 inch plow is used the rounds can be varied. The main factor in this case is to have the starting width = 13 feet, the distance A equal to 4 1/2 feet, and B equal to one and one-half feet.

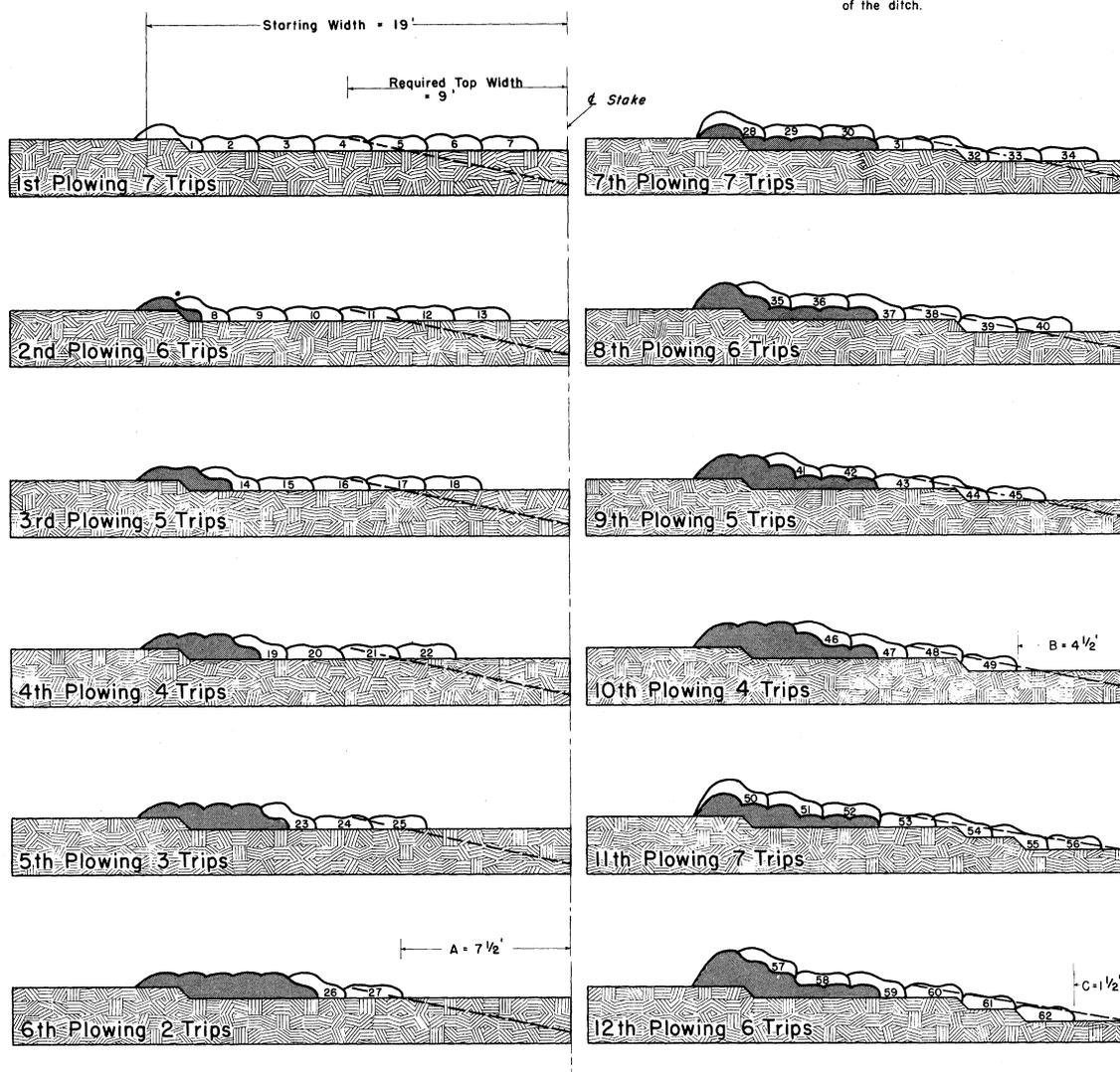
Remove crop residue and disk heavy sod well before plowing. Remove jointers. Coulters may be left on. Use sharp shares. Maintain enough speed to turn the furrow slice completely over.

First, the high points should be found. They may be plowed off by laying out short lands and plowing them out. In this plowed out area the top width which is clear of furrows must equal the top width. After the high points are worked down near to the desired grade, the plowing may be started as shown above and go from end to end of the ditch.

The first round should start as indicated in the drawing. If other cross sections are desired they may be obtained by variation of the plowing as is indicated in Figure 11.20

FIGURE 11.18 PLOW METHOD OF CONSTRUCTING DRAINAGE DITCH 1' DEEP WITH 6 TO 1 SIDE SLOPES

NOTE: All dimensions are given from the ϵ .
The top width as indicated on the drawing
is in reality one-half the final top width
of the ditch.



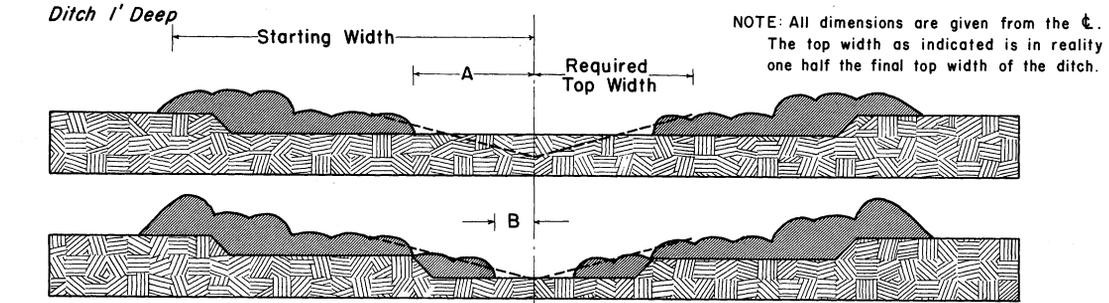
This drawing is based on the use of a two bottom 14-inch plow, plowing 6 inches deep. If other than a 14 inch plow is used the rounds can be varied. The main factor in this case is to have the distance A equal to $7\frac{1}{2}$ feet, B equal to $4\frac{1}{2}$ feet and C equal to $1\frac{1}{2}$ feet with a starting width of 19 feet.

Remove crop residues and disk heavy sod well before plowing. Remove jointers. Coulters may be left on. Use sharp shares. Maintain enough speed to turn the furrow slice completely over.

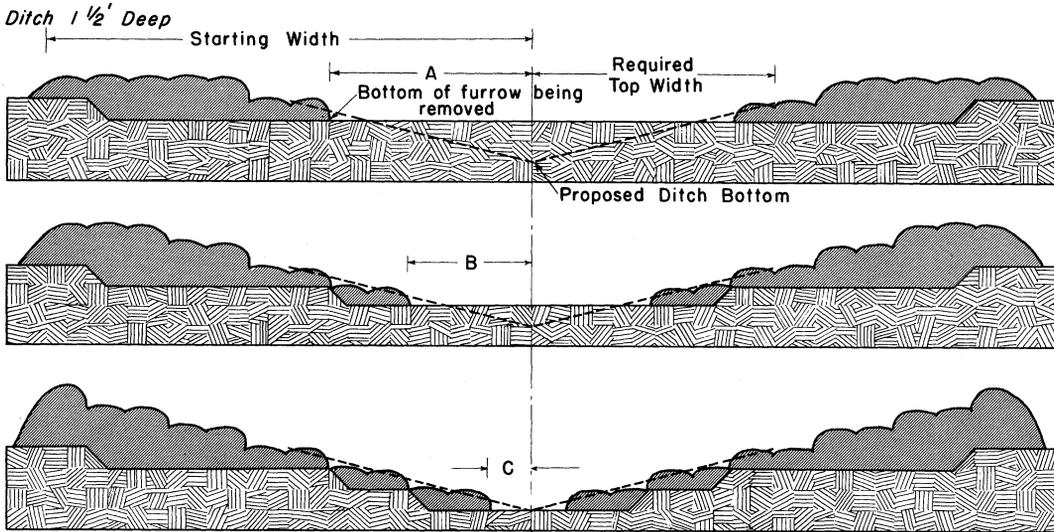
First the high points should be found. They may be plowed off by laying out short lands and plowing them out. In this plowed out area the top width which is clear of furrows must equal the top width. After the high points are worked down near to the desired grade, the plowing may be started as shown above and go from end to end of the ditch

The first round should start as indicated in the drawing. If other cross-sections are desired they may be obtained by variation of the plowing as is indicated in Figure 11.20

FIGURE 11.19 PLOW METHOD OF CONSTRUCTING DRAINAGE DITCH $1\frac{1}{2}$ ' DEEP WITH 6 TO 1 SIDE



SIDE SLOPES	STARTING WIDTH	A-WIDTH	B-WIDTH	REQUIRED TOP WIDTH
4 TO 1	8'	3'	1'	4'
10 TO 1	20'	7 1/2'	2 1/2'	10'



SIDE SLOPES	STARTING WIDTH	A-WIDTH	B-WIDTH	C-WIDTH	REQUIRED TOP WIDTH
4 TO 1	12'	5'	3'	1'	6'
10 TO 1	30'	12 1/2'	7 1/2'	2 1/2'	15'

Formula for use of different side slopes:

Starting width = 2 times (required top width)

A, B or C = (Distance from proposed ditch bottom to the bottom of furrow being removed + 1/4') times (ratio of side slopes)

If a flat ditch bottom is desired, add one-half of desired bottom width to "starting width" "A", "B" and "C".

FIGURE II.20 DIMENSION CHART FOR CONSTRUCTING DRAINAGE DITCHES

(2) Spoil spreading is very important in surface ditch construction. Spoil should be spread over large enough area in the field adjacent to the ditch so that it will not block water movement from the field to the collection ditch, or in depressional areas. Spoil spreading is done with drags, motor patrols, blade graders, bulldozers, carry-alls, and rotary scrapers. However, a more recently developed piece of equipment known as the "land leveler" appears to have merit for spoil leveling.

(3) Since ditch gradients are usually very flat in surface drainage systems they require extreme care in construction, and a thorough check should be made before equipment leaves the job so that necessary corrections can be made.

11.68 Land Smoothing (Grading) for Surface Drainage

a. General

While land smoothing is not in itself a type of surface drainage, its use is so closely associated that it is included in this part of the handbook. Land smoothing is the grading or planing by mechanical means of the land surface to eliminate or reduce elevated areas and fill minor depressions. It should be clearly understood that land smoothing is not land leveling. The purpose is not to make the field level but to make it "smooth" so that surface water will flow off, due to the natural fall of the land. Many ills of drainage could be corrected by this simple expedient. It has application especially in conjunction with the installation of surface drainage systems.

b. Land Conditions Where Smoothing is Applicable

(1) Land smoothing has application under a rather wide variety of conditions, but its primary use is in depressional topography on the heavier soils. On these soils water flows to the depressions and the soil is too impervious to allow infiltration, consequently these parts of the field remain wet for several days following a rain. By smoothing out these depressions water is distributed or runs off and the field dries more uniformly, allowing it to be worked sooner. Water will collect in very slight depressions scarcely visible by eye; smoothing out these irregularities in the ground surface eliminates the opportunity for water to accumulate. Most fields have enough natural fall to permit the excess water to flow off, provided it does not concentrate in a low spot.

(2) Adequate soil investigations should be made prior to smoothing to determine the depth of topsoil. The field to be smoothed should have sufficient depth of soil to prevent exposure to harmful amounts of subsoil.

(3) Field ditches may be needed to collect and remove surface runoff; consequently outlets for these surface ditches should be available.

c. Specifications for Land Smoothing

(1) Depth of Grading

Depth of grading should be controlled so as to prevent exposing harmful subsoil. Adequate investigations shall be made to determine the depth of topsoil, and the depth of grading that will be permissible.

(2) Finished Surface

Specifications for the finished surface will vary for each job since every field is a different problem. It should be kept in mind that the objective is to grade the field so that runoff will have unobstructed flow to collection or field ditches. It is not necessary to grade the field to the extent that there is a uniform slope over the entire field length. The finished surface should be smooth and free of all minor depressions, but the slope may vary whenever it will decrease the amount of earth to be moved.

(3) Field Drains

Field drains should be provided to drain depressions too deep to fill. In addition collection ditches should be installed to collect surface water from the field and reduce length of row drainage. Suitable outlet ditches should be available to remove the runoff.

d. Land Smoothing Operations

Land smoothing generally can be accomplished more satisfactorily in two operations: First, rough grading the area by eye; second, smoothing or finishing sometimes known as "floating." These operations can be done in the same year, but if there are depressions of appreciable depth better results probably will be obtained if the work is done over a 2-year period in order to give the fills a chance to settle.

(1) Rough Grading the Area

Rough grading the area by eye is the first step. The method of doing this and the type of equipment used will depend upon the amount of cutting and filling to be done. For small amounts of earth moving, if the cuts are only 6 inches and the hauls 300 feet or less, then the work may be accomplished with a land leveler or even farm tractors and rotary Fresno. But where large amounts of earth are to be moved either a bulldozer or contract equipment are more economical. The maximum distance for economical moving of earth with the

bulldozer is generally 300 to 400 feet, with a skilled operator, preferably 300 feet; with a partially skilled operator, 200 feet. Moving appreciable amounts of earth for greater distances generally can be accomplished more economically with heavy contract equipment.

If there is a deep depressional area or a wide shallow depression it may be more economical to drain these areas by field ditches rather than to fill them.

In making cuts avoid completely removing topsoil from any one area. Instead, take thin layers of topsoil from a much larger area. Since the slope is usually gradual the soil can be moved into the depression by cutting high ground uphill, downhill, or to the side, thus permitting round-trip operations. In rough grading by eye keep in mind that the purpose is to make the field drain and not to uniformly grade the entire area. Figure 11.21, page 11-56. After the area has been rough graded the land leveler or land plane should be run over the area from two to four times depending on the roughness of the land. It should be operated across the area and then diagonally both ways. Prior to the last pass with the land leveler clean the existing field ditches, distributing the spoil as far back from the ditch as is feasible. The final pass with the land leveler will then smooth out the spoil. When rough grading is completed the area should be reasonably free of depressions where water will stand.

(2) Final Smoothing Operations

Following rough grading it is desirable to allow at least a few months for settlement of the soil before final smoothing operations. If possible, it would be desirable to wait a full year. The field to be smoothed should be dry, either plowed or disked, and free of vegetation and trash.

Rainfall following rough grading will give indications of the need for additional cutting and filling. However, some topographic survey information is generally required, to locate small depressions missed during rough grading operations, and to select and plan the type of surface drainage system best suited for the field. Then construct any new surface ditches required for the selected surface drainage system. The spoil from the new ditches can be used to fill adjacent depressions that were not completely filled by the rough grading. Fill remaining depressions as indicated by the topographic survey. The last phase in the land preparation is to operate the land leveler or plane diagonally both ways of the field and then across the field in the direction of planting operations.

A method of running levels that has proved satisfactory is to set grade stakes where the need for additional work is

ADVANTAGES OF LAND SMOOTHING

- 1** Land smoothing eliminates the small low areas and pockets that collect and hold water. This makes possible earlier planting, a longer growing season and uniform stands and crop yields.
- 2** Prepares an ideal seed bed, firms the soil and leaves a smooth uniform surface which will hold sub-moisture near the surface in dry weather and afford a well drained seed bed in wet weather.
- 3** Permits uniform planting depths and covering of seed with well-pulverized soil, all of which insures faster and more uniform germination of seeds, better stands, hardy and rapid-growing plants.
- 4** Makes cultivation more uniform and weed-removal more complete by providing a smooth surface on which to work.
- 5** Makes mechanical harvesting faster and more efficient, especially on low-growing or vine crops by allowing operation of pickup devices closer to the ground.
- 6** Saves wear and tear on planting, cultivating and harvesting machinery. Farm machinery will operate better and last longer with fewer repairs on smoothed fields.

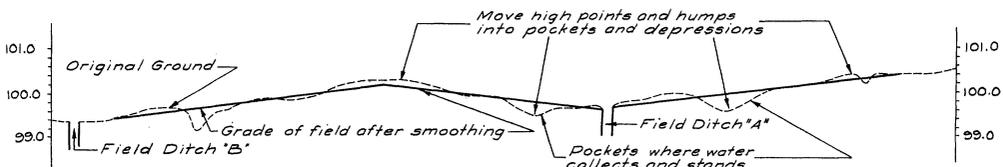
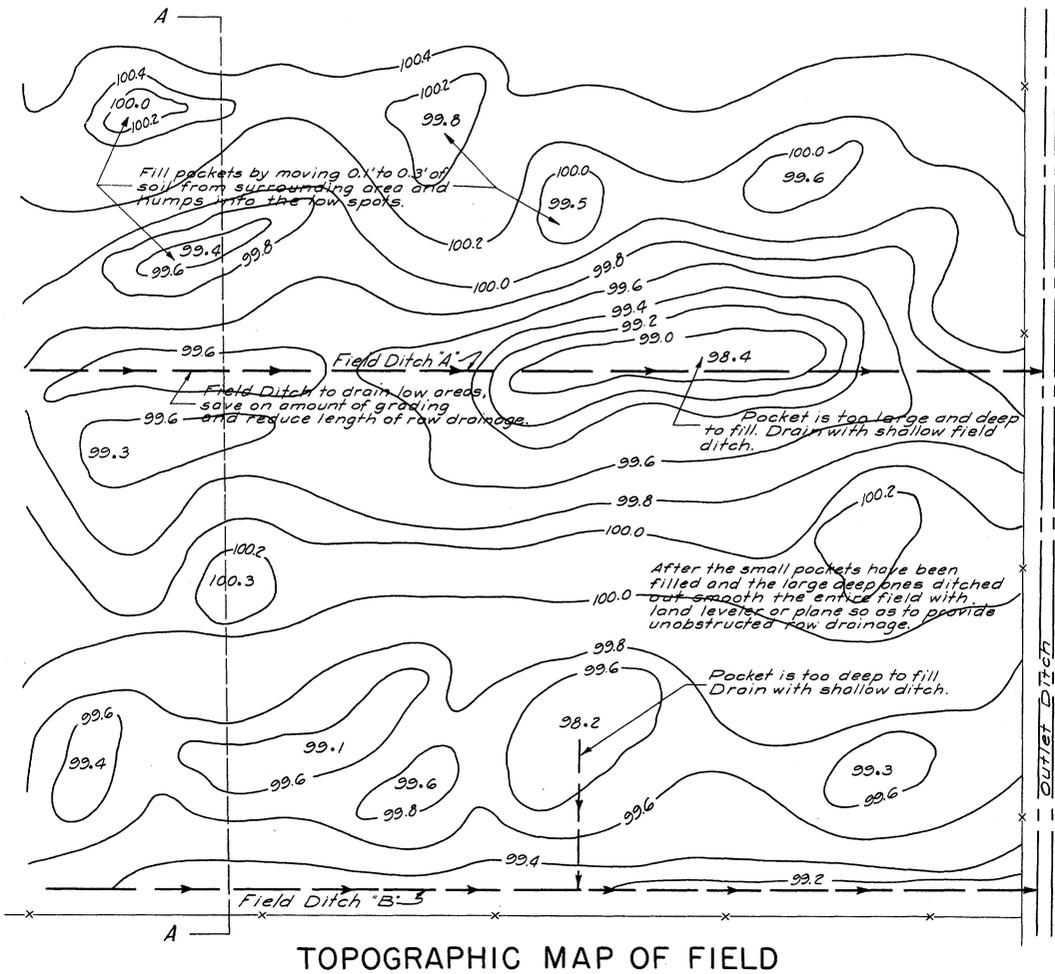


FIGURE 11.21 EXAMPLE OF FIELD WHERE LAND SMOOTHING IS APPLICABLE

indicated. Grade the area by setting stakes on approximately 100 foot intervals, marking the amount of cuts on the stakes and a line on the fill stakes to indicate the height of fill. The area can be worked in lanes leaving the cut stakes on islands of earth, and not disturbing fill stakes until the proper fill has been made. This work is done with earth-moving equipment as used for rough grading. The land leveler can then be used to smooth out surface irregularities and remove the islands at the cut stakes. Generally rough grading machinery is used to within 0.10 foot of the finished grade before using the land leveler.

Final grading need not be carried to the point of obtaining uniform slopes over long distances since the primary purpose is merely to grade the field so that it will drain. However, some fields are nearly level and water will not run off. These fields should be provided with some grade. The minimum grade should be 0.05 foot fall per 100 feet (0.05%). This grade can be established only where there is sufficient topsoil on the lower end of the field to provide the necessary borrow for the higher side.

e. Maintaining Fields in Smooth Condition

In the farm tillage operations ridges, back furrows, or irregularities develop where water will stand, and it is therefore vitally important on tight soils to maintain the land in a smooth condition. The best way to accomplish this is by using the land leveler as the last step in seedbed preparation prior to seeding or planting operations.

11.69 Maintenance of Surface Drainage Systems

No other practice used in soil and water conservation work is more dependent on meticulous maintenance for proper functioning than surface drainage systems. This is particularly true of bedding systems. The following points in maintenance especially should be observed.

a. Maintenance of Field Ditches

Outlets and collection ditches should be cleaned and reopened periodically as required to permit them to function properly. Small deposits of silt will oftentimes greatly reduce capacities and cause partial or complete failure of the system. After each heavy rain the ditches should be inspected and silt deposits or other obstructions removed. Cattails, water tolerant grasses, willows, and cottonwood are a menace to surface ditches and should be cut or sprayed once or twice each year as required.

b. Maintenance of Bedding Systems

(1) When the field is in row crops the dead furrows generally need to be opened after each cultivation. This is

especially important on very flat land and during the time the plants are small. A V-shaped drag is useful for this purpose.

(2) On fields that drain very slowly to slow, beds once established should be maintained permanently in the same location. A properly shaped bed should have a continuous slope totalling 3" to 5" from center of bed to shoulder of dead furrow, and dead furrow should have an additional depth of 3" to 4" below the shoulder line, making a total difference of from 6" to 9" from center of bed to bottom of dead furrow.

(3) Once a permanent type of bed is established a particular method of plowing is required so as to prevent the beds getting too high in the center and the dead furrows developing into a progressively wider sterile area. One method is to use a two-way plow. Plowing is started at one side of a field and continued across the field, throwing all the furrows in one direction. This will merely move the center of the beds and dead furrows over one furrow width. The next plowing is started on the opposite side of the field; thus, the beds are always maintained about the same height. However, it may be necessary after each plowing to open up the dead furrows with a small V-drag or the plow itself. Unfortunately there are very few two-way plows on the farms in this region.

(4) Another method is to use the common one-way plow and plow two beds as a land. By alternating the starting points on each successive plowing the bed heights and dead furrow widths are maintained about as originally established. See Figure 11.22, page 11-59.

11.70 TILE DRAINAGE

11.71 General

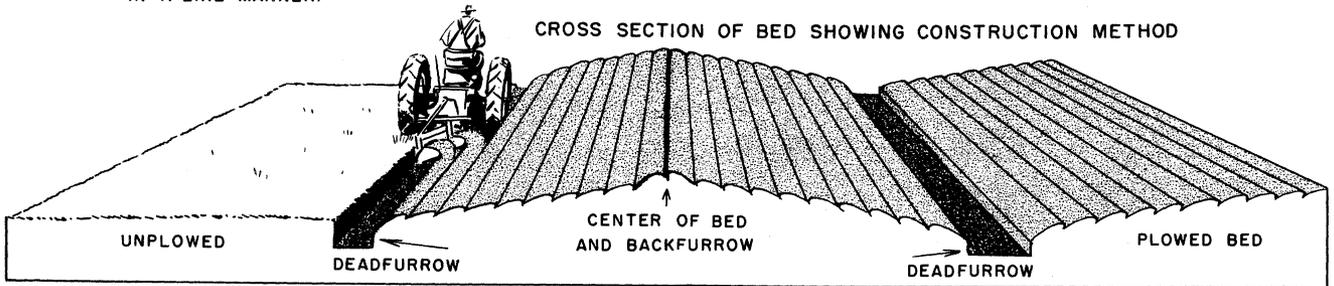
a. Tile drainage is accomplished by means of a series of tile laid in a continuous line at a specified depth and grade so that free water entering the tile joints will flow out by gravity. It differs in principle from surface drainage in that water percolates into the soil and is taken out by drains below the ground surface. The purpose is to lower the ground water level below the root zone of the plants.

b. A tile drainage system consists of a drainage outlet, tile main, sub-mains, and laterals. The function of the laterals is to remove the free water from the soil; the function of the sub-mains and mains is to carry the tile water to the drainage outlet.

CONSTRUCTION OF BEDS

EXTREME CARE MUST BE USED DURING THE FIRST PLOWING TO DEVELOP BEDS OF UNIFORM WIDTH THROUGHOUT THEIR ENTIRE LENGTHS.

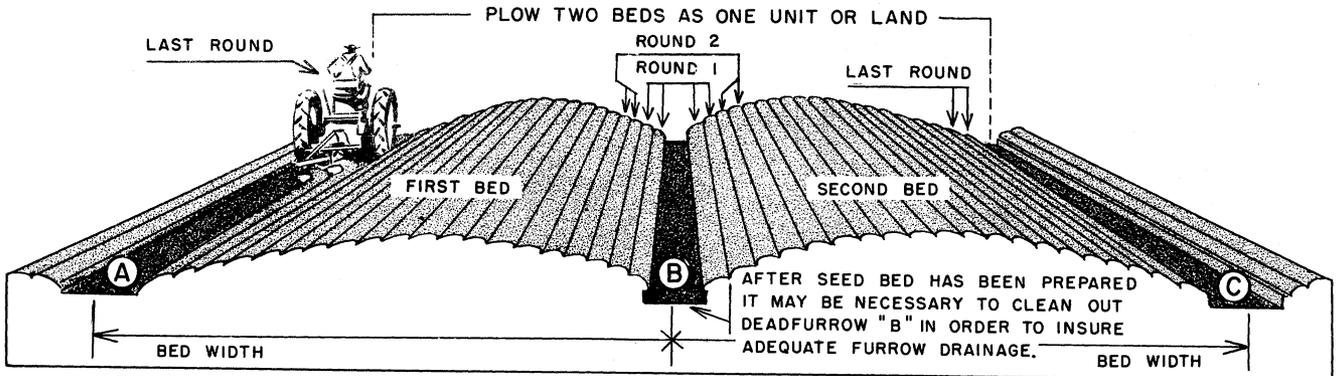
START PLOWING BY BACKFURROWING AT CENTER OF BED, THROWING FIRST TWO FURROWS TOGETHER. CONTINUE THROWING FURROWS TOWARD THE BACKFURROW UNTIL WIDTH OF BED HAS BEEN PLOWED. IF THE REQUIRED CROWN HEIGHT AND SIDE SLOPE OF BED HAS NOT BEEN SECURED, REFLOW THE BED IN A LIKE MANNER.



MAINTAINING BEDS

FIRST PLOWING AFTER BEDS ARE ESTABLISHED

START PLOWING OPERATIONS TO THE OUTSIDE OF DEADFURROW "B", THROWING FIRST BACKFURROW SLICE ON EACH SIDE ONLY PARTIALLY INTO THE DEADFURROW SO THAT AT LEAST A 12-INCH WIDTH OF THE OLD DEADFURROW REMAINS. CONTINUE PLOWING BY THROWING FURROWS TOWARD DEADFURROW "B" UNTIL DEADFURROWS "A" & "C" ARE REACHED. MOVE TO NEXT TWO ADJOINING BEDS AND REPEAT OPERATION.



MAINTAINING BEDS

SECOND PLOWING AFTER BEDS ARE ESTABLISHED

START PLOWING AT DEADFURROWS "A" & "C", THROWING FIRST BACKFURROW SLICE ONLY PARTIALLY INTO THE DEADFURROW SO THAT AT LEAST A 12-INCH WIDTH OF THE OLD DEADFURROW REMAINS WHEN THE ADJOINING BEDS ARE PLOWED. CONTINUE PLOWING BY THROWING FURROWS TOWARD DEADFURROWS "A" & "C" UNTIL DEADFURROW "B" IS REACHED. THE THIRD TIME THE FIELD IS PLOWED, FOLLOW PROCEDURE FOR FIRST PLOWING.

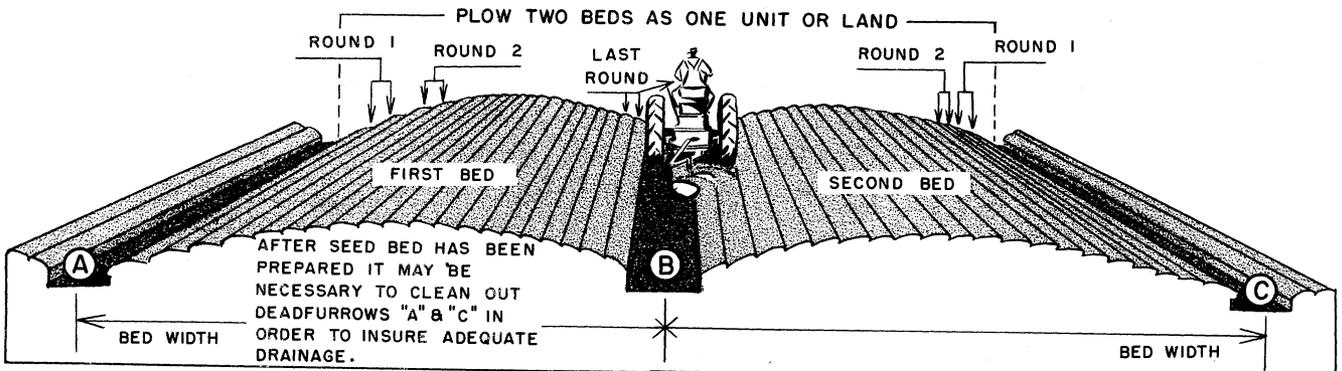


FIGURE 11.22 CONSTRUCTING AND MAINTAINING BEDDING SYSTEMS FOR SURFACE DRAINAGE

11.72 Conditions Under Which Tile Drainage Is Applicable

a. Tile drainage is applicable to more or less saturated soil conditions where it is physically and economically feasible to remove free water through tile under drains to the normal depth of the plant root zone. The inherent fertility of the soils must be such that after drainage the land will produce sufficient additional crops to justify the expense of tiling.

b. Soils Suitable For Tile Drainage

(1) Tile drainage is affected primarily by the rate of movement of water percolation in the soil. This in turn depends upon the size and number of connecting pore spaces. In general the finer textured soils have a slower rate of percolation. In heavy soils the pore spaces are small and clogged with colloidal material obstructing gravitational flow into the tile line. Some of these soils are so tight that the tile remove the free water from only a limited area. If such soils are to be drained the tile would have to be placed so close together that the crop returns would not justify the expense. The use of tile in clay soil, therefore, is limited to soil physical conditions where the spacing of the tile lines are at such a distance that the cost of installation is not greater than the benefits derived.

(2) In some sandy soils and in peat and muck the pore space is large and the movement of water is rapid. Wetness occurs because of a high water table particularly in the spring. This must be lowered by drainage if maximum crop yields are to be produced. Soils of this type can be successfully tile drained but many of them present certain hazards.

(a) In some fine sandy soils there is insufficient colloidal material to hold the particles together and there is danger of excessive movement of the sand particles into the tile line. Some of these soils cannot be tilled and on others, special precautions in construction are necessary.

(b) In peat and muck soils there is also some tendency for the fine soil particles to enter the tile line, and in addition there is a danger of shifting of the tile alignment due to the unstable nature of the soil. Furthermore, there is a tendency for newly drained muck and peat soils to settle considerably. For this reason, generally, it is not desirable to lay tile in these soils until the initial settlement has taken place.

(c) Both sandy soils and peat and mucks present some hazards of over-drainage. Being very porous they have a low capillary attraction and if the water table is lowered too much by the tile line the capillary "pull" is not sufficient to bring the water into the plant root zone.

(d) There are still other soil conditions where tiling is hazardous or impossible. In some soils boulders or stones are encountered so frequently that tiling costs are prohibitive. In other soils the topsoil is satisfactory but it is underlaid with sand at the depth where tile would be installed, thus making installation more difficult or impossible. In still other soils there is a tendency for the tile joints to seal over due to a chemical action that takes place.

c. Economic Factors to Consider

(1) Some soils can be tile drained satisfactory but the cost of installation is so great that the accrued benefits do not justify the expense. This condition is true on extremely tight soils where spacing must be very close. A rule-of-thumb that has quite general application is that when tile spacings are closer than two rods (33 feet) the cost usually is greater than the benefits. An exception to this is where high value crops are involved. An example of this is the tile drainage of Nappanee soils in Michigan that are planted to orchards. The benefit here not only is in the removal of excess water for tree growth but also in drying up the land so that spray rigs can be hauled through the orchard without bogging down.

(2) Some soils could be drained by tile satisfactorily but the inherent productivity is so low that the yields do not justify the expense involved.

(3) Another economic factor that prohibits many tile installations is the lack of a suitable outlet. To provide for a tile outlet, in some cases, would be prohibitive in cost.

(4) Most tile drainage is expensive and in many cases farmers do not have the money to spend on an installation. The amount of indebtedness that should be incurred is difficult to decide. Over a period of years the installation may pay for itself; but if a series of reverses occurs in farming the debt may be too great to finance during periods of low income. A good rule to follow is to not encourage borrowing for tile drainage installation unless the returns by increased crop yields will pay for the installation in a five- to seven-year period.

d. In conclusion it may be said that before undertaking tile drainage of any piece of land a careful analysis should be made of the physical and economic conditions involved in the installation.

11.73 Field Surveys For Tile Installations

a. General

(1) Prior to making a field survey for tile installation the technician should make a preliminary investigation and

inspection of the field to be drained. The various factors affecting drainage outlined in Part 11.72 should be carefully investigated and considered. These should be discussed fully with the landowner. Before making the survey the following decisions should have been reached:

- (a) That the soils will respond to tile drainage and that there are no physical soil conditions prohibiting the installation of tile.
- (b) That a suitable arrangement of tile is feasible and an outlet is available. If this is not evident by eye, sufficient preliminary levels should be taken to reach a decision.
- (c) The areas in need of drainage should be delineated preferably on an aerial photo. The technician should have a general idea of the type of tile system required. Such a determination in advance is desirable so that the nature of survey can be planned before starting the survey.

Two kinds of field information especially are required for the design of tile drainage installations: topographic data of the field to be drained, and soil borings or knowledge of the soil profile.

b. Topographic Information Required

(1) The amount of topographic information depends on the lay of the land. Where the slope of the land is obvious by eye very little and sometimes no topographic information is needed to plan the location of tile lines. But on flat land where the location of tile lines is not obvious, a topographic survey is necessary. The general tendency is to obtain too little topographic data. Lack of topographic information results in a piecemeal system of tile drainage that frequently is more expensive than if sufficient information had been obtained to plan a complete job on paper in advance of installation.

(2) The method of making topographic surveys and preparation of topographic maps is outlined in Part 1.40, and further explanation is given in Parts 11.52 and 11.53 under Surface Drainage. These procedures are generally applicable to obtaining topographic information for tile drainage installations.

c. Soil Borings

(1) Unless sufficient soil borings are taken when the preliminary inspection was made of the area these should be taken as a part of the survey. The number of borings to make on any particular area under investigation will depend on

several factors but principally on apparent differences in soil appearances, or as indicated by soil surveys. A sufficient number of borings should be made so that the technicians will definitely know if there are undesirable soil conditions or if there is a wide variation in the texture of the soil to be drained. This information is definitely needed to determine the spacing and depth of the laterals and construction hazards.

11.74 Types of Tile Drainage Systems

In order to plan a tile drainage system, knowledge is needed of the various types of tile drainage systems. The six types of tile drainage systems commonly used are shown in Figure 11.23, page 11-63 and Figure 11.24, page 11-64. The choice of systems

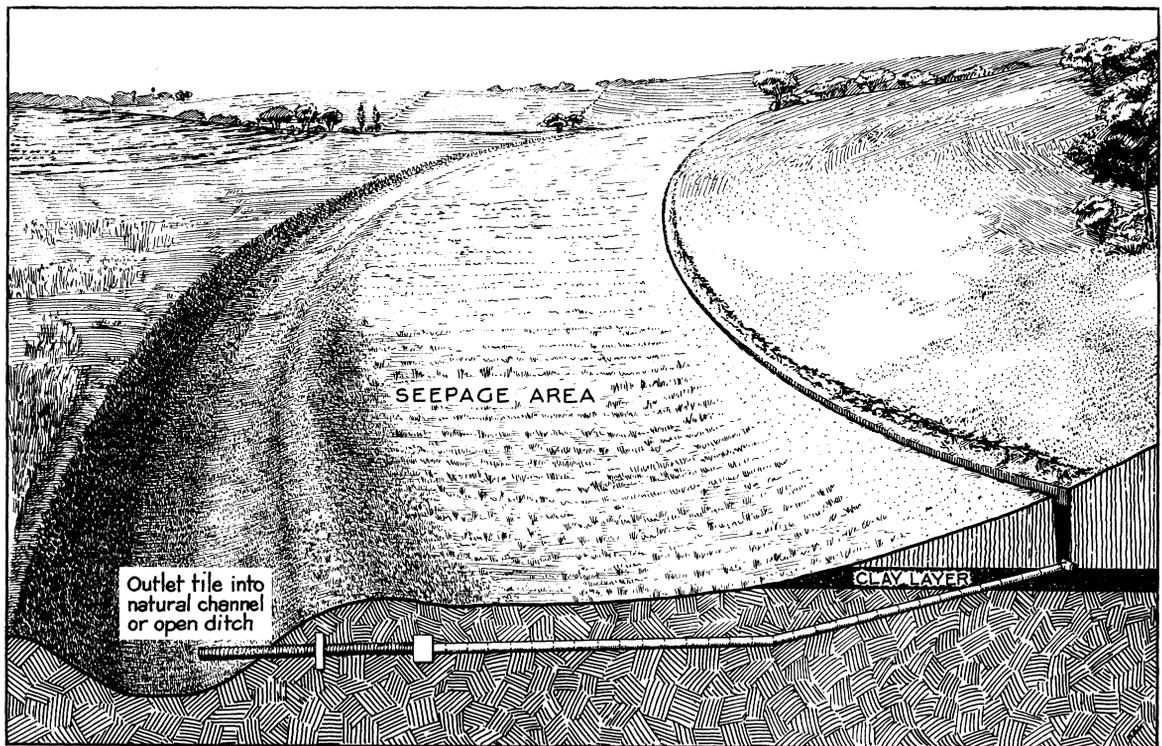


FIGURE 11.23 DRAINAGE AT SEEPAGE AREAS

to use is determined by the topography of the land, source of water to be removed, and other field conditions. The different types of tile drainage systems are described as follows:

a. Random System

This system is used where there are scattered wet areas in a field somewhat isolated from each other. Tile lines are laid more or less at random to drain these wet areas. In most cases the tile main follows the largest natural depression in the

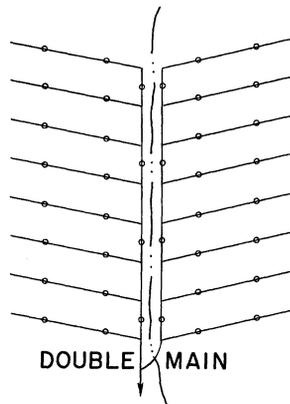
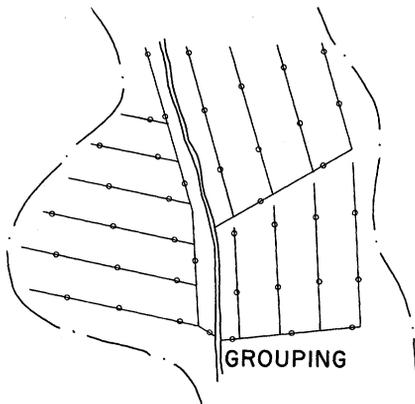
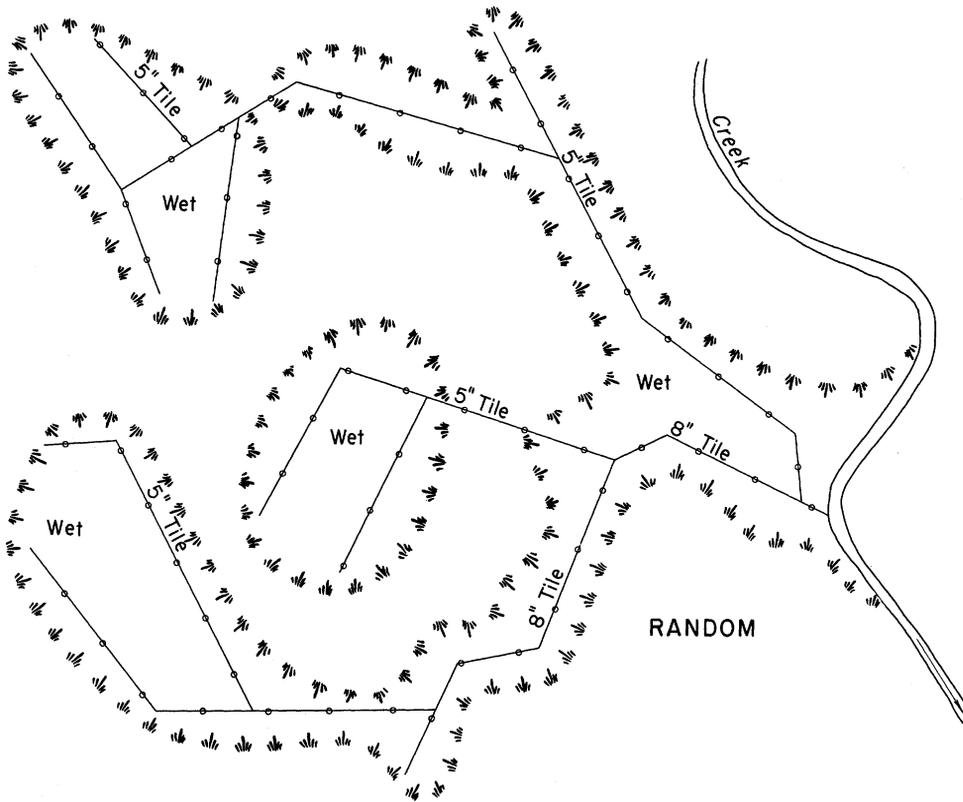
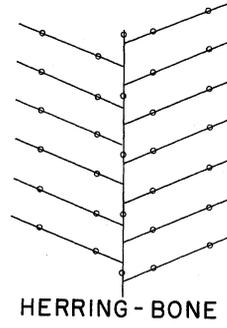
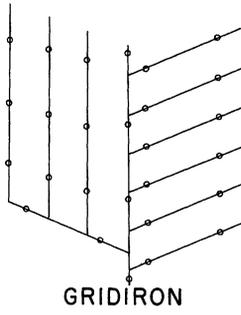
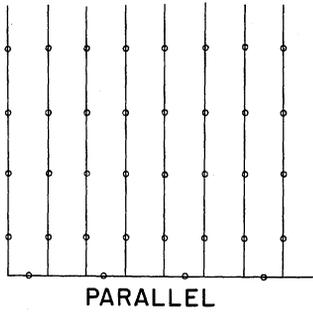


FIGURE 11.24 TYPES OF TILE DRAINAGE SYSTEMS

field and the sub-mains and laterals extend to the individual wet areas. If the individual wet areas are large the arrangement of the sub-main and laterals for each wet area may utilize one or more of the other systems shown in Figure 11.24.

b. Gridiron and Parallel Systems

The principle employed in these two systems is that one main or sub-main serves as many laterals as possible. Thus the length and number of outlets is kept to a minimum. Since the laterals enter the sub-main from one side only there is less "double drainage" than where laterals enter the sub-main from both sides. This system is applicable on land that is uniformly wet where there is a gentle slope toward the sub-main.

c. Herringbone System

This system is applicable where the sub-main lies in a narrow depression and the laterals must enter from both sides. It is a less economical system, since there is considerable double drainage where the laterals and mains join. However, if the depression over the sub-main is unusually wet this system will provide better drainage at this point and thus be an advantage.

d. Intercepting System

This system involves the interception of seepage water from adjoining high lands. A line of tile properly located will intercept the seepage water and relieve the wet conditions. The proper location of the tile for interception of the seepage water is highly important. The seepage plane should first be located by soil borings, or with a post-hole auger, and the tile installed on or just slightly above the impervious layer. Refer to Figure 11.23, page 11-63.

e. Double-Main System

This is a modification of the gridiron system and it is applicable where the sub-main is located in a broad, flat depression which is frequently a natural watercourse. In some cases this depressional area may be wet because of small amounts of seepage water from adjacent slopes. Placing a sub-main on each side of the depression serves the double purpose of intercepting the seepage water and as a sub-main for the laterals. If the depression is unusually wide and only one sub-main is used in the center it may be necessary to break the grade line of the laterals before they reach the sub-main. Placing a sub-main on each side of the depression permits a more uniform lateral grade line without an abrupt break in grade.

f. Grouping System

This system employs the use of a combination of the individual systems. It is applicable where there are variable conditions

of wetness on the field to be drained and the pattern of drainage must be varied to fit the individual conditions.

11.75 Planning the Tile System

a. General

The purpose of the field survey, soil borings, and other field information as described in Part 11.73 is to provide adequate information from which the most economic system of tile drainage can be planned. This information should be studied and utilized fully in planning the system. The importance of thorough planning in advance of layout cannot be over-emphasized.

b. The Tile Outlet

(1) The starting point in planning a tile drainage system is the location of the outlet. Tile drains may outlet by gravity into natural or artificial channels or tile outlet mains. Any of these are suitable provided they are deep enough and of sufficient capacity to take away all the drainage water from the tile line. Before proceeding with the design of the system the technician should be satisfied with the adequacy of the outlet.

(2) Capacity and Depth of Open Channel Outlets

The outlet channel shall be large enough to remove the drainage runoff from the watershed in a period of time sufficient to prevent crop damage. It shall be deep enough so that when tile lines are laid at the specified depth there is at least one foot of clearance between the flow line of the tile outlet and the low water stage in the channel. This clearance may be reduced where the outlet channel is on such a grade that silting will not occur and where the stream recedes to low water stage a few hours after a storm.

(3) Capacity and Depth of Tile Mains

When existing tile mains are used as the outlet, it shall be in good condition, free of failures, and working properly. The main shall have sufficient available capacity, based on the area served, to handle the proposed tile drainage system, and the depth should be sufficient to permit the new tile system to be laid at the depth specified for good tile drainage (excepting small depressions where minimum cover of two feet is permissible).

(4) Outlet by Pumping

Where a gravity outlet is not available the possibilities of an outlet by pumping should be considered. This is a special problem that should be investigated by an engineer. See Part 11.42e, page 11-11, for additional information.

c. Some General Principles in Planning the Tile Systems

(1) The success of the tile drainage system depends upon the efficiency with which the laterals remove the free water from the soil. Therefore they are a very important part of the system. The determination of the proper depth and spacing of the laterals and their relation to the main should receive careful consideration. Especially the following:

(a) The laterals should be laid out to be as long as possible, within the limits of topography. A good rule to follow is to make the laterals long and the mains and sub-mains short.

(b) The laterals should enter the mains at nearly right angles whenever possible. Long slanting junctions should be avoided because this results in more double drainage. Do not use designs where laterals enter a main or sub-main from both sides, such as the herringbone system, unless it is necessary for good drainage, as this also results in double drainage.

(c) Avoid laying tile lines within 100 feet of water-loving trees, such as willow, elm, cottonwood, or etc. and maintain a distance of 50 feet from all other tree species with the exception of orchard trees. Where this distance cannot be maintained the tile line should be constructed of bell joint or tongue and groove tile with joints sealed with mortar.

d. Determining Tile Size

(1) Drainage Coefficient

The tile should be of sufficient capacity to remove a required amount of water (inches) from the area to be drained in 24 hours. This amount of water is referred to as "drainage coefficient." The drainage coefficient to use depends on soil and crop conditions and the method of disposal of surface water. Truck crops require the removal of water within a few hours' time following a rain, and therefore a higher drainage coefficient is required. Where there are surface inlets the inflow into the tile is greater than where surface water is excluded. The following table gives recommended drainage coefficient for tile systems without surface inlets and with surface inlets.

(2) Size of Tile to Use

(a) The size of tile needed is based on the size of area drained, grade of tile, and the specified drainage coefficient. With this basic information tile size can be determined from Figure 11.25, page 11-69, "Tile Drainage Chart."

**DRAINAGE COEFFICIENT FOR VARYING CROP AND SOIL CONDITIONS
WITH AND WITHOUT SURFACE INLETS**

Soil Permeability	Without <u>2/</u> Surface Inlets		With <u>3/</u> Surface Inlets	
	Field Crops <u>1/</u>	Truck Crops	Field Crops <u>1/</u>	Truck Crops
Mineral Soils	3/8"	3/4"	3/4"	1 1/2"
Peats & Mucks	3/4"	1 to 1 1/2"	3/4 to 1 1/2"	1 1/2 to 4"

- 1/ For mineral soils with sandy or otherwise permeable subsoils the drainage coefficient may be reduced - never less than 1/4".
- 2/ Figure only the area to be tiled as the drainage area. It is understood that surface water is removed by field ditches or watercourses.
- 3/ Use entire contributing watershed as the drainage area.

(b) The smallest tile generally recommended is five inches, even though the chart calls for the use of smaller tile. Four-inch tile may be used on single laterals not exceeding 1,000 feet, where the grade is .15 percent or less, and this length can be increased to 1,300 feet for grades steeper than .15 percent. In deep peat and muck soils six-inch tile should be the minimum size used because of shifting of the tile alignment. Also for intercepting areas of considerable seepage or strongly flowing springs the minimum size tile should be six inches.

(c) Individual tile lengths for mineral soils usually are one foot. For peat and muck soils tile lengths 18 to 24 inches are recommended in order to avoid tilting of the tile.

e. Depth and Spacing of Tile Lines

(1) General

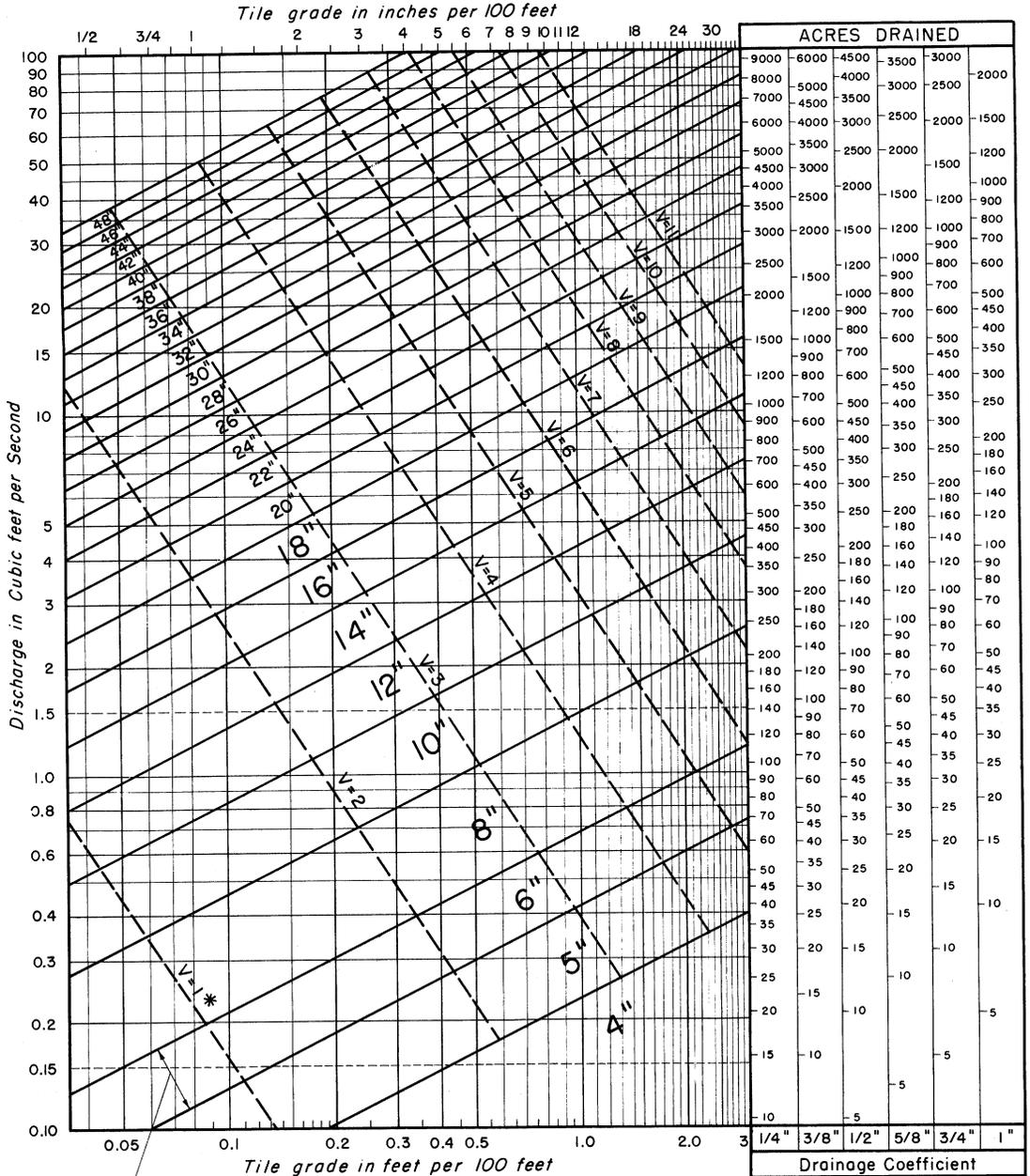
The depth and spacing of tile should be such as to lower the depth of ground water between tile lines within 24 hours after a rain to that required to prevent crop injury. Generally, crops are not injured if the water table is lowered to at least six inches below the ground surface in the first 24 hours following a rain. During the second and third day following a rain the ground water level should be lowered approximately to the 1 foot and 1.5 foot level respectively.

(2) Minimum Tile Depths

(a) Laterals should have an average minimum depth of three feet in mineral soils. Generally it will be found that even greater depths, 3-1/2 to 4 feet, will give

TILE DRAINAGE CHART

Acres Drained by Various Sizes of Tile



Space between lines is the range of tile capacity for the size shown between Lines.

Reference: Yarnell-Woodward Formula $v = 138 r^{2/3} s^{1/2}$ U.S.D.A. Bulletin 854

* V. equals velocity in feet per second

REVISED 11-21-51

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SOIL CONSERVATION SERVICE

3-L-7215

FIGURE II.25 TILE DRAINAGE CHART

better results and there has been a growing tendency to use deeper placed laterals. For slowly permeable soils where laterals are spaced approximately 50 feet the depth may be reduced to 2.5 feet under certain conditions. In deep organic soils where settlement has occurred the minimum depth should be 4 feet.

(b) In small depressional areas where it is uneconomical or impractical to place tile at the depth specified above, the depth may be reduced to a minimum of 2 feet of cover. This minimum depth is necessary in order to prevent frost damage and to prevent breakage by farm machinery loadings. For depths shallower than 2 feet use continuous length of frost-resistant pipe of sufficient strength to resist farm machinery loadings such as corrugated metal pipe or extra strength bell joint or tongue and groove tile.

(c) The mains and sub-mains should be deep enough to provide the specified depth for laterals.

(3) Tile Loading

The maximum depth at which tile can be laid varies with the width of trench and it is dependent upon the crushing strength. The allowable maximum tile depth for various widths of trenches is given in the following table:

MAXIMUM ALLOWABLE TILE DEPTH IN FEET FOR DRAIN TILE WITH VARYING WIDTHS OF TRENCH ^{1/}

Tile Size	Tile Strength	Width of Trench - Inches								
		14	16	18	20	22	24	26	28	30
5"	Standard	*Inf.	16.5	8.7	7.2	7.2	7.2	7.2	7.2	7.2
	Extra Quality	"	Inf.	Inf.	12.0	9.5	9.5	9.5	9.5	9.5
6"	Standard	"	"	8.8	6.7	6.5	6.5	6.5	6.5	6.5
	Extra Quality	"	"	Inf.	12.1	8.6	8.5	8.5	8.5	8.5
8"	Standard	"	"	9.0	6.9	5.7	5.1	5.1	5.1	5.1
	Extra Quality	"	"	Inf.	12.3	8.8	7.3	6.6	6.6	6.6
10"	Standard	"	"	9.2	7.1	5.9	5.2	4.6	4.6	4.6
	Extra Quality	"	"	Inf.	12.4	9.0	7.5	6.5	5.7	5.6
12"	Standard	"	"	9.4	7.3	6.1	5.4	4.8	4.4	4.2
	Extra Quality	"	"	Inf.	12.6	9.2	7.7	6.7	5.9	5.4
15"	Standard			11.3	8.5	6.9	6.2	5.5	5.0	4.7
	Extra Quality			Inf.	12.9	9.5	8.0	7.0	6.2	5.7
18"	Standard				9.9	7.9	6.9	6.3	5.6	5.3
	Extra Quality				19.2	11.5	9.7	7.5	7.2	6.7

*Inf. = infinity

^{1/} Reference: Based on Marston's formula.

(4) Tile Spacing

The spacing between laterals should vary according to soil types. The following spacings are general recommendations. These may be varied according to local experience as specified in Technical Guides.

RECOMMENDED TILE SPACING FOR VARIOUS SOILS

Soil	Permeability	Spacing
Clay and clay loam	Very slow	30 to 70 ft.
Silt loam	Slow to moderately slow	60 to 100 ft.
Sandy loam	Moderately to rapid	100 to 300 ft.
Muck and peat	---	80 to 200 ft.

f. Tile Grade Limitations

There are both maximum and minimum grade specifications for drain tile that are considered good drainage practice.

(1) Minimum Recommended Grades For All Tile Lines

4 inch, 5 inch, and 6 inch tile	- 0.1 percent
8 inch and 10 inch tile	- 0.08 percent
Larger size tile	- 0.05 percent

In sandy soils the minimum allowable grade should produce a velocity of at least 2 feet per second.

(2) Maximum Grades For Tile Lateral

(a) The maximum grade for tile laterals frequently must vary with topographic conditions and it is not always possible to adhere to a specified maximum grade. Single laterals are not likely to give difficulty due to steepness of grade under most soil conditions (excepting fine sandy soils), provided the line is not overloaded; furthermore, failure of a single lateral is not so serious as it affects only one line. Tile sizes should be carefully determined for adequate capacity. If there is a change from a steep to a lesser grade the size of tile may need to be increased to provide adequate capacity. In fine sandy soils the maximum grades for laterals need more careful consideration and special construction precautions as outlined below under tile mains in sandy soils are applicable.

(3) Maximum Grade For Tile Mains and Sub-Mains (excepting in fine sandy soils)

The following maximum grade specifications apply to all soils except fine sandy soils which are treated separately below:

(a) Where tile mains and sub-mains are designed for near-capacity flow and installed without special construction features, the maximum grade should be one percent. This may be increased to two percent provided the tile are laid without a gap between the joints and clay is tamped thoroughly under and around the tile. Where the line is designed for capacity 50% greater than the estimated tile flow and special construction precautions as mentioned above are used, the grade may be increased to four percent.

(b) Where the slope exceeds two percent and the tile main is designed for near-capacity, sealed bell-type tile should be used.

(c) A breather should be installed at or near the beginning of a steep section of the main. A relief well should be provided at the point where the steep section changes to a flat section, unless the capacity of the flat section exceeds the capacity of the steep section by 25%. Figure 11.32, page 11-80.

(4) Maximum Grade For Tile Mains in Sandy Soils

Because of the lack of cohesiveness of the sand particles, tile laid in sand on any appreciable grade are likely to cause trouble because the free water entering the joints carries the sand particles with it. Also, irregularities in tile joints cause disturbed flow in the tile. As velocity increases on steeper grades turbulence becomes greater with the result that a hole may develop on the outside of the joint which may cause shifting and blocking of the tile line. Consequently, in sandy soil conditions tile mains should not be laid on grades steeper than one percent unless bell-type or tongue and groove-type tile are used. Even on grades under one percent special precautions in construction are desirable such as the following:

(a) Use only good quality tile, uniform in shape and size with smooth ends so that the closest possible joints can be made.

(b) The wrapping of the joints with tar roofing paper or similar material is frequently resorted to under extreme conditions. Other methods are to use slough grass, straw, or similar material as a filter around the tile to keep out the sand.

(c) It is important to blind the tile with topsoil to a

minimum depth of 12 inches immediately after placing to preserve grade and alignment. The trench should not be backfilled further until the free water has been removed and the tile have become stabilized.

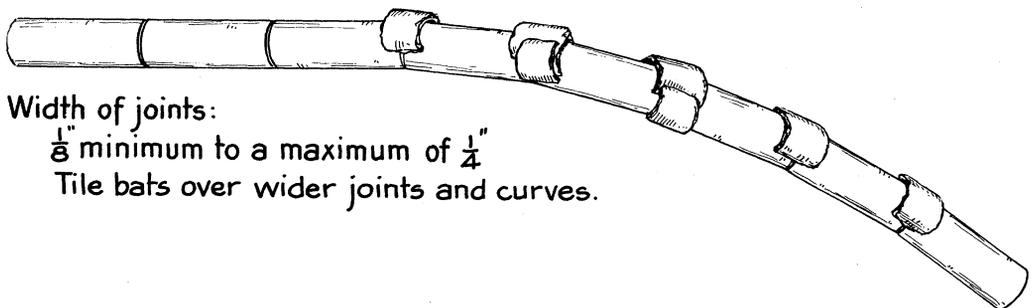
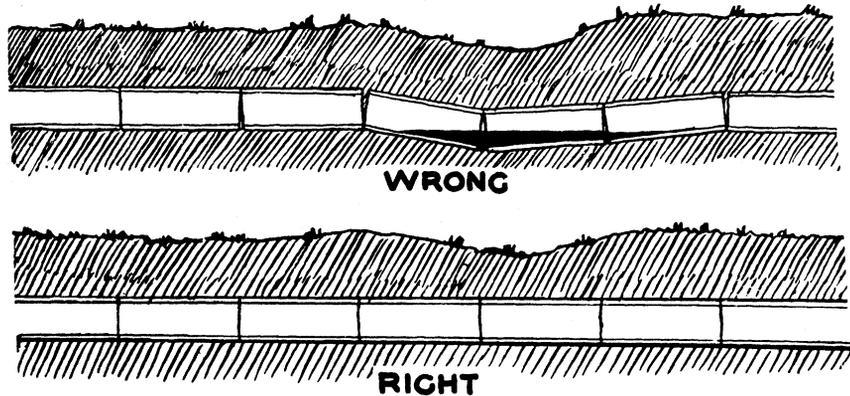
(d) The more complicated problems involving tile placement in quicksand are not discussed here because it is beyond the scope of this handbook. For these, as well as other unusual sand conditions, consult an engineer for recommendations.

g. Miscellaneous Specifications For Tile Systems

The following additional specifications are important and should be considered a part of the construction specifications:

(1) Alignment

Curves in mains or lateral lines should have a minimum radius of 50 feet. Where the gap between tile on the outer side of a curved line exceeds $\frac{1}{4}$ inch in clay soils and $\frac{1}{8}$ inch in sandy soils it should be covered with broken pieces of tile, Figure 11.26. However, at the junction of tile laterals



Width of joints:

$\frac{1}{8}$ " minimum to a maximum of $\frac{1}{4}$ "

Tile bats over wider joints and curves.

FIGURE 11.26 CORRECT METHODS OF LAYING TILE

with mains this curvature is not necessary and the laterals may enter at right angles. Use a manufactured "T" or other approved method of making the connections. See paragraph 11.75h(2), page 11-77. To compensate for the possible loss of head for a right-angle junction, an additional drop of 0.1 or 0.2 foot can be planned for the last 25 to 50 feet of the lateral where it enters the main.

(2) Connections

Manufactured connections or branches for joining two tile lines are recommended, Figure 11.27.

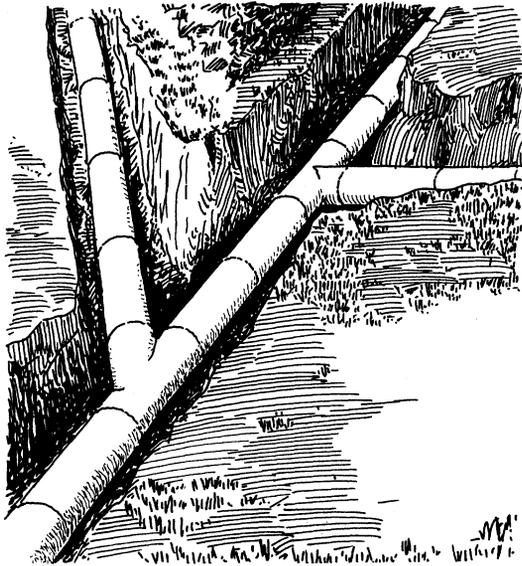


FIGURE 11.27 TILE JUNCTION USING Y AND T CONNECTIONS

If connections are not available, the junction should be chipped and fitted and the connection sealed with mortar. Laterals should be connected into the main tile at the midpoint.

(3) Joints

The gap between tile should be about $1/8$ inch unless the soil is sandy; then the width of the gap should be reduced to a tight fit. When the gap exceeds $1/8$ inch in sandy soils and $1/4$ inch in clay soils the opening should be covered with pieces of broken tile carefully placed or wrapped with heavy tar roofing paper. In sandy soils roofing paper is preferable.

(4) Blinding

As soon as the tile are placed and inspected they should be "blinded" by covering them to a depth of 6 to 12 inches with

loose mellow topsoil shaved from the sides of the trench. All tile should be blinded by the end of the day's work. In tight soils a layer of several inches of gravel spread over the tile before blinding prevents the joints from sealing and facilitates drainage. Hay, straw, corncobs, and similar material can be used as a substitute covering over the joints but its period of usefulness is limited.

(5) Crossing Waterways and Roads

Special precautions should be taken where tile are placed under waterways or roads. If the cover over the tile is 2.5 feet or less, one of the following practices should be followed:

- (a) Encase the drain tile in concrete.
- (b) Use extra strength sewer tile with the joints cemented.
- (c) Use continuous metal pipe.

See Figure 11.42, page 11-91 for details.

h. Appurtenances to Tile Systems

All tile systems require certain appurtenances that are essential to successful functioning. The various appurtenances are outlined below. These should be used and considered a part of the specifications when applicable.

(1) Surface Inlets

Surface inlets should be used in low areas to remove excess water where surface drainage is not provided. See Figure 11.29, page 11-76. Unless properly constructed, surface inlets will wash out and considerable silting of the tile line will result. Never use surface inlets, however, if it is possible to drain the area by means of a surface relief ditch. This is especially necessary in areas where movement of silt to the ponded area and thence into the open inlet is a problem. In these cases a blind inlet, Figure 11.28,

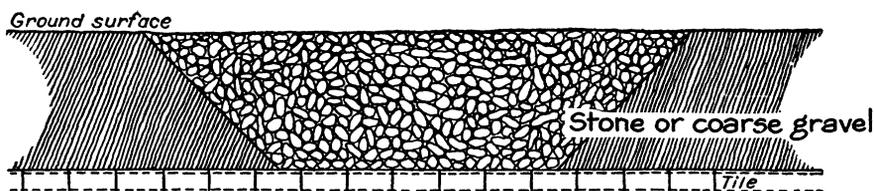


FIGURE 11.28 BLIND INLET TO TILE LINE

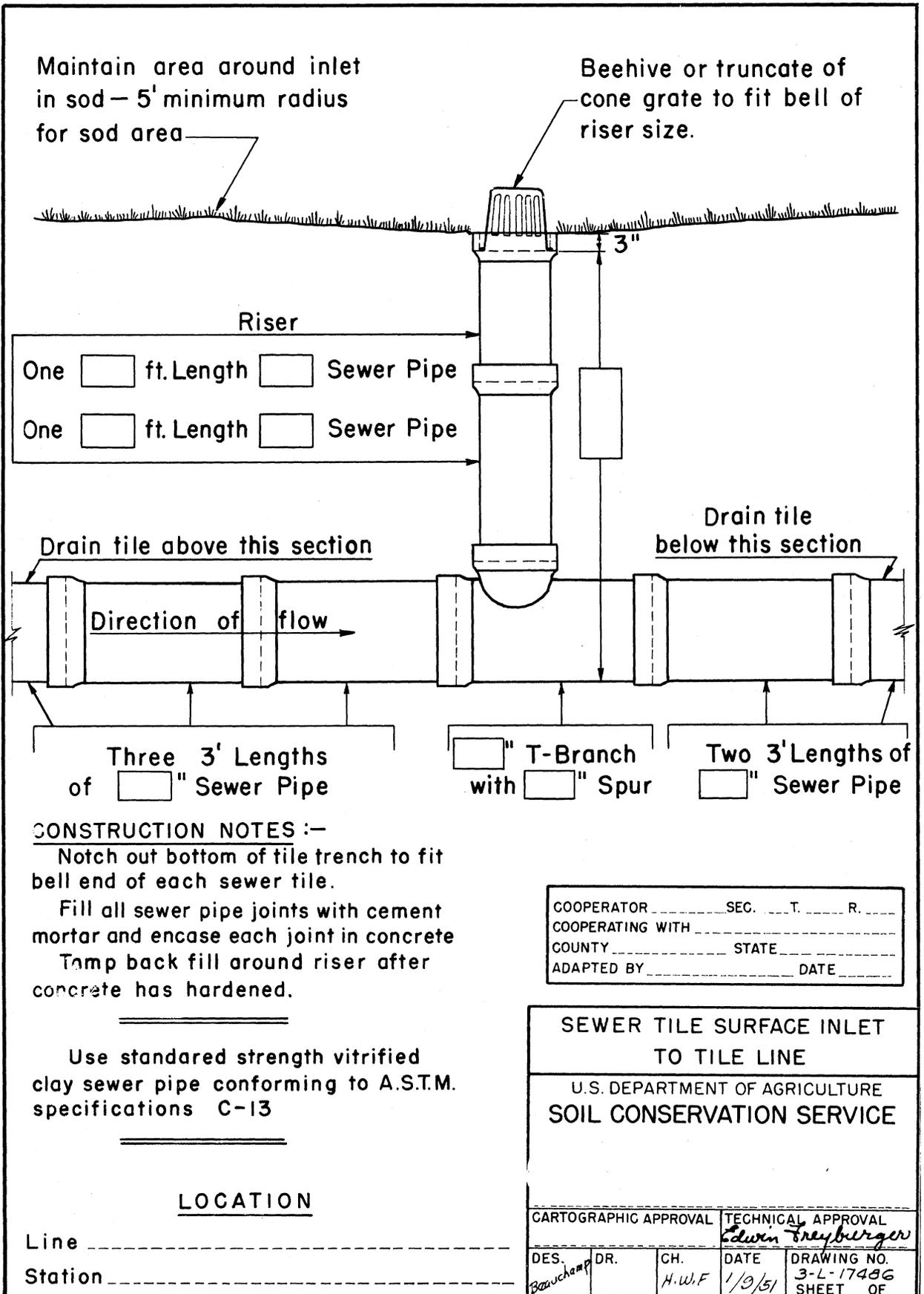


FIGURE 11.29 SURFACE INLET TO TILE LINE

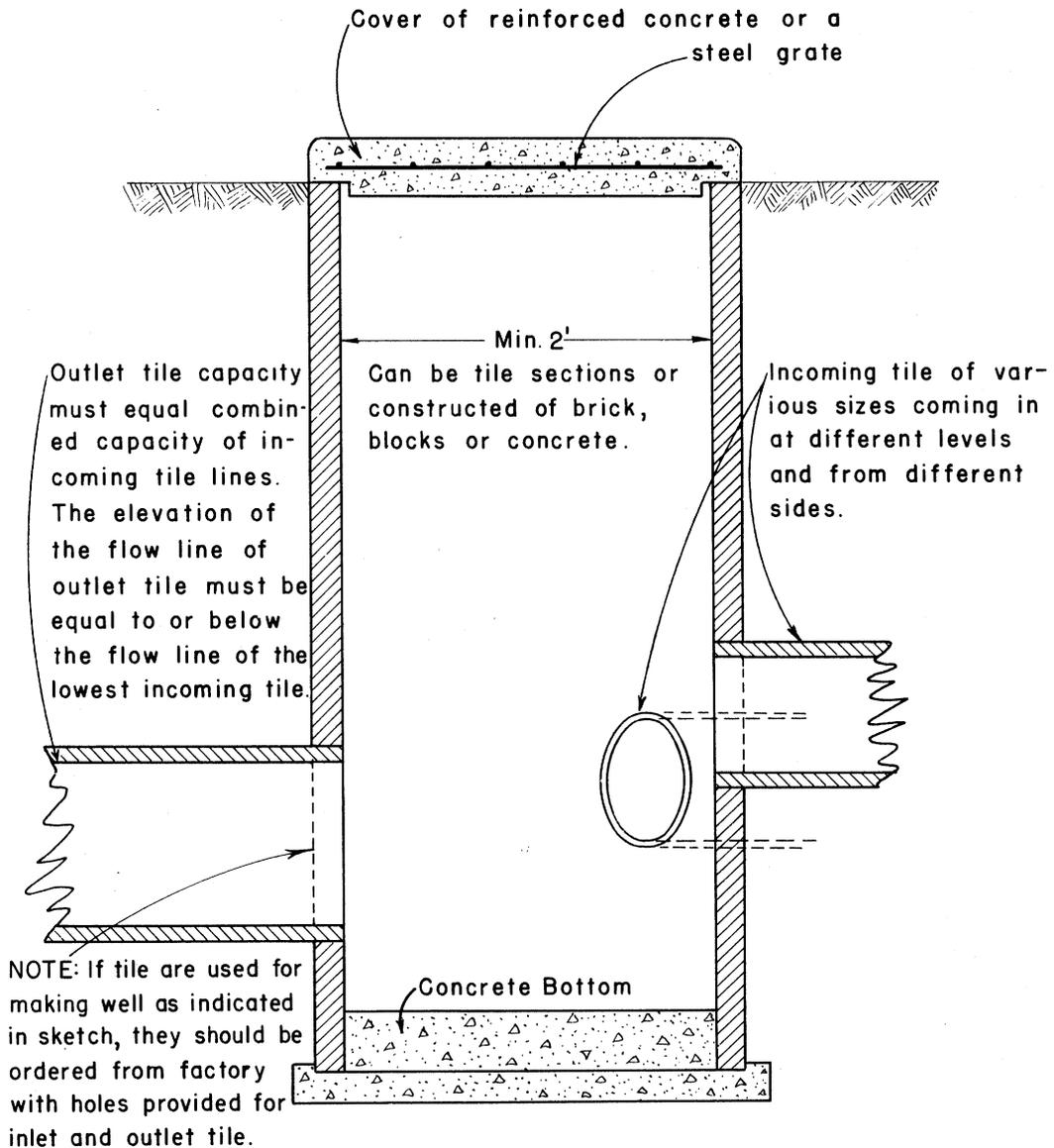


FIGURE 11.31 JUNCTION BOX FOR TILE LINES

(3) Breathers and Relief Wells

Breathers or vents should be provided approximately every 1/4 mile on long tile mains. They should be located where the tile lines cross permanent fences.

The primary function of relief wells is to relieve pressure in the tile line that might otherwise cause it to blow out. Relief wells should be used where the steep section of a tile line changes to a flat section unless the capacity of the flat section exceeds the capacity of the steep section by 25 percent. They should also be used on lines that have

surface inlets and particularly below large surface inlets. See Figure 11.33, page 11-80.

(4) Tile Outlet Protection

Where tile mains outlet into an open ditch the end of the tile should be protected. If surface water enters the outlet ditch at the same location as the tile, some type of structure is necessary. Where there is no surface water a section of metal pipe at least 16 feet long should be installed with approximately two-thirds of its length embedded into the ditchbank, and the overhanging length discharging just beyond the toe of the ditch slope, Figure 11.34, page 11-81. Swinging gates or some type of screen on all outlets should be used to exclude rodents or other animals unless the outlet is located so that it would be impossible for rodents or other animals to enter the tile at the outlet end, Figure 11.35, page 11-82 and Figure 11.36, page 11-83. Where there is insufficient cover at the outlet end of the tile this condition should be handled by one of the methods shown in Figure 11.42, page 11-91.

i. Estimating Tile Installation Costs

Figure 11.32 gives the tile requirements for different spacing.

DRAIN TILE SIZE & WEIGHT DATA				TILE REQUIRED/ACRE	
Inside Dia. Inches	Outside Dia. Feet	Approx. Wgt. per Foot	Average Wgt. Feet/Carload	Feet Spacing	Feet Required per Acre
4	0.42	7#	5,700	20	2,178
5	0.51	11	3,600	25	1,742
6	0.59	12	3,300	30	1,452
8	0.79	17½	2,000	33	1,320
10	0.97	27½	1,300	40	1,089
12	1.17	37½	930	50	872
14	1.34	47	780	66	660
15	1.43	53½	650	80	545
16	1.54	62½	560	100	436
18	1.71	74	470	150	291
20	1.88	84	420	200	218
22	2.08	108	320		
24	2.29	132	260		
26	2.48	154	230		
28	2.69	174	200		
30	2.88	211	170		

FIGURE 11.32 DRAIN TILE INFORMATION

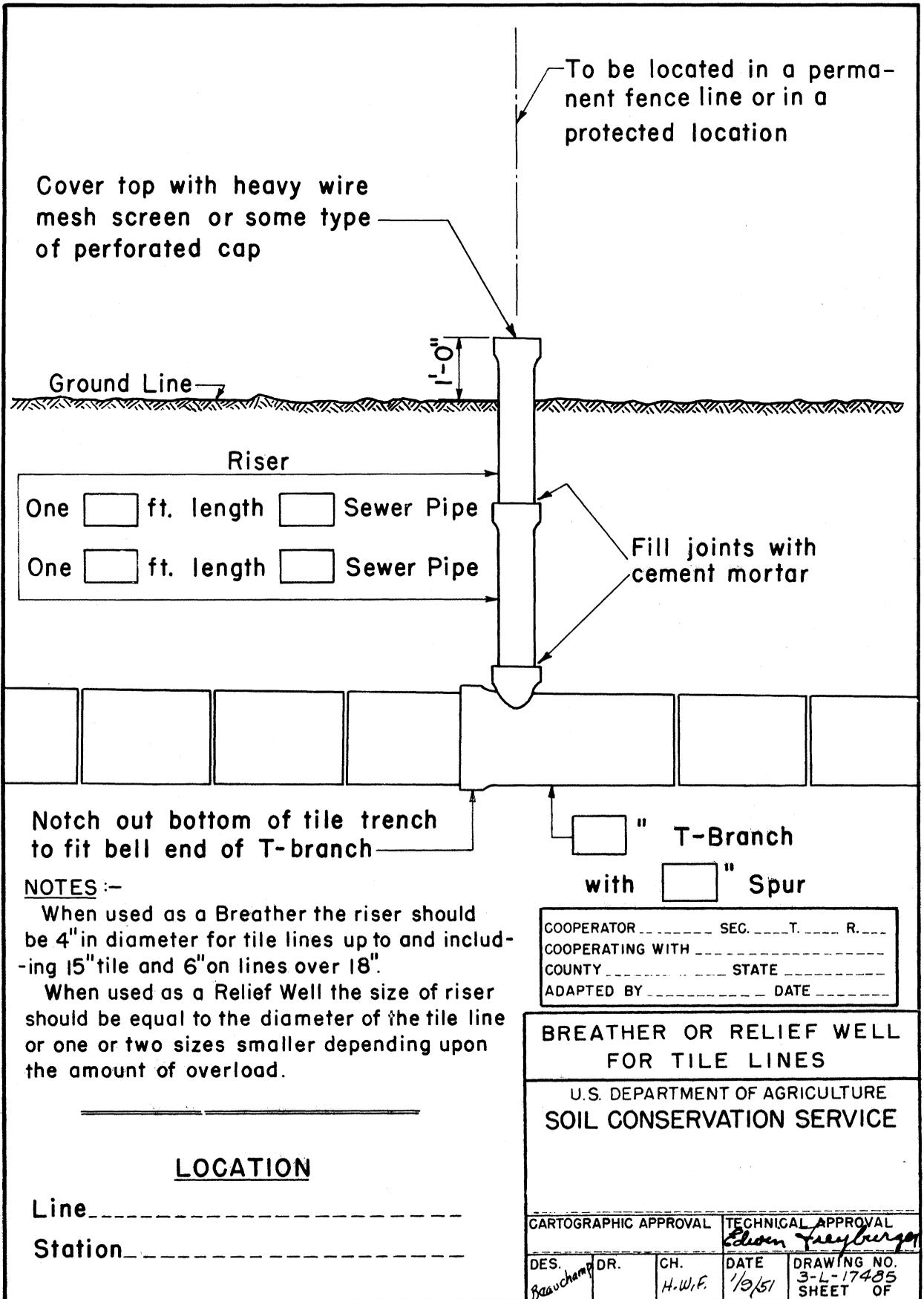
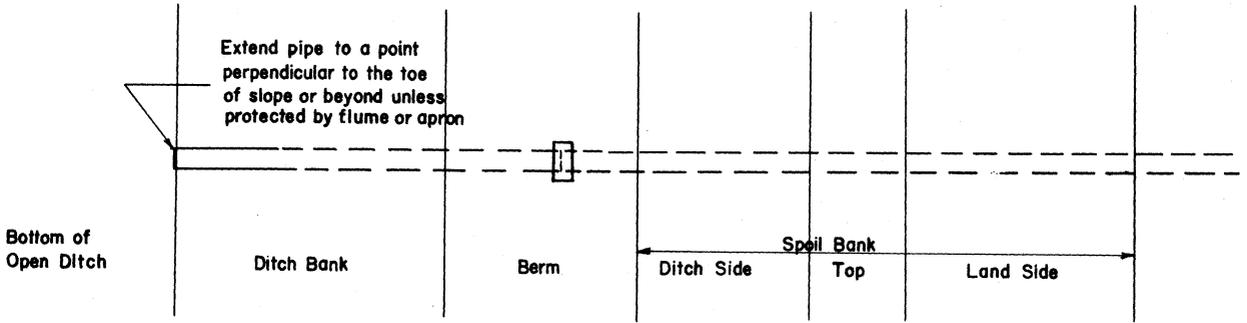
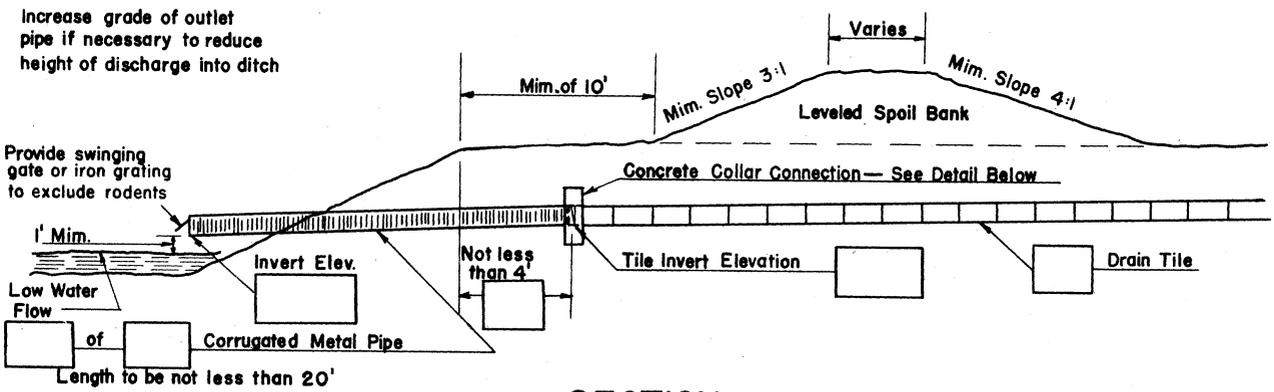


FIGURE 11.33 BREATHER OR RELIEF WELL FOR TILE LINES

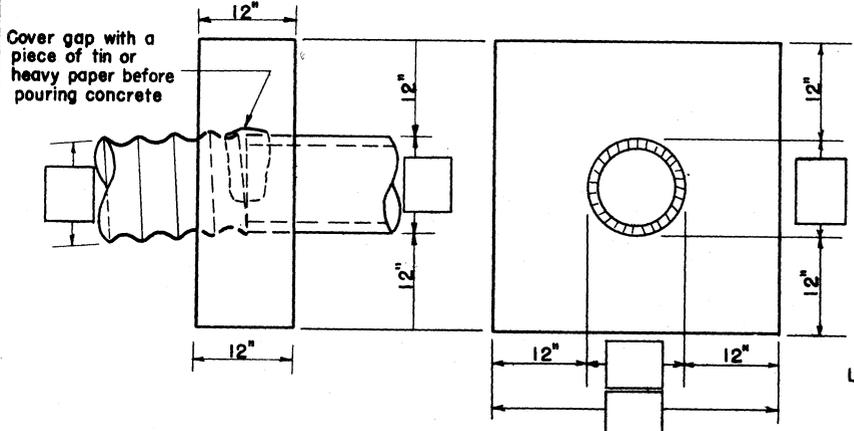


PLAN

Scale: 1" = 5'



SECTION



DETAIL-CONCRETE COLLAR

Note:
For detail plans of device to exclude rodents from end of pipe see Drwg. No. _____

_____ Cu. yds. of concrete required for collar.

LOCATION; MAIN _____

COOPERATOR _____	SEC. _____	T. _____	R. _____
COOPERATING WITH _____			
COUNTY _____		STATE _____	
ADAPTED BY _____		DATE _____	

CORRUGATED PIPE OUTLET FOR TILE DRAIN

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
DESIGNED BY _____	DRAWN _____	CHECKED _____	DATE _____
DRAWING NUMBER		SHEET 1 OF 1	

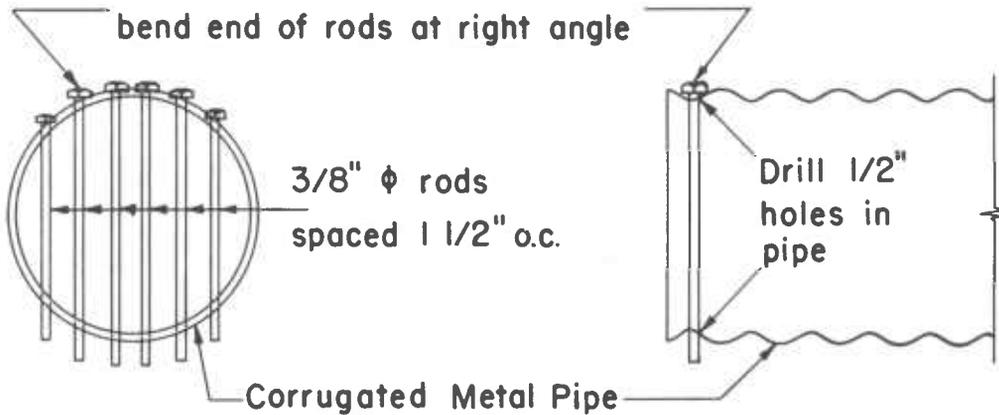
Note:
If ice and floating debris are a problem the corrugated pipe should be placed at about a 30° angle downstream instead of outletting perpendicularly to the stream as shown.

If corrugated pipe is placed on steeper slope than tile, same size may be used. Use pipe 2" larger than tile if on same slope.

FIGURE 11.34 CORRUGATED PIPE OUTLET FOR TILE DRAIN



Thread and use 3/8" square nut or bend end of rods at right angle



END VIEW

ELEVATION

MATERIAL



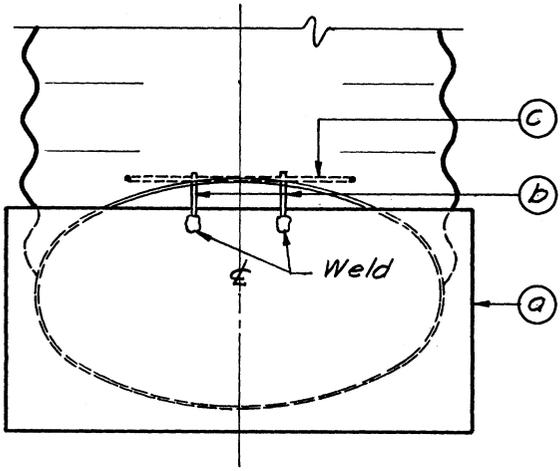
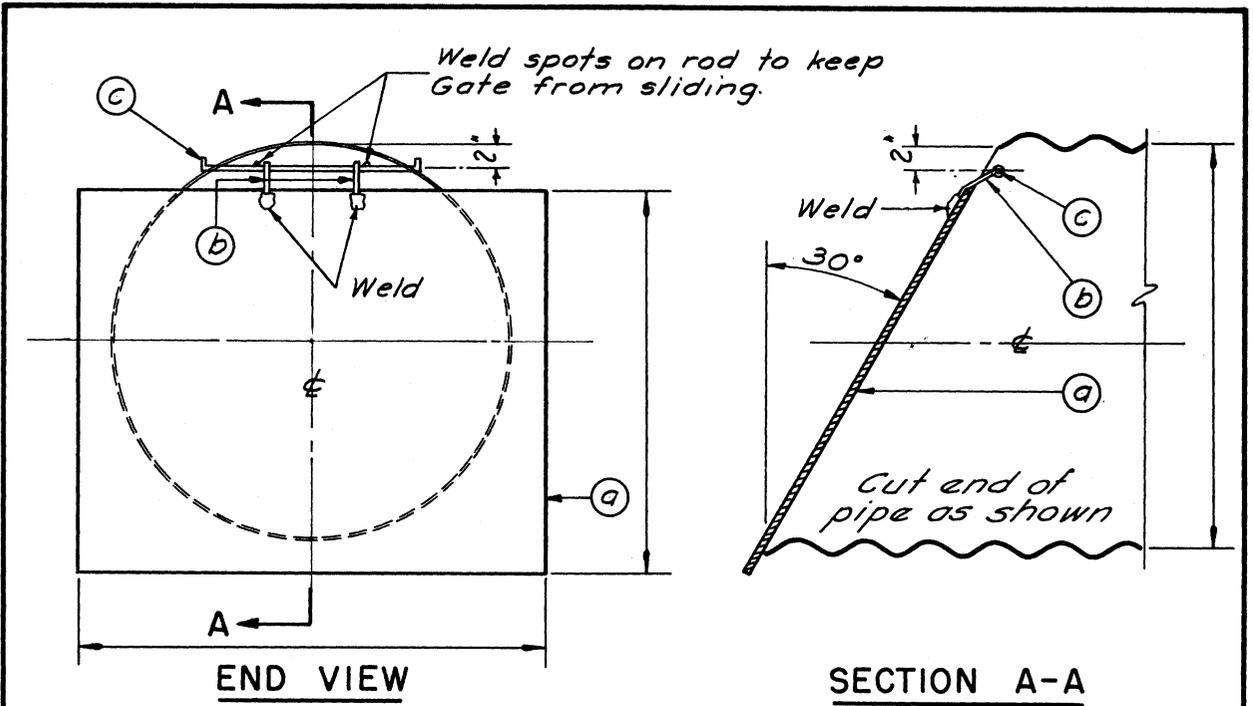
Feet of 3/8" ϕ rod

LOCATION _____

GRATING FOR END OF TILE OUTLET PIPE			
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL <i>Erwin Freyburger</i>	
DES. <i>Beauchamp</i> DR.	CH. <i>H.W.F.</i>	DATE <i>1/9/51</i>	DRAWING NO. <i>3-L-24526</i> SHEET OF

COOPERATOR _____	SEC. _____	T. _____	R. _____
COOPERATING WITH _____			
COUNTY _____	STATE _____		
ADAPTED BY _____	DATE _____		

FIGURE 11.35 GRATING FOR END OF TILE OUTLET PIPE



- (a) Steel Plate 1/8" to 3/16" thick.
- (b) Eye bolts to be welded to Gate
- (c) 3/8" Rod to be bent at each end.

Revised 12/5/51

No Scale

NOTE: The gate can either be a solid plate or made up of rods.

"HOMEMADE" TILE OUTLET GATE

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

REFERENCE:				
CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL:		
		<i>Edwin Freyburger</i>		
COMPILED:	TRACED:	CHECKED:	DATE	DRAWING NO.
OSCAR SMITH	D. F. LEDSKI	PAUL JONES	7-24-50	3-L-24035

COOPERATOR _____ SEC. _____ T. _____ R. _____

COOPERATING WITH _____

COUNTY _____ STATE _____

ADAPTED BY _____ DATE _____

FIGURE 11.36 "HOMEMADE" TILE OUTLET GATE

By determining the number of tile required per acre and by using local costs for tile, digging, and laying, a reasonably accurate estimate of the cost per acre can be determined.

11.76 Constructing Tile Systems

a. Selecting Drain Tile

Only first-grade tile should be used in tile systems. The tile should be free from chips or cracks that would decrease the strength materially and when dry they should give a clear ring if stood on end and tapped with a light hammer. The American Society of Testing Materials has prepared specifications for drain tile. These specifications are available upon request and it is good practice in making purchases to stipulate that the tile furnished meet these specifications. Either clay or concrete tile are satisfactory under normal soil conditions; however, under acid or strongly alkaline conditions clay tile are generally more satisfactory since some concrete tile disintegrate under these conditions. Concrete tile should be made with proper proportion of cement, well graded, clean sound aggregate, and water well mixed and adequately compacted. Proper curing of the concrete after manufacture (30 days is recommended) is essential before the tile are laid so that they have sufficient strength to support the back fill.

b. The Tile Plan

Some sort of a tile plan should be made of every tile layout. For very simple jobs such as single laterals or wet draws this may be an "as constructed plan," such as Figure 11.37, page 11-85. But where entire parts of a field are to be drained a more economical and satisfactory installation will result if the entire system is planned in advance. An example of a tile plan prepared on a standard data sheet is given in Figure 11.38, pages 11-86 and 11-87. The use of this data sheet will greatly facilitate preparation of plans of the smaller tile installations.

c. Equipment For Laying Tile

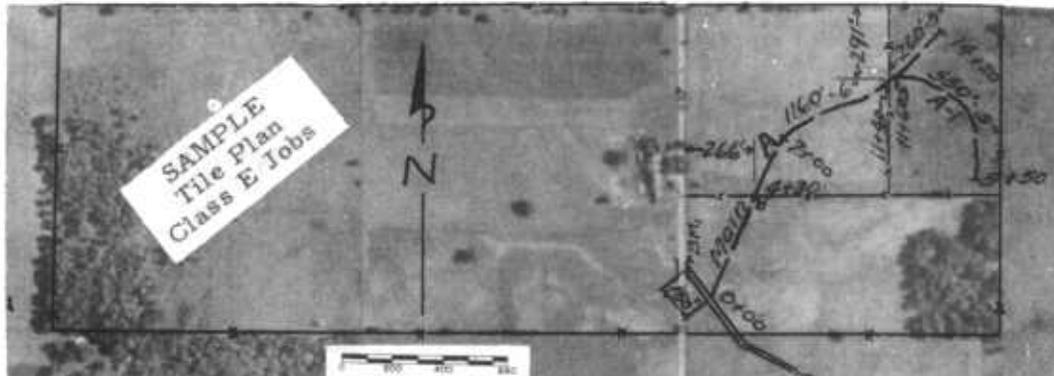
The tools most commonly used in trenching and laying tile by hand are tile spades, shovel, drain scoop, and tile hook. See Figure 11.39, page 11-88. Tile systems involving several thousand tile usually are installed by machine.

d. Laying Tile

Extreme care should be taken in staking tile lines, setting grade stakes, placing the tile, and checking the line afterwards.

(1) Grade Stakes

Grade stakes should be set every 50 feet if tiling is to be done from a string line. If string is used, a weight should



MAIN "A"					
Sta.	Elev.Grnd.	Elev.Grade	Cut	Tile Grade	
Outlet Ditch		427.32			Ditch bottom Tile 6"
0/00	433.00	428.80	4.20	0.20%	
1/00	433.00	429.00	4.00	↓	
2/00	433.45	429.20	4.25		
3/00	433.30	429.40	3.90		
4/00	433.47	429.60	3.87	0.20	
5/30					E-W Fence
5/00	433.78	429.90	3.88	0.30	
6/00	434.00	430.20	3.80	↓	
7/00	434.40	430.50	3.80		
8/00	434.65	430.80	3.85		
9/00	434.80	431.10	3.70	↓	
10/00	435.13	431.40	3.73	0.30	
11/00	435.80	431.80	4.00	0.40	
11/60					N-S Fence Junction Lat. A-1; Main A 5" begin
12/00	435.94	432.04	3.90	↓	
13/00	435.95	432.20	3.75		
14/00	436.20	432.60	3.60	↓	
14/60	436.60	433.00	3.60	0.40%	End Main A
15/20	436.58	433.08	3.50		
Lateral A-1 5" Tile					
0/00	435.94	432.09	3.85	0.40%	Enters Main A Sta. 11/60
1/00	436.31	432.49	3.82	↓	
2/00	436.23	432.53	3.70		
3/00	436.27	432.57	3.70		
4/00	436.26	432.61	3.65	↓	
5/00	436.05	432.65	3.40	0.40%	End Lat. A-1
5/50	436.35	432.85	3.50		

B.M. #1 Cross chiseled on Top of N.E. wingwall of concrete bridge approx. 300' S. of Dave Smith residence. Elev. 436.12

Note: Design based on 3/8"/24 hrs.

Farm Dave Smith
 Sec. 34, T. 13N, R. 4W, Lucky Co., State
 Tile placed June, 1946
 Open ditch _____
 Farm boundary fence — X — X — X —
 Interior fence — X — X — X — X —

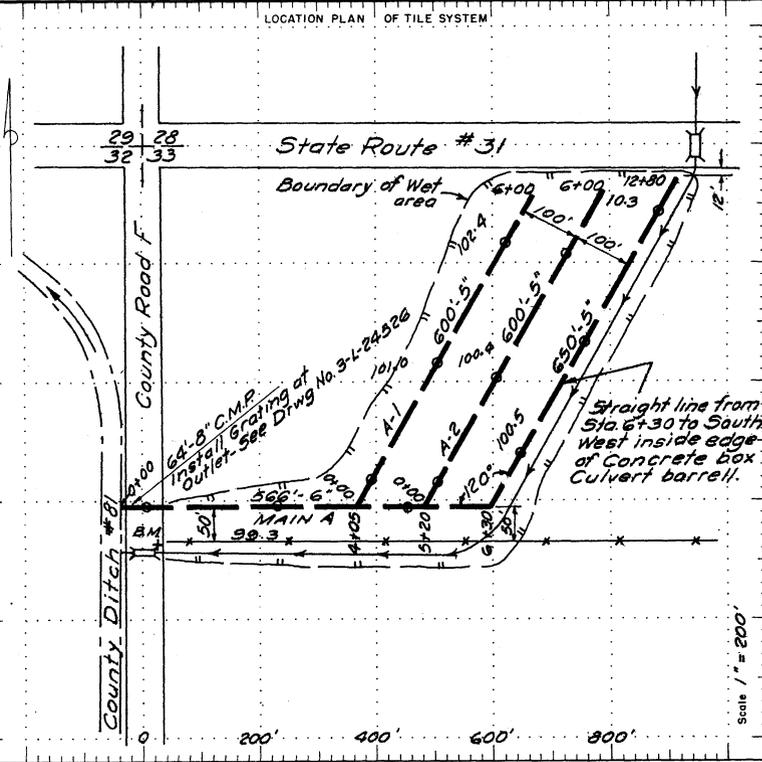
TILE PLAN DAVE SMITH FARM			
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
REFERENCE: FIELD Book #3			
UPPATUM S.C.D. LUCKYVILLE, STATE			
CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL:	
		<i>Jim Bunn P. 2</i>	
COMPILED:	TRACED:	CHECKED:	DATE
<i>J. Jones</i>		<i>Bunn</i>	7/6/46
			DRAWING NO. L-

FIGURE 11.37 SAMPLE TILE DRAINAGE PLAN

FIGURE 11.38 STANDARD DATA SHEET TILE DRAINAGE PLAN (1 OF 2)

Sta.	Cut.	Grade	Tile Size	Sta.	Cut.	Grade	Tile Size	Sta.	Cut.	Grade	Tile Size
MAIN A				LATERAL A-1				LATERAL A-2			
0+4	2.10			0+00	3.60			0+00	3.57		
0+12	4.03			1+00	3.37			1+00	3.38	0.2%	
0+52	3.55			2+00	3.44			2+00	3.32	0.3%	
1+00	3.53			3+00	3.60			3+00	3.87		
2+00	3.58	0.1%		4+00	3.91			4+00	3.77	0.5%	
3+00	3.71			5+00	4.00			5+00	3.47		
4+00	3.53			6+00	4.26			6+00	4.06		
5+00	3.70										
6+00	4.02										
7+00	3.91										
8+00	3.40										
9+00	3.11										
10+00	3.28	0.5%									
11+00	3.38										
12+00	3.52										
12+80	3.73										

SAMPLE
 CLASS "E" PLAN ON
 STANDARD DATA SHEET
 DWG. No. 3-N-26888



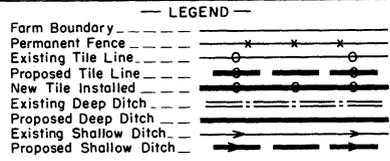
Bench Mark Description: Top of North-east corner of East Concrete headwall of Concrete Box Culvert on County Road F. Assumed Elevation=100.0

Materials: 64' of 8" Corrugated Metal Pipe
 566' of 6" Standard Drain Tile
 1850' of 5" For Grating - 5" of 3/8" round rod
 6" of 3/8" square nuts

SPECIFICATIONS

- Tile shall meet ASTM specifications.
 - Design based on 3/8 in./124 hrs.
 - Min. depth of tile to be 30"
 - Average depth of laterals to be 42"
 - Min. grade of laterals 0.3 ft./100.
 - Gap between tile shall be 1/8"
 - All connections for joining 2 lines must be sealed with mortar unless manufactured connections are used.
 - Tile shall be blinded by covering to a depth of 6" with loose mellow top soil. All tile laid must be blinded by end of days work.
9. Secure permission and specification from County for crossing County Road F.

REGULAR INSPECTION OF THE TILE SYSTEM IS ESSENTIAL. PROMPT REPAIR OF ANY FAILURE WILL KEEP THE SYSTEM IN WORKING ORDER AND MAINTENANCE COSTS LOW.



SECTION 33
 TOWNSHIP 16 N RANGE 12 E
 COUNTY Utopia STATE Blank
 COOPERATOR S.C. Service
 COOPERATING WITH Utopia, S.C.D.
 SURVEYED BY D. Robot 12/10/51

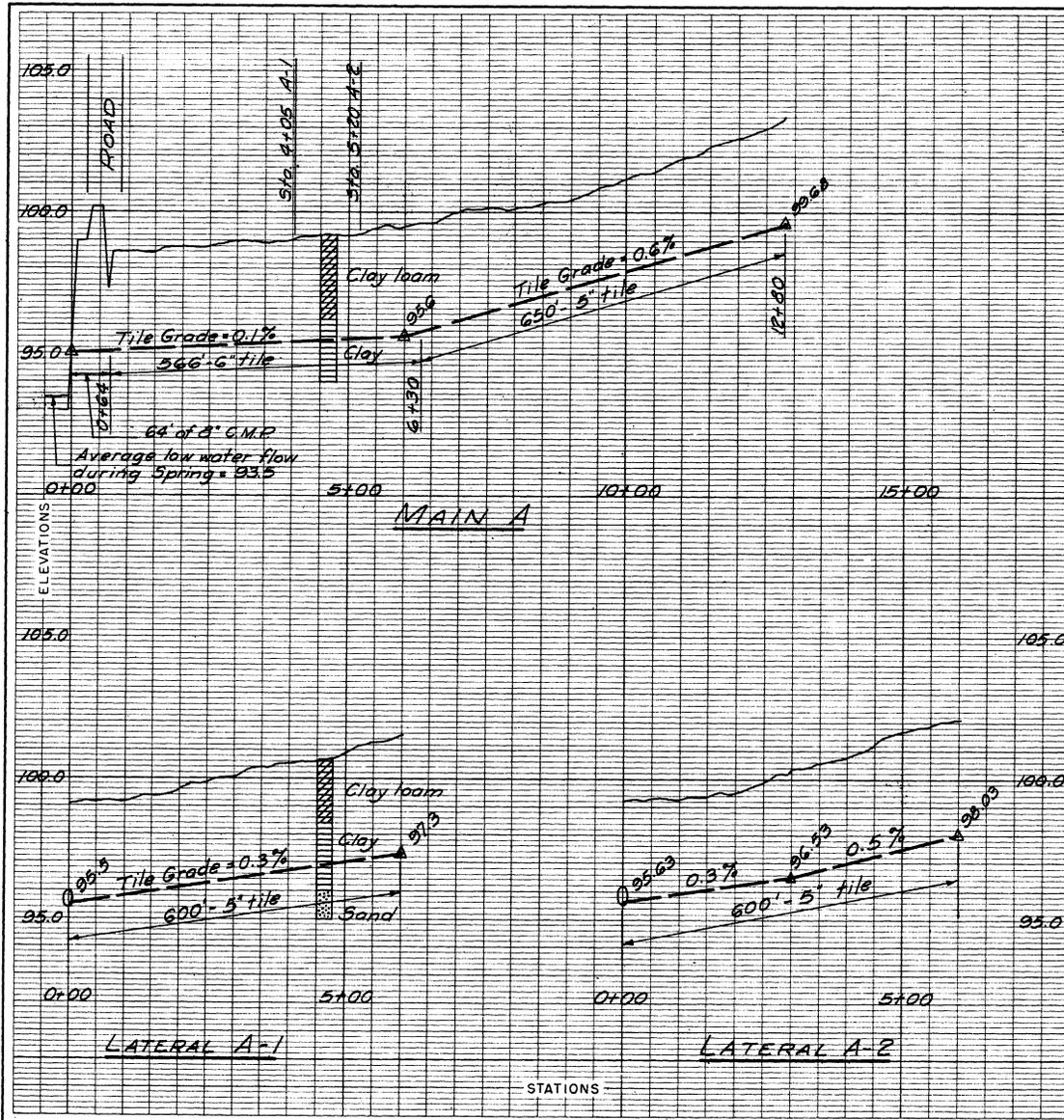
CONSTRUCTION REPORT
 Date Installed June 19, 1952
 Contractor Best Tiling Company
 Staked By D. Robot
 Amount of Tile Installed 566'-8"
1850'-5" 64'-8" C.M.P.

TILE DRAINAGE PLAN
 U. S. DEPARTMENT OF AGRICULTURE
 SOIL CONSERVATION SERVICE

Remarks:
 D. Robot
 6/19/52
 SIGNATURE DATE

CARTOGRAPHIC APPROVAL		TECHNICAL APPROVAL	
A. H. Wood		Edwin Freyburg	
DESIGNED	DRAWN	CHECKED	DATE
			1/10/52
DRAWING NO. 3-N-00000			SHEET 1 OF 2

FIGURE 11.38 STANDARD DATA SHEET TILE DRAINAGE PLAN (2 OF 2)



Sta.	B.S.	H.I.	F.S.	* Elev.	# Tile Bottom	Remarks
			MAIN A			
B.M.				100.0		
	4.84	104.84				
0+00			11.31	93.53		Water level
0+12			5.80	99.04	95.01	Ditch Bank
0+40			4.60	100.24		to Road
0+50			7.52	97.32		Road ditch
0+52			6.24	98.60	95.05	East sideditch
1+00			6.21	98.63	95.1	
2+00			6.06	98.78	95.2	
3+00			5.83	99.01	95.3	
4+00			5.77	99.07	95.4	
5+00			5.64	99.20	95.5	
6+00			5.22	99.62	95.6	
7+00			4.73	100.11	96.2	
			4.51	100.33		
T.P.	5.98	106.31				
8+00			6.11	100.20	96.8	
9+00			5.80	100.51	97.4	
10+00			5.03	101.28	98.0	
11+00			4.33	101.98	98.6	
12+00			3.59	102.72	99.2	
12+80			2.90	103.41	99.68	
			6.11	100.20		
T.P.	5.62	105.82				
			LATERAL A-1			
0+00			6.72	99.10	95.5	0+00=4+05
1+00			6.65	99.17	95.8	
2+00			6.28	99.54	96.1	
3+00			5.82	100.00	96.4	
4+00			5.21	100.61	96.7	
5+00			4.82	101.00	97.0	
6+00			4.26	101.56	97.3	
			LATERAL A-2			
0+00			6.62	99.20	95.63	0+00=5+20
1+00			6.51	99.31	95.93	
2+00			6.27	99.55	96.23	
3+00			5.42	100.40	96.53	
4+00			5.02	100.80	97.03	
5+00			4.12	101.70	97.53	
6+00			3.73	102.09	98.03	
			5.80	100.02		Check on BM - OK
* Elev. is top of hub which is about 0.1' above the ground.						

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

COOPERATOR S. C. Service

COUNTY Utopia STATE Blank

SHEET 2 OF 2 DRAWING NO. 3-N-00000

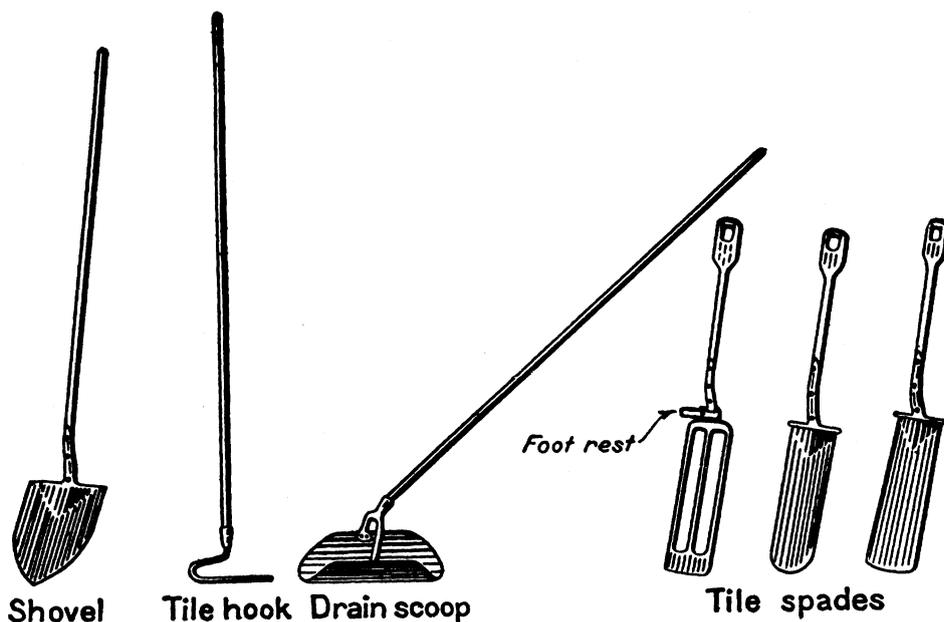


FIGURE 11.39 TILE DRAINAGE TOOLS

be tied to each end and hung over the support, so that the string is tight at all times. If the target method is used or a tiling machine, grade stakes can be set at 100-foot intervals. Always have three targets set ahead of the machine. Grade stake lines usually are offset from two to four feet from the centerline of the tile. A method of setting grade for hand dug trench is shown in Figure 11.40, page 11-89.

(2) Placing Tile

In hand trenching the bottom of the tile trench should be shaped with a drain scoop (Figure 11.39), so that about one-quarter the circumference of the tile is laying on solid ground. Tiling machines shape the trench properly as a part of the trenching operation. Where tile are laid through unstable pockets of soil use additional construction features. Depending on the seriousness of the condition, one of the following should be placed in the bottom of the trench before laying the tile: stable soil, coarse hay, straw, tough sod, crushed limestone, or cradle the tile. Where cradling is used the rail and cleat method should be used as shown in Figure 11.41, page 11-90.

Correct methods of laying tile are given in Figure 11.26, page 11-73. The importance of these suggestions is obvious.

(3) Protection During Construction

At the end of each day's work the end of the tile line being

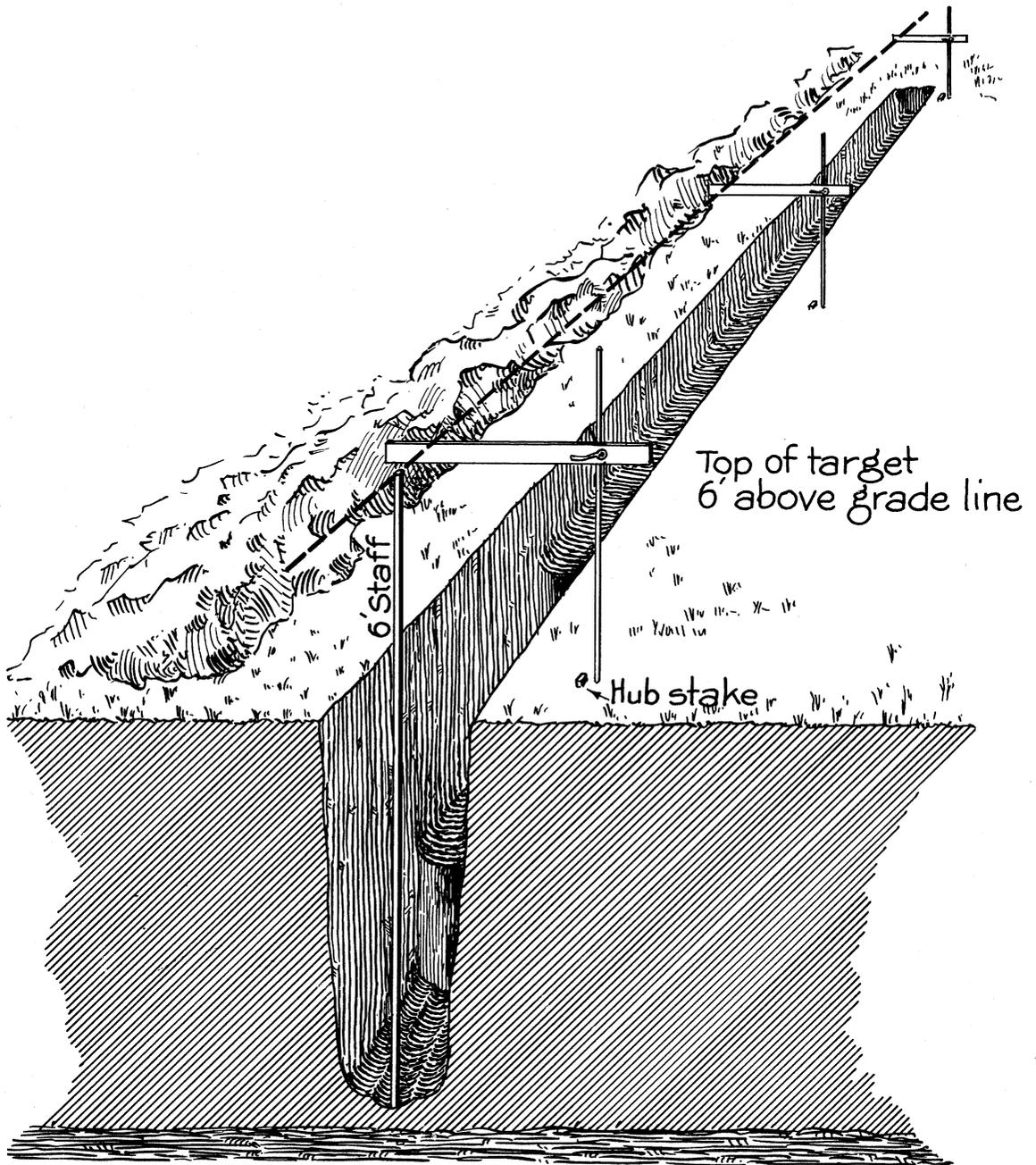


FIGURE 11.40 METHOD OF USING TARGETS FOR LAYING TILE

placed shall be completely closed by a wooden or metal plate or some other device to prevent silt or debris from entering the line in the event of rain. Upon completion of the line, the end of the tile should be closed tightly with a plate, brick, pieces of tile, or some other suitable material.

(4) Checking Tile

Be sure to check with a surveyor's level all flat grades, all breaks in grades, and all turns after the tile has been

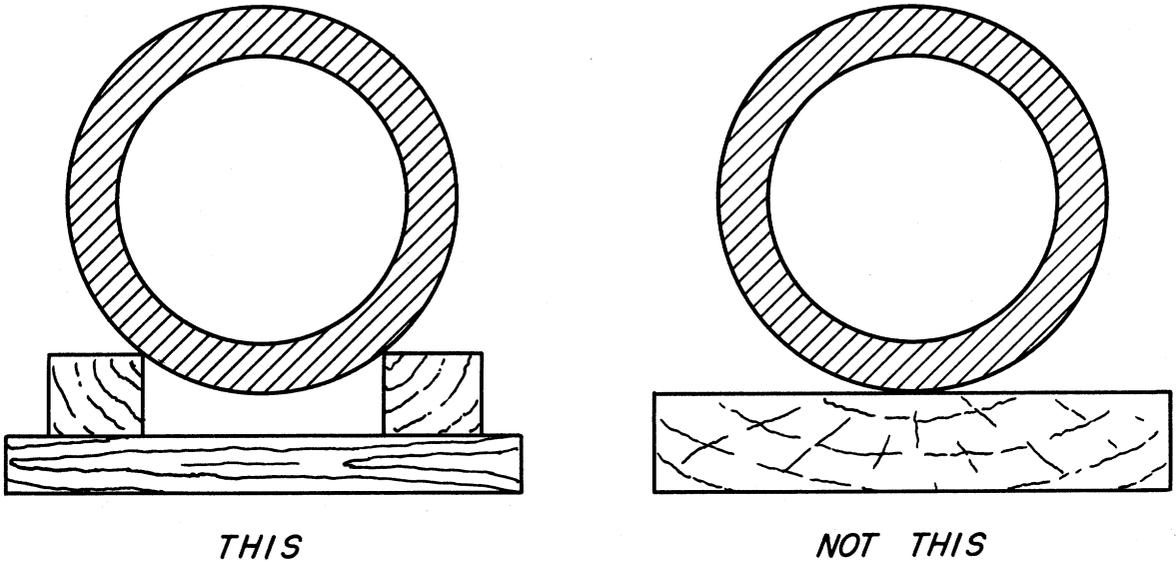


FIGURE 11.41 CRADLING TILE IN UNSTABLE SOILS

installed. Do this after the tile has been laid and before the trench is backfilled.

(5) Blinding the Tile

Follow specifications given in Part 11.75g(4) for blinding tile. Never leave a line of tile exposed over night without blinding, as surface water from a heavy rain could do considerable damage to the newly laid line. This is true even though the tile have not been checked, as checking can be done through the blinding material.

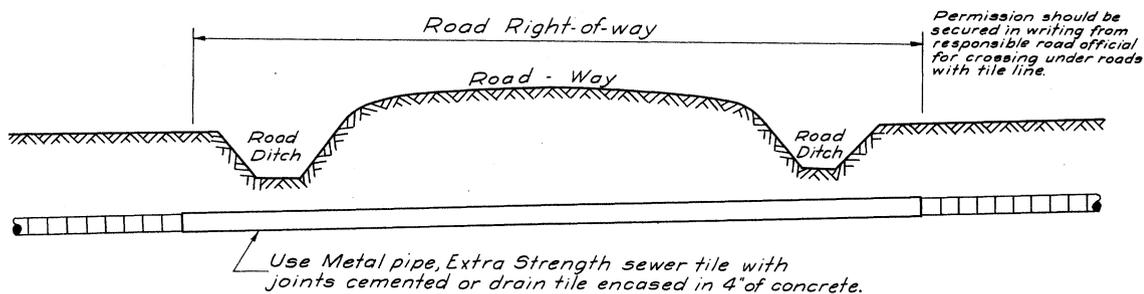
11.77 Maintenance of Tile Drainage Systems

Tile drainage systems do not require extensive maintenance but the maintenance that is required is extremely important. One broken tile will stop up an entire line. Many tile systems and frequently parts of farms have been destroyed because of neglect of the outlets. The outlet should be kept free at all times. If erosion is occurring at this point, due to tile water, immediate steps should be taken to correct the situation.

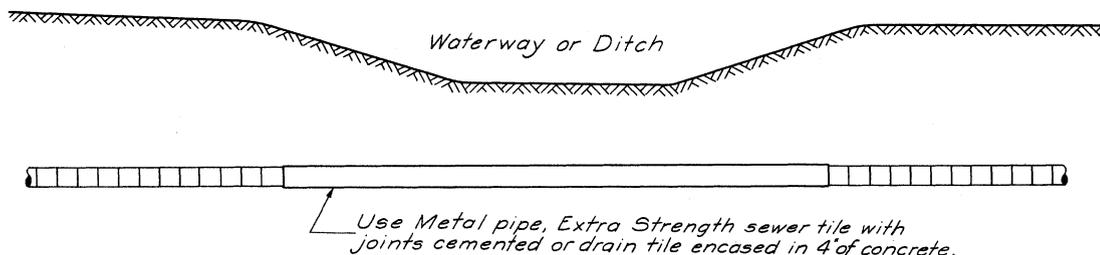
11.78 Don'ts in Tile Drainage

- a. Do not attempt to install a drainage system on flat lands without surveying the lines and working from grade stakes.
- b. Do not lay soft or inferior quality of tile. All tile should conform to "American Society for Testing Materials" specifications for farm drain tile.
- c. Do not establish an outlet for a tile system in a ditch or stream at such a depth that it will be submerged during ordinary low water flow.

TILE LINE CROSSING UNDER ROAD



TILE LINE CROSSING UNDER WATERWAY OR DITCH



METHODS FOR HANDLING SHALLOW DEPTHS AT TILE OUTLET

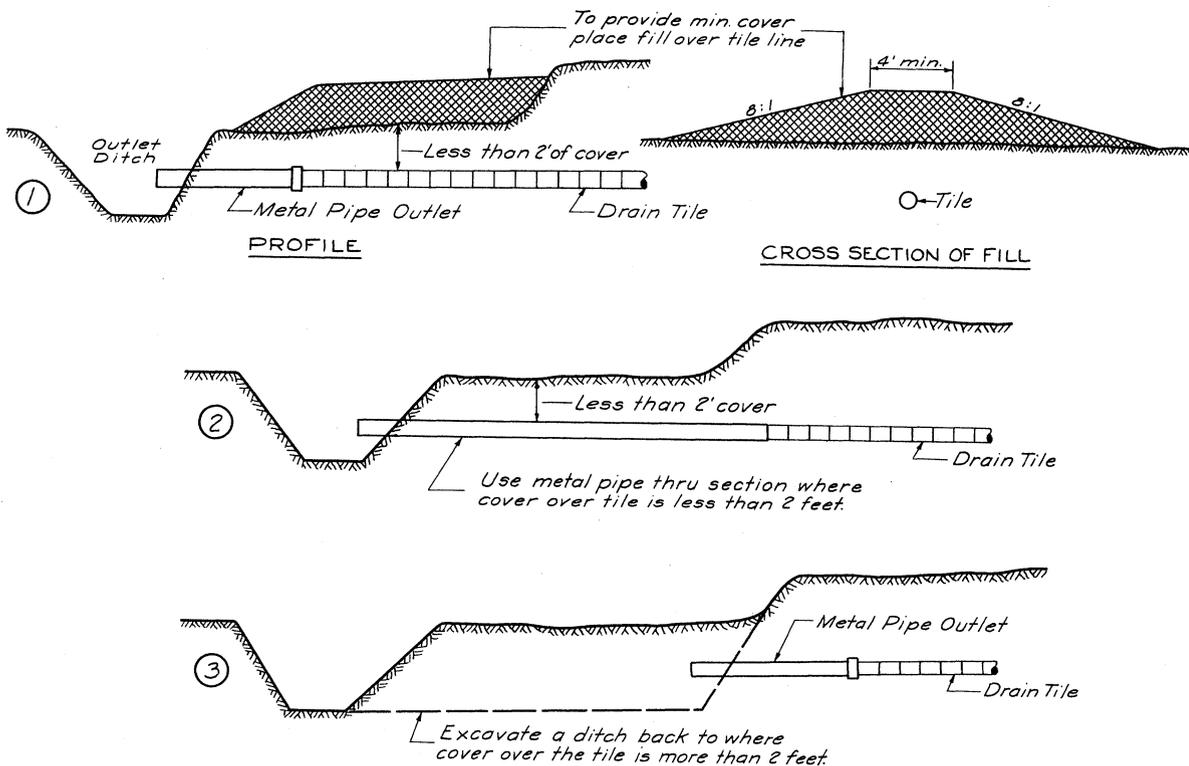


FIGURE II.42 TILE LINE CROSSINGS AND HANDLING SHALLOW TILE OUTLETS

- d. Do not extend a tile line into an open ditch without proper protection. Either install a section of pipe or an outlet structure. This will prevent erosion and washing of the tile line back into the field.
- e. Do not fail to provide a "flap gate" or other adequate protection on the outlets of tile 10 inches or over in diameter. This is to prevent animals of various sorts from hiding or denning in the line.
- f. Do not lay tile in a trench with a flat bottom. The bottom should be rounded with "drain cleaner," a special tool to fit the outer circumferences of the tile wall.
- g. Do not make joints too tight between tiles in heavy clay soils as all water must enter the tile at the joints; nor should joints be left too open in sandy or silty soils. In the former instance joints may become sealed with clay and water will not enter; in the latter, too much soil may enter joints and eventually fill tile lines.
- h. Do not attempt, as a general rule, to join the lines together without using special junctions called "Y's" or "T's." Make-shift junctions formed by breaking and fitting tile together very often leave cracks that will eventually cause holes to appear in the fill over the lines at such junctions.
- i. Do not think tile can be laid in fine sand, quicksand, or muck, without special provisions for keeping this material out of the tile. Only an experienced tile layer can handle construction under such conditions.
- j. Do not install long lines of tile, 1,000 feet or over, without providing "vents" where the line crosses under a permanent fence line. Use a "T" connection in the line and cement a section of small sewer pipe vertically into the "T." Put a heavy wire screen over the upper end.
- k. Do not construct surface inlets or junction boxes on tile lines in open cultivated fields unless necessary, since they create hazards to stock and the use of farm machinery, and are a nuisance, generally.
- l. Do not attempt to install a system of tile drains without proper tools. If such work is to be done by hand, the excavation should be done with ditching spades; loose dirt or crumbs should be removed with long-handled shovels, and the bottom of the trench should be finished with drain scoop or "cleaner." If several thousand feet are to be laid, a trenching machine is desirable, as it will do the work rapidly and usually as economically as by hand labor.
- m. Do not backfill tile lines with heavy subsoil clay next to the tile, as this may tend to seal the openings between joints.

It is better to use 8 to 12 inches of topsoil, placed immediately on top of the tile. In sand, fine gravel, or muck, it may be necessary to partly fill the trench with straw, weeds, or hay. Do not use material that is too bulky as settlement will occur in the trench when the material eventually decays.

n. Above all, do not install an expensive system of underdrains and pay no further attention to it. For the first two or three years after installation the lines should be inspected annually or oftener and holes over the lines dug into and repairs made. Usually a wide joint will be found at such points. A piece of broken tile or "bat" should be placed over the crack, and the trench carefully backfilled and tamped. Trees and brush, particularly those of water-loving nature, such as willow, cottonwood, and elm, should not be permitted to grow within 40 or 50 feet of a tile line.

11.80 CULVERTS

11.81 Scope of Discussion

a. Crossings over outlet ditches and field ditches are encountered frequently in drainage ditch construction and rehabilitation. On state or federal roads, county, and even township roads, these crossings may be bridges or large culverts of such a size that they are beyond the scope of the farm planning technicians. This part of the handbook is limited to a discussion of the small sizes of pipe culverts commonly used for field road and farm lane crossings over watercourses or small open ditches. Farm road crossings may be designed only for drainage flow if the landowner accepts responsibility of loss of the structure or overflow during floods. At some locations the farm road crossings will need to be designed for flood flows for road protection or other purposes. The larger size farm culverts and other types not covered by this discussion should be designed by an engineer, as well as all culverts and bridges in connection with all public roads or highways.

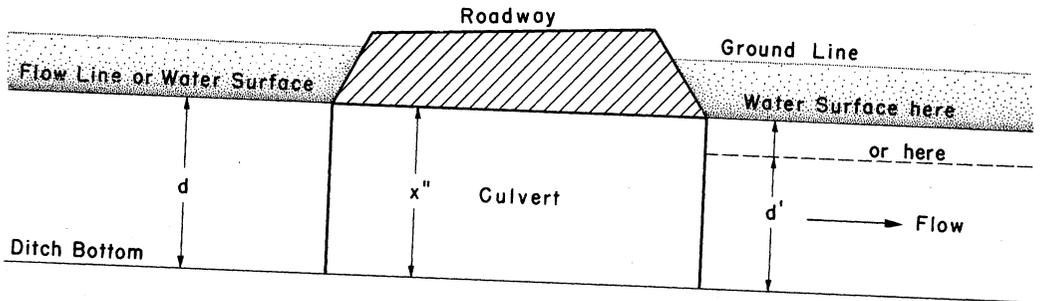
b. While the discussion in this handbook is primarily concerned with culverts, the possibility of using a bridge type of crossing should not be ignored. Bridges are desirable in large drainage areas with high rates of runoff, and also in relatively flat country where loss of head must be kept to a minimum. The bridge has the advantage of low discharge velocity and is not as likely to clog by debris and ice. Its efficiency with respect to drainage flow increases as the cross-sectional area of the bridge approaches that of the ditch. Construction is generally more difficult than for culverts, and costs are higher for the low rates of discharge.

c. Three kinds of pipe culverts are discussed; namely, corrugated metal, bell and spigot vitrified clay tile, and concrete culvert pipe. These are the types in common use.

11.82 Types of Culvert Flow

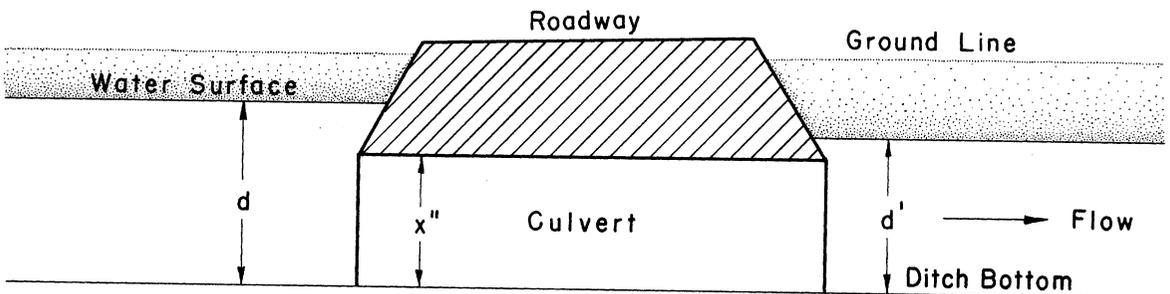
a. There are many types of flow through culverts and under some situations the design requires detailed knowledge of hydraulics. The types of flow discussed are those commonly encountered by farm planners, which are the two following conditions:

- (1) Where the water surface at inlet is the same elevation as the top of the pipe culvert, and the outlet is free.



X equals d, and is equal or greater than d'
Figure 11.43 applies under above conditions

- (2) Where the water surface at inlet is above the elevation of the top of the culvert entrance and the outlet is submerged.



d and d' are greater than X
Figures 11.44 & 11.45 apply under above conditions

b. Where other conditions of culvert flow than those listed above are encountered, assistance should be obtained from an engineer in making the design.

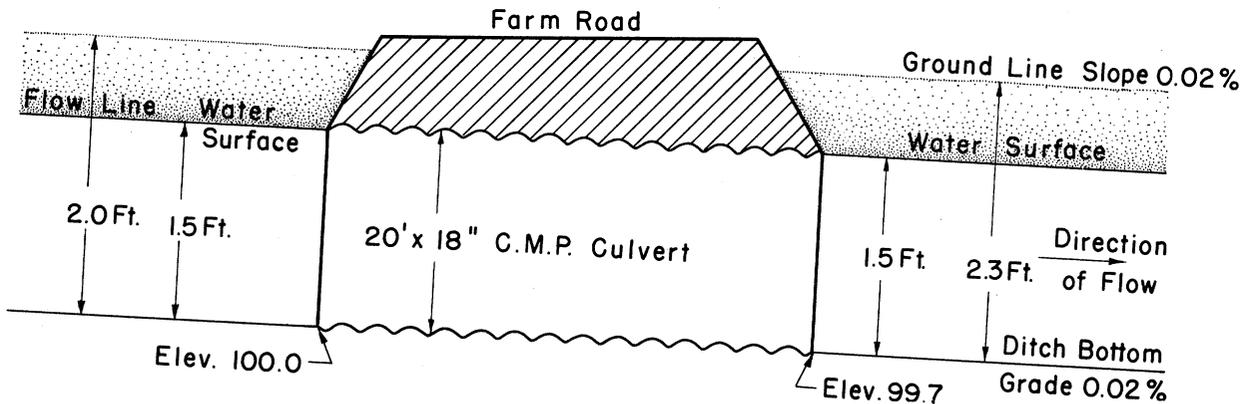
11.83 Determining Culvert Capacity

The criteria for design of culverts for farm lanes and field roads by farm planners are given by the examples following:

- a. (1) Given: Designed drainage flow 7 c.f.s.
 Ditch bottom grade 0.02%
- (2) Required: 20' - C.M.P. culvert for farm road crossing
 on lateral ditch
- (3) Solution:
- (a) From Figure 11.6, page 11-21 through 11-23a inclusive:

Ditch with 4:1 side slopes would need 4-foot bottom and 1.5 depth. Then from Part 11.54b the constructed ditch would be 2.0 feet deep.

(b) Next, from Figure 11.43, page 11-96, find that both 12-inch and 15-inch pipes are too small. An 18-inch pipe will discharge the 7.0 c.f.s. on a slope of 1.4%. Therefore, fall in 20 foot length of culvert (C.M.P.) is $20 \times .014$ or 0.3 ft. Now with bottom of ditch parallel to ground surface, depth of ditch downstream from the culvert is 2.0 ft. + 0.3 ft. or 2.3 ft.



Note that the depth of the ditch at the outlet end of the culvert is greater than at the inlet end and is greater than necessary for proper drainage flow. This is because of the increased grade through the culvert necessary to make it function efficiently.

(c) The problem illustrated above is fairly common in the field and is applicable when the water surface at drainage design flow in the ditch downstream from the culvert is at or below the top (invert) of the culvert pipe at the downstream end. Any backing up of water downstream which would tend to cover or submerge the downstream end of the culvert would require a different solution. In some instances this condition can be avoided by widening the ditch below the culvert, which results in a lowering of the water surface at drainage design flow. This provides the free outfall condition upon which the preceding example was developed.

- b. (1) Given: Designed drainage flow 10 c.f.s.
 Ground line and ditch bottom grade 0.02%
 Minimum depth 4.0 ft.
 Max. velocity (due to soil conditions) 5 ft. per second
- (2) Required: 20 ft. C.M.P. culvert for farm road crossing on lateral ditch entering main ditch 4 foot deep.
- (3) Solution:
- (a) From Figure 11.6, page 11-21 to 11-23a inclusive

CORRUGATED METAL PIPE - FREE OUTLET

CAPACITY IN Cubic Feet per Second

DIAMETER OF PIPE IN INCHES	SLOPE IN PER CENT														
	.1	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
12	0.6	1.0	1.3	1.5	1.7	1.9	2.1	2.3	2.4	2.5	2.6	2.6	2.6	2.6	2.6
15	1.3	2.0	2.4	2.8	3.0	3.3	3.7	4.0	4.3	4.4	4.5	4.6	4.6	4.6	4.6
18	2.1	3.1	3.9	4.4	4.9	5.4	6.1	6.5	6.8	7.0	7.1	7.1	7.1	7.1	7.1
21	3.3	4.7	5.9	6.8	7.5	8.1	9.0	9.6	10.	10.	10.	11.	11.	11.	11.
24	4.7	6.8	8.3	9.5	10.	11.	13.	14.	14.	15.	15.	15.	15.	15.	15.
30	8	12	15	17	19	21	23	24	25	25	26	26	26	26	26
36	12	19	25	28	31	33	37	39	40	40	40	40	40	40	40
42	20	30	37	42	46	50	55	57	59	59	59	59	59	59	59
48	25	42	53	62	68	72	77	80	82	83	83	83	83	83	83
54	36	57	72	83	90	97	100	110	110	110	110	110	110	110	110
60	47	77	97	110	120	130	140	140	150	150	150	150	150	150	150
	4		6				8		10						

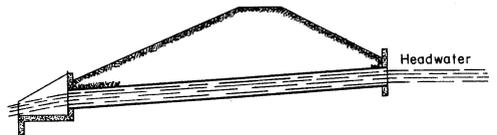
SMOOTH PIPE - FREE OUTLET

CAPACITY IN Cubic Feet per Second

DIAMETER OF PIPE IN INCHES	SLOPE IN PER CENT														
	.1	.2	.3	.4	.5	.6	.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4
12	1.2	1.8	2.2	2.3	2.4	2.5	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
15	2.1	3.2	3.8	4.1	4.4	4.5	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
18	3.5	5.0	5.9	6.5	6.8	7.0	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
21	5.4	7.6	8.9	9.7	10.	10.	11.	11.	11.	11.	11.	11.	11.	11.	11.
24	7.5	10.8	12.8	13.9	14.4	15.	15.	15.	15.	15.	15.	15.	15.	15.	15.
30	14	19	23	24	25	26	26	26	26	26	26	26	26	26	26
36	22	31	37	39	40	40	40	40	40	40	40	40	40	40	40
42	34	47	54	58	59	59	59	59	59	59	59	59	59	59	59
48	50	67	77	83	83	83	83	83	83	83	83	83	83	83	83
54	70	95	104	108	110	110	110	110	110	110	110	110	110	110	110
60	90	125	137	142	145	150	150	150	150	150	150	150	150	150	150
	4		6				8								

NOTE: The values in bold face type indicate discharge at the approximate "critical slope" beyond which the discharge remains constant for any given size culvert. The "stairs" of heavy horizontal lines beginning at the upper left and reading downward and to the right indicate approximate velocities of 2, 4, 6, 8, and 10 feet per second.

Reference: Regional Drawings 3-L-7279 and 3-L-7280



Critical velocity in feet per sec. = $V = 4.475 \sqrt{D}$
 Critical slope in percent = $S = \frac{1.04}{D^{1/3}}$
 Maximum discharge in c.f.s. = $Q = 2.58 D^{5/2}$
 D = diameter of pipe in feet
 n = 0.015 Smooth pipe, n = 0.021 Corrugated pipe

FIGURE 11.43 CAPACITY OF PIPE WITH WATER SURFACE AT INLET THE SAME ELEVATION AS THE TOP OF PIPE AND FREE OUTLET

SQUARE CORNERED ENTRANCE CAPACITY

Cubic Feet per Second



DIAMETER OF PIPE IN INCHES	AREA OF PIPE SQ. FT.	HEAD ON PIPE IN FEET																								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.5		
12	0.79	1.3	1.8	2.2	2.5	2.8	3.0	3.3	3.5	3.7	3.9	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.3	6.6	6.8	7.0	7.2	7.3		
15	1.23	2.1	2.9	3.5	4.0	4.5	4.9	5.4	5.7	6.1	6.4	7.1	7.6	8.1	8.6	9.0	9.5	9.9	10	11	11	11	12	12		
18	1.77	3.1	4.3	5.3	6.1	6.8	7.4	8.1	8.6	9.2	9.7	11	11	12	13	14	14	15	15	16	17	17	18	18		
21	2.40	4.3	6.0	7.3	8.4	9.5	10	11	12	13	13	15	16	17	18	19	20	21	21	22	23	24	25	25		
24	3.14	5.7	8.1	9.8	11	13	14	15	16	17	18	20	21	23	24	25	26	28	29	30	31	32	33	33		
30	4.91	9.1	13	16	18	20	22	24	25	27	28	31	33	36	38	40	42	44	46	47	49	51	52	53		
36	7.07	13	19	23	26	29	32	35	37	39	41	45	49	52	55	58	61	64	67	69	72	74	76	77		
42	9.62	18	25	31	35	40	43	47	50	53	56	62	66	71	75	79	83	87	91	94	97	101	104	105		
48	12.57	24	33	40	46	52	57	62	66	70	74	81	87	93	99	104	109	114	118	123	127	132	135	138		
54	15.90	30	42	51	59	66	72	78	83	88	93	102	110	117	124	131	137	144	150	155	161	166	171	174		
60	19.63	37	52	63	72	82	88	97	102	109	115	126	135	145	154	162	170	178	185	192	199	206	211	215		
		3			4			5			6			8			10									

BEVELED LIP ENTRANCE UPSTREAM CAPACITY

Cubic Feet per Second



DIAMETER OF PIPE IN INCHES	AREA OF PIPE SQ. FT.	HEAD ON PIPE IN FEET																								
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.5		
12	0.79	1.3	1.8	2.3	2.6	2.9	3.2	3.5	3.7	3.9	4.1	4.5	4.9	5.2	5.5	5.8	6.1	6.4	6.6	6.9	7.1	7.4	7.6	7.7		
15	1.23	2.2	3.1	3.7	4.3	4.8	5.2	5.7	6.1	6.5	6.8	7.5	8.0	8.6	9.1	9.6	10	11	11	11	12	12	13	13		
18	1.77	3.3	4.7	5.7	6.5	7.4	8.0	8.7	9.2	9.8	10	11	12	13	14	15	15	16	17	17	18	19	19	19		
21	2.40	4.6	6.5	8.0	9.1	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	27		
24	3.14	6.2	8.7	11	12	14	15	16	17	18	19	21	23	24	26	27	29	30	31	32	34	35	36	36		
30	4.91	10	14	17	20	23	25	27	28	30	32	35	38	40	43	45	47	49	51	53	55	57	59	60		
36	7.07	15	21	26	30	33	36	39	42	45	47	52	56	59	63	66	70	73	76	79	81	84	87	88		
42	9.62	21	29	36	41	46	51	55	58	62	66	72	77	83	88	93	97	101	106	109	113	117	121	122		
48	12.57	28	39	48	55	62	67	73	77	82	87	95	102	109	116	122	128	134	139	145	150	155	159	162		
54	15.90	36	50	61	70	79	86	93	99	105	111	122	131	140	149	156	164	172	179	185	192	199	204	206		
60	19.63	43	62	76	87	98	107	116	123	131	138	152	163	174	185	195	204	214	223	232	239	248	254	259		
		3			4			5			6			8			10									

NOTE: Based on Yarnell, Ngqler, Woodward experiments. University of Iowa.
 50 foot length of pipe used in computations.
 See Figure 86 for critical slopes.
 Dark lines across chart indicates velocities of
 3-4-5-6-8-10 feet per second.

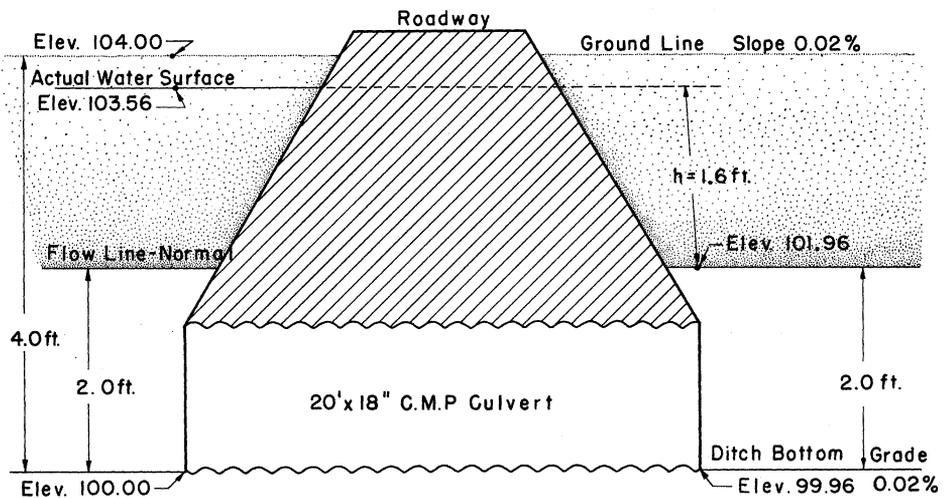
Compiled by R.J. 1-7-48
 Revised 2-25-53
 Checked by H.W.F. 3-8-48

FIGURE 11.44 CAPACITY OF CONCRETE CULVERTS 20 TO 40 FEET IN LENGTH WITH SUBMERGED OUTLET

Ditch with 2:1 side slopes, and 4 foot bottom width would flow 2 feet deep. However, as this lateral ditch outlets into main ditch 4 foot deep, construction dimensions of lateral ditch would be 4 foot depth, 4 foot bottom, with 2:1 side slopes.

(b) Now from Figure 11.43 note that 18 inch C.M.P. has maximum capacity of 7.1 c.f.s., which is not sufficient for the given situation. Therefore this size culvert will have to "head up," which means the entrance will be submerged.

(c) Now using Figure 11.45, page 11-99, find that to discharge the given 10 c.f.s. the 18 inch C.M.P. culvert requires a head of 1.6 feet. This means that the elevation of the water surface at the upstream end of the culvert needs to be 1.6 feet above the water surface at the outlet end of the culvert. Therefore, the culvert is operating under a "submerged condition." The problem can be illustrated as below.



(d) Also, it should be noted from Figure 11.45 that when the 18 inch C.M.P. discharges the 10 c.f.s. under a head of 1.6 feet, the discharge velocity is almost 6 feet per second. This is a rather high velocity, and unless a special channel lining were to be used below the culvert, the solution arrived at does not meet our given condition of a maximum allowable velocity of 5 feet per second.

(e) Further, it should be noted from the above sketch that when the required head of 1.6 feet is reached, the water surface at the inlet is slightly less than 0.5 foot below the ground line, which in this example may be all right. However under some field conditions, in order to provide the required head, the water surface at the inlet may reach the ground line or even flood over. Naturally such a solution is not acceptable.

CORRUGATED METAL PIPE CAPACITY

Cubic Feet per Second

DIAMETER OF PIPE IN INCHES	AREA OF PIPE SQ. FT.	HEAD ON PIPE IN FEET																						
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.5
12	0.79	1.0	1.4	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.0	3.3	3.5	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.5	5.6
15	1.23	1.7	2.3	2.9	3.3	3.7	4.0	4.4	4.6	5.0	5.2	5.7	6.2	6.6	7.0	7.4	7.7	8.1	8.4	8.7	9.0	9.4	9.6	9.8
18	1.77	2.5	3.6	4.4	5.0	5.6	6.1	6.7	7.1	7.5	7.9	8.7	9.4	10	11	11	12	12	13	13	14	14	15	15
21	2.40	3.6	5.1	6.3	7.2	8.1	8.8	9.6	10	11	11	12	13	14	15	16	17	18	18	19	20	20	21	21
24	3.14	5.0	7.0	8.6	9.8	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	27	28	29	29
30	4.91	8.2	12	14	16	18	20	22	23	24	26	28	30	32	34	36	38	40	41	43	44	46	47	48
36	7.07	12	17	21	24	27	30	32	34	37	39	42	46	49	52	54	57	60	62	64	67	69	71	72
42	9.62	17	24	30	34	38	42	45	48	51	54	59	64	68	72	76	80	84	87	90	93	97	99	101
48	12.57	23	32	39	45	51	55	60	64	68	71	79	84	90	96	101	106	111	115	119	124	128	132	134
54	15.90	29	41	51	58	65	71	77	82	87	92	101	108	116	123	129	136	142	148	153	159	164	169	172
60	19.63	37	52	63	72	82	88	96	102	109	115	126	135	145	154	162	170	178	185	192	199	206	211	215
		2	3	4	5	6	8	10																

VITRIFIED CLAY PIPE BELL UPSTREAM CAPACITY

Cubic Feet per Second

DIAMETER OF PIPE IN INCHES	AREA OF PIPE SQ. FT.	HEAD ON PIPE IN FEET																						
		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.5
12	0.79	1.6	2.2	2.6	3.0	3.4	3.7	4.0	4.3	4.6	4.8	5.3	5.7	6.1	6.5	6.8	7.1	7.4	7.7	8.0	8.3	8.6	8.9	9.0
15	1.23	2.5	3.6	4.3	5.0	5.6	6.1	6.6	7.0	7.5	7.9	8.7	9.3	9.9	11	11	12	12	13	13	14	14	15	15
18	1.77	3.7	5.2	6.4	7.3	8.3	9.0	9.8	10	11	12	13	14	15	16	16	17	18	19	19	20	21	21	22
21	2.40	5.1	7.2	8.8	10	11	12	13	14	15	16	18	19	20	22	23	24	25	26	27	28	29	30	30
24	3.14	6.8	9.6	12	13	15	16	18	19	20	21	23	25	27	28	30	31	33	34	35	37	38	39	40
30	4.91	11	15	18	21	23	25	28	29	31	33	36	39	42	44	47	49	51	53	55	57	59	61	62
36	7.07	15	21	26	30	34	37	40	42	45	48	52	56	60	64	67	71	74	77	80	83	85	88	89
42	9.62	21	29	35	40	45	49	54	57	61	64	70	76	81	86	90	95	99	103	107	111	115	118	120
48	12.57	26	37	45	52	59	64	69	74	78	83	91	98	104	111	116	122	126	133	138	143	148	152	154
54	15.90	33	46	56	64	72	79	86	91	97	102	112	120	128	137	144	151	158	164	170	177	183	188	191
60	19.63	39	55	68	77	87	95	103	109	117	123	135	145	155	165	173	182	191	198	205	212	220	226	230
		3	4	5	6	8	10																	

NOTE: Based on Yarnell, Nagler, Woodward experiments. University of Iowa.
 30 foot length of pipe used in computations.
 See Figure 86 for critical slopes.
 Dark lines across chart indicates velocities of
 2-3-4-5-6-8-10 feet per second.

Compiled P.J.-1-7-48
 Checked H.W.F-3-8-48

Revised 2-25-53

FIGURE II.45 CAPACITY OF CORRUGATED METAL PIPE AND VITRIFIED CLAY PIPE 20 TO 40 FEET IN LENGTH WITH SUBMERGED OUTLET

(f) Also, when the water level is "heading up" at the culvert entrance, the velocity of the water in the ditch upstream is very slow, and the ponding extends a considerable distance upstream. This is an undesirable situation, as any silt load in the drainage flow will tend to deposit in the ditch bottom. In time, capacity will be lost, and a cleanout job is necessary.

(g) The next step in arriving at a solution is to try a larger culvert size. Referring again to Figure 11.43, note that a 24 inch C.M.P. has a capacity of 10 c.f.s. on a slope of 0.5%, with velocity of less than 4 feet per second. This then is the same type of situation covered in example "a." While this solution calls for a design of a 24 inch culvert which is a Class D job (Reg. Memo 60), it points out that the farm planner can make the design, but needs the approval only of a qualified engineer to go ahead with the job.

c. In applying the above criteria keep in mind that it applies to farm roads and field lanes and it does not apply to culverts and bridges for township, county, state, or federal roads. These large size structures should be designed by an engineer.

PART 12

IRRIGATION

12.10 GENERAL

The information contained in this part is intended to give a basic concept of the place of irrigation in developing the farm conservation plan. By enumerating some of the needs for, and methods of accomplishing irrigation, it is hoped that proper recognition can be given to this practice where it is applicable. It is not intended that the information given herein will enable one to design an irrigation system. That responsibility rests with engineering-trained personnel in accordance with current policy (Regional Memorandum #60). The material covered does provide sufficient information so that irrigation needs (short of actual system to apply water) can be discussed intelligently with farmers. For more detailed information refer to USDA Farmers' Bulletins Nos. 1846 (Supplemental Irrigation) and 1922 (Practical Irrigation).

12.11 The Need For Irrigation in the Humid Section

a. Conservation irrigation on the farm is simply the use of the irrigation and cropping methods that best fit the particular soil, slope, crop, and water supply. It makes possible irrigation without erosion damage, waterlogging, or undue water loss. Supplemental irrigation, as the name indicates, means the artificial watering of crops in areas where rainfall is ordinarily depended upon to furnish the necessary moisture. Even in areas of this kind, periods of one, two, or three weeks occur in which rainfall is not sufficient and artificial applications of water will be of great benefit. This application of additional water is then called supplemental irrigation.

b. A study of the rainfall pattern of the humid section gives reasons why supplemental irrigation is of importance. The probable average number of periods of deficient rainfall per year are:

<u>State*</u>	<u>1 to 2 weeks</u>	<u>2 to 3 weeks</u>
Illinois	6 periods	1 period
Indiana	6 "	1 "
Iowa	8 "	1 "
Michigan	7 "	1 "
Minnesota	6 "	2 "
Ohio	5 "	1 "
Missouri	Figures not available	
Wisconsin	" "	"

*From "Electric Power for Irrigation in the Humid Region," published by Committee on the Relationship of Electricity to Agriculture, 11017, No. 2.

Periods of deficient rainfall refer to those periods when the rainfall is insufficient to meet the needs of the crop being grown. While various crops require different amounts of water, the average needs will approximate 1 inch per week.

In the humid region, studies in 18 states indicate further:

Once in seven years, a period of six weeks occurred in which precipitation was less than one-quarter inch.

Once in two years, a like period of four weeks or more occurred.

c. For any locality, information on need for supplemental irrigation can be made by a study of local rainfall records for the months of May, June, July, August, and September, with special emphasis on underlined months. For ordinary conditions for maximum crop production, one inch of water for every seven days is required. For rains of more than one inch in a 24-hour period, a large portion may be lost by runoff and cannot be considered available for crop production.

d. The application of water by means of supplemental irrigation has many benefits beyond the prime one of insuring a crop. Optimum moisture conditions such as can be obtained by irrigating, usually assure better seed germination. Better quality crops, as well as increased yields, are obtained by eliminating any short periods of drought which might occur because of deficient rainfall. Frost control for crops growing in low-lying pockets is another benefit which can be obtained by the use of a properly designed sprinkler irrigation system. Protection through a long period of very low temperature cannot be hoped for, and further in a long, cold spell, even of only moderate intensity, damage from broken stems and branches due to accumulating ice load may be as harmful as possible frost damage. Protection is obtainable only on the area that can be watered at one time during the entire frost period.

12.12 Physical Aspects of Irrigation

a. Effect of Soil Types on Irrigation

The table following shows the relation of soil texture and organic matter content to the permeability and water-holding capacity. Unless these relationships are clearly understood by the irrigator, damaging or wasteful water application may result. Care must be exercised that water is not applied too rapidly or in too great a quantity. In addition to being wasteful, harm may be done to growing plants due to a water-logged soil.

COMPARISON OF PHYSICAL AND WATER-HOLDING PROPERTIES OF SOILS

Texture of Soil	Permeability (Inches Water Per Hour)	Water Holding Capacity (Inches Per Foot of Depth)	Depth of Soil Wetted by One Inch of Water (Inches)
Very light	1.5 to 2.0	0.2 to 0.6	60 to 20
Light	1.0 to 1.5	0.6 to 1.2	20 to 10
Mod. light	0.6 to 1.0	1.2 to 2.0	10 to 6
Medium	0.25 to 0.6	2.0 to 2.5	6 to 5
Mod. heavy	0.15 to 0.25	2.0 to 2.5	6 to 5
Heavy	0.05 to 0.15	2.0 to 2.5	6 to 5
Very heavy	0.01 to 0.05	1.9 to 2.4	6 to 5
Peat & muck	?	3.0	4

Note: Range due to low, and medium to high organic matter content.

b. Water Requirements

The amount of water required to produce a pound of dry matter varies with the crop grown. The table below shows the result of some research work on this subject in Wisconsin.

WATER REQUIREMENTS FOR SOME COMMON FIELD CROPS

Crop	Lbs. Water Per Lb. Dry Matter Produced	Acre Inches Water Needed For Yield Shown	Yield	Inches
Alfalfa	844	4 T/Ac.		28
Corn	350	75 Bu./Ac.		14
Oats	583	60 " "		12
Wheat	557	30 " "		11
Barley	518	40 " "		10
Soybeans	646	20 " "		8
Potatoes		400 " "		40

c. Working Depth, Root Zone

The depth to which plant roots will penetrate the soil in search of plant food and moisture under normal conditions determines the depth to which any crop should be irrigated. It follows that this depth will influence the amount of water that would be applied at each irrigation. If the soil is wetted to less than the working depth of the root zone, more frequent wetting is necessary. This involves needless additional labor and expense. If the soil is wetted below the working depth of the roots, this of course is a waste of badly needed water, may result in leaching of plant nutrients, and results in needless pumping costs.

The following table lists some common crops which might be irrigated, showing working depth of root zone and peak daily use of soil moisture.

**ROOT WORKING DEPTHS AND VALUES OF PEAK DAILY USE
OF SOIL MOISTURE FOR OPTIMUM YIELDS OF COMMON IRRIGATED CROPS**

Crop	Working Depth Root Zone (Feet)	Peak Daily Use of Soil Moisture (Acre-inches Per Acre Per Day)		
		Cool <u>1/</u> Climate	Moderate <u>2/</u> Climate	Hot <u>3/</u> Climate
Alfalfa	3.0	0.15	0.20	0.25-0.30
Apples (cult.)	5.0	0.15	0.20	0.25
Apples (cover crop)	5.0	0.20	0.25	0.30
Beans, bush	3.0	0.12	0.15	0.20
Cherries (cult.)	4.0	0.15	0.20	0.25
Cherries (cover crop)	4.0	0.20	0.25	0.30
Corn, field	3.0	0.12	0.15	0.20
Corn, sweet	2.0	0.12	0.15	0.20
Cucumbers	3.0	0.10	0.12	0.14
Garden root crops	2.0	0.10	0.12	0.14
Grain	3.0	0.15	0.20	0.22
Pasture, bluegrass	1.5	0.12	0.16	0.20-0.25
Potatoes	1.5	0.10	0.12	0.14
Raspberries	2.5	0.10	0.12	0.14
Red clover	3.0	0.15	0.20	0.25-0.30
Strawberries	1.0	0.10	0.12	0.14
Sugar beets	3.0	0.12	0.15	0.20
Tomatoes	3.0	0.10	0.12	0.14

1/ Cool to moderate temperatures - 40° to 55°F

2/ Moderate temperatures - 55° to 75°F

3/ High temperatures - 75° to 95°F

d. When to Irrigate

When a soil's moisture is depleted to the extent that no moisture is available for plant growth, the soil has reached its wilting point. The object of supplemental irrigation is to apply water at the proper time to prevent the soil from reaching this point, thus preventing a retardance or complete cessation of plant growth. In order to determine when water needs to be applied, some practical method of measuring the amount of soil moisture available for plant growth must be used.

One method, and perhaps the most reliable, is to use plaster of paris electrical resistance blocks which have been buried in the soil at various depths. For a shallow-rooted crop, blocks should be buried at depths of about 4 to 10 inches, while for deeper-rooted crops, blocks should be placed about 6, 12, 24, and possibly 36 inches in depth. The blocks are equipped with lead wires, to which a moisture meter is connected to give a direct recording of the percent of moisture in the soil. (Moisture capacity in blocks will equalize itself with soil in a period of 24 hours.)

Another method, less scientific, with which fairly good results may be obtained, relies entirely on the "feel" of the soil. Samples of the soil would be taken from the depths indicated in the paragraph preceding. The sample of soil is squeezed in the hand and the resulting evidences of moisture are noted. The following table gives the criteria for determining moisture conditions by the "feel."

DETERMINATION OF SOIL MOISTURE BY THE "FEEL" METHOD

Degree of Moisture	Feel	Amount of Moisture
Dry	Powder dry.	None
Low	Crumbly, will not hold together.	25% or less (critical)
Fair	Somewhat crumbly, but will hold together.	25 to 50%
Good	Forms ball; will stick slightly with pressure.	50 to 75%
Excellent	Forms a ball and is pliable; sticks readily; a clear water sheen will come to the surface when ball is squeezed in the hand.	75 to 100%
Too wet	Can squeeze free water.	Over field capacity

Regardless of the method used, it is essential that the irrigator have some means available which will enable him to determine if water is needed. The Michigan Experiment Station recommends that water be applied on light soils when the moisture capacity is down to about 50% of the field capacity; whereas, on medium textured soils water should be applied when the soil is at about 35% capacity. Field capacity is the amount of water a soil will hold after all free (gravitational) water has been removed. The figures given are not arbitrary. In all cases the time at which irrigation is to start will have to be determined by such factors as the irrigation frequency, size of area to be irrigated, capacity of irrigation system, etc.

e. Is the Water Supply Adequate?

One of the common mistakes made in practicing irrigation is trying to irrigate too much land with too little water. The water supply should be great enough to irrigate crops during a prolonged dry period. There is no point in irrigating a large acreage half-way through a drought period and then allowing your crops to suffer from a water shortage. If the water supply is not large enough for the acreage desired, then this acreage must be reduced. Before investing money in irrigation equipment, the

irrigator should make certain that he has enough water for his contemplated irrigation operations. If a pond is used, it must be large enough to store all of the water needed during the irrigation season, plus evaporation, and seepage losses. Drainage area must be large enough to replenish supply for next irrigation season.

Krimgold and Minshall,* in analyzing evaporation losses from ponds in four zones of the claypan areas, found net losses (evaporation minus precipitation on pond area) of from 14 to 36 inches for the 5-month period of May through September. Obviously this loss, in addition to that from seepage, which may run from 2 to 12 inches, is an important factor in the net amount of water available for irrigation purposes.

f. Fertilizer Application

Any water soluble fertilizer is easily applied to the land through sprinkler irrigation methods. The area on which water is being applied at any given setting can be determined and from this figure the desired amount of fertilizer to be distributed for each setting can be calculated. The depth to which fertilizer is to be placed can also be controlled by introducing the fertilizer into the distribution system at the proper time. If deep penetration of the fertilizer is desired, it will be allowed to enter the sprinkler system at the beginning of the sprinkling period. Conversely, if it is desired to have the fertilizer placed near the surface of the soil, it will be applied near the end of the period. It is not considered practical to apply phosphorous fertilizers through the irrigation system because of losses due to fixation.

12.20 WATER SUPPLY

12.21 Types of Water Supply For Irrigation

a. Streams or lakes, shallow wells, deep wells, and farm ponds are the usual sources of water. The water supply should be near the field to be irrigated in order to avoid expensive supply lines. The cost of pumping will generally be low if the water can be obtained from a stream, lake, or shallow well where it can be used without pumping any great distance. Deep well installations are usually expensive and the cost of pumping may be excessive.

b. In the Upper Mississippi Valley Region not every farmer has an adequate supply of water available for extensive irrigation. Therefore, supplemental irrigation of large tracts is likely to be limited to those farms having a natural stream, large pond, or an abundance of underground water close to the surface for shallow well pumping. However, there are many opportunities for the irrigation of small tracts of one-half to two acres of truck

*Hydraulic Design of Farm Ponds and Rates of Runoff for Design of Conservation Structures in the claypan areas. SCS-TP-56, May 1945.

or garden crops which produce high income per acre. The total water needs for these smaller areas are relatively low and often the need may be supplied by the farm water supply system or by an inexpensive supplemental source which can be developed. Small electric pumps, windmills, overhead storage tanks, all have possibilities for use in irrigating these small tracts.

c. Water Rights For Irrigation Purposes

When water for irrigation purposes is pumped from a natural stream or lake, the state laws governing use of such water should be explored. Some states have definite regulations relative to the damming and use of water from streams. Some states require permits before ground water can be pumped when the quantity exceeds a specified amount. In the absence of statutory provisions, it is often the custom to initiate a water right by filing a notice of the intent to divert water and recording this action in the county record.

12.30 GENERAL TYPES OF IRRIGATION

12.31 Gravity Irrigation (Flooding)

a. Basin Irrigation

The purpose of this method is to fill a diked area of land with water to the desired depth quickly and allow the water to go into the soil. When basins are properly graded and built to the right dimensions for the kind of soil and the water supply, water can be applied efficiently.

b. Border Irrigation

This is a controlled way of flooding the surface of a field. The idea is to advance a sheet of water down a narrow strip between low ridges or borders and to get the water into the soil as the sheet advances. It requires that the strip be well leveled between the border ridges and the grade down the strip be fairly uniform to avoid ponding. The ridges should be low and rounded so they can be planted with the strips. Then no land is taken out of production.

c. Contour or Bench Border Irrigation

This method is adapted to fairly uniform moderate slopes with deep soils. The strips are laid out across the slope on a controlled grade and the ridges are constructed parallel to each other.

d. Corrugation Irrigation

In this method the water is applied in small furrows. It then moves laterally through the soil between the furrows to wet the entire area. The method is designed for heavy soils that take water slowly and that seal over and bake when flooded.

e. Furrow Irrigation

Furrow irrigation is a method of irrigating row crops. The water is applied in the furrows between the plant rows. Many of the present furrows are too steep for safe irrigation. This fact has been the greatest single cause of erosion by irrigation water. Because cultivation to control weeds keeps the soil in the furrows loose, it is easily eroded.

f. Contour-Furrow Irrigation

This is the method of applying water in furrows across rather than down sloping land. The furrows are given just enough grade for water to flow, but not enough to cause soil washing. There is a "critical" furrow grade for each irrigable soil. Below the "critical" grade it is safe to apply any size stream of water that the furrow will hold without causing erosion in the furrow. Deep-furrow row crops can be irrigated safely by the contour-furrow method on cross slopes up to about 8 percent.

g. Broad-Furrow Irrigation

On slopes not exceeding 3 percent for most soils, the use of broad-bottom furrows in place of the usual narrow V-type furrow will increase the rate of water intake and reduce furrow erosion. This method is recommended for orchards planted on contour benches as a means of eliminating erosion resulting from grade variation along the benches.

h. Controlled Floodings

In this method, water is flooded down slope between closely spaced field ditches which keep the water from concentrating and causing erosion. Frequent openings in the ditches allow a uniform distribution of water over the field.

12.32 Sub-irrigation or Controlled Drainage

This is usually used in connection with controlled drainage of peat, muck, or sandy soils. It may be accomplished by tile or ditches with water table height controlled by outlet structure in main outlet. Water is actually supplied to cropland from outside source by seepage, pumping, or gravity flow.

12.33 Sprinkler Type Irrigation

a. This method of irrigation adapts itself well to varied conditions existent in this region. Water may be applied with sprinklers at a rate which the soil will absorb without runoff. Sprinklers can be turned off when the soil has absorbed the right amount of water for the crop needs. Water can be applied uniformly on land of uneven topography, thus eliminating the need for land leveling operations. Evaporation losses are usually high, particularly in hot, windy climates. On heavy

soils, because of the low permeability, the rate of applying water may be so low that much of it is evaporated before it enters the soil.

b. Several types of equipment are available for applying water by the sprinkler method. Perforated pipe, overhead oscillating pipe and portable rotary spray are the common types. The overhead oscillating type, which is a fixed installation, is particularly adapted to nursery and small truck crop needs. Portable rotary spray systems are suitable for larger acreages. Overhead and portable rotary spray systems are illustrated in Figure 12.1, page 12-10.

12.40 ADAPTATION OF TYPES OF IRRIGATION SYSTEMS TO THE REGION

12.41 Gravity irrigation is particularly adapted to relatively flat uniform slopes of medium- to heavy-textured soils. Flat lands requiring surface drainage can often be irrigated with a combination irrigation and surface drainage system. Small flat areas in hilly country may be irrigated by gravity methods using a farm pond as the source of water. It should be kept in mind that all types of gravity irrigation systems require relatively large amounts of water at the outset in order to get the flooding action needed for uniform coverage of the area to be watered.

12.42 Sub-surface Irrigation

Best adapted to peat, muck, and sandy soils. Where the permanent water table or an impervious layer lies several feet below a highly permeable surface soil, successful sub-irrigation can be accomplished by holding water in parallel ditches or tile lines until the water table over the whole area has been raised almost to the ground surface. The water is then allowed to drain from the ditches and the water table gradually falls to its original position.

12.43 Sprinkler Type Irrigation

a. Overhead Pipe System

The overhead pipe system is commonly called the oscillating sprinkler system of overhead irrigation. It is well suited to growing truck crops on small areas under ten acres and particularly for areas of about two acres where the crops grown are lettuce, spinach, cauliflower, and berries which may be injured by a heavy spray. The first cost of installation of this system is high, but the installation is permanent and it can be operated with very little labor. Similar to the portable pipe system, it can be used on an irregular tract without ground leveling. The permanent uprights somewhat impede field operation and are objectionable particularly in ordinary field crops or truck crops grown on an extensive scale. The length of pipe varies from 100 to 700 feet and operating pressures vary from 20 to 50 pounds per square inch. Ordinarily pipes are spaced 50 feet apart. Nozzles are installed on pipes at intervals of three to four feet so that all are in one plane. See Figure 12.1, page 12-10.

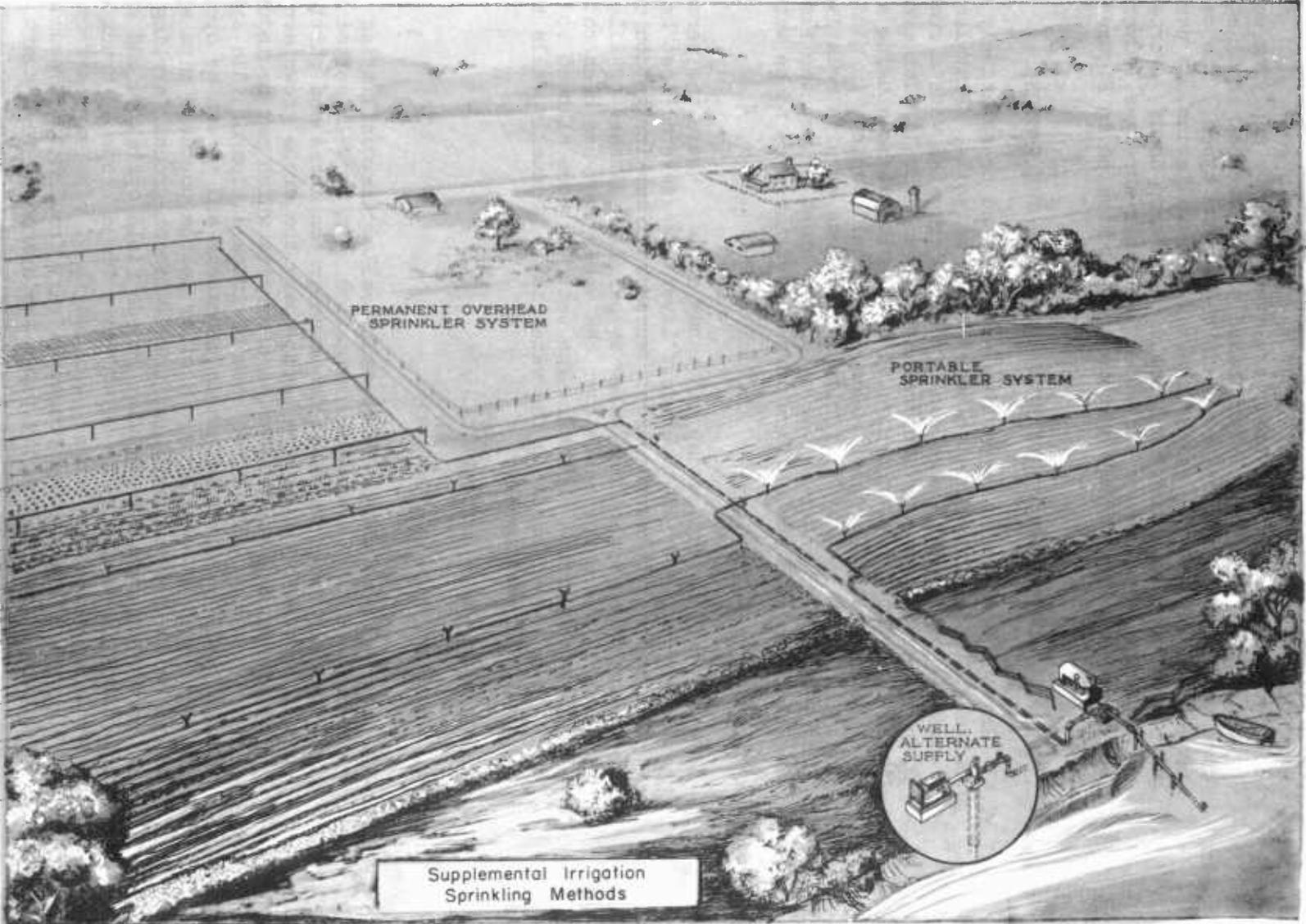


FIGURE 12.1 TYPES OF SPRINKLER IRRIGATION

From "Supplemental Irrigation" by courtesy of Johns-Marville

b. Perforated Pipe

A system of 3-, 4-, and 5-inch diameter light-weight pipe connected by easily joined slip joints. Low pressures, ranging from 4 to 15 pounds per square inch, are used. Under the 15 pound pressure, if conditions are favorable, a strip of ground 30 feet wide or more (15 feet each side of pipe) may be wetted at one setting. Water is usually applied at a rate of one-half inch or more per hour, limiting its use to the more permeable soils. Since pipe spacings are close, the acreage irrigated will be rather small, unless a large quantity of pipe is available.

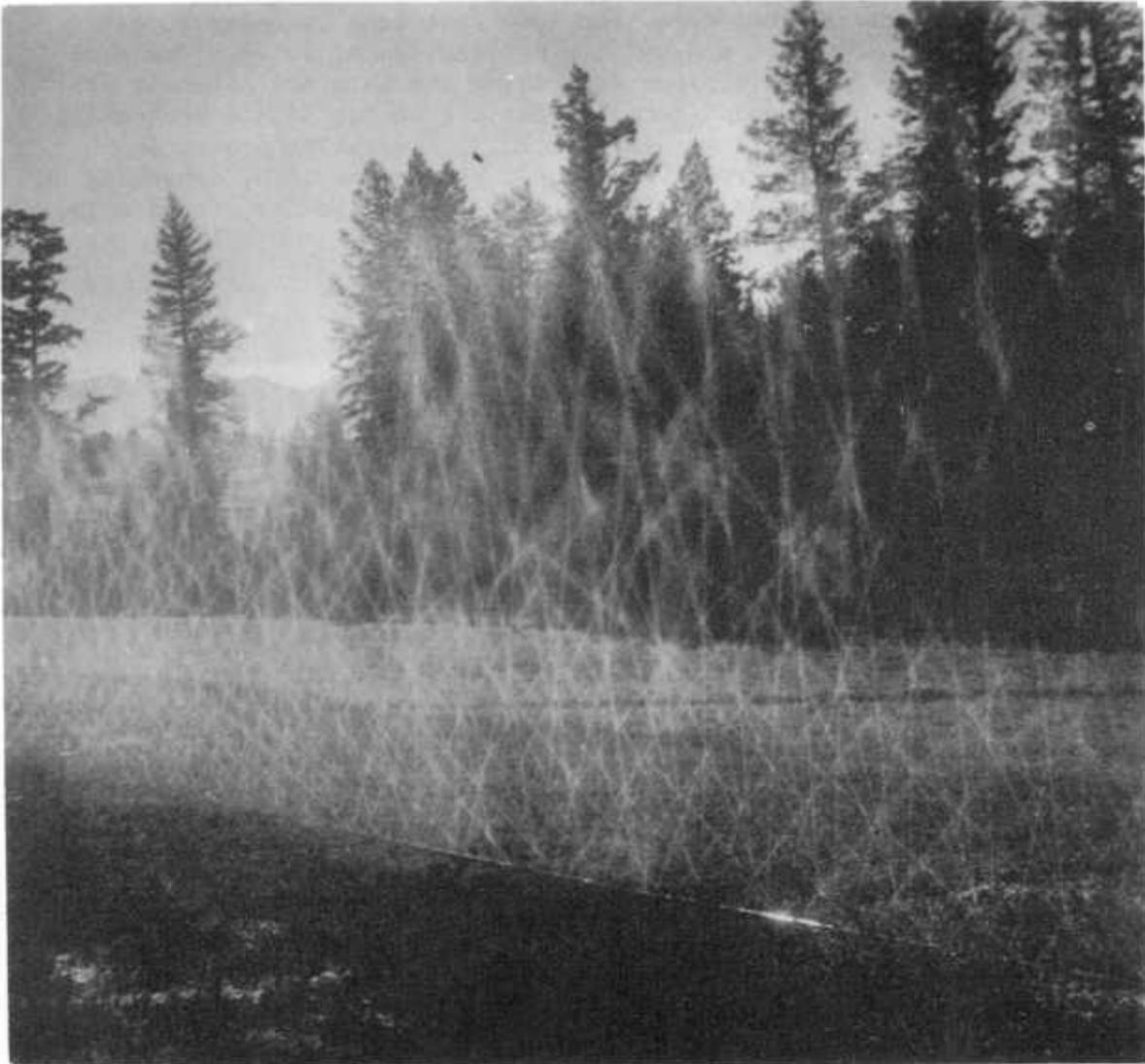


FIGURE 12.2 IRRIGATION BY PERFORATED PIPE

c. Portable Rotary Spray System

(1) Medium pressure, 20-50 pounds per square inch

This system usually consists of a main line running from the pump at the source of water to the field or fields which are to be irrigated. Lateral lines with sprinkler heads spaced from 20-60 feet are connected to the main at intervals from 40-80 feet across the field. Since the lateral lines are usually made of lightweight pipe 2-4 inches in diameter, they can be moved easily to new locations along the main. The system required to irrigate the field in the predetermined time may consist of one or more laterals. Laterals are usually not more than 1300 feet long in order to get more efficient and uniform application of water. The ends of the portable pipes comprising the main and laterals are fitted with quick coupling devices to facilitate connecting and disconnecting. (Figure 12.3) Operating pressures usually vary from 20-50 pounds per square inch, depending on such factors as pipe sizes used, pump capacity, topography, etc.

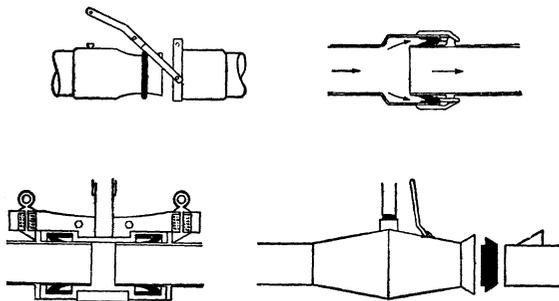
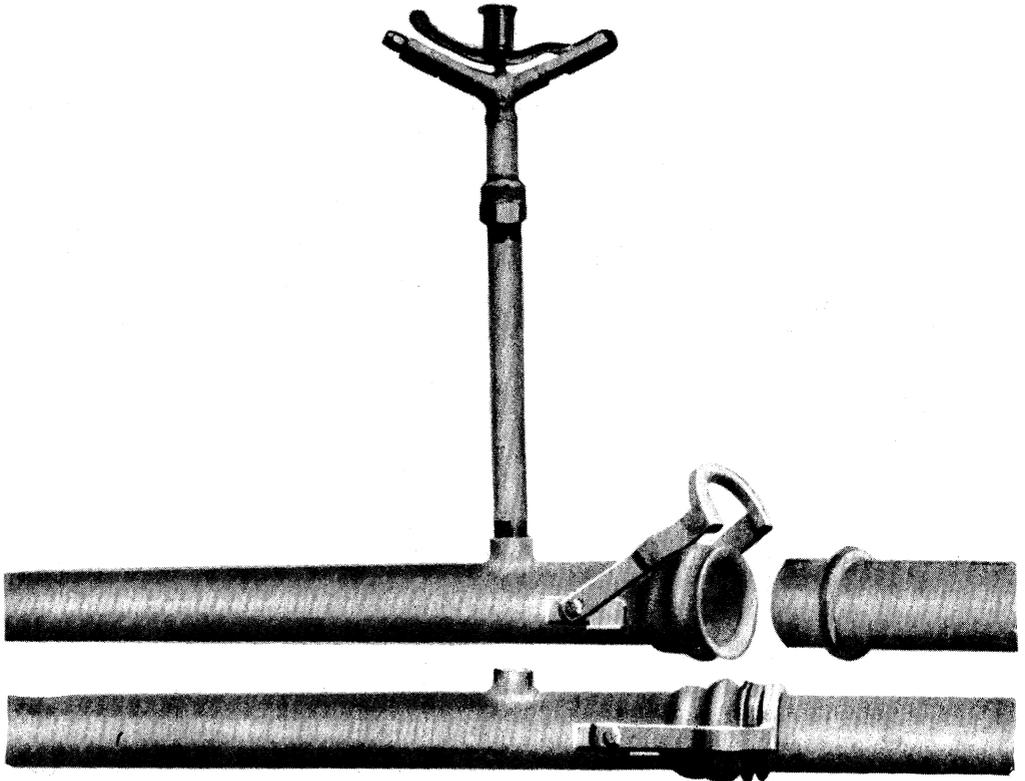


FIGURE 12.3 SEVERAL TYPES OF OF QUICK-ASSEMBLING PIPE JOINTS

Lightweight, portable pipe sections vary in size from 2-6 inches in diameter and from 8-30 feet in length. Sprinkler risers are of $3/4$ inch to $1-1/4$ inch pipe attached to a portable section. They are variable in length, depending on the height of crop to be irrigated. (See Figure 12.4, page 12-13.)

Sprinkler heads are spaced as determined by the operating pressure and type of nozzles used. Forty feet between sprinklers is a common spacing, although they may be placed as close as 20 feet when irrigating certain crops such as



By courtesy of Atlas Supply Division-Jones & Laughlin Supply Co.

FIGURE 12.4 SPRINKLER RISER AND HEAD

orchards. Discharge rates vary with the pressure and size sprinkler used. A 1-inch sprinkler with $1/4$ inch x $7/32$ inch nozzles operating at 40 pounds per square inch pressure will sprinkle 19.9 gallons per minute. If these sprinklers are spaced 40 feet on the line with lines 80 feet apart an amount of precipitation equivalent to 0.6 inches of rain per hour will be produced in the 60-minute period.

(2) High pressure, 50-100 pounds per square inch

High pressure sprinkler systems are similar to the medium pressure systems described in (1) above. Greater discharge rates are obtained by the use of larger nozzles operating under high pressure, usually around 100 pounds per square inch. While the medium pressure sprinkler system operating at 50 pounds pressure may discharge as much as 70 gallons per minute, the high pressure head operating at 100 pounds pressure may discharge as much as 560 g.p.m. These simple data bring out some of the advantages and disadvantages of the latter type system. Principal advantages are: reduced labor requirements due to wider spacings of pipes, less pipe required for distribution system, and large area covered by one sprinkler head. Principal disadvantages are: higher pumping costs due to increased pressures, larger pipe required,

considerable crop damage results from jet produced at beginning and ending of sprinkler operating period (after operating pressure is reached, fine spray is produced which does no damage), and losses due to winds which are high because of fine spray produced.

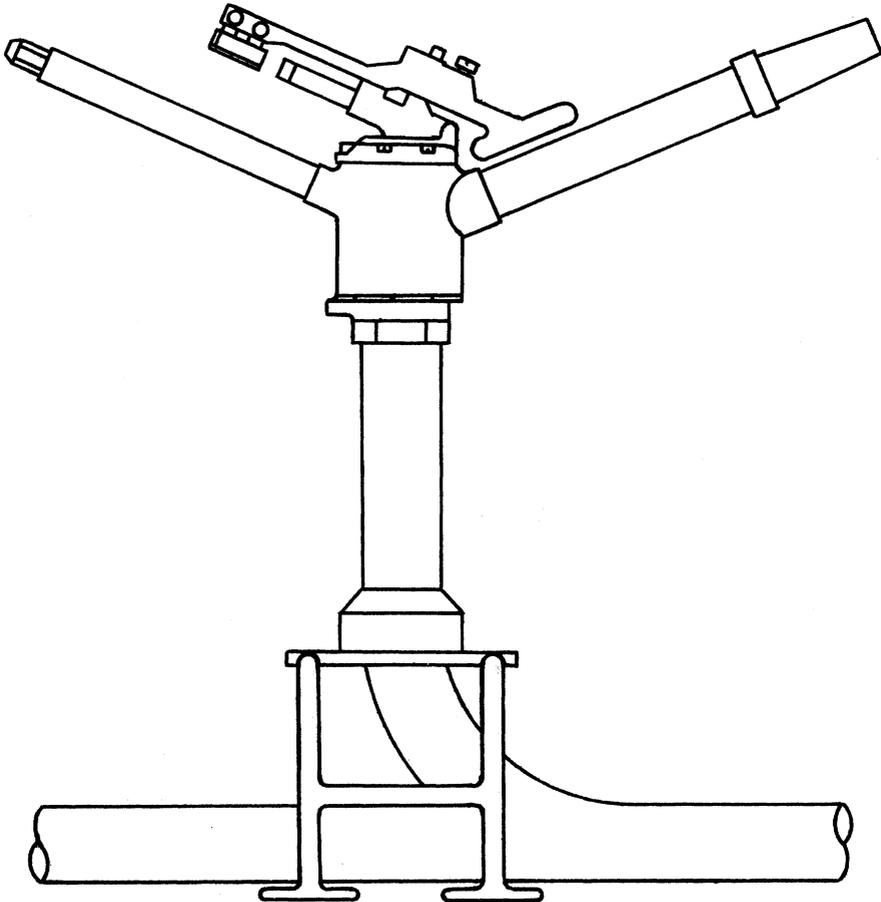


FIGURE 12.5 HIGH PRESSURE SPRAY NOZZLE

12.50 COSTS OF IRRIGATION SYSTEMS

Cost of applying water artificially vary considerably depending on such factors as system used, land preparation needed, and size of acreage to be irrigated. In flooding types of irrigation the major cost is usually in the land preparation or leveling operations needed. This cost may vary from \$25 per acre to as high as \$100, with an average cost of about \$38 per acre. The distribution system itself, which may consist of easily constructed shallow ditches (on heavy soils), is relatively inexpensive on a per acre basis. Sprinkler type systems on the other hand involve little or no land preparation costs, but do have a relatively high per acre cost for the distribution system. The following table shows the average cost for

irrigation equipment based on a study made on 58 farms in Michigan in 1946.

AVERAGE COST OF SPRINKLER IRRIGATION EQUIPMENT

Range of Acreage Per Farm Under Irrigation	Soil Texture	No. Farms Reporting	Average Acreage Per Farm	Average Cost of Equipment Per Acre
55-125	Light	13	80	\$ 63
25- 54	"	16	38	88
2.5- 24	"	21	12	176
5-125	Muck	8	36	50

PART 13

STREAMBANK EROSION CONTROL

13.10 GENERAL

13.11 Purpose and Scope

The purpose of streambank erosion control is to control bank cutting in order to protect valuable adjoining farm land and reduce the silt load of the stream. This control will be mainly through the use of vegetation supplemented by whatever mechanical installations are necessary to insure the satisfactory establishment of the vegetation.

Streambank protection work is one of the best methods of improving wildlife conditions, because it usually provides food, cover, and water close together and improves the stream for fish.

Streambank work done on any segment of a stream will be affected by the condition of the stream above and below the segment being considered. Therefore, it is desirable to protect the entire length of the stream at the same time. Frequently it will not be possible to protect the entire stream at one time, but a plan for the entire stream can be made so that work done on any segment will later fit into the entire job.

13.20 INVESTIGATIONS

13.21 Physical Features

The behavior of streams at flood stage or near flood stage is often unpredictable without detailed study. This makes it advisable to avoid jobs of large size unless good engineering assistance is available.

Before treatment of any streambank is started, several things should be considered:

Size of watershed draining into the stream.

Expected runoff and flood peaks.

Expected ice and debris load carried by the stream.

Causes of existing meandering and erosion. Included among them may be:

Fallen trees deflecting the water from its normal direction of flow.

Trees or brush growing on the inside of a curve deflecting water against the cutting bank.

Water from a waterway or smaller stream entering the channel and depositing sediment, thus deflecting the water against the cutting bank.

13.22 Legal and Economic Aspects

The flow line of a stream is often the property boundary between adjacent farms. Care must be taken not to divert a stream from its natural channel; the ultimate result may be to trespass on another man's property.

The economic soundness of any project should be determined at the very outset. The cost and damages of the control should be weighed against the resulting benefits.

13.30 TREATMENT

13.31 Vegetation

Most of the streambank protection with which the farm planner should be concerned can be accomplished by the establishment of a suitable type of vegetation (grass, shrubs, or trees). In order to satisfactorily establish vegetation, it may be necessary to protect the vegetation during establishment by mechanical means such as stakes, mats, pile, or rock jetties according to the conditions present.

13.32 General Treatment Recommended

a. Protect the stream from livestock. If stock water is needed, provide watering places where cattle will not have to cross a steep bank. Often it is desirable to provide more than one watering place so they can be used alternately to prevent the stock from denuding them of vegetation.

b. Correct the causes of meandering by removing fallen trees, removing trees or brush on inside curves, or by eliminating the sediment carried by waterways and smaller streams through conservation practices on the watersheds or desilting dams in their channels.

13.33 Mechanical Control May Be Needed

Control for small stream (up to six feet wide) with low banks (three to four feet high) and small watersheds (one to two square miles), protection from grazing is frequently all that is needed. If after one or two years of protection from grazing, there still are raw eroding curves, they may be treated as indicated under Paragraph 13.34.

13.34 Jetted Willow Poles For Stream Protection

Control for medium-size streams (six to twelve feet wide) with banks not more than eight to ten feet high, and with watersheds

of three to ten square miles, protection from grazing may be all the treatment needed. However, for most streams of this size, the following treatment is suggested:

Drive or jet in willow poles on the cutting side only at or just above the normal waterline in a double row with the poles two to four feet apart and staggered between rows (Figure 13.1, page 13-4). The poles should be six to nine feet long, three to five inches in diameter, and should be cut from willows if available. About two-thirds of the pole should be below the ground line. Supplement with plantings of willow cuttings or plants.

Some sharp curves or higher banks may need supplementary brush and rock wing dams or willow matting treatment described below.

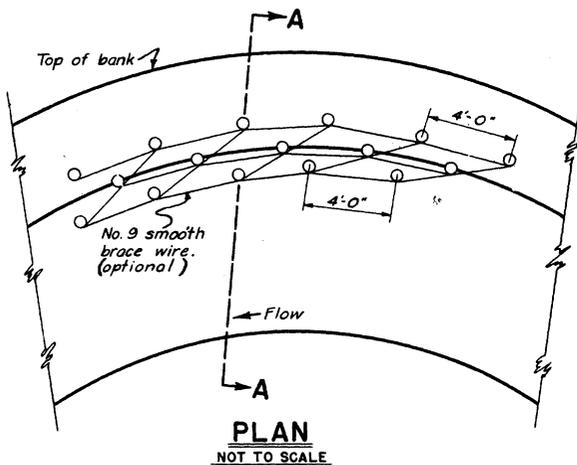
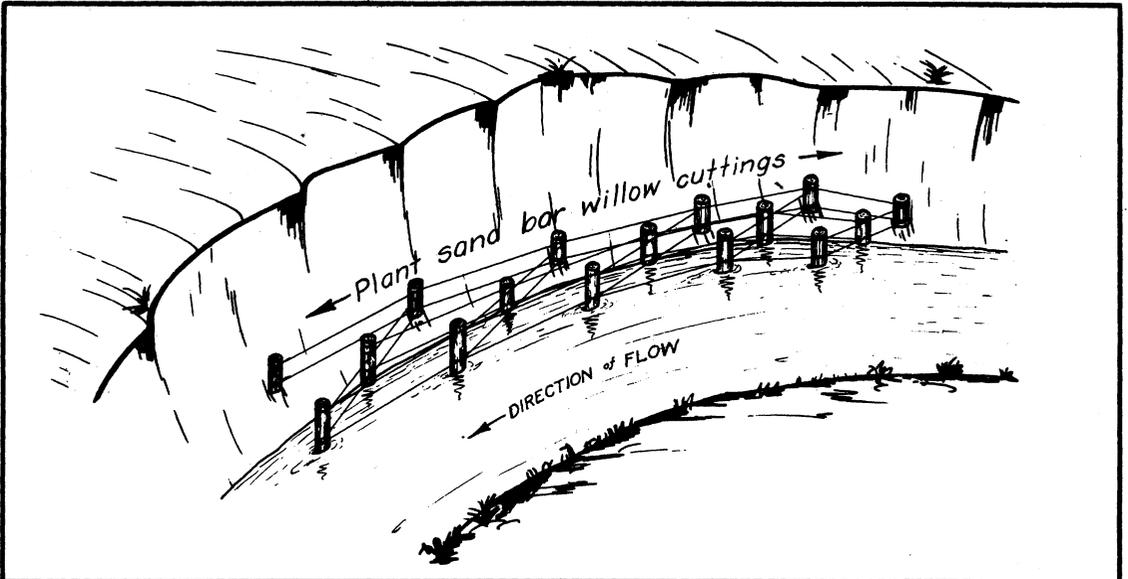
13.35 Rock and Willow or Piling Jetties

Control for larger streams (more than twelve feet wide) with higher banks (over ten feet high) and with watersheds of more than ten square miles, or in situations where the safety of high-value improvements such as farm buildings or highways are involved, or where ice and debris hazards are high, the following treatment is suggested:

a. Construction of a Willow Rock Deflecting Jetty (Figure 13.2, page 13-5)

- Step 1. Tying willows into bundles. Willows composing a bundle should be as nearly uniform in length as possible. Tie at two places with No. 9 black annealed wire (long bundles should be tied in three places.) If each bundle is tied at the same relative positions the subsequent operation of tying the bundles together to form an integral mat will be facilitated. Willows can be tied into tight bundles quickly by using a device similar to the one described as follows:

Two or three sawhorses spaced six to ten feet apart are tied together with longitudinal stringers. Fastened to the top of each sawhorse is a 2" x 6" which has been shaped to leave a curved surface (concave upward) on which the willows are laid for bundling. When enough willows to make a twelve- to eighteen-inch diameter bundle have been placed on the rack they are tied tightly together with No. 9 wire while the willows are being compressed by means of a double lever device consisting of two 1" x 2" hardwood sticks connected at one end of each with a short piece of suitable rope or cable. (One stick is passed under and around the bundle, then crossed with the other

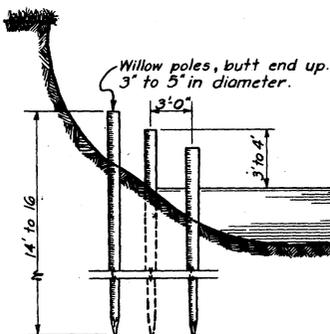


Equipment:
Centrifugal or other suitable pump, 150 G.P.M., (10' head), 2" discharge, 45' discharge hose, 15' inlet hose and 6' of 1 1/4" pipe for a jet.

Method:
Prepare a hole with jet pipe and hose by working the jet up and down to a depth of 10' to 12'. Leave jet in for half minute or so to be sure enough sand has been displaced to allow easy placing of pole. After the pole has been placed it should be secured by shoving the jet in a few times at an angle near the top of the hole. Use two rows of poles on long curves and four or five rows in sharp bends. Sand bar willow cuttings should be planted to form a living revetment. Protect against livestock until willows or other applicable species are established.

Application:
This method is used in the smaller streams where there is no heavy ice or debris load and where the stream bed is sand or fine gravel.

Performance:
In a typical job, 800 feet long, 15 man days were used to cut and jet poles and tie the brace wires; jet pump was operated a total of 3 hours.



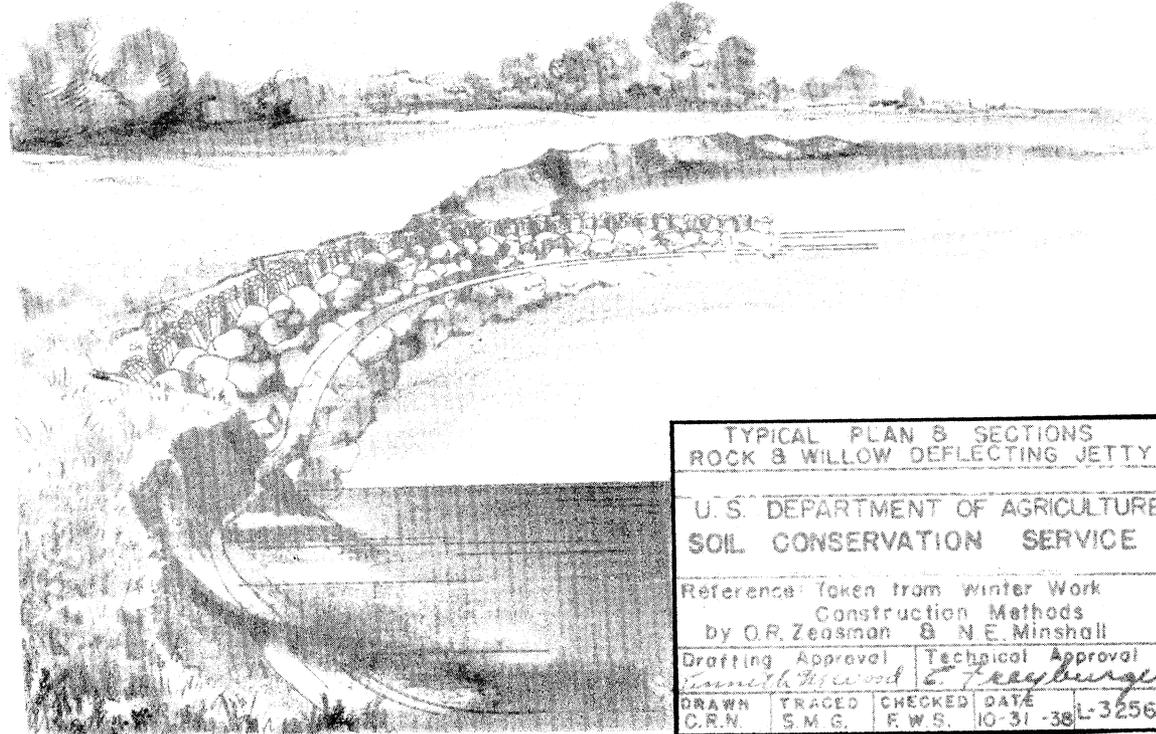
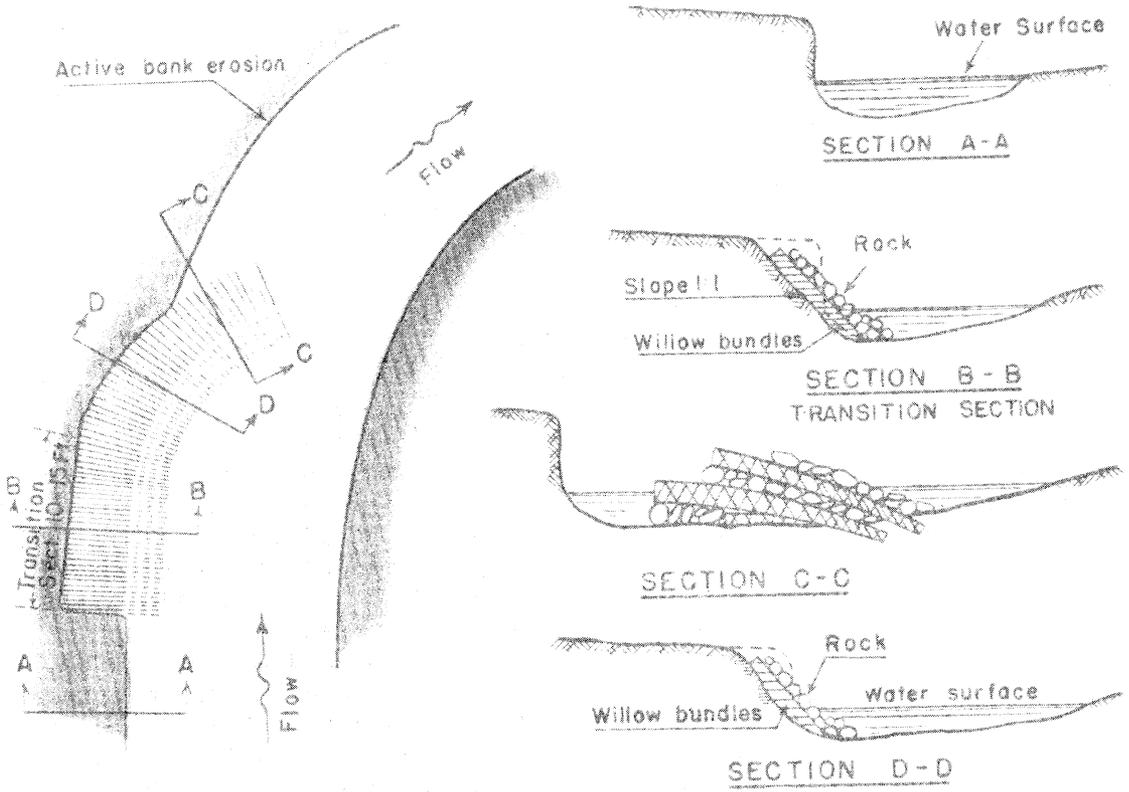
Clear and grub heavy brush or willow growth from this site which may be deflecting the stream against the eroding bank opposite.



JETTED WILLOW POLES

REGION 5 REGIONAL OFFICE
U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

CARTOGRAPHIC DIVISION APPROVAL: *Thomas M. ...* TECHNICAL APPROVAL: *Edwin ...*
DESIGNED: L.E. Nelson DRAWN: W.G. Espy CHECKED: G.W. Foster DATE: 3-10-42 DRAWN BY: 5-L-3251



TYPICAL PLAN & SECTIONS ROCK & WILLOW DEFLECTING JETTY			
U.S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
Reference: Taken from Winter Work Construction Methods by O.R. Zeasman & N.E. Minshall			
Drafting Approval <i>James H. Wood</i>		Technical Approval <i>E. Freyburger</i>	
DRAWN C.R.N.	TRACED S.M.G.	CHECKED F.W.S.	DATE 10-31-38
			L-3256

FIGURE 13.2 ROCK AND WILLOW DEFLECTING JETTY

stick, and when pressure is applied to the ends of the sticks, the rope on the upper side and the crossed sticks on the sides and top serve to compress the bundle.)

Step 2. Preparing the site. At the location selected for the deflecting jetty, the bank should be sloped for a "transition section" at least 1:1 for a distance of ten to fifteen feet upstream from the point where the jetty will swing away from the bank into the stream.

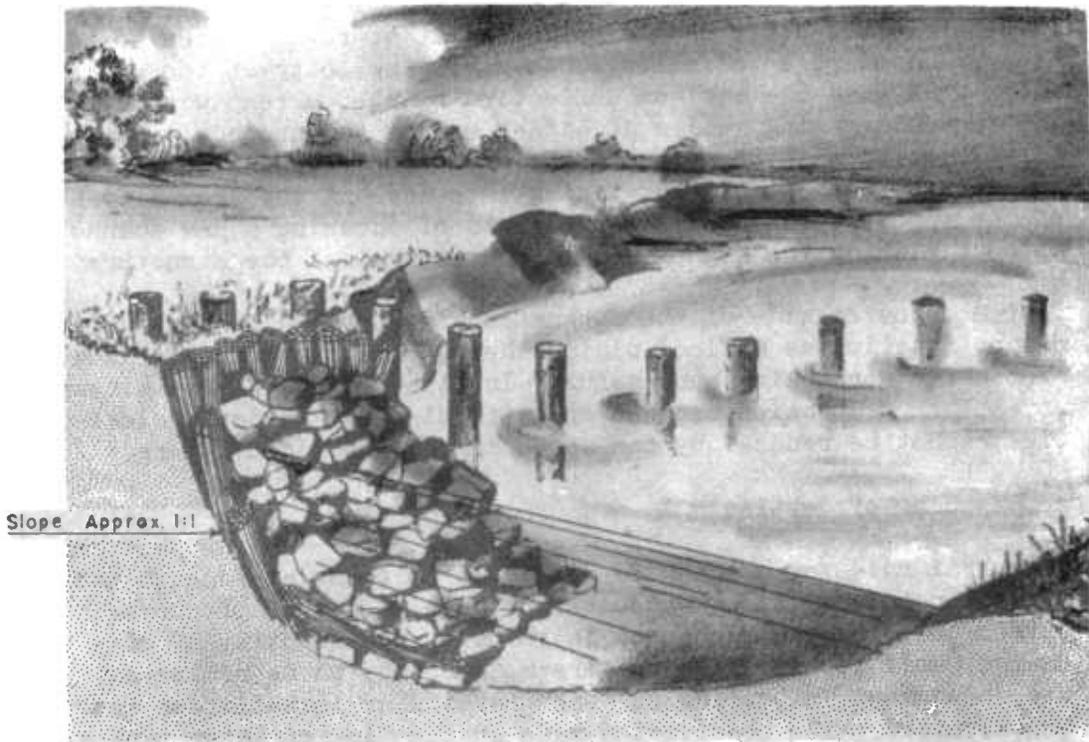
Step 3. Constructing the jetty. Beginning at the upper end of the transition section, lay the willow bundles closely together with the butt end up working the tips into the stream bed. Tie each bundle to the adjacent bundle to form an integral mat. (Occasionally it will be necessary to place a bundle or two with the butt ends down to avoid a "fan" effect.) The portion of the jetty extending into the stream must be higher on the bank side as indicated in Section C-C, Figure 13.2. In order to obtain this condition, place a wedge-shaped pile of rock in the stream bed with the higher portion of the wedge underneath the butt ends of the initial willow mat layer. The top of the mat is then covered with rock, with the heaviest rock placed near the butt ends to resist displacement by high water velocities. Successive layers of willow mat and rock are added until the desired height is obtained. Be sure to work the tips of the willows into the stream bed. When unusually high velocities are encountered, it is advisable to place a layer of hog wire on the bed on the stream under the initial rock and willow layer, bringing the wire around the tip of the jetty, up and over the top of the mat and fastened to it.

b. Constructing the piling deflecting jetty (Figure 13.3, page 13-7). The upper end of this jetty is constructed the same as the rock and willow deflecting jetty. Piling is then driven or jettied as indicated in Figure 13.3.

13.36 General Points Applicable to Both the Jetties

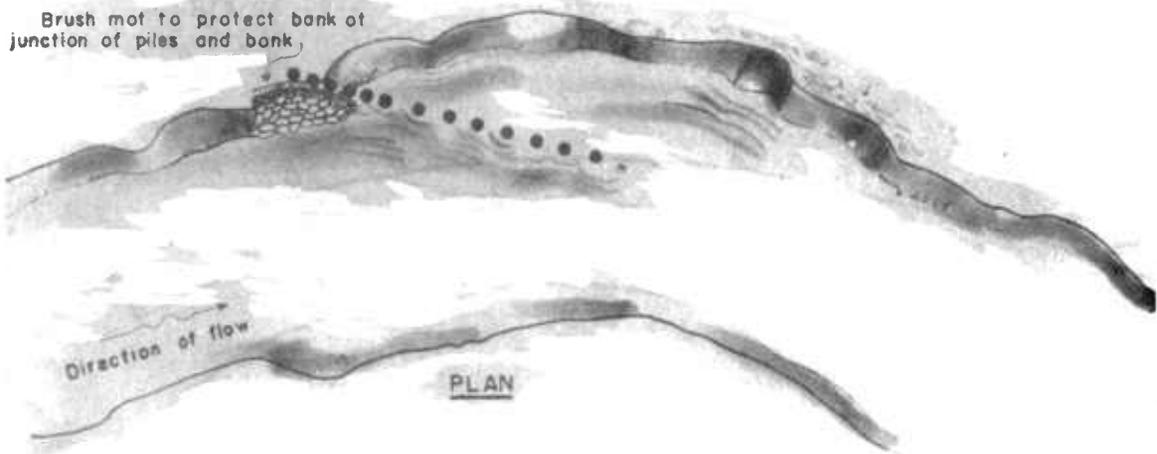
a. Slope of the Jetty

The mat should be bank high at the junction with the bank. The jetty should slope toward the downstream end to produce the desired effect of deflecting the stream away from the eroding bank and depositing silt behind the jetty.



PERSPECTIVE SKETCH

Brush mat to protect bank of junction of piles and bank,



PLAN

NOTE.

Space piles 1'-6" min. out approx. 6'-0" from bank, then 3'-0" min. the balance of the way out in the stream.

Piles to be driven to $\frac{1}{2}$ to $\frac{2}{3}$ of their total length.

PLAN & PERSPECTIVE OF PILING DEFLECTING JETTY				
REGION				
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE				
Reference: Taken from Winter Work Construction Methods by O.R. Zeasman and N.E. Minshall				
DRAFTING APPROVAL		TECHNICAL APPROVAL		
<i>Kenneth McLeod</i>		<i>G. Freyburger</i>		
Drawn	Traced	Checked	Date	L-3259
C.R.N.	S.M.G.	F.W.S.	11-1-38	

FIGURE 13.3 PILING DEFLECTING JETTY

b. Angle of Jetty With Bank

In general, the jetty should not be built at right angles to the bank. A good rule to follow is to place the jetty at the angle which will give the maximum deflection of the current without setting up damaging eddies at either end of the protective work. Consideration must be given to the amount of restriction of the channel that can be allowed taking into account the proximity of the opposite bank and the prospects of scouring a new channel without placing too high a head of water against the structure.

If the opposite side of the stream consists of a high bank which cannot function as a flood plain, there is little chance of the protective work being successful. In other words, do not attempt streambank protection between opposite high banks where velocities cannot be reduced by the spreading of the flood waters.

c. Spacing of Jetties

A general rule for spacing is difficult to formulate due to the variation in conditions encountered, such as degree of curvature of eroding bank, changes in velocity and quantity of discharge, soil types, width of stream, property to be protected, etc. Judgment in "sizing up" each particular installation must be exercised. The observation made on the flow of water past a completed upper jetty will help locate the next structure below, taking into account, of course, the effect that various stages of flow may have on the behavior of the current. One "rule-of-thumb" method for spacing is illustrated in Figure 13.4.

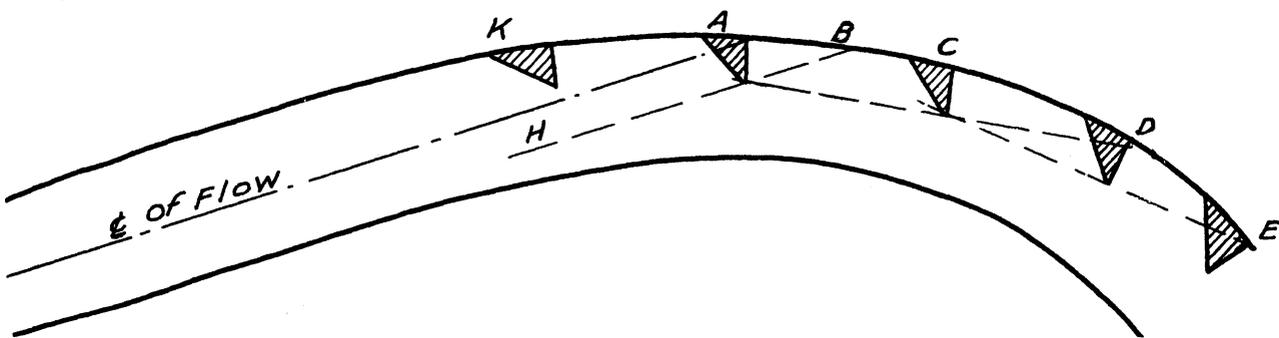


FIGURE 13.4 METHOD OF LOCATING JETTIES

Point "A," location of first jetty, is the intersection of the centerline of flow and the eroding bank. Jetty "C" is located by drawing HB parallel to the flow line and across the toe of jetty "A." AC is twice AB. Jetty "D" is located by projecting a line across the toe of jetties "A" and "C." The remaining jetties are located the same as "D." Supplementary jetty "K" located AC distance upstream from "A" should be approximately one-half regular size.

Generally, when curvature of the eroding bank exceeds 30 degrees (190-foot radius), it is safer and more economical to use some type of revetment for protection instead of jetties.

d. Vegetative Treatment

Deposition of silt should occur in the area immediately adjacent to and below the jetty. The area between jetties should be planted with bush willow cuttings and other desirable species and protected from grazing. On all types of streambank jobs, plant moisture-tolerant shrubs. Other suitable plantings can be made between the bank and the fence. If enough area is available, timber species of some value like cottonwood and black walnut should be planted.

e. Maintenance of Streambank Work

All types of streambank control involving the use of willows will require maintenance. Better protection will be obtained if the willows are cut periodically to keep the stems small and pliant so they will bend over and "shingle" the streambank during periods of high water. Willows and other trees planted for bank protection should always be cut out before they reach two inches in diameter. Debris lodged against banks during floods should be removed immediately afterwards. Brush growing on inside curves should be cut down periodically.

13.37 Jacks for Streambank Control

A third method of streambank control which can be used rather easily by farmers consists of placing one or more rows of jacks along the streambank. They can be used on any of the streams previously mentioned.

a. Construction of "Jack"

1. These are constructed by cutting three poles 10 to 16 feet in length, depending on the depth of stream which is to be controlled. (Multiply depth of stream by 1.4 to determine length of poles required.)
2. These are crossed and wire together at the midpoints.

The ends are then tied together with No. 9 wire, as shown in Figure 13.5, page 13-11.

3. The next step is to place the "jack" in the stream. A series consisting of enough to protect the area where cutting occurs should be constructed. They should be spaced as close together as possible, with not over one jack space apart. This will provide an almost continuous line of revetment. (See Figure 13.6, page 13-12.)

4. They are held in place by tying the center of the jack with cable clamps to a main cable which is carried around through the center of the jacks on the area to be protected. The upper end of this cable is tied to a dead man, which in turn anchors all the "jack" as a unit. The cable should be 1/2" to 3/4", depending on length and depth of stream. The dead man should consist of about a 6' timber about 8" to 10" in diameter. Each jack should be weighted by rock which can be wired onto the poles.

5. If permanence is desired and vegetation will not furnish the ultimate control, angle irons or reinforced concrete posts can be substituted for the poles in the "jacks" as mentioned above. Also some steel fabrication plants make them for sale on a contract basis.

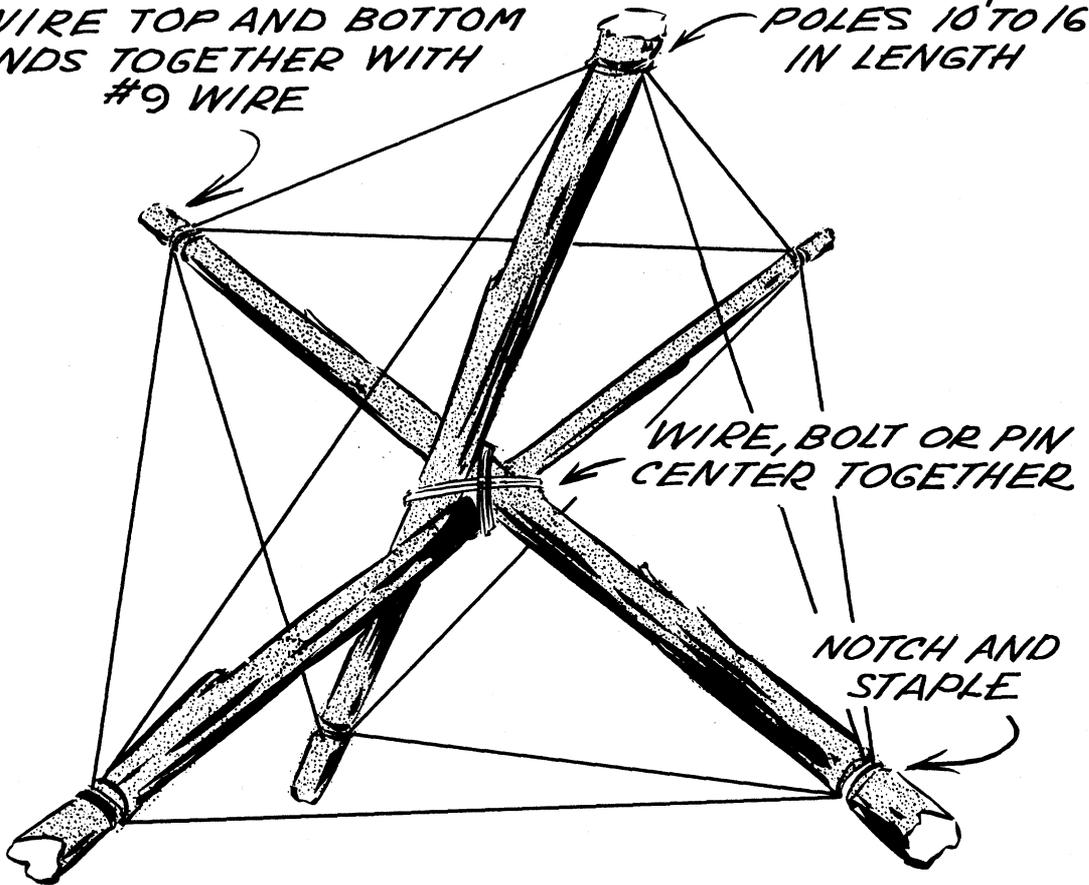
13.38 Stream Straightening

Straightening of stream channels for control of streambank erosion should rarely be undertaken as it is very expensive and may result in further bank cutting due to the increase in grade of the shortened channel. Where straightening may seem advisable the assistance of an engineer should be secured before recommendations are made.

"JACK"

WIRE TOP AND BOTTOM
ENDS TOGETHER WITH
#9 WIRE

POLES 10' TO 16'
IN LENGTH



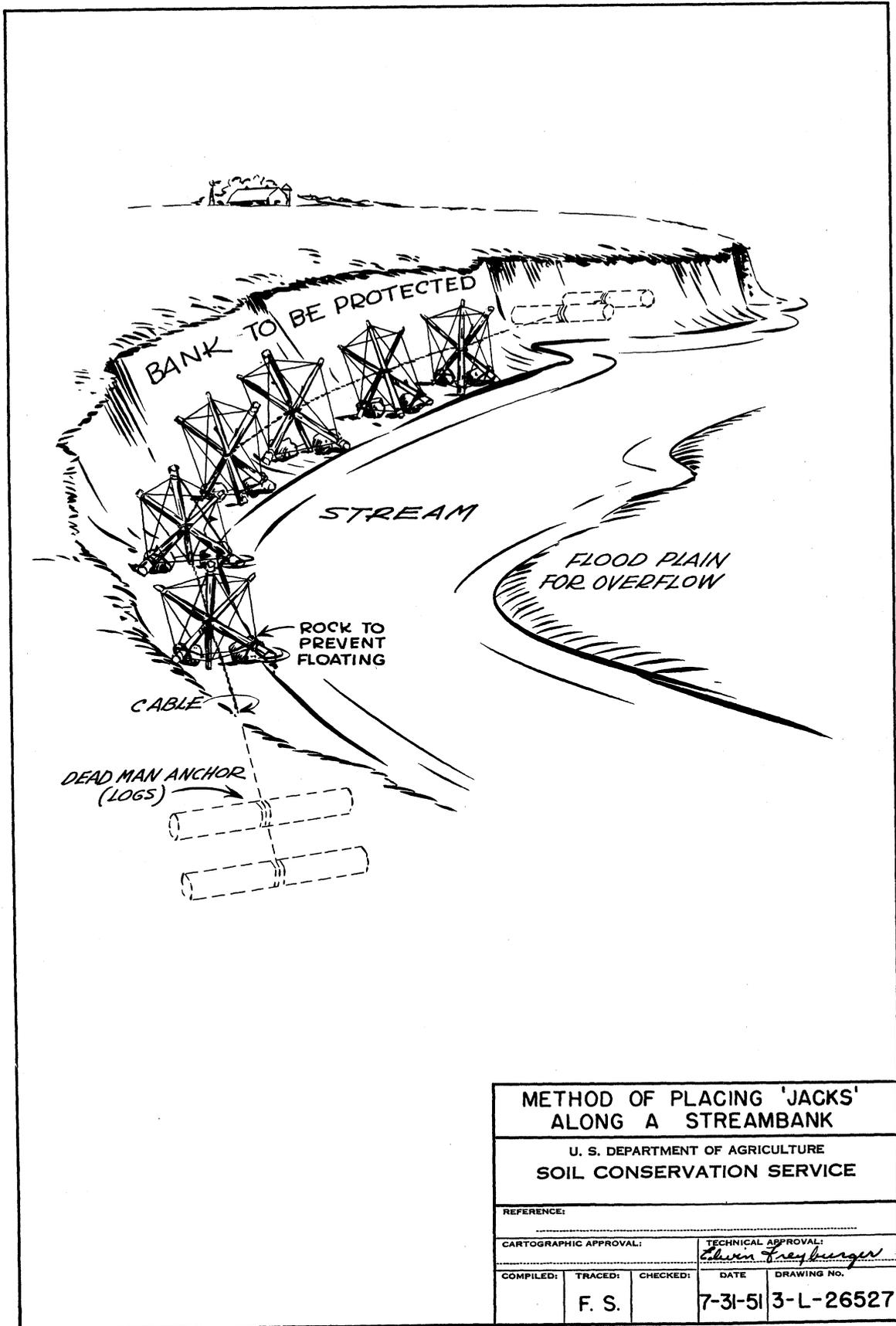
WIRE, BOLT OR PIN
CENTER TOGETHER

NOTCH AND
STAPLE

FOR STREAMS OF HIGH VELOCITY A MORE
STURDY CONSTRUCTION WOULD BE TO TIE
ALL ENDS TOGETHER.

DETAILS OF JACK				
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE				
REFERENCE:				
CARTOGRAPHIC APPROVAL:			TECHNICAL APPROVAL:	
COMPILED:	TRACED:	CHECKED:	DATE	DRAWING NO.
	F. S.		7-31-51	3-L-26528

FIGURE 13.5 DETAIL OF "JACK"



METHOD OF PLACING 'JACKS' ALONG A STREAMBANK			
U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE			
REFERENCE:			
CARTOGRAPHIC APPROVAL:		TECHNICAL APPROVAL: <i>Oliver Freyberger</i>	
COMPILED:	TRACED:	CHECKED:	DATE
			7-31-51
F. S.		DRAWING NO. 3-L-26527	

FIGURE 13.6 STREAMBANK CONTROL WITH "JACKS"