Irrigation Structures And Equipment

Extension Service
Montana State College
Bozeman, Montana
# CONTENTS

Dams .................................................................... 7  
Headgates, Drops and Checks ................................. 12  
Turnouts and Siphons ........................................ 20  
Soil Auger ................................................................ 24  
Leveling .................................................................. 25  
Ditchers ................................................................ 32  
Dikes and Dikers .................................................. 33  
Furrowers and Corrugators ................................ 36  
Turnouts and Spiles .............................................. 36  
Levels and Surveying Equipment ......................... 40  
Portable Dams ....................................................... 45  
Soil Moisture Prober ............................................ 47

Montana Extension Service in Agriculture and Home Economics, R. B. Tootell, Director.  
Montana State College and United States Department of Agriculture Cooperating.  
IRRIGATION STRUCTURES AND EQUIPMENT

By
H. L. Dusenberry and O. W. Monson

INTRODUCTION

Modern irrigation equipment and adequate structure are required to do an efficient job of irrigation. Just as necessary are proper land preparation, adequate ditches kept clean and dikes properly maintained. When these requirements are met, water can be controlled easily and many man hours of labor with a shovel will be saved.

Control begins at the diversion dam which is built into the stream or channel. It diverts the desired amount of water to the ditches and permits surplus or high water to by-pass without damage to the dam or the channel.

Headgates, checks, drops, wasteways and other devices are required at critical points in the ditch through which the water flows to the farm. These are necessary to prevent washouts and channel erosion.

Every farm requires a different set of structures and equipment. For this reason the devices for controlling irrigation should be carefully planned to fit the needs of the farm.

Some of the needed structures can be built in place by the farmer out of concrete and wood. Many of the smaller structures such as headgates and turnouts are now being made commercially of concrete and steel. These can be purchased and installed by the farmer.

There must be a dam or check in the main canal at the farm turnout to hold the water high enough so the water can be turned into the farm supply ditch. A good permanent headgate, preferably of steel and concrete is recommended. The permanent farm supply ditch and head ditches should have adequate banks. Provision for cleaning is important. Headgates should be installed at every permanent ditch turnout on the farm. Drops are necessary when the ditch must run down a steep grade. Temporary portable equipment such as canvas or plastic dams and large siphon tubes for turn-
outs will give excellent control under certain conditions, such as for contour or border ditches or border dikes. They also reduce the cost of turnout structures and leave the ditch open for mechanical cleaning.

The purpose of this bulletin is to provide information on the construction of irrigation devices and equipment which can be made on the farm. The use of commercial equipment will also be discussed and illustrated. While every farm has different requirements for structures, an illustration of the ones which might be needed for some common methods of irrigation are shown in Fig. 1.

Several methods are shown for illustration purposes. It is unlikely that a farm would be adapted to this many different methods. Ordinarily one or two methods are used on each farm. On flat land where the slope is less than 3 percent the border ditch or border dyke method will likely be best adapted. On steeper lands the contour ditch will be used. Row crops require irrigation by furrows. On steep, uneven or extremely flat land, or when the water supply is short, the corrugation method will be most efficient.

In each case the method requires certain equipment. First there is the implements needed to level the land. Then the equipment to construct the ditches, dikes and furrows.

Controls are needed at every turnout in the ditch. They may be permanent or temporary. Usually the structures such as checks, headgates and turnouts should be permanent when placed in the head ditches. Temporary controls, such as canvas dams, are used in the field where the ditches are also temporary.

In Figure I the drop checks may or may not be needed, depending on whether or not the soil washes. If the erosion is not a problem, only the check will be needed. If this is true the check can be permanent or temporary. The concrete check has the advantage of requiring very little upkeep after it is once installed. If ditch maintenance is a problem, requiring annual use of the ditcher, it may be more practical to use temporary checks such as canvas or steel dams.

Where large syphon tubes are indicated in Figure I, permanent checks and turnouts could be substituted. The permanent structures would require a much greater initial investment but would be more convenient for the irrigator to use. The large tubes are portable and thus can be moved with the water. The irrigator uses only enough tubes to take care of the amount of water he is using. Where Figure I shows small syphon tubes, wooden lath spiles or straight steel tubes installed in the bank could be used. Here again it is a question of the farmer's preference and adapting the equipment to the farm.
NOTE: This spillway requires approximately 80 yds. of stone and 20 yds. of mortar. Mortar: 4 parts sand to 1 part cement. (about 150 sacks of cement)

RUBBLE MASONRY: SPILLWAY FOR AN EARTH DAM

Fig. 2
DAMS

a. Masonry.—Fig. 2 shows the general plan and proportions of a rock masonry dam which, with minor changes, can be adapted to a wide variety of conditions. It is of the overflow type and the center section of the dam serves for a spillway for flood waters whenever the flow in the creek exceeds the capacity of the diversion canal. This type of dam is recommended wherever rock and boulders are accessible within convenient reach of the dam site. The dimensions given for the dam provide for a minimum use of cement in order to cut down cash outlay. To offset this saving on cement, a liberal use of rock is recommended in order to give strength and stability to the structure.

For the shell of the dam, use clean stone laid in cement mortar. The mortar should be fairly rich. Not over 6 gallons of water should be used per sack of cement, with only enough sand to make a good mortar. If the sand is wet, cut the amount of water to 5½ gallons per sack. Sand must be clean and sharp. Even small amounts of vegetable matter and dirt will reduce the strength of the mortar.

The downstream sides and wing walls should also be laid up in mortar with a thickness of not less than 12 inches. The floor or apron should be increased to 18 inches if the drop exceeds 4 feet. The length of the apron should be about twice the amount of drop, with a minimum of 8 feet. For the structure illustrated in Fig. 2, having a drop of 8 feet, the apron should be 16 feet long and 18 inches thick. Note also that a check wall at the lower end provides for a water cushion, and the water discharges at slightly below the grade level in the creek.

The capacity of the spillway is 10.5 cubic feet per second per foot of crest when the depth on the crest is 2.5 feet.

Concrete Dam

Fig. 3 shows a design for a reinforced concrete diversion check dam with 4 bays.

When building concrete structures for water control, it is highly important that attention be given to the selection of sand and gravel used and to the proportioning of the concrete mixture.
Only clean sand and gravel, free from vegetable matter and dirt, should be used. A small amount of dirt will neutralize a considerable amount of cement.

It is important also to use a rich mixture. To skimp on the amount of cement used is really a waste, because the resulting structure will not stand up under the erosive action of water and weather. A 1:2½:5 mixture that is, 1 part cement, 2½ parts sand and 5 parts gravel, represents a good proportion of cement and aggregate. The most reliable basis for designating a mixture, however, is the so called cement-water ratio. By this is meant limiting the amount of water used per sack of cement. For the structure shown in Fig. 3, it is recommended that not more than 6 gallons of water be used per sack of cement, using only enough sand and gravel to make a good workable mixture.

Reinforcing by steel strengthens the structure. Steel is placed on the side of the wall subject to tensile stresses. The rods should be imbedded in the concrete 1 inch deep. Side walls and floors also need a small amount of reinforcing to protect against excessive erosion. This can be supplied in the form of hog wire fencing embedded in the concrete 1 inch deep.

Other important features in the construction of a concrete diversion dam, as shown in Fig. 3, are the cut-off walls. The upstream wall in particular, should extend down into solid material from 2 to 3 feet. The downstream cut-off wall should extend deeply enough to prevent backwash under the floor. If the structure is to be built upon a porous formation, such as sand or gravel, drainage must be provided to carry away water which percolates under the structure tending to cause uplift when the flash boards are in place. This is carried away by means of a 4-inch tile laid under the floor with an outlet branch as shown in Fig. 3.

Concrete structures are expensive, but there is no justification for skimping in the materials used; since this usually results in failure and a waste of the entire structure rather than in any net saving.

A simple test to determine the suitability of sand or gravel for use in concrete is to fill a bottle, such as a fruit jar, one-half full of sand or gravel; then fill it completely with water and
shake thoroughly. After this, allow the bottle to stand several hours to settle. After settling, so that the water has cleared up, the material will be well sorted out: the gravel will be on the bottom, the sand next, then the dirt, and the vegetable matter will be on top. If any considerable amount of vegetable matter and dirt appears, it must be washed or screened out before the sand or gravel will make good concrete.

Fig. 3—Concrete Diversion Dam

Bill of Materials

| Reinforced Concrete                           | 113.75 cu. ft. |
| Wing Walls and Side Walls                     | 50.00 cu. ft.  |
| Cut-off Walls                                 | 47.00 cu. ft.  |
| Center Piers                                  | 85.25 cu. ft.  |
| Floor                                         |                |

Reinforcing Steel
32 — 1½"x5½’ reinforcing rods.
66 linear feet of 42” hog wire.
8 — ½”x8” carriage bolts.

Lumber
4 — 2”x10”x16’ No. 1 fir for flash boards.
2 — 2”x12”x18’ No. 1 fir for foot walk.

Tile
36 linear feet of 4” tile.
Brush And Rock Dam

Fig. 4 shows a type of construction for a diversion dam which is adapted to many parts of Montana. The governing principle in its design is the use of local materials. Only rock, brush and native logs are used. Therefore, it is possible to build this dam with little, if any, cash outlay. The dam is built by placing alternate layers of rock and willows, backed up with earth fill, with each succeeding layer set back to give a stairway effect to the spillway. It should be constructed with a general slope of 2 to 1; that is, a 1 foot rise to 2 feet run. The rock serve to hold the willows in place and anchor them into the dam. They also give weight and stability to the structure. The dam is made watertight by an earth fill on the upstream side, which is also built on a slope of 2 to 1. The earth fill should be built up at the same time that the brush and rock are placed, so that the brush ties in and forms a good bond with the earth dam. The head wall, side walls, and wing walls are constructed of logs notched together at the corners. Binding them with wire strengthens the construction.

The crest or top of the dam should be built high enough to divert the required amount of water when the stream is low. The
diversion channel must be protected with a headgate so that the amount of diverted water may be controlled, especially during high water. A double wall and double wing headgate is better than a single wall structure. At the lower end of the spillway the channel should be heavily riprapped the full width for a distance of 4 to 6 feet. This riprapping should be placed below the grade line of the channel so that the water will be discharged below the grade, and thereby prevent erosion or backwash.

This type of structure is to be recommended wherever brush, rock and logs are available convenient to the dam site. If carefully constructed, such a structure should be safe for conditions where the height or fall does not exceed 10 feet. Since the materials used are cheap, these should be used in liberal proportions.

Temporary Low Cost Diversion Dams

Where a small ditch of water is to be taken from some of the smaller rivers, it is often necessary to build a diversion dam that will be inexpensive and be within a reasonable cost-benefit ratio. Where the stream bed is rock and gravel, a dam can be made with a bulldozer by pushing a thick layer of rocks and gravel across the stream bed to hold the water up against the diversion gate. The surplus water spills over the rock dam and goes on down the stream. A dam of this kind may require some maintenance from year to year, but the original cost and the maintenance are not high on streams where the channel is fairly stable and the seasonal flow does not fluctuate excessively.

Where a ditch is taken from a stream the ditch should be taken out at a level lower than the bottom of the stream bed if possible. If this is done a diversion dam may not be needed.

Rock piers are sometimes built at 10 or 15 feet intervals across the stream. During the irrigation season, poles are suspended between these piers. If the poles do not divert enough water, boards are placed in front of the poles. This may be supplemented with straw or manure to form a still tighter diversion. The poles and boards are removed in the fall after the irrigation season is over, leaving only the piers in the channel over winter. On streams
where heavy flooding occurs and lots of debris is carried, the piers are likely to be lost and may have to be replaced.

A rock basket dam can be made by laying woven wire on the stream bed, covering it with rock. Place the loose ends of the wire on top and tie to the wire beneath. The wire holds the rock in place.

Whenever benefits will justify cost, a good concrete diversion structure should be designed and installed to save annual maintenance and provide a permanent structure.

**HEADGATES**

Fig. 5 shows the general plan for a wooden headgate capable of handling a large flow of water. It has two 5-foot gates and should have a capacity of about 100 cubic feet per second. It is recommended that 2-inch material be used throughout and, to add to the durability of the structure, this lumber should be creosoted before nailing in place. The posts used may be of any native wood, instead of the sawed 6x6's illustrated in Fig. 5. These posts also should be creosoted to preserve them against decay. Heavy cross bracing is necessary to keep the walls from warping and being pushed inward.

An important feature is the setting of the posts to a depth of at least 3 feet to hold the structure firmly in place. It is also important to build cut-off walls and wing walls down into the bed of the canal sufficient to prevent washing under the structure. Unless the posts are deeply set, firmly tamped and anchored in place, the whole structure is liable to be raised by the water getting under the floor and uplifting or floating it away.

An added feature to the design shown in Fig. 5 would be the use of a wheel and screw stem on each of the gates to facilitate opening and closing them. It may also be necessary to protect the downstream end by riprapping with stone to prevent backwash and undercutting. The floor of the structure should be set level with or even slightly below the bottom of the channel. This tends to reduce the danger of undercutting and erosion around the structure.
WOODEN HEADGATE

WING WALLS

DIAGONAL BRACES

EARTH FILL

2 FIVE FOOT GATES

FLOW

FLOOR WALLS

WING WALLS

TIES

CUT OFF WALLS

GATES

GATE GUIDES

DIAGONAL BRACES

BILL OF MATERIALS

POSTS

12 - 6" x 3/4" x 9' 6"
4 - 6" x 3/4" x 9'

FLOOR

10 - 3/4" x 3/4" x 9'

WALLS

12 - 3/4" x 3/4" x 9'

WINGS

12 - 3/4" x 3/4" x 9'

TIES

14 - 3/4" x 3/4" x 9'

CUT OFF WALLS

2 - 3/4" x 3/4" x 9'

GATES

6 - 3/4" x 3/4" x 9'

GATE GUIDES

1 - 3/4" x 3/4" x 9'
6 - 3/4" x 3/4" x 9'
1 - 3/4" x 3/4" x 9'

DIAGONAL BRACES

2 - 3/4" x 9'

SECTION THRU CENTER

Fig. 5
Concrete Headgate

Fig. 6 shows a plan for a concrete headgate to be placed in a main ditch for diversion into a farm lateral. The use of this structure provides complete control of the water, both in the canal and in the lateral. It saves a great deal of work, as well as unnecessary digging of the ditch banks, when diverting water from a main ditch.

![Concrete Diversion Headgate Diagram](image)

The headgates are made of wood, controlled with a screw stem and handwheel. Concrete in this headgate structure should be made of clean, sharp sand and gravel containing no vegetable matter or dirt. Full dimensions should be used, to provide stability to the structure. Placing of heavy chicken wire or hog wire imbedded 1 inch in the concrete will add greatly to its strength without increasing the cost very much. Cut-off walls should extend into the ground sufficiently to prevent undercutting. A minimum of 1 1/2 feet is recommended. When mixing the concrete, not more than 6 gallons of water per sack of cement should be used.
Concrete Checks and Drops

Fig. 7 shows the dimensions and plan of construction of a simple concrete drop and check. This structure consists of only a single wall built at right angles to the stream or canal. A notch

SIMPLE CONCRETE CHECK WALL

TABLE I.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>14'–0&quot;</td>
<td>4'–0&quot;</td>
<td>4'–0&quot;</td>
<td>1'–6&quot;</td>
<td>0'–8&quot;</td>
<td>1'–6&quot;</td>
<td>1'–8&quot;</td>
</tr>
<tr>
<td>19'–0&quot;</td>
<td>6'–0&quot;</td>
<td>6'–0&quot;</td>
<td>2'–0&quot;</td>
<td>0'–8&quot;</td>
<td>1'–6&quot;</td>
<td>2'–0&quot;</td>
</tr>
<tr>
<td>24'–0&quot;</td>
<td>8'–0&quot;</td>
<td>8'–0&quot;</td>
<td>3'–0&quot;</td>
<td>0'–8&quot;</td>
<td>2'–0&quot;</td>
<td>3'–0&quot;</td>
</tr>
</tbody>
</table>
through the center provides a passage for the water when not in use. Grooves in the wall, into which flash boards can be fitted, provide for checking or raising the water surface when desired for diversion. Since this check does not have the bracing effect of side walls, it must be rather wide and thick in order to be stable. To protect the channel against erosion, a heavy rip-rapping of rocks should be placed on the lower side. This may slope up to the crest of the check, or simply be placed in the bottom of the channel onto which the water will fall. It is important that the water should be discharged at grade level to prevent eddies and undercutting.

In building concrete structures, the farmer is cautioned against undue economy in the use of cement. Either sufficient cement should be used to make a durable structure, or else its use
TABLE II.

<table>
<thead>
<tr>
<th>Capacity of ditch in c.f.s.</th>
<th>Width of opening (W) ft.</th>
<th>(H) in.</th>
<th>(C) in.</th>
<th>(A) ft.</th>
<th>(B) ft.</th>
<th>(E) &amp; (F) ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>12</td>
<td>6</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>12</td>
<td>6</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2½</td>
<td>15</td>
<td>6</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>18</td>
<td>8</td>
<td>2½</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>3½</td>
<td>18</td>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DROP LENGTH OF APRON (D) Feet

<table>
<thead>
<tr>
<th>DROP (D) Feet</th>
<th>LENGTH OF APRON (L) Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2½</td>
</tr>
<tr>
<td>1½</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

Wooden drops should be abandoned entirely. Too much economy in the mixture or in the dimensions of the structure may result in total failure and loss. The mixture should be based upon the use of 6 gallons of water per sack of cement. Steel reinforcing may be used although heavy hog wire in the upper face of the wall will add greatly to its strength. The dimensions given in the Table I indicate the proportions to which the concrete check should be built under various conditions.

A concrete drop like the one shown in Fig. 8 may be built in farm head ditches. This drop can be built according to the dimensions given in Table II. In areas where freezing and thawing in winter cause upheaval of structures with a floor, it is best to use the single wall concrete drop or check as shown in Fig. 7.

WOODEN DROPS

Drops are used in ditches to slow down the velocity of water and protect the channel. When it is necessary to run water on a grade steep enough to cause cutting, it is advisable to use either
pipe, concrete ditch lining or drops. The drop is usually the lowest cost installation. They can be made of cement, tile pipe or wood. Figure 9 shows a wooden drop which is satisfactory for farm ditches. Two-inch material should be used in the construction. Treating the wood with a preservative is recommended. Table II gives the dimensions for construction, using different ditch capacities. The drop should be installed so the discharge crest is level with the bottom of the ditch. This puts the floor of the drop below the bottom of the ditch.

READY MADE DROPS

Drops can be made from concrete pipe. Some of the concrete companies are now making drops ready for installation. These may be had in various sizes to fit the capacity of the ditch. Figure 10 shows the general plan of installation for a concrete pipe drop. Metal or tile pipe may also be used. An elbow is required for the turn and a concrete collar for the intake end is necessary. A concrete discharge apron is also necessary.
Fig. 10—Ready Made Drop (Concrete)

WOODEN CHECK

Fig. 11 shows a wooden check for use in a farm lateral or head ditch. Its purpose is to raise the level of the water in the ditch to make it flow onto the field. It consists of 2 cut-off

<table>
<thead>
<tr>
<th>8 C.F.S.-6 C.F.S.</th>
<th>10 C.F.S.-14 C.F.S.</th>
<th>12' 0&quot;</th>
<th>14' 0&quot;</th>
<th>3' 0&quot;</th>
<th>3' 0&quot;</th>
<th>3' 0&quot;</th>
<th>3' 0&quot;</th>
<th>0' 6&quot;</th>
<th>0' 4&quot;</th>
<th>0' 6&quot;</th>
</tr>
</thead>
</table>

Fig. 11
walls extending into the banks and bottom of the ditch, securely imbedded to prevent the water from cutting around. The water level is controlled by placing flash boards in the grooves of the side walls. These grooves are built on a slant. This prevents the flash boards from floating out when put in place, since the pressure of the water will hold them down.

It is highly important that the cut-off wall be set deep enough into the bottom of the ditch to prevent undercutting. For gumbo soils a minimum of 12 inches is recommended for the $F$ dimension, and for large structures 18 inches is justified as given in Fig. 11. For the construction of this check, 2-inch lumber should be used; as lighter material would rot out very quickly. Treating of the lumber with creosote before nailing in place is desirable.

**TURNOUTS**

Turnouts are needed to provide a quick and easy means of taking water from the head ditch to field ditches or border dikes. They can be made of wood, metal or concrete. Fig. 12 shows a wooden turnout which can be easily built and installed. Dimensions for various sizes are given in Table III. Two-inch lumber should be used. The floor of the turnout should be installed level with the ditch bottom. An enclosed wooden turnout is shown in Fig. 12a.

![Fig. 12—Wooden Turnout (S.C.S. design)](image-url)
TABLE III.

<table>
<thead>
<tr>
<th>D</th>
<th>W</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>18&quot;</td>
<td>12&quot;</td>
<td>3' 3&quot;</td>
<td>2' 6&quot;</td>
<td>4' 3&quot;</td>
<td>3' 6&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>18&quot;</td>
<td>3' 3&quot;</td>
<td>2' 6&quot;</td>
<td>4' 3&quot;</td>
<td>4' 0&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>2' 0&quot;</td>
<td>3' 3&quot;</td>
<td>2' 6&quot;</td>
<td>4' 3&quot;</td>
<td>4' 6&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>3' 0&quot;</td>
<td>3' 3&quot;</td>
<td>2' 6&quot;</td>
<td>4' 3&quot;</td>
<td>5' 6&quot;</td>
</tr>
<tr>
<td>18&quot;</td>
<td>4' 0&quot;</td>
<td>3' 3&quot;</td>
<td>2' 6&quot;</td>
<td>4' 3&quot;</td>
<td>6' 6&quot;</td>
</tr>
<tr>
<td>2' 0&quot;</td>
<td>12&quot;</td>
<td>4' 0&quot;</td>
<td>3' 0&quot;</td>
<td>5' 0&quot;</td>
<td>3' 6&quot;</td>
</tr>
<tr>
<td>2' 0&quot;</td>
<td>18&quot;</td>
<td>4' 0&quot;</td>
<td>3' 0&quot;</td>
<td>5' 0&quot;</td>
<td>4' 0&quot;</td>
</tr>
<tr>
<td>2' 0&quot;</td>
<td>2' 0&quot;</td>
<td>4' 0&quot;</td>
<td>3' 0&quot;</td>
<td>5' 0&quot;</td>
<td>4' 6&quot;</td>
</tr>
<tr>
<td>2' 0&quot;</td>
<td>3' 0&quot;</td>
<td>4' 0&quot;</td>
<td>3' 0&quot;</td>
<td>5' 0&quot;</td>
<td>5' 6&quot;</td>
</tr>
<tr>
<td>2' 0&quot;</td>
<td>4' 0&quot;</td>
<td>4' 0&quot;</td>
<td>3' 0&quot;</td>
<td>5' 0&quot;</td>
<td>6' 6&quot;</td>
</tr>
<tr>
<td>2' 0&quot;</td>
<td>5' 0&quot;</td>
<td>4' 0&quot;</td>
<td>3' 0&quot;</td>
<td>5' 0&quot;</td>
<td>7' 6&quot;</td>
</tr>
</tbody>
</table>

Wooden Turnout

Scale 1/2" = 1'
Concrete pipe turnouts similar to the one shown in Fig. 13 can be purchased and installed by the farmer. Ready made steel headgates are available. These ready-made headgate turnouts are usually available in sizes of 12”-18” and 24” in diameter. They are merely a concrete or metal pipe long enough to go through the ditch bank with shoulders and a slide gate attached to one end. The shoulder extends well out from the pipe so that water will not wash out the dirt along the pipe when it is installed. A trench is cut through the ditch bank and the turnout installed level with the ditch bottom then covered with dirt. The 12” diameter pipe will carry about 5 cubic feet per second of water with a 1 ft. head. The 18” pipe will deliver about 10 c.f.s. and the 24” about 15½ c.f.s. with 1 ft. of head. The head is the difference in water levels taken at the intake and outlet ends of the turnout.

**SIPHON TUBE TURNOUTS**

Under certain conditions large siphon tubes 4” to 8” in diameter and 5 to 12 ft. long may be used to advantage as turnouts. Where these can be used they have the advantage of reducing the cost because they can be moved with the water which reduces the number required considerably. They also have the advantage of leaving the ditch open for cleaning. When using these tubes for turnouts, a portable canvas, plastic or metal dam is used to check the water in the ditch.

The tubes are adapted for border ditch operation. In this case the head ditch is usually on a slow grade and has high banks. They work well for taking water out of a raised ditch. They are also adapted for turning water out of contour ditches on a hillside where there is a high bank on the low side of the ditch.

Priming is accomplished by filling the tube with water, closing one end with a rubber ball, wooden plug or canvas sleeve, then lifting the closed end over the bank and releasing the water. As long as the water is lower on the discharge end than it is in the supply ditch, it will continue to operate with both ends submerged. The greater the difference
in water level, the faster will be the flow through the tubes. Fig. 14 shows 6-inch metal tubes running water into border dikes. The tubes are available in metal, rubber or plastic. A 6" diameter tube will deliver about 1 c.f.s. of water when the head is 1 ft.

One of the greatest difficulties encountered in the use of the large tubes is priming. A little experience and "know how" will overcome this. First the tube is laid in the head ditch with both ends open. Be sure to let all of the air out of the tube as it fills with water. When it is completely submerged and full of water, close the end which is to be lifted over the bank. If a good seal is made with the plug or canvas there is no hurry about getting the tube over the bank. Be sure to keep the open end under water as the tube is dragged over the bank. The end which is plugged must be placed lower than the water level in the ditch before the plug is removed. When this is accomplished and the plug removed,
the water will start running and continue as long as the water remains higher in the ditch.

One of the difficulties which is apt to happen is air getting into the tube from the discharge end after the water starts. This may be overcome by digging a small notch in the dirt for the end of the tube to lay in. If this is done before priming is attempted the water will come up around the discharge end and form a perfect seal to prevent air from entering the tube.

Frequently a small amount of air will get into the tube during the priming process but the water will continue to flow. When this happens, the flow is restricted. It is therefore advisable to reprime the tube if you suspect this may have happened. With plastic tubes you can see the air bubble but with steel or rubber tubes you cannot be sure whether or not you have an air bubble. If you think the flow should be greater, it is best to re-prime the tube.

**SOIL AUGER**

A soil auger may be used to explore the subsoil and determine the depth to which grading may be safely undertaken. It is also used to determine the texture, structure, and depth of the soil in relation to irrigation practices and methods.

A simple type of soil auger is shown in Fig. 15. It consists of a spiral-shaped bit made from a 1\(\frac{1}{2}\)-inch carpenter’s standard wood auger-bit welded to a handle made of 2 short pieces of 1-inch pipe fixed to a tee coupling. The screw-point and the side cutting edges of the carpenter’s auger are removed in preparing the bit for boring. A post hole type auger also may be used.
LEVELING

The purpose of leveling is to plane the surface and even up the small irregularities left by the plow and grader. The land must be plowed before the leveler will work to advantage. Leveling, or floating, as it is sometimes called, must be done at a time when the soil is rather dry, as it will roll up when too wet.

The leveler or float should pulverize the clods and pack the soil as well as even up the surface. Floating does not move the earth to any extent but smooths and compacts the surface. The leveler is one of the most important and useful implements in irrigation farming and should be used every time the seedbed is prepared for planting.

HOME MADE LEVELER OR BOX FLOAT

Levelers are constructed in many forms but to do the best work they should be comparatively long—at least 3 times their width. A common size for a general purpose tractor or 8 horses is 8 feet wide by 24 feet long as shown in Fig. 16. In constructing the leveler the cross pieces are fastened at right angles to the runners. The two center cross pieces are set vertically with the lower edges flush with the bottom of the sides and shod with strap or angle iron to prevent excessive wear. The front and rear pieces slant backward at the bottom. The front crosspiece, of 2x6-inch material does not extend to the bottom of the runners and serves merely as a crossbrace. As the leveler is pulled across the field, the center crosspieces load up with dirt when crossing ridges or knolls. The dirt is carried until a low place is crossed, where it is dumped. The rear cross piece leaves the surface smooth. Adequate bracing and tie rods, as shown, are essential to hold the float rigid. Fields should be floated both ways to insure a good seedbed and a smooth surface for irrigation.

Smaller levelers are built with only 3 cross pieces, with one vertical or cutting blade located in the center. The usual size for 4 to 6 horses, is 6 feet wide by 18 feet long. Larger sizes similar to Fig. 16, are often built 30 to 36 feet in length and 10 to 12 feet in width. These larger sizes require 3x10-inch or 3x12-inch timbers.
HOME MADE LEVELER

ISOMETRIC VIEW

CROSS SECTION THRU A-B

BILL OF MATERIALS

- BRACE BLOCKS 18 PCS 2" X 4" X 10'
- FOOT BOARD 1 PC 2" X 12" X 24'
- BLADES 3 PCS 2" X 10" X 8'
- BLADE, FRONT 1 PC 2" X 6" X 8'
- BRACES 4 PCS 2" X 6" X 8'
- BRACES 2 PCS 2" X 6" X 7'

RUNNERS 2 PCS. 2" X 10" X 24'
W I TIE RODS 4 PCS 1/2" X 8'6"
MACHINE BOLTS 36 PCS 3/8" X 4'
CLEVIS STOCK 2 PCS 1/4" X 2" X 30"
ANGLE IRON 2 PCS 2 X 2 1/2" X 8" (FOR CUTTING EDGES)

Fig. 16—Home made leveler or box float.

COMPiled BY THE DEPT. OF AGRONOMY, MONT. Exp Sta., WITH THE
ASSISTANCE OF W.P.A. PROJECT No. WP 1905--OP 405-91-3-75.
SIDNEY ADJUSTABLE BLADE LEVELER

Fig. 17 shows a home-made adjustable blade leveler that is popular around Sidney on the Lower Yellowstone project. The blade may be set to cut at any desired depth by adjusting the lever at the front. The lever assembly, taken from an old grain drill, is mounted out in front so it may be operated by the tractor driver. Light draft is assured by the rollers at the rear. The rollers are from a cultipacker. Usual dimensions are 20 feet long and 8 feet wide with side pieces of 2x10-inch timber.

THE AUTOMATIC STEEL LEVELER AND LANDPLANE

Several of the farm implement companies are now making steel levelers with an hydraulic control to raise and lower the blade. These levelers come in various lengths and widths and are used to smooth out the small irregularities in the field and prepare the seed bed. In general they are lighter draft than the
homemade leveler and more easily controlled. The lengths usually run from 20 to 30 feet. A commercial leveler is shown in Fig. 18.

For fields that require a small amount of dirt moving or for finishing a field after heavy dirt moving equipment, the land plane (Fig. 19) has come into use. This implement is very similar to the small steel leveler except that it is much longer and is carried on wheels. These planes are available from 40 to 80 feet in length. They require considerable power to pull and are more expensive to own and operate. They are usually owned by a group of farmers or a contractor and work is done on a fee or rental basis.
Wherever grading and leveling of large areas is necessary it is often more economical to hire the work done than for the farmer to purchase such equipment. Heavy power equipment used by contractors for grading and leveling includes revolving scrapers or "tumble bugs," "bull dozers," and the large "carry-alls" used in highway and reservoir construction that carry up to 30 cubic yards each load.

Grading and leveling with such large outfits can be handled on a daily rental basis for the use of the equipment, with the farmer purchasing the fuel and paying the wages of the operator. Often the contractor does only the rough grading, and the farmer finishes the leveling and installs the distribution system.

Fig. 20 shows heavy dirt moving machinery being used in leveling land for irrigation in Montana.
HOMEMADE DITCHER

Fig. 21—Home made ditcher with wheel

Fig. 22—Double-wing ditcher
DOUBLE WING TYPE DITCHER

- ½ x 2½" L iron sharpened on outer edge
- 2" x 12½' Plank Covered with 20 ga. gal. iron
- ½ x 2½" L iron for adjustment
- ⅝ x 4'6" Beam
- ⅝ x 8" Bolts
- ⅝ x 3½" Mach. bolts 12 center
- ⅝ x 4" Flat iron on bottom of 4' x 4"
- ⅝ x 2½" L with point on bottom end
- 1½" plate for nose
- ⅝ x ½" Strap iron hitch
- ⅝ x 1½" Strap for skid
- ½ x 8" Bolts
- ⅝ x 6" Mach. bolt
- ¾ x 4" Log Screw
- ⅛ x 2½" L from end
- 6'6" - 8'7" Beam
- ½ x 6" Bolts
- ⅝ x 6" Mach. bolt
- 2½" x 2½" x 28" L
- ⅛ x 4" Bolt thru both sides and both straps
- ⅝ x 2½" L
- ½ x 2" x 18" strap with twist hinges beam to brace strap
- ⅛ x 2½" L
- ⅛ x 1½" Strap iron brace
- 2½" x 2½" L
- ⅝ x 2½" L
- ⅛ x 3" Log Screw
- Plate for nose
- Over all length of one side of plow-68½"

Fig. 23—Double-wing ditcher
Most of the ditchers in use are commercial machines made of steel. For those who may want to make their own, Figs. 21 and 23 are included to show construction details for the "homemade ditcher with wheel" and "the double wing ditcher." These ditchers may be used for cleaning an old ditch or shaping up a ditch made by plowing a single plow furrow.

In buying a commercial ditcher, it is well to select one that can be operated by one man, one that has sufficient weight or hydraulic pressure to give penetration in hard, dry soil, also a design of blade that will leave a clean, smooth ditch bottom and uniform banks. It should also do a good job of cleaning ditches. If different sizes of ditches are needed, a ditcher with adjustments for size of ditch should be selected. There are several good ditchers on the market that answer these requirements. Fig. 24 shows a commercial ditcher in operation.

Fig. 24—Commercial Farm Ditcher

Ditch fillers are usually made similar to a disc. Three or four discs are mounted on each side of a frame to move the dirt to the center. The disc units on each side should be adjustable so they can be moved closer together or farther apart to fit the ditch. Several of the manufacturers of ditchers also make ditch fillers. Field laterals and contour ditches should be filled in before harvesting crops. Fig. 25 shows a ditch filler in operation.
Border dikes are built parallel to the direction of slope on 15-to-50-foot spacings. They confine the water to a narrow strip as it floods across the field. Dikes are installed before the crop is planted. The crop is seeded over the dike. Border dikes are best adapted to uniform slopes under 2%. The ground must be level at right angles to the dikes to give an uniform spread of the water as it moves down the slope between the dikes.

Dikes may be constructed with any of a number of different implements. Those in common use are the plow, disc, blade and V-type ridger. Before making the dike, the ground should be leveled. An easily made device which virtually makes dikes in one operation, is the V-type diker. Fig. 26 shows construction details for this diker.

This particular design has a three point hitch which keeps it in line with the tractor at all times. It also has the advantage of setting close to the tractor to enable the operator to get close to the ends of the field. A hoist can be easily rigged up so the tractor will carry it across the ends of the field and it can be backed up close to the ditch to start the dike. This diker gives the proper form to the dike as it moves along, sloping the sides and controlling the height.

Since most dikers do not take dirt from the entire area between dikes, they leave a borrow pit next to the dike. It is then necessary to level the ground between the dikes after they are made, to fill in the area close to the dike.
Fig. 26—V-Type Border Diker
Another means of making dikes, is by installing a long blade on a regular grader. By making two or three rounds to form each dike a thin layer of dirt can be taken from the entire area between dikes.

Some machine companies are now building hydraulically controlled blades which will pull dirt at right angles to the dikes. This type of equipment is operated cross-wise of the field dumping the dirt on the dike with the hydraulic lift. It works something like raking hay with the old fashioned dump rake.

This method has the advantage of being able to take dirt from the entire area between the dikes and leaves no borrow pit. A certain amount of leveling between dikes is also necessary. When this method is used, it should be followed with a V-type drag on the dike to straighten it up and smooth it out. Fig. 27 shows a V-type border diker working.

![Fig. 27—V-Type Border Diker (S.C.S. photo)](image)

Border dikes will work on fields that have a slight side slope. Side slope may be described as a difference in elevation of the ground level between the dikes when taken on a line at right angles to the dikes. When side slope is present, refer to Table IV for spacing of dikes. Border dikes should be at least 5 inches high when settled on slopes under 2% and at least 4 inches high when settled on slopes over 2%. For further information on border dikes, consult Montana Extension Service Bulletin 259, entitled, “Irrigation.”
TABLE IV.
MAXIMUM BORDER WIDTHS FOR DIFFERENT FIELD SLOPES. CENTER TO CENTER OF DIKES

<table>
<thead>
<tr>
<th>DOWN FIELD SLOPES</th>
<th>SIDE SLOPE PER 100 FEET</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BORDER WIDTHS IN FEET</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 to 1%</td>
<td>36</td>
<td>36</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>1% to 1.5%</td>
<td>36</td>
<td>28</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>1.5% to 2%</td>
<td>34</td>
<td>24</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>2% to 2.5%</td>
<td>31</td>
<td>22</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>2.5% to 3%</td>
<td>30</td>
<td>21</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>3% to 3.5%</td>
<td>27</td>
<td>19</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>3.5% to 4%</td>
<td>24</td>
<td>17</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>4% to 5%</td>
<td>21</td>
<td>15</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

FURROWERS AND CORRUGATORS

The furrow or corrugation method of irrigation is used for irrigating alfalfa, grain and other field crops, as well as for gardens and orchards. It consists essentially of irrigating in small furrows which generally run down the slope.

For orchards, berries, potatoes, cabbage and corn, large lister type furrows or small ditches 6 to 8 inches deep and 30 to 49 inches apart are used to spread the water. Somewhat smaller furrows are used for beans, sugar beets and other root and vegetable crops. Regular irrigating shovels of various sizes are available for cultivators.

For alfalfa, pasture grain and peas, the furrows are about 4 inches deep and spaced 2 feet apart. A beet cultivator with irrigation shovels attached is widely used.

SPILES AND SIPHON TUBES

Wherever corrugations are maintained year after year, on steep land subject to erosion and especially when ditches are new and fields have been planted for the first time, small pipes or lath turnout boxes are used to distribute the water from the ditches into the corrugations. These spouts may be made by nailing four laths together or cutting short sections of iron pipe. The spouts are
made in lengths of 2 to $3\frac{1}{2}$ feet. Fig. 28 shows a field being irrigated with the corrugation method in which the water is regulated through lath spouts placed at intervals in the ditch bank. On flat land, one spout is needed for each furrow. On steeper lands a single lath box spout will supply enough water for 2 or 3 furrows.

Small siphon tubes are also used to take water from the supply ditch to run rows or corrugations. These tubes are made commercially and are available in metal, plastic and rubber. Sizes used for row irrigation are usually from $\frac{3}{4}$ inch to 2 inches. Small tubes are recommended for heavy soils and steep slopes. The larger tubes are best for soil with fast penetration and less slope. For efficient use of tubes, the supply ditch should have a high, rather narrow bank.

The furrow should start close to the ditch bank so the tube can be laid over the bank with one end in the water and the other in the furrow. Tubes are primed by filling with water and then closing one end by hand while lifting over the bank. The water must be high enough in the ditch to give good operation of tubes. Table V gives information that will provide a basis for estimating how many tubes are needed for a given water supply. Fig. 29 shows siphon tubes in operation.
Rate of Discharge in Gallons per Minute and Number of Siphon Tubes Required to Deliver 1 Cubic Foot per Second and 100 Miner's Inches of Water at Different Heads.

**TABLE V**

<table>
<thead>
<tr>
<th>SIZE OF TUBE</th>
<th>Head in inches</th>
<th>1&quot;</th>
<th>1¼&quot;</th>
<th>1½&quot;</th>
<th>1¾&quot;</th>
<th>2&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge in gallons per minute</td>
<td>2&quot;</td>
<td>5</td>
<td>8¼</td>
<td>13</td>
<td>17</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>4&quot;</td>
<td>7</td>
<td>12</td>
<td>19</td>
<td>25½</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>6&quot;</td>
<td>9</td>
<td>15½</td>
<td>24</td>
<td>32</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>9&quot;</td>
<td>11</td>
<td>19</td>
<td>29</td>
<td>39</td>
<td>50</td>
</tr>
<tr>
<td>No. tubes required to deliver 1 cubic foot per second</td>
<td>4&quot;</td>
<td>64</td>
<td>37</td>
<td>24</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>6&quot;</td>
<td>50</td>
<td>29</td>
<td>19</td>
<td>14</td>
<td>11</td>
</tr>
<tr>
<td>No. tubes required to deliver 100 miner's inches</td>
<td>4&quot;</td>
<td>160</td>
<td>92</td>
<td>60</td>
<td>45</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>6&quot;</td>
<td>125</td>
<td>73</td>
<td>47</td>
<td>35</td>
<td>28</td>
</tr>
</tbody>
</table>
GATED PIPE

Gated pipe gives better control of the water at the row turns. This pipe is made in various sizes usually from 4 to 8 inches diameter. Slide gates are set in the pipe at the same spacings the rows. The pipe is used in place of a head ditch across the side of the field with the gates between the rows or over the rows. Water is run into the pipe by gravity and the slide gate settings provide a means of giving complete control of the amounts water for each furrow. Gated pipe gives good control of water slopes too steep for effective use and distribution from an open ditch. Fig. 30 shows gated pipe working in a pasture in corrugation furrows.

Spiles made in the shape of a T have also been used successfully. This is two pipes 2 to 3 inches in diameter welded together to form a T. The stem of the T is buried in the ditch banks with the open end free to take water. The cross arm lays across three rows of crop and discharges into four furrows through holes in the pipe. The flow is controlled by a slide gate in the intake end of the stem. Fig. 31 shows a T spile which is not installed.

Fig. 30—Gated Pipe Distributing Water to Corrugations

Fig. 31—T Spile for Distributing Water to Furrows
LEVELS AND SURVEYING EQUIPMENT

To apply the irrigation water with the least trouble and expenditure of time, the ditches should be run to the proper grade; and weirs, headgates, checks, turnouts, and other devices should be properly installed before the water is ready for the ditches. To accomplish this requires the use of levels.

HOME MADE “CRICKET” LEVEL

A practical home-made device used for surveying ditches with a uniform grade is the “cricket” level shown in Fig. 32. It consists of a straight edge 16½ feet long, equipped with well-braced legs 3 feet long. A carpenter’s level rests in a small frame in the middle of the straight edge and is adjusted so that the level bubble is in the center when the device stands on level ground. When used to locate a ditch, a small block of wood is fastened to the bottom of one of the legs to allow for fall in the ditch.

Fig. 32—Surveying contour ditches with “cricket level”

The top board or straight edge of the cricket shown in Fig. 32 was cut from a pine board 1½ inches thick and 8 inches wide. Pine is both light and rigid. The ends were tapered to about 4 inches and the center to about 7 inches in width to reduce the weight. The legs are 1x4-inches x 3 feet long. For braces, 1x3-inches x 7 feet pieces were used, a pair on each side to prevent warping. The grade block was bolted edgewise to the side of the bottom of the leg to provide the proper grade and also to prevent the leg sinking into soft soil.

A 5/8-inch block will give about 0.3-foot fall per 100 feet and a 1/8-inch block, which is the thickness of a lath, will give 3/8-inch fall per rod or nearly 0.2 foot per 100 feet. Table I, gives the size of block to use for different grades.
TABLE I. THICKNESS OF BLOCK FOR DIFFERENT GRADES FOR 16$^{1/2}$-FT. "CRICKET" LEVEL

<table>
<thead>
<tr>
<th>Thickness of block and grade in inches per rod</th>
<th>inches per 100 feet</th>
<th>feet per 100 feet</th>
<th>feet per mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{3}{4}$</td>
<td>2$\frac{1}{4}$</td>
<td>.19</td>
<td>10.0</td>
</tr>
<tr>
<td>$\frac{1}{2}$</td>
<td>3</td>
<td>.25</td>
<td>13.3</td>
</tr>
<tr>
<td>$\frac{5}{8}$</td>
<td>3$\frac{3}{4}$</td>
<td>.32</td>
<td>16.7</td>
</tr>
<tr>
<td>$\frac{3}{4}$</td>
<td>4$\frac{1}{2}$</td>
<td>.38</td>
<td>20.0</td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>.50</td>
<td>26.6</td>
</tr>
</tbody>
</table>

When locating a contour ditch, the operator places the device with the short leg 2 or 3 inches below the water surface in the head ditch and swings the other end around until the bubble in the level comes to the center, with both legs resting on the ground. A helper marks the point by driving a small stake beside the longer leg or else turns up a shovelful of dirt. The "cricket" is then carried forward placing the short leg beside the stake or shovelful of dirt, swinging the other end around until the bubble returns to the center, and so on, repeating the process across the field.

A ditch so located conforms to the warped surface of a field in a series of easy bends, and water will flow in it with uniform velocity. Contour ditches are made with a grade of 0.2 to 0.4 foot per 100 feet from $\frac{3}{8}$ to $\frac{3}{4}$ incher per rod. The most common grade is 0.25 foot per 100 feet or $\frac{1}{2}$ inch per rod. A flatter grade is desired for ditches designed to carry more than 2 cubic feet per second. Small ditches carrying smaller streams require steeper grades.

A grade of $\frac{3}{8}$ inch per rod or 0.2 foot per 100 feet is the least for which the "cricket" is reasonably accurate. This limits the use of the "cricket" to the steeper lands where all ditches may be given a grade of 0.2 foot per 100 feet or more.

**THE HAND LEVEL**

For running contour ditches on a grade of 0.2 feet or more per 100 feet, the ordinary hand level is sufficiently accurate for most conditions. On fields with less than $\frac{1}{2}$ percent slope, the surveyor's level should be used. On fields that have $\frac{1}{2}$ percent slope or over, the hand level can be used for locating ditches, running contour lines or laying out a field for border dikes. It is faster than the "cricket" level and requires less skill to operate than the regular surveyor's level.
A rod made of wood 1"x4"x8' is very usable. The rod, a 1"x2" board staff about eye level height and the hand level is all the equipment needed for surveying by this method. The only thing to purchase is the hand level which is inexpensive. The rod is marked as shown in Fig. 33 by three lines across the broad side. The center line is made at a point located by standing the rod and staff side by side on a level area, resting the hand level on the staff and tilting it until the center cross bar cuts the bubble in half. The point where the line of sight hits the rod should be the center mark on the rod. This is the only mark needed for running a contour line.

\[ \text{LEVEL LINE OF SIGHT} \]

For running contour ditches with a slight grade, a mark both above and below should be added. For a ditch with 0.2 percent grade the mark should be 0.1 foot above and 0.1 below the center line when readings are being taken at 50 foot intervals. Since the hand level does not magnify, it is best to read at 25 to 50-foot distances. For a grade of 0.4 percent the cross lines on the rod should be made 0.2 ft. above and below the center line when readings are to be taken at 50 foot intervals. On Fig. 33 the rod is marked to give 3 inches drop in 100 ft. for a contour ditch. This is 0.25 of a foot or \( \frac{1}{4} \) of 1 percent.

In surveying a contour ditch, the rod man sets the rod near the supply ditch where water is to be taken out. The level is taken out in the field 50 feet in the direction the water will run. It is rested on the staff and sighted through, tilting it up or down until the bubble comes to rest at the center with the cross hair of the lens intersecting the rod. The man with the level then moves up or down the slope, repeating the sighting processes until the cross hair is on the lower line on the rod and the bubble is centered at
the same time. When this point is found, the staff is held on this spot and the rod man moves on across the field in the direction the water will run, 50 feet past the man with the level.

This time the rod man moves the rod up or down the slope until the level line of the sight is hitting the top mark on the rod. The rod man then marks this spot and holds the rod on it while the man with the level goes past him 50 ft. and locates a new point where he is reading the lower mark. The two go around each other alternately, always 50 feet and the man in the lead always moves up or down the slope to find the new point. The man with the level should remember to read the top mark on the rod when sighting in the direction the water is to run and the bottom mark when sighting in the opposite direction. Points should be marked either by a shovelful of dirt or a stake. If a third man and ditcher equipment is available, it can follow along through the points as they are located and no marking is necessary.

For running contour lines, the same procedure is followed, except that the center mark on the rod is the only one used.

**USE OF THE SURVEYOR’S LEVEL**

Running a contour ditch grade with a surveyor’s level requires two persons, the instrument man and the rod man. The level is set up about 300 feet out from the head ditch down the side of the field and a little above the elevation where the first contour ditch is to be taken out, so that when leveled, the telescope or line of sight is 4 or 5 feet above the proposed turnout. When using a small farm level the length of sight should be limited to 200 feet each way from the instrument. Fig. 34 shows a farm level and a surveyor’s rod often used in laying out farm ditches.

The rodman places the lower end of the rod 2 or 3 inches below the water surface in the head ditch or turnout box, care being taken to hold the rod vertically. The levelman sights through the telescope and reads the figure on the level rod intercepted by the horizontal cross-hair. For example, assume that the cross-hair intercepts the figure 4.8 feet. Then the target is set at that figure which is the initial reading. (Surveyors’ level rods are usually marked off in feet and tenths of a foot, being easier to read and calculate than one marked in feet and inches). A stake is placed or a shovelful of dirt turned up to mark the place of beginning. The rodman then paces approximately 100 feet from the starting point in the direction of the ditch is expected to go and sets the target at 5.0 feet which allows 0.2 foot fall if the grade is to be 0.2 per hundred ft. The rod is then held up by the rodman, for a reading. If the target center is above the horizontal line of
sight of the cross hair in the telescope the location is too high and should be moved down hill slightly until the cross hair of the telescope intercepts the center of the target. Conversely, if a reading shows the target below the line of sight the rod should be moved uphill until the center of the target and the cross hairs intercept each other. The proper rod readings may be made by the instrument man without the aid of the target, but faster progress is made if the rod man sets the target for the proper reading at each point.

For station two, 100 feet farther ahead, the target is moved up 0.2 feet to 5.2, indicating a fall of 0.2 feet from the last station. This operation is repeated for each 100 ft. station until a point about 300 feet beyond the level is reached, when the instrument must be moved ahead. Then set up and level the instrument and take a back sight on the rod which has remained at the last point established. The target is now set on a new reading corresponding to the height of instrument again. If for example, the new reading is 3.4, the station 100 feet ahead must read 3.6 ft., the next 3.8 ft. and so on.

When running a grade line down hill, the target is moved up for necessary stations. Where a grade line is run up hill the target is moved down. In locating a level grade line, the target remains constant.

**PROPER GRADES FOR FARM LATERALS**

The typical farm lateral as made with a plow and ditcher is usually run on a grade of about 0.2 foot per 100 feet. Where it is necessary to keep the ditch “up” to reach some certain point, or on heavy clay soils, flat grades as low as 0.1 foot per 100 feet may be used. On the other hand, ditches with grades of more than 0.3 foot per 100 feet are subject to serious erosion where the soil is light. The flat grade is desirable for ditches designed to carry more than 2 cubic feet per second. Small ditches require...
steeper grades. Table VI on this page gives the carrying capacity of farm ditches at varying depths at grades of 0.1 and 0.2 foot per 100 feet. Ordinary V-type ditches carry considerably less water than these sizes.

**TABLE VI—CARRYING CAPACITY OF FARM DITCHES**

<table>
<thead>
<tr>
<th>Depth in inches</th>
<th>Cross section - sq. ft.</th>
<th>Velocity - feet per second</th>
<th>Discharge in cubic feet per second</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Grade .001 or .1 ft/100</td>
<td>Grade .002 or .2 ft/100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grade .001</td>
<td>Grade .002</td>
</tr>
</tbody>
</table>
| Bottom width of ditch 2 feet
| 9               | 2.06                    | .80                       | 1.15                              | 1.65 (Grade .001) 2.36 (Grade .002) |
| 12              | 3.00                    | .96                       | 1.38                              | 2.88 (Grade .001) 4.14 (Grade .002) |
| 15              | 4.06                    | 1.10                      | 1.57                              | 4.46 (Grade .001) 6.38 (Grade .002) |
| 18              | 5.25                    | 1.24                      | 1.75                              | 6.50 (Grade .001) 9.20 (Grade .002) |
| 21              | 6.56                    | 1.35                      | 1.92                              | 8.85 (Grade .001) 12.60 (Grade .002) |
| 24              | 8.00                    | 1.46                      | 2.03                              | 11.70 (Grade .001) 16.20 (Grade .002) |
| Bottom width of ditch 3 feet
| 9               | 2.81                    | .88                       | 1.24                              | 2.47 (Grade .001) 3.48 (Grade .002) |
| 12              | 4.00                    | 1.06                      | 1.47                              | 4.25 (Grade .001) 5.88 (Grade .002) |
| 15              | 5.81                    | 1.20                      | 1.70                              | 6.36 (Grade .001) 9.02 (Grade .002) |
| 18              | 6.75                    | 1.34                      | 1.90                              | 9.05 (Grade .001) 12.82 (Grade .002) |
| 21              | 8.31                    | 1.44                      | 2.04                              | 11.98 (Grade .001) 16.92 (Grade .002) |
| 24              | 10.00                   | 1.58                      | 2.26                              | 15.80 (Grade .001) 22.60 (Grade .002) |

**PORTABLE DAMS**

The canvas dam is indispensable. Each irrigator should have several. They are made from 12 to 20-ounce canvas, and should be about 4 feet wide and 6 feet long, but may be larger.
for larger ditches. The 6-foot side is fastened to a 10-foot 2x2, a 2x4, or a pole, either by nails through a lath, or by sewing a large hem through which the stick or pole may be inserted. This makes it possible to withdraw the pole and fold the canvas when not in use. Heavy burlap will also make a satisfactory dam.

Fig. 35 shows a canvas dam used to divert water from a contour ditch to the land. The dam is usually put in place before the water reaches the point of diversion and is laid in the ditch with the canvas extending up stream and the pole spanning the ditch and resting on each bank. Some earth should be thrown on the edges of the canvas to hold it in place. With two dams on each lateral, one may be placed while the water is spreading from the one above. Canvas dams will last much longer if cleaned, dried and placed under cover after each irrigation.

Plastic dams are coming into common use. They serve the same purpose and are used in the same manner as the canvas dam. They are somewhat more expensive, but are reported to have a longer life than the canvas dam. These dams will tear under rough use but can be vulcanized. They do not accumulate much weight when wet and only a small amount of mud sticks to them when they are removed from the ditch.

Fig. 36 shows a by-pass type of dam. This type of dam makes it possible to divert water onto the land and at the same time permits some to flow past the diversion to lower sets in the field.
It is particularly suited to the irrigation of row crops where siphon tubes or spiles are used as turnouts and the water level in the ditch must be held at a uniform level to operate them.

Portable metal dams are used successfully for small ditches in soils that do not erode readily. They consist of a half circle or triangle-shaped piece of heavy gage galvanized iron or steel, reinforced across the top and usually with a single metal peg through the center that sticks into the bottom of the ditch.

SOIL MOISTURE PROBER

The depth to which the soil should be filled with water during irrigation depends upon the kind of crop, whether deep or shallow rooted, as well as whether annual or perennial, and the stage of growth. Moisture requirements for annual crops are relatively light early in the season and tend to increase as the plant grows. Perennial crops such as alfalfa and pastures require rather uniform amounts of water throughout the growing season according to the depth of the root system.

The soil moisture prober shown in Fig. 37 is helpful to determine the depth in the soil to which moisture has penetrated during or just after irrigation. With a little pressure the probe can be pushed through moist soil, but cannot be pushed through dry soil.

ACKNOWLEDGEMENT

The authors hereby express appreciation for information, photographs and designs furnished by the Soil Conservation Service, Bureau of Reclamation and Farmers Home Administration. Much of the material in this bulletin was in the original Extension Service bulletin No. 180, Irrigation Structures and Equipment. Assistance was also given by farmers and others.