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IRRIGATION STRUCTURES & EQUIPMENT

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MONTANA STATE COLLEGE, BOZEMAN

CONT

Use recommended plans	4
Local materials lessen expense	8
Diversion dams are inexpensive	9
Drops protect channel	15
Turnouts easy to use	15
Large tubes efficient	17
Soil auger is aid	20
Heavy equipment uses	20
Use land plane for finishing	20
Leveler smooths surface	21
How to build dikes	23
Furrow or corrugation methods are excellent	26
How to use spiles	26
Gated pipe aids control	27
Leveling is necessary	27
When to use hand level	30
Using surveyor's level	31
How to make laterals	33
Portable dams useful	33
Probe for moisture	35

(COVER)

The use of this equipment for removing silt and vegetative growth from ditches has replaced the dragline in many areas because of its speed and lower costs.

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Irrigation Structures and Equipment

by

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Modern irrigation equipment and adequate structures 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 hours of labor with a shovel will be saved.

Control begins at the diversion dam built into the stream or channel. The dam 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 devices prevent washouts and channel erosion.

Every farm requires a different set of structures and equipment. For this reason carefully plan the devices for controlling water to fit the needs of the farm.

Some of the needed structures can be built in place out of concrete and wood. Many of the smaller structures such as headgates and turnouts are now being made com-

mercially of concrete and steel. These can be purchased and installed.

There must be a dam or check in the main canal at the farm turnout to hold the water high enough so it 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. Install headgates at every permanent ditch turnout on the farm. Put in drops where the ditch runs down a steep grade.

Temporary portable equipment such as canvas or plastic dams and large siphon tubes for turnouts 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, an illustration of the structures which might be needed for some common methods of irrigation are shown in Figure 1.

Several methods are illustrated. It is unlikely that a farm would need this many different methods. Ordinarily one or two methods are enough. On land with less than a 3 percent slope the border ditch or border dike method will likely be best. On steeper lands the contour ditch is best.

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.

Each method requires certain equipment. First are the implements to level the land, then the equipment to construct the ditches, dikes and furrows.

Have controls at every turnout in the ditch. They may be permanent or temporary. Checks, headgates and turnouts generally should be permanent when placed in the head ditches. Use temporary controls, such as canvas dams, in the field where the ditches are temporary.

In Figure 1 the drop checks may or may not be needed, depending on whether or not the soil washes. If erosion is not a problem a temporary or permanent check is enough.

The concrete check requires very little upkeep after it is once installed. If ditch maintenance is a problem, requiring annual use of the ditcher, it is more practical to use temporary checks such as canvas or steel dams.

Where large syphon tubes are indicated in Figure 1, you can substitute permanent checks and turnouts. The permanent structures require a much greater initial investment but are more convenient for the irrigator to use.

Large tubes are portable and can be moved with the water. Use only enough tubes to take care of the amount of water you have.

Where Figure 1 shows small syphon tubes, wooden lath spiles or straight steel tubes installed in the bank could be used. Plastic, canvas or aluminum gated pipe could replace the head ditch. Here again it is a question of your preference and adapting the equipment to the farm.

Use Recommended Plans

a. **Masonry** — Figure 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. 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 within convenient reach of the dam site. The dimensions given for the dam provide for the least amount of cement to cut down cash outlay. To offset this saving on cement, use rock liberally 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. Never use more than 6 gallons of water per sack of cement, with only enough sand to make a good

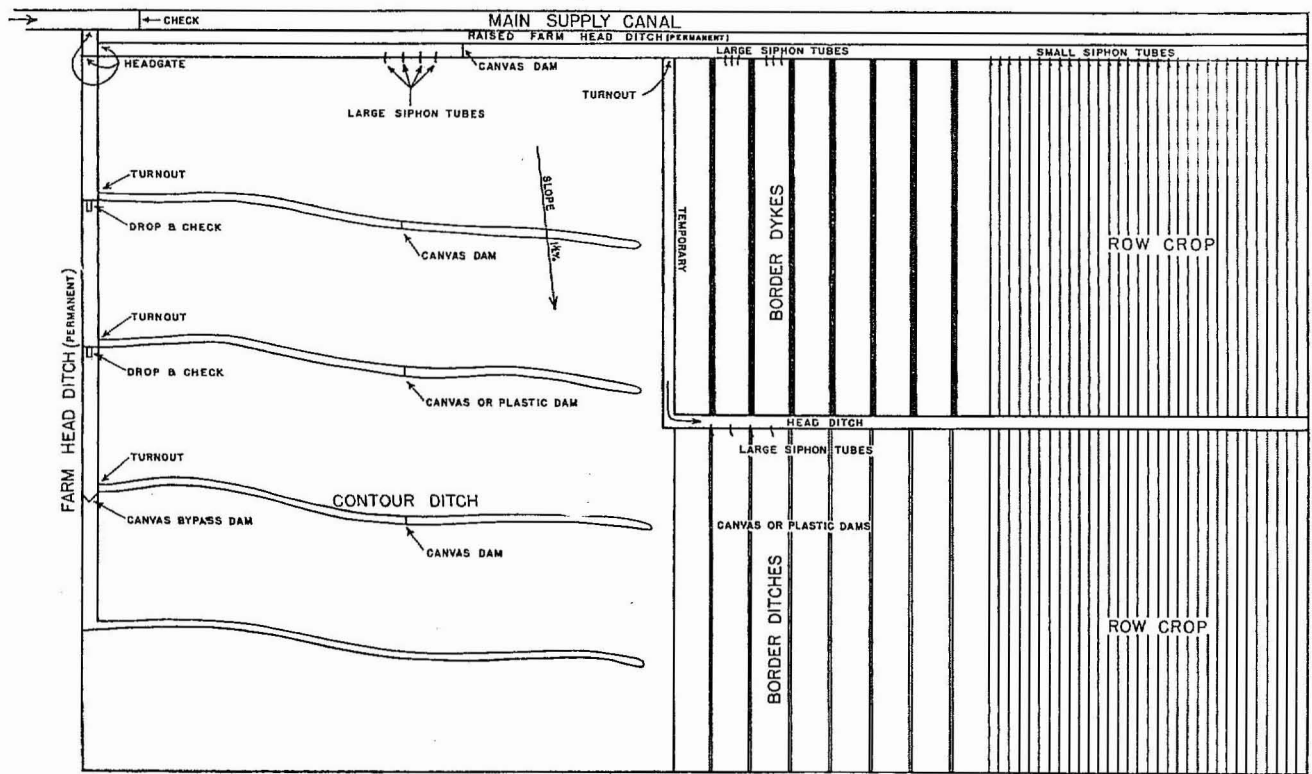


Figure 1—Farm layout

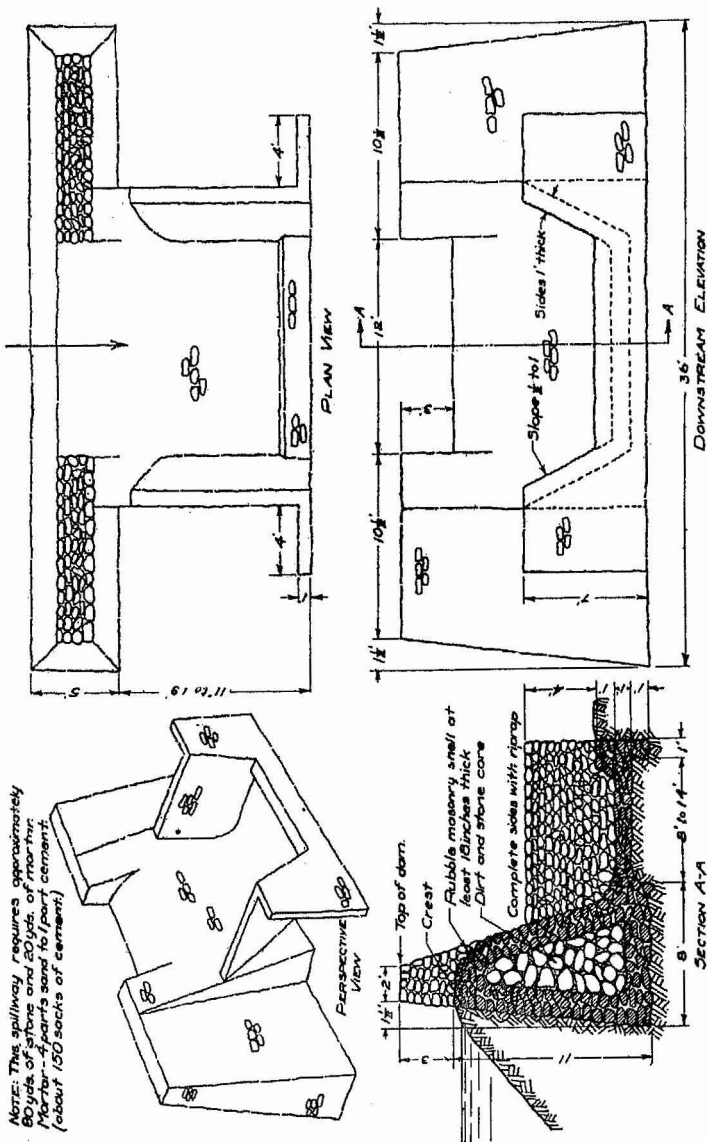


Figure 2—Rubble masonry spillway for an earth dam

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.

Lay the downstream sides and wing walls in mortar not less than 12 inches thick. Increase the floor or apron 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 Figure 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.

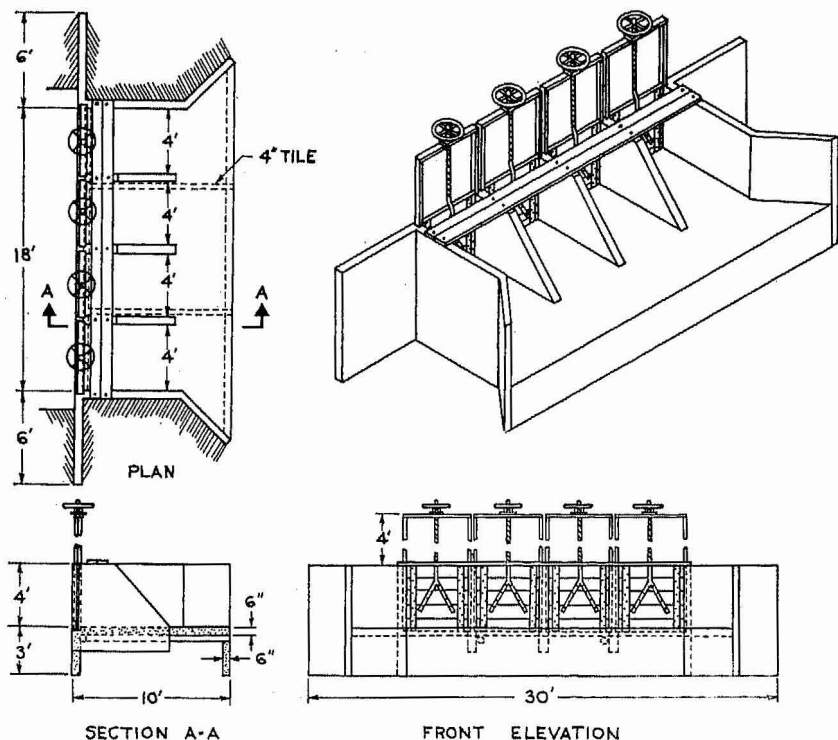


Figure 3—Concrete diversion dam with headgates

Figure 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 to select sand and gravel and to proportion the concrete mixture carefully.

Use only clean sand and gravel, free from vegetable matter and dirt. 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 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 (1 part cement, 2½ parts sand and 5 parts gravel) represents a good proportion of cement and aggregate.

The most reliable basis for a mixture is the so-called cement-water ratio. This means limiting the amount of water used per sack of cement. For the structure shown in Figure 3, do not use more than 6 gallons of water per sack of cement, and only enough sand and gravel to make a good workable mixture.

Reinforcing with steel strengthens the structure. Place the steel on the side of the wall subject to tensile stresses. Imbed the rods in the concrete 2 inches deep. Side walls and floors also need a small amount of reinforcing to protect against cracking. Regular wire mesh imbedded in the concrete will do.

Concrete structures are expensive, but skimping on materials

usually results in failure and a waste of the entire structure rather than in any net saving.

A simple test 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. Then let the bottle stand several hours to settle.

After settling, so that the water has cleared, the material will be well sorted out; the gravel will be on the bottom, the sand next. The dirt and the vegetable matter will be on top. If there is a considerable amount of vegetable matter and dirt, wash or screen it out so the sand or gravel will make good concrete.

Local Materials Lessen Expense

Figure 4 is a diversion dam suitable for 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.

Build the dam by placing alternate layers of rock and willows, backed up with earth fill. Set back each succeeding layer to give a stairway effect to the spillway. Construct with a general slope of 2 to 1; that is, a 1 foot rise to 2 feet run. The rock holds the willows in place and anchors them into the dam. They also give weight and stability to the structure. Make the dam watertight by an earth fill on the upstream side with a slope of 2 to 1.

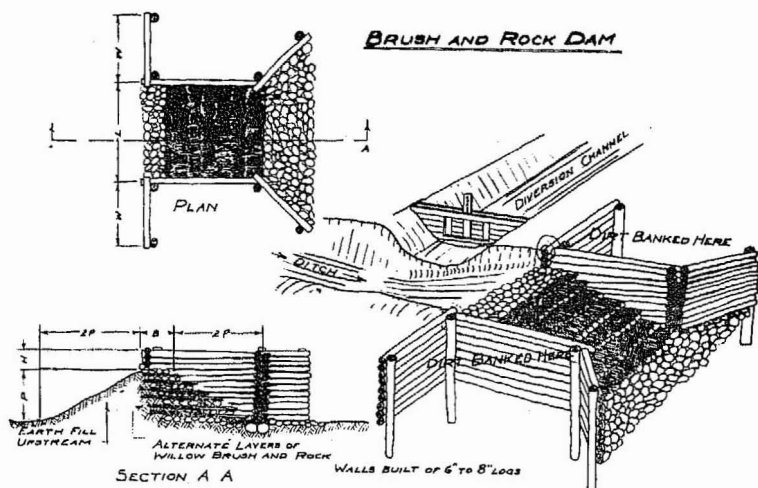


Figure 4—Brush and rock dam

Build the earth fill up at the same time that you place the brush and rock, so the brush ties in and forms a good bond with the earth dam. Construct the head wall, side walls, and wing walls of logs notched together at the corners. Strengthen by binding them with wire.

Build the crest or top of the dam 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 riprap the channel heavily the full width for a distance of 4 to 6 feet. Place this riprapping below the grade line of the channel so the water will be discharged below the grade, and thereby prevent erosion or backwash.

This type of structure is recommended wherever brush, rock and logs are 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 are cheap, use them liberally.

Diversion Dams are Inexpensive

Where a small ditch of water is to be taken from some of the smaller rivers, a diversion dam that is inexpensive enough to be within a reasonable cost-benefit ratio is advisable. Where the stream bed is rock and gravel such 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 vary very much.

Where a ditch is taken from a stream, take out the ditch at a level lower than the bottom of the stream bed. If this is done a diversion dam is not needed.

Rock piers are sometimes built at 10 or 15-foot intervals across the stream. During the irrigation season, suspend poles between these piers. If the poles do not divert enough water put boards in front of the poles. Straw or manure will make a tighter diversion.

Remove the poles and boards in the fall after the irrigation season is over, leaving only the piers in the channel over winter. On streams where heavy flooding oc-

curs and lots of debris is carried, the piers are likely to be lost.

Another type is a rock basket dam. Make this dam by laying woven wire on the stream bed and covering all but the ends 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 justify cost, install a well designed concrete diversion structure to save annual maintenance and provide a permanent structure.

Figure 5 shows a plan for a combination ready-made metal headgate and concrete pipe drop. These come in various sizes to fit the capacity of the ditch. Metal or tile pipe may also be used. This structure gives complete control of the water both in the canal and in the lateral. It saves a great deal of work. Headgates installed at such sites eliminate erosion.

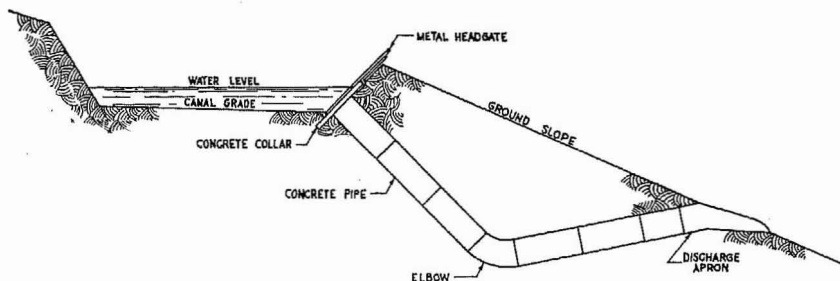


Figure 5—Metal headgate and concrete pipe drop

Figure 6 shows the dimensions and plan of construction of a simple concrete drop and check. This structure consists of a single wall built at right angles to the stream

or canal. A notch through the center provides a passage for the water when not in use. Grooves in the wall, into which flash boards can be fitted, will check or raise

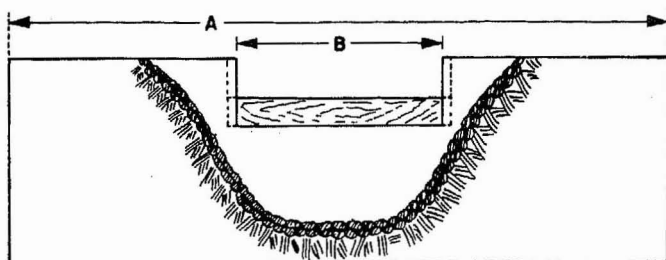
the water surface when desired for diversion. Since this check does not have the bracing effect of side walls, it must be rather wide and thick in order to be stable.

To protect the channel against erosion, place a heavy riprapping of rocks 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, do not skimp on the amount of cement. Either use sufficient cement to make a durable structure, or none at all. Too much economy

SIMPLE CONCRETE CHECK WALL



PLACE A STONE RIP-RAP ON THE WALLS AND APRON, EXTENDING DOWNSTREAM A DISTANCE TWICE THE HEIGHT OF THE CHECK.

FORM GROOVES AT EITHER SIDE OF SPILLWAY AS GUIDES FOR FLASHBOARDS.

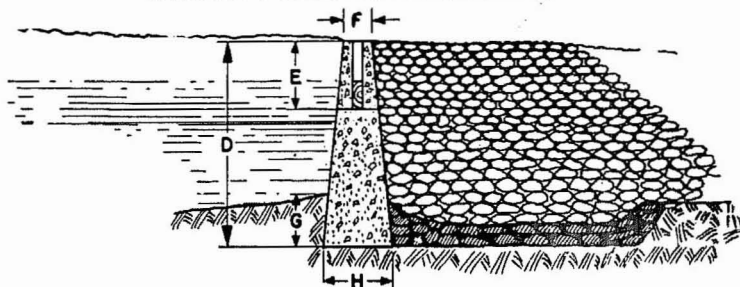
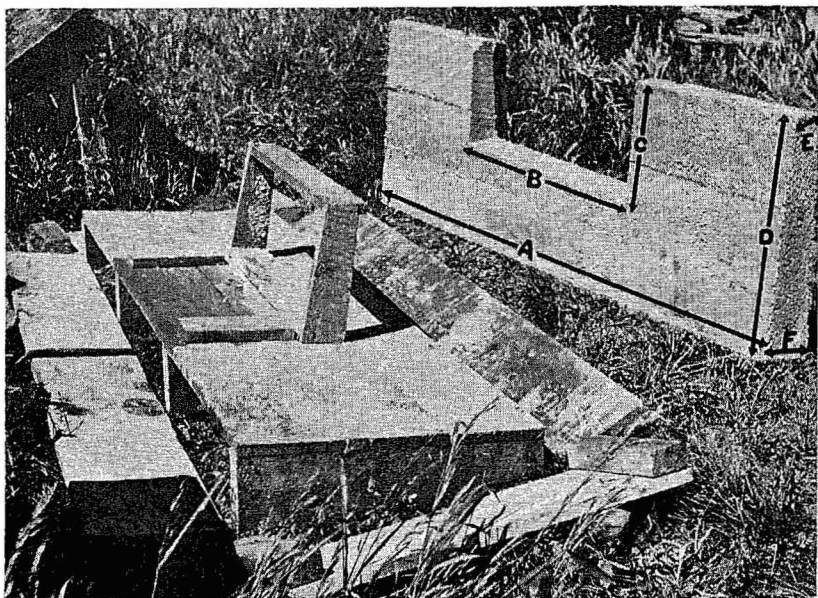


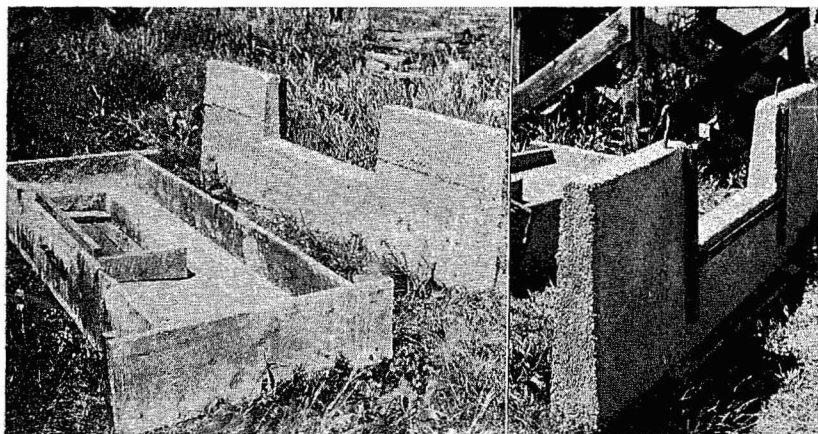
Figure 6—Sample Concrete Check Wall

Table I

A	B	D	E	F	G	H
14'-0"	4'-0"	4'-0"	1'-6"	0'-8"	1'-6"	1'-8"
19'-0"	6'-0"	6'-0"	2'-0"	0'-8"	1'-6"	2'-0"
24'-0"	8'-0"	8'-0"	3'-0"	0'-8"	2'-0"	3'-0"



The form with the headgate removed. The sides, ends and opening are removable.



The form ready for pouring concrete

Front view showing angle iron gate guides.

Figure 7—Concrete headgates

in the mixture or in the dimensions of the structure may result in total failure and loss. Base the mixture upon 6 gallons of water per sack of cement. Table I gives the di-

mensions of concrete checks under various conditions.

Checks for smaller head ditches can be built in the farm shop and hauled to the field by truck or by

tractor equipped with an hydraulic lift. One advantage in farm shop construction is that it can be done during slack periods of the year. Another feature is that the form can be used over and over again.

A single wall with a notch, will serve as a combination headgate, check and turn out. One of these installed in the ditch will check the water for turnouts. It will also serve as a turnout when installed in the ditch bank. Two or three of them can be set at right angles to each other to form a two or three-way headgate. It takes about one sack of cement to make each single wall. Riprap the downstream side after it is installed to prevent under cutting.

Installation involves digging a trench across the ditch or into the bank of the ditch for the wall. After it is in place, fill in around it with dirt. Have the top of the wall slightly above the ditch bank and the bottom 6"—8" below the bottom of the ditch. Use flash boards or a slide gate to control the flow of water.

Figure 7 shows the construction of the forms and finished product. Table II has dimensions for the size of stream you will be using. If the size of the stream is over 7½ c.f.s. (300 miner inches) it would be best to use the dimensions in Table I. In this case, make the form and pour in place.

Table II

Ditch Capacity		A	B	C	D	E	F
c.f.s.	Miners Inches	Ft.	Ins.	Ins.	Ins.	Ins.	Ins.
2	80	4'	12"	10"	22"	3"	5"
3	120	5½'	18"	12"	24"	3"	6"
5	200	6'	24"	12"	24"	3"	6"
7½	300	6½'	30"	12"	24"	3"	6"

The Form — Make the base of 1" material nailed to 2"x6" pieces tapered to 3" on one end and set on edge. The 1 x 10 side boards are held in place by a wire loop through holes in the boards with a pin through the loop on the outer sides. The end boards are 1 x 10 with 2 x 4 pieces on the end to hold the ends of the side boards in place.

End boards can be held in place by a rope or wire loop connecting them, if necessary. The form for the gate opening is merely a frame set in place and held by two boards nailed to the base.

Reinforcement — Place an 18" rod with a hook on each end in the concrete about 3" to the side of the gate opening and parallel to the sides of the gate opening. This is for reinforcing and handling. Let the hooks on one end of the rod stick out about 3" from the concrete. A rod for reinforcement can also be laid in the center of the wall running the full length below the gate opening.

Gate Guides — To avoid making gate guides in the concrete and thus weakening it, use angle iron. Weld three bolts to each angle iron so they set in the concrete about

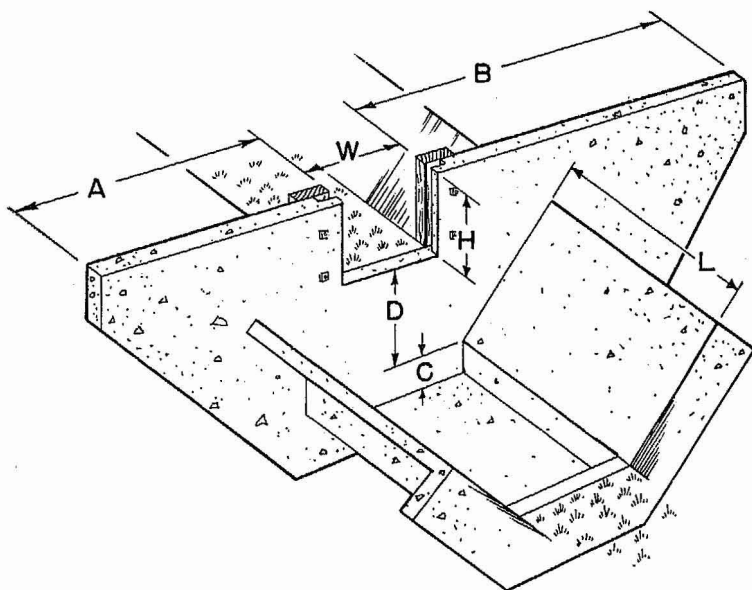


Figure 8—Concrete drop

Figure 7
Table III

Capacity of ditch in c.f.s.	Width of opening (W) ft.	(H) in.	(C) in.	(A) (B)
2	1	12	6	2
6	2	12	6	2
8	2½	15	6	2
10	3	18	8	2½
14	3½	18	8	3
Drop (D) Feet		Length or Apron (L) Feet		
1		2½		
1½		3		
2		4		

2". Set the angle irons about 2" back from the gate opening and set those forming the side of the gate opening the full width of the wall. Set the third angle iron across the bottom of the gate opening.

The angle irons must be set in the concrete to hold a one-inch flash board to control the water.

Concrete Mix—Use a 1-2-3 concrete mix with a maximum of 1" for the coarse aggregate.

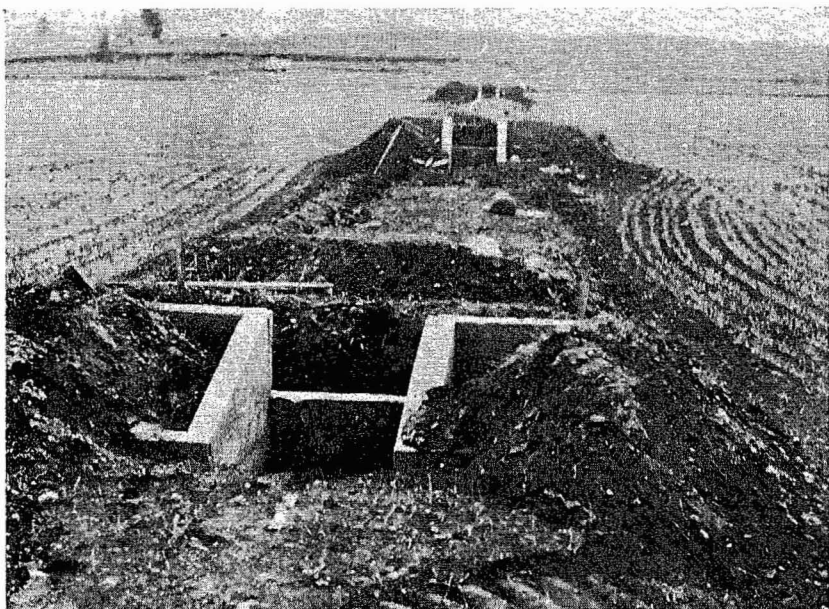


Figure 9—A series of concrete drops

Use 5½ gallons of water per sack of cement when using dry sand. Mix the concrete thoroughly and work it into the corners, sides and ends. Moist curing of seven days or more will increase the strength materially.

Drops Protect Channel

A concrete drop like the one shown in Figure 8 may be built in farm head ditches. This drop can be built according to the dimensions given in Table III.

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, use pipe, concrete ditch lining or drops. Where the ground slope is less than 4% the drop is usually the cheapest. They can be made of concrete, tile pipe or wood.

Figure 10 shows a wooden drop which is satisfactory for farm ditches. Use two-inch material. Treat the wood with a preservative for longer service. Table III gives the dimensions for construction with different ditch capacities.

Install the drop 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. Maximum drop recommended is 2 feet.

Turnouts Easy to Use

Turnouts 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. Figure 11 shows a wooden turnout which can be built and installed easily.

Dimensions for various sizes are given in Table IV. Use two-inch

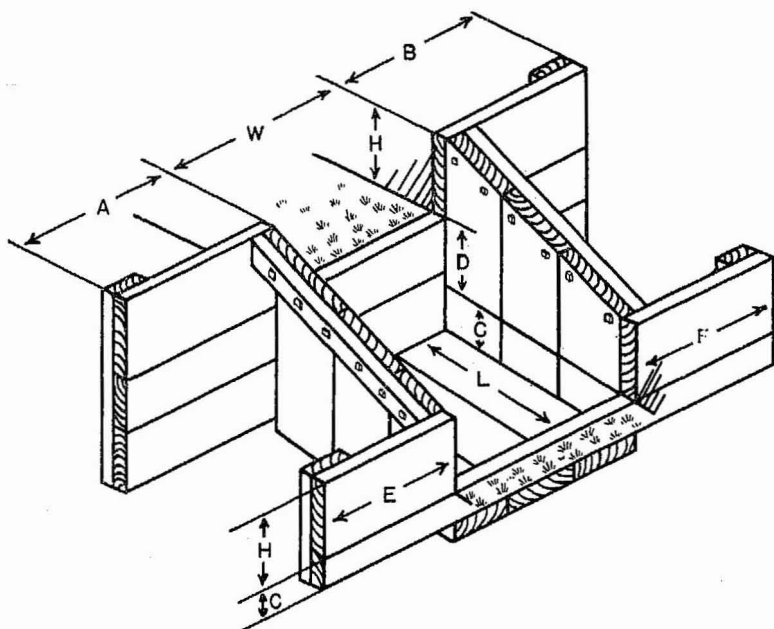


Figure 10—Wooden drop structure

Table IV

D	W	L	M	N	P
18"	12"	3'3"	2'6"	4'3"	3'6"
18"	18"	3'3"	2'6"	4'3"	4'0"
18"	2'0"	3'3"	2'6"	4'3"	4'6"
18"	3'0"	3'3"	2'6"	4'3"	5'6"
18"	4'0"	3'3"	2'6"	4'3"	6'6"
2'0"	12"	4'0"	3'0"	5'0"	3'6"
2'0"	18"	4'0"	3'0"	5'0"	4'0"
2'0"	2'0"	4'0"	3'0"	5'0"	4'6"
2'0"	3'0"	4'0"	3'0"	5'0"	5'6"
2'0"	4'0"	4'0"	3'0"	5'0"	6'6"
2'0"	5'0"	4'0"	3'0"	5'0"	7'6"

lumber. Install the floor of the turnout level with the ditch bottom. Treat lumber with a preservative before nailing in place.

Pipe turnouts similar to the one shown in Figure 12 can be pur-

chased and installed easily. Ready-made steel headgates are available. These ready-made headgate turnouts are usually 12", 18", and 24" in diameter. They are merely a concrete or metal pipe long enough

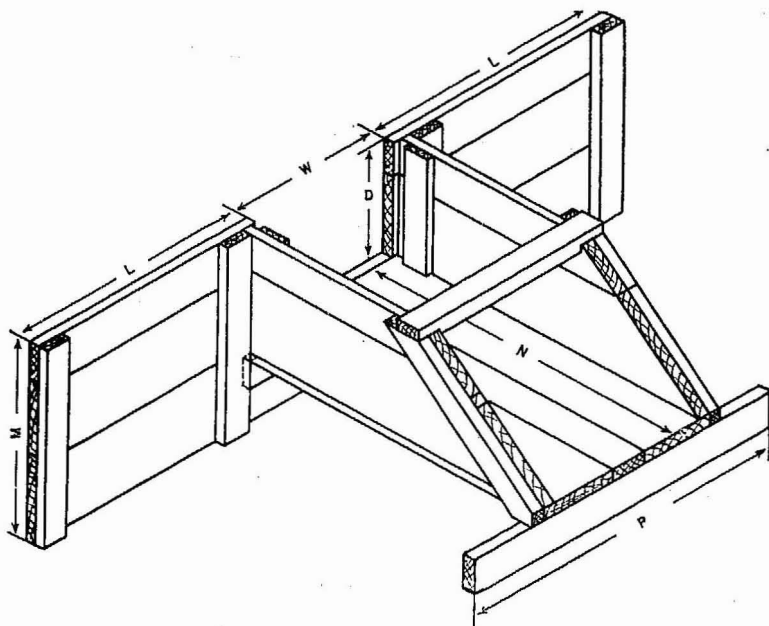


Figure 11—Wooden turnout (SCS design)

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. Cut a trench through the ditch bank and install the turnout level with the ditch bottom, then cover 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.

Large Tubes Efficient

Under certain conditions large siphon tubes 4" to 8" in diameter

and 5 to 12 ft. long can be used to advantage as turnouts. Where these can be used they have the advantage of reducing the cost because they can be moved, which

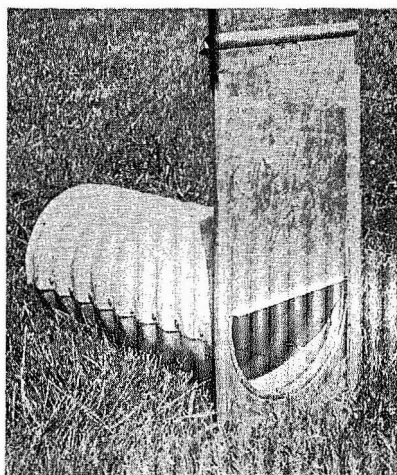


Figure 12—Metal corrugated pipe turnout

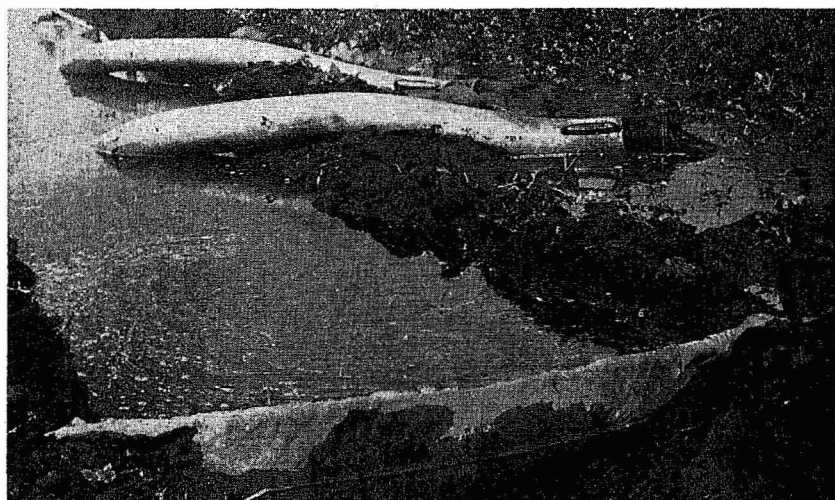


Figure 13—Metal tubes for running water into border dikes

reduces the number required considerably. They also have the advantage of leaving the ditch open for cleaning.

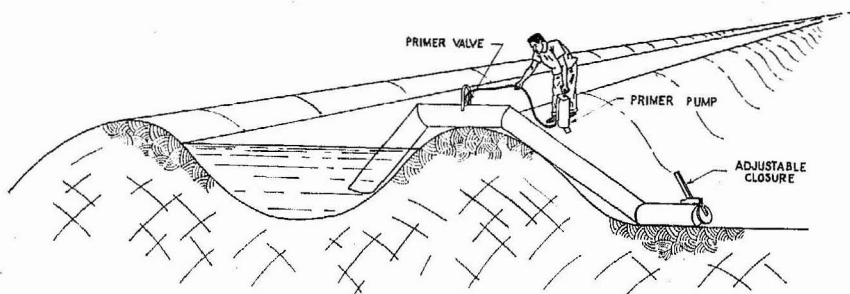
When using these tubes for turn-outs, use a portable canvas, plastic or metal dam to check the water in the ditch.

The tubes are adapted for border dike 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.

The greater the difference in water level, the faster will be the flow through the tubes.

Figure 13 shows 6-inch metal tubes running water into border dikes. The tubes are available in



**LARGE SIPHON TUBE
WITH PRIMER PUMP**

Figure 14

metal, rubber or plastic. A 6" diameter tube will deliver about 1 c.f.s. of water when the head is 1 foot.

One of the greatest difficulties in using large tubes is priming. A little experience and "know how" will overcome this. First lay the tube 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.

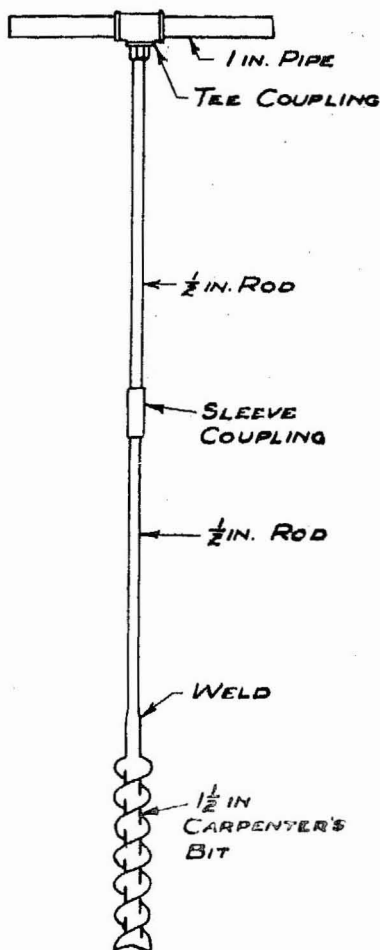
When the tube is completely submerged and full of water, close the end which is to be lifted over the bank. If a good seal is made with a plug or canvas there is no hurry about getting the tube over the bank. The end which is plugged must be lower than the water level in the ditch before removing the plug. When this is done and the plug removed the water will start running and continue as long as the water is higher in the ditch.

One of the difficulties which is likely to happen is air getting into the tube from the discharge end after the water starts. This may be overcome by digging a small hole in the soil for the end of the tube to lie in. If this is done before priming 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. 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, reprime the tube.

Some of the larger siphon tubes have adjustable gates on the discharge end. They can be primed by pumping the air out of the tube with a pump on the valve at the top of the tube.



SOIL AUGER

Figure 15



Figure 16—Heavy dirt moving equipment is available through contractors and soil conservation districts

Soil Auger Is An Aid

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

Figure 15 is a simple type of soil auger. It consists of a spiral-shaped bit made from a 1½-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.

Remove the screw-point and the side cutting edges of the carpenter's auger in preparing the bit for boring. A post hole type auger also can be used.

Heavy Equipment Uses

Whenever grading and leveling of large areas is necessary it is

often more economical to hire the work done than to buy such equipment and do it yourself. 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.

Grading and leveling with such large outfits is usually contracted at a certain price per cubic yard of earth moved. Sometimes the equipment and its operator can be obtained on a daily rental basis.

Use Land Plane for Finishing

The land plane is effective for moving a small amount of earth or for finishing a field after heavy earth moving equipment.

This implement is much larger than the regular farm leveler, and

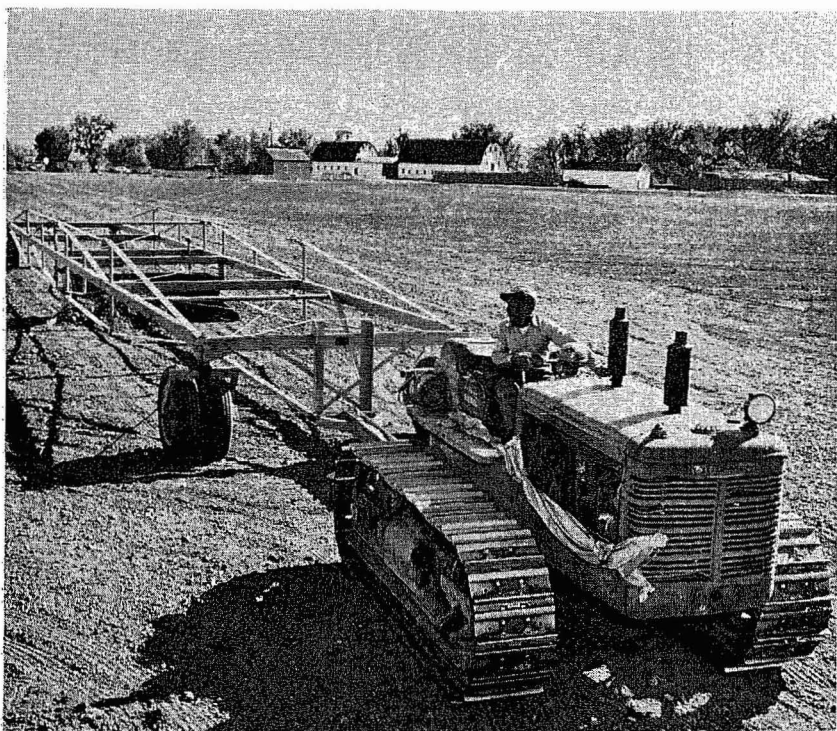


Figure 17—Long planes do a better job

varies from 40 to 80 feet in length. Usually the longer planes are preferred if power is available to pull them. These machines are often owned by a Soil Conservation District, a group of farmers, or earth moving contractors. Work is done on a fee or acreage rental basis.

Leveler Smooths Surface

The purpose of the farm leveler is to smooth rough irregularities on the surface of a field left by plane, graders or other tillage implements. Do the land smoothing or floating as it is sometimes called, when the soil is rather dry. Land smoothing doesn't move the earth

to any great extent but smooths and compacts the surface.

Most farm levelers now in use are commercially made. They are one of the most important implements in irrigation farming and should be used every time the seed bed is prepared for planting.

Most of the ditchers in use are commercial machines made of steel.

In buying a commercial ditcher 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

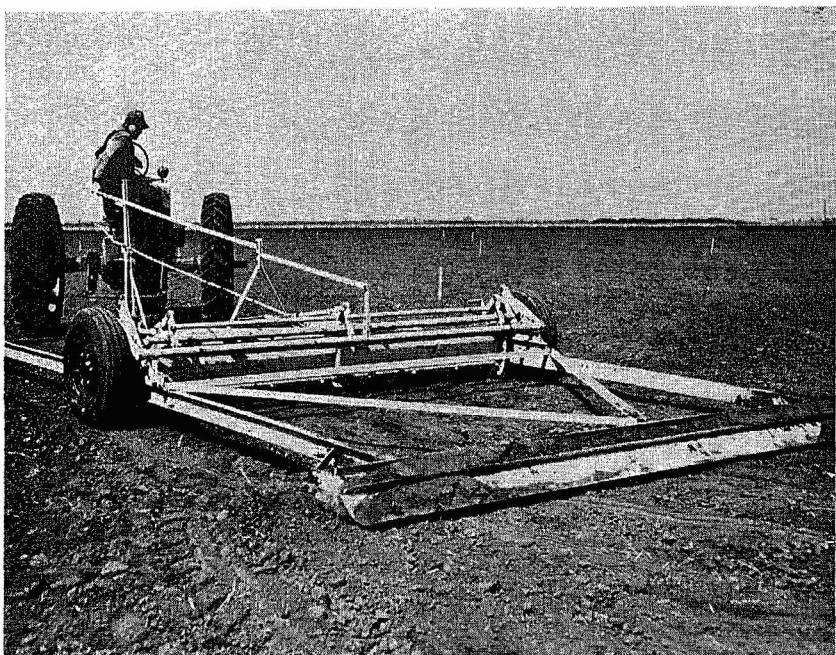


Figure 18—Farm leveler

and uniform banks. It should also do a good job of cleaning ditches.

ditches, select a ditcher with adjustments for size of ditch. There

If you have different sizes of

are several good ditchers on the

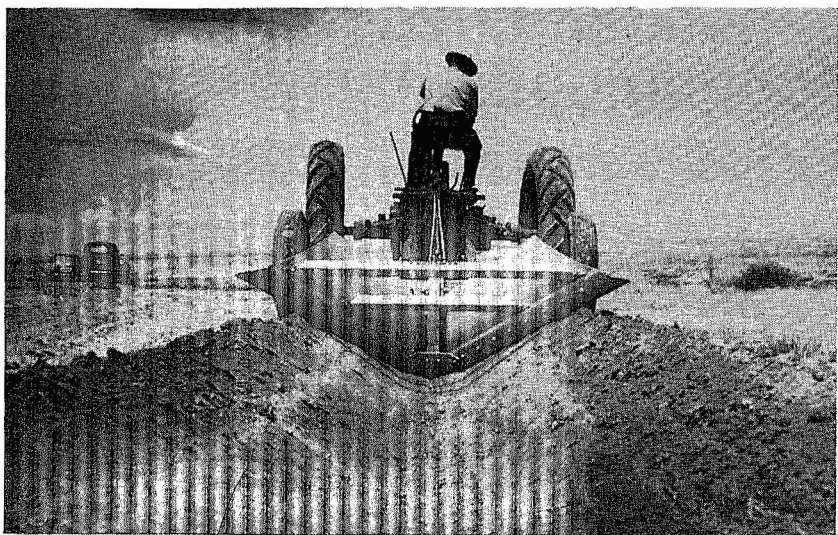


Figure 19—Commercial ditcher

market that answer these requirements. Figure 19 shows a commercial ditcher in operation.

Ditch fillers are usually similar to a disc. Three or four discs, mounted on each end of a frame, 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.

How to Build Dikes

Build border dikes 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. Construct the dikes before the crop is planted. Seed the crop over the dike. Border dikes are best for uniform slopes under 2%.

The ground must be level at right angles to the dikes to give a 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, level the ground. An easily made device which virtually makes dikes in one operation, is the V-type diker. Figure 20 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 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. It slopes the sides and controls the height. Sometimes it is necessary to add weight to the back end of the diker to hold it down.

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.

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 and dumps 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 does not leave a borrow pit. A certain amount of leveling between dikes is also necessary. When this method is used, follow with a V-type drag on the dike to straighten it up and smooth it out. Figure 21.



Figure 21—This homemade device makes dikes in one operation

shows a V-type border diker working. Other companies build farm levelers with blades that can be adjusted to make dikes.

Border dikes will work on fields that have a slight side slope. Side slope is the difference in elevation of the ground level between the dikes when taken on a line at right angles to the dikes. When there is a side slope, refer to Table V for

spacing of the dikes. Make your border dikes at least six inches high when settled on slopes under 2% and at least 4 inches high when settled on slopes over 2%. For specific information as to border dike spacing and length of run, **Irrigation Guides** have been set up for major soil types throughout the state. Soil Conservation Service technicians use these guides in laying out border irrigation systems.

Table V—Maximum border widths for different field slopes.
Center to center of dikes.

Down Field Slopes	Slide Slope Per 100 Feet		
	0.2	0.3	0.4
	Border Widths in Feet		
0 to 1%	36	36	28
1% to 1.5%	36	28	22
1.5% to 2%	34	24	19
2% to 2.5%	31	22	18
2.5% to 3%	30	21	17
3% to 3.5%	27	19	15
3.5% to 4%	24	17	14



Figure 22—Siphon tubes in operation

Furrow or Corrugation Methods Are Excellent

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

For orchards, berries, potatoes, cabbage, and corn, use large lister type furrows or small ditches 6 to 8 inches deep and 30 to 42 inches apart, to spread the water. Use somewhat smaller furrows for beans, sugar beets and other root and vegetable crops. There are regular irrigating shovels of various sizes for cultivators.

For alfalfa, pasture grain and peas, make the furrows about 4 inches deep and 2 feet apart. A

beet cultivator with irrigation shovels attached is widely used.

How to Use Spiles

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, use small pipes or lath turnout boxes to distribute the water from the ditches into the corrugations.

These spiles can be made by nailing four laths together or cutting short sections of iron pipe. Make the spiles 2 to 3½ feet long. On flat land, provide one spile for each furrow. On steeper lands a single lath box spile will supply enough water for 2 or 3 furrows.

Small siphon tubes also take wa-

ter from the supply ditch to run rows or corrugations. These tubes are made commercially of metal, plastic and rubber. Sizes used for row irrigation are usually from $\frac{1}{4}$ 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.

Start the furrow 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. Prime the tubes by filling with water and then close one end with your hand while lifting over the bank.

The water must be high enough in the ditch to give good operation of tubes. Table VI gives information that will provide a basis for estimating the number of tubes needed for a given water supply. Figure 22 shows siphon tubes in operation.

Table VI

Rate of discharge and number of siphon tubes required to deliver 1 cubic foot per second (40 miner's inches) of water at different heads.

	Head in inches	Size of Tubes				
		1"	1 $\frac{1}{4}$ "	1 $\frac{1}{2}$ "	1 $\frac{3}{4}$ "	2"
Discharge in gallons per minute	2"	5	8 $\frac{1}{4}$	13	17	21
	4"	7	12	19	25 $\frac{1}{2}$	32
	6"	9	15 $\frac{1}{2}$	24	32	41
	9"	11	19	29	39	50
No. tubes required to deliver 1 cubic foot per second	4"	64	37	24	18	14
	6"	50	29	19	14	11

Gated Pipe Aids Control

Gated pipe gives better control of the water at the row turnouts. This pipe comes in various sizes, usually from 4 to 12 inches in diameter. The slide gates set in the pipe have the same spacings as the rows.

The pipe is used in place of a head ditch across the top side of the field with the gates between the rows or over the furrows. Water runs into the pipe by gravity and the slide gate openings give complete control of the amounts of water for each furrow.

Gated pipe gives good control of water on slopes too steep for effective distribution from an open ditch. Figure 23 shows gated pipe irrigating a pasture in corrugation furrows.

Flexible gated pipe is also made of canvas and plastics. Openings, in the pipe can be obtained to fit the row spacings of the crop.

Leveling Is Necessary

To apply irrigation water with the least trouble and time, run ditches to the proper grade; and

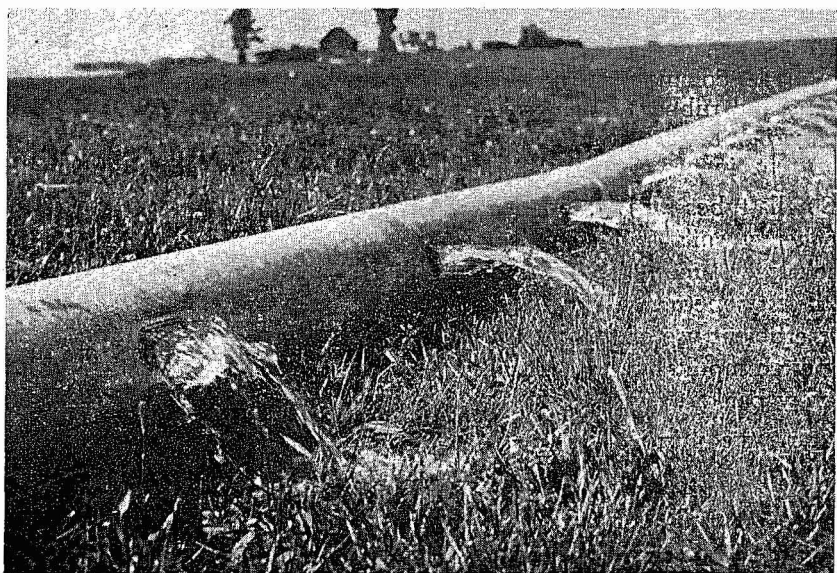


Figure 23—Gated pipe irrigating a pasture

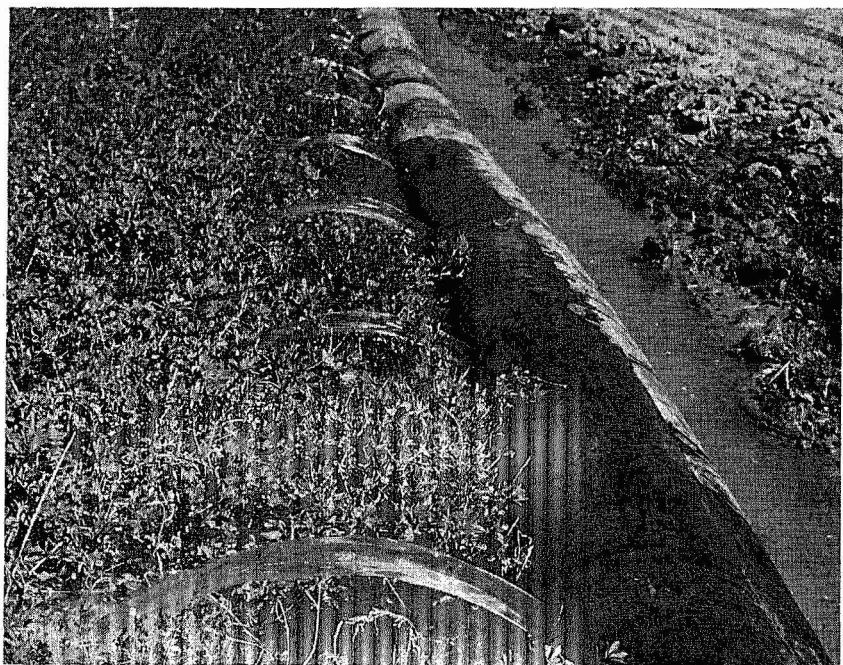


Figure 24—Twelve-inch flexible pipe irrigating alfalfa

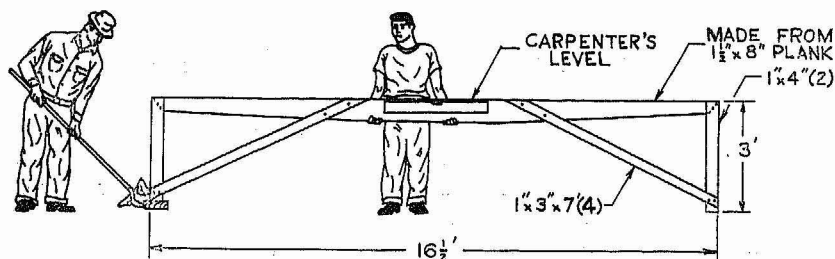


Figure 25—Surveying with a cricket level

properly install weirs, headgates, checks, turnouts, and other devices before the water is ready for the ditches. This requires the use of levels.

A practical home-made device for surveying ditches with a uniform grade is the "cricket" level shown in Figure 25. 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.

The top board or straight edge

of the cricket shown in Figure 25 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 inch x 3 feet long. The braces are 1x3 inch x 7 foot pieces—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 ¾-inch block will give about 0.3-foot fall per 100 feet and a ½-inch block, which is the thickness of a lath, will give ¼-inch fall per rod or nearly 0.2 foot per 100 feet. Table VII gives the sizes of blocks to use for different grades.

Table VIII—Thickness of block for different grades for 16½-ft. "Cricket" level

Thickness of block and grade in inches per rod	Approximate Grade		
	inches per 100 feet	feet per 100 feet	feet per mile
¾	2¼	.19	10.0
½	3	.25	13.3
⅜	3¾	.32	16.7
¼	4½	.38	20.0
1	6	.50	26.6

When locating a contour ditch, place the short leg of the cricket level 2 or 3 inches below the water surface in the head ditch and swing 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 turning up a shovel-ful of dirt.

Then carry the "cricket" forward. Place the short leg beside the stake or shovel-ful of dirt, and swing the other end around until the bubble returns to the center. Repeat this 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.

Make contour ditches with a 0.2 to 0.4-foot grade per 100 feet. This is the same as $\frac{1}{5}$ to $\frac{1}{4}$ inch per rod. The most common grade is 0.25 foot per 100 feet or $\frac{1}{2}$ inch per rod.

Use a flatter grade for ditches designed to carry more than 2 cubic feet per second. Small ditches carrying smaller streams require steeper grade.

A grade of $\frac{1}{4}$ -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.

When to Use Hand Level

The ordinary hand level is generally accurate enough for running contour ditches on a grade of 0.2 feet or more per 100 feet. On fields with less than $\frac{1}{2}$ percent slope use the surveyor's level. 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" x 4" x 8' is very usable. The rod, a 1" x 2" 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. Mark the rod with three lines across the broad side as shown in Figure 26. Mark the

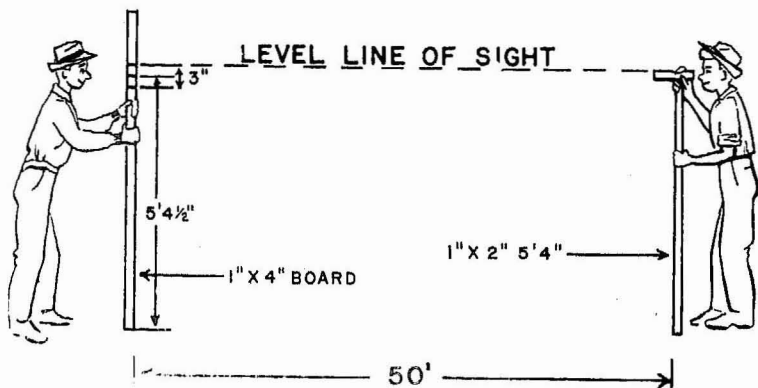


Figure 26—Surveying with a hand level

center line at a point located by standing the rod and staff side by side on a level area. Rest the hand level on the staff and tilt it until the center cross bar cuts the bubble in half. The point where the line of sight hits the rod is the center mark on the rod. This is the only mark needed for running a contour line.

For running contour ditches with a slight grade add a mark both above and below. For a ditch with a 0.2 percent grade make the mark 0.1 foot above and 0.1 below the center line when readings are 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 of the rod should be made 0.2 ft. above and below the center line when readings are taken at 50-foot intervals.

In Figure 26 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 have the rod man set the rod near the supply ditch where water is to be taken out. Take the level out in the field 50 feet in the direction the water will run. Rest the level on the staff and sight 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. 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 feet and locates a new point where he is reading the lower mark.

The two men 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.

Mark the points either by a shovelful of dirt or a stake. If a ditcher is available, it can follow along through the points as they are located and no marking is necessary.

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

Using Surveyor's Level

Running a contour ditch grade with a surveyor's level requires two persons, the instrument man and the rod man.

Set up the level about 300 feet out from the head ditch down the side of the field and a little above where the first contour ditch is to be taken out, so that when leveled,

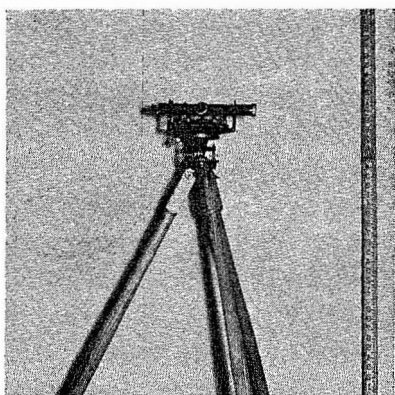


Figure 27—Surveyor's level

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 no more than 200 feet each way from the instrument. Figure 27 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 rod man sets the target at that figure which is the initial reading. (Surveyor's level rods are usually marked off in feet and tenths of a foot because readings are easier than feet and inches). Set a stake or turn up a shovelful of dirt to mark the place of beginning.

The rodman then paces approximately 100 feet from the starting point in the direction the ditch is expected to go. He sets the target a 5.0 feet which allows 0.2 feet fall if the grade is to be 0.2 per hundred ft. He holds the rod 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 the rod man moves 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 man moves 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 it is faster 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 200' feet beyond the level is reached.

Then the instrument must be moved ahead. Set up and level the instrument and take a back sight on the rod which has remained at the last point. 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.

How to Make Laterals

The typical farm lateral made with a plow and ditcher, is usually run on a grade of about 0.25 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 can 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 VIII 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 VIII—Carrying capacity of farm ditches

Depth in inches	Cross section sq. ft.	Velocity—feet per second		Discharge in	
		Grade .001	Grade .002	cubic feet per second	
		or .1 ft/100	or .2 ft/100	Grade .001	
Bottom width of ditch 2 feet					
9	2.06	.80	1.15	1.65	2.36
12	3.00	.96	1.38	2.88	4.14
15	4.06	1.10	1.57	4.46	6.38
18	5.25	1.24	1.75	6.50	9.20
21	6.56	1.35	1.92	8.85	12.60
24	8.00	1.46	2.03	11.70	16.20
Bottom width of ditch 3 feet					
9	2.81	.88	1.24	2.47	3.48
12	4.00	1.06	1.47	4.25	5.88
15	5.31	1.20	1.70	6.36	9.02
18	6.75	1.34	1.90	9.05	12.82
21	8.31	1.44	2.04	11.98	16.92
24	10.00	1.58	2.26	15.80	22.60

Portable Dams Useful

The canvas dam is indispensable. Each irrigator should have several. Make them from 12- to 20-ounce canvas, and about 4 feet wide and 6 feet long. They can be larger for larger ditches. Treated canvas dams will outlast the regular canvas so are recommended.

Fasten the 6-foot side to a 10-foot 2x2, 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.

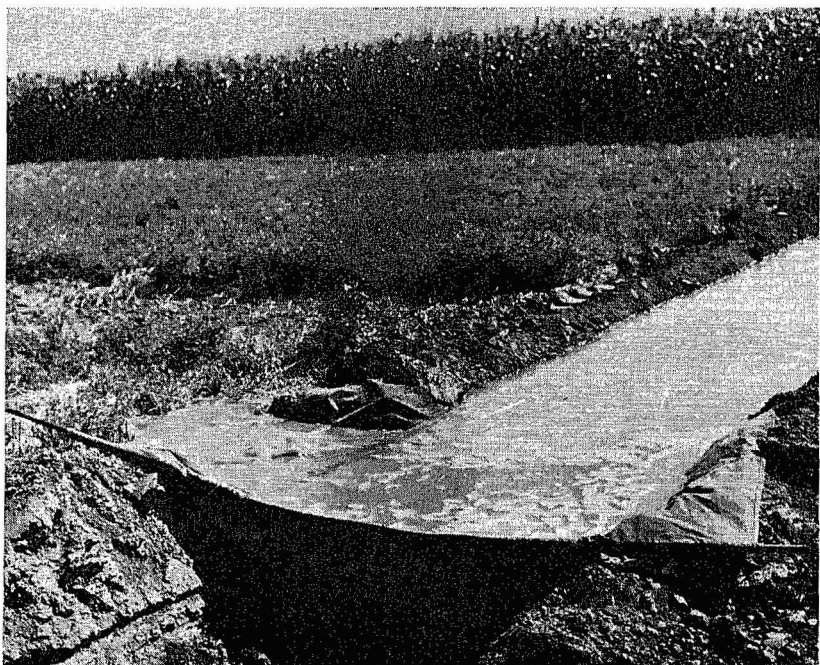


Figure 28—Portable canvas dam

Figure 28 shows a canvas dam used to divert water from a contour ditch to the land. Generally, put the dam in place before the water reaches the point of diversion and lay it in the ditch with the canvas extending up stream and the pole spanning the ditch and resting on each bank. Throw some earth on the edges of the canvas to hold it in place. With two dams on each lateral, place one 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 quite common. They serve the same purpose and are used much the same 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 after use. Dams are also made of nylon. This material is very light and durable.

Figure 29 shows a by-pass type of dam. This type 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. The water level in the ditch must be held at a definite level to operate them.

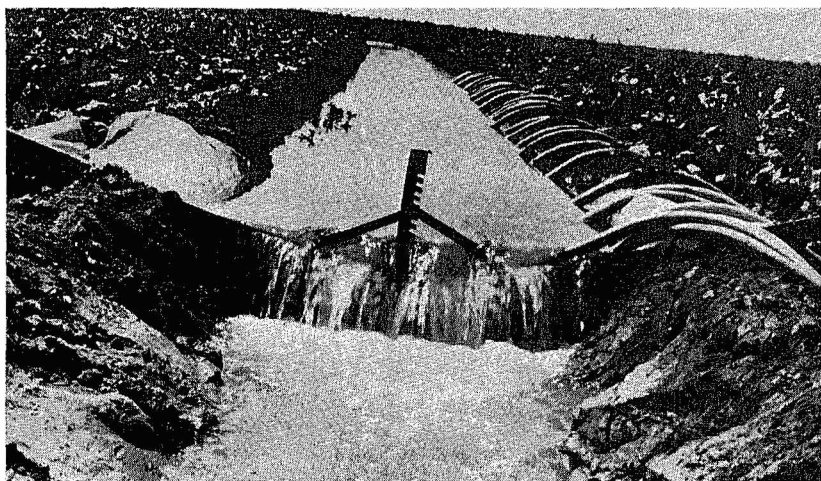


Figure 29—A by-pass type dam

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 gauge galvanized iron or steel, reinforced across the top. They usually have a single metal peg through the center that sticks into the bottom of the ditch.

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 quite light early in the season and increase as the plant grows. Perennial crops such as alfalfa and pastures require rather uniform amounts of water throughout the growing season depending upon the depth of the root system.

Probe for Moisture

The soil moisture probe shown in Figure 30 will help 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.

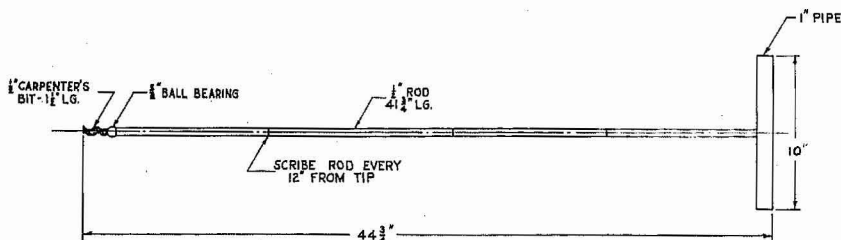


Figure 30—Soil moisture probe

OTHER IRRIGATION PUBLICATIONS

Bulletin 237—Irrigating Field Crops in Montana

Bulletin 259—Irrigation

Bulletin 289—Measuring Devices for Irrigation Water

Circular 257—Irrigation Efficiency Pays

Circular 1064—Sealing Ditches and Ponds with Bentonite

Folder 36—Aids to Water Control and Development from
State and Federal Programs

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