Farmers' Storage Reservoirs, Diversion Dams and Dikes

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SUGGESTIVE PLANS FOR EARTH RESERVOIRS.

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Farmers' Storage Reservoirs and Dams

A small storage reservoir that can be used for irrigation is one of the best assets that a dry farmer in Montana can have. With from ten to forty acres of irrigated land to go with his dry farming operations, there is no need of his buying feed for his stock. He can enlarge on his livestock operations and be insured of plenty of feed to carry the stock through, and the degree of risk in his farming operations is greatly diminished.

There are a great many of these small reservoirs in Montana that are giving good service. A number of the owners will say, "well, if I had to depend absolutely on my dry farming operations, there would be nothing to hold me here." There should be many more of these reservoirs for there are any number of places they could be put in and be insured of being filled practically every year.

The lack of knowledge in regard to constructing these reservoirs is the reason for there not being a great many more in Montana. Some have tried and failed and discouraged others from trying, saying: "There is no dirt dam that will hold in one of these erratic coulees." However, it is possible to put in a dirt dam, in nearly any of the coulees, that will hold if it is put in well and certain precautions taken to keep it from washing out.

The first thing is to get the water so that it is available for use; the next is to use it efficiently. In this circular some of the things to take into consideration when building a reservoir are pointed out.

In many cases these dams can be put in with the farmer's own labor, taking but very little cash. If they are put in well they are permanent and will always give service. It is much easier and better to put them in right to begin with than it is to have to build them over after an exceptional downpour.

CAUSES OF FAILURE.

Dams may fail by sliding, overturning or being washed out. The most common cause for farmers' earthen dams failing is
washing out either by water overtopping the dam or by water finding its way along fissures and cracks or by forcing its way through walls too thin to prevent its passage through them.

About 90 per cent of the dams that have washed out were equipped with an insufficient spill-way. The dam was either too low or the spill-way not low enough or not wide enough to take off the enormous amount of water that came down the coulee at some time. Few people realize when they make a dam across a coulee how much water really comes down at some time during the year. The spill-way has to have capacity to carry all the water that might ever come down the coulee at any one time, and drop that water back to the coulee level without cutting the dirt away. Sometimes after the reservoir is full from the melting of winter snow, there will come a heavy rain or cloudburst and swell the coulee to the proportions of a young river. If the spill-way is not large enough to take care of this excess water it will run over the dam and in a very short time the whole thing will be washed out, for there are no earthen dams that will stand a rush of water over them for even a few minutes.

Another reason why a dam washes out is because the dam is not made wide enough or strong enough. Water seeps through high up on the dam or it is pushed out by water pressure. Many of the dams that have washed out were built to a peak. If the dam is not made wide on top with a gentle slope, well riprapped on the water side, it is in danger of being pushed out by water pressure or washed out by wave action when the reservoir is full. A good many will stop just before they get through with the job where 10 per cent more work would have made it secure.

The outlet of many reservoirs has been the cause of the break. A plank box through a dam is almost certain to give trouble and cause a break within a few years’ time. If a dam is worth building it is certainly worth fitting the reservoir with a permanent outlet, one that can be absolutely controlled at any time of the year. Seepage will follow the line of pipe through the dam, or rodents will cut their way beside it if there are not some collars of concrete or other material around the pipe to cut off this direct line through the dam. The materials used for this outlet should be vitrified sewer tile, reinforced concrete, iron well casing, or cast iron pipe. Wood, or concrete that is not
rich and reinforced is very apt to give trouble when in the body of a dam across one of these coulees.

CHOOSING RESERVOIR SITES.

In selecting a reservoir site one wants to take into consideration the fall of the land that is to be submerged, the character of the soil, the use he will have for the water, and whether or not he can get the water out by gravity for use on the land that is to be irrigated. There are very few places where it will pay to store water to be pumped on the land afterward.

There are a great many natural reservoir sites in the coulees of Montana. They are ordinarily a wide flat bottom in the coulee with a narrow outlet. Figure 1 is a contour map of a reservoir and a section of dam. Figure 2 is a picture of a reservoir site with dam under construction. If there is a natural spill-way somewhere away from where the dam is to be, it is a great advantage, and farmers can afford to do quite a bit of extra work to be able to use the natural spill-way. Sometimes the reservoir site will not be in the main coulee at all but away from it in some natural lake bottom, in this case a diversion ditch is necessary to carry the flood water to the reservoir, and should be made large enough to fill the reservoir within the average flood season.
of the coulee that it is to be taken from. In any case the reservoir
site should be selected that will hold the most water with the
least amount of labor and cash outlay in building the dam, diversion
and spill-way, and in getting the water to the land that is to be
irrigated.

When the reservoir site has been selected and the dam site
determined, definite figures should be obtained as to the height
of the dam, the width at the top and bottom, the slopes of the
upper and lower faces, the size of the spill-way to take care of
the full head of water that might happen to come down, the type,
length, and size of outlet to be used for irrigation, and the amount
of water that will be stored when the dam is completed.

EARTHEN DAM.

The farmer's storage dam will nearly always be made of
earth. When a high dam or one of concrete, masonry, steel or
other expensive materials is to be built, it should be designed
by a competent engineer and constructed under his direction. But
there are many places where the farmer can build a dam at small
expense outside of his own labor.

The earthen dam can be built on a variety of foundations
and when properly constructed furnishes a safe and reliable
structure. The foundation for an earthen dam should contain
an impervious stratum at a moderate depth. Compact clay or
hardpan makes the best foundation. Solid rock without fissures
also forms a good foundation. Solid, well compacted clay should
be used near the upper face of the dam.

Imperviousness may be secured when necessary by the use
of a core wall. It may be made of puddled clay, masonry, concrete,
steel or other suitable material. It should be built near the
upper face of the dam.

PREPARATION OF THE FOUNDATION.

The junction between the dam and the earth or other founda-
tion must be carefully made tight so no seepage will start along
this surface to produce leakage. If seepage does start there is
great danger that the water will eventually wash out the dam.
All vegetation, and humus should be removed from the foundation
to the outer toe of the dam and a trench dug through the soil
to the impervious stratum to be filled with impervious clay.
MAKING THE FILL.

The methods followed will depend somewhat on the size of the dam and the equipment the farmer may have on hand to do the work. The materials in the embankment should be placed in even layers and out to the full width of the slopes. Each layer should not be more than ten inches thick and should be well packed before another layer is added. All sod, roots, vegetable matter and large rocks should be removed from the material before placing in the embankment. If the work is carefully done there will be but little settlement, but heavy packers are not always available for the work so it is recommended that the center of the dam be built considerably higher than the edges so as to provide for settlement. Loose dirt will settle from 8 to 10 per cent and if the dam is built level across the top the center will settle more than either end and water will run over it. The center should be the strongest part of the dam, because it is generally the place that gives the most trouble. The water side should be riprapped the full length with rock, willows, brush or other material to keep the waves from washing the dirt away from the dam. Figures 3 and 4 show methods of protecting dams from wave action.

PRESSURE

The pressure of the water on the dam is frequently not understood and this short paragraph is added so as to briefly explain the principles for those wishing it. The pressure on a strip of the dam a foot wide running from the top to the bottom tending to push it down stream when the water is eight feet deep is a ton, when 16 feet deep it is 4 tons, when it is 24 feet deep it is 9 tons, and so forth. This pressure does not depend on the size of the lake above the dam but on the depth of the water at the dam. Ice may cause a much greater pressure. The pressure in pounds on a square foot equals the depth of water in feet multiplied by 62.5. The total pressure on a strip of the face of the dam a foot wide tending to push it down stream is equal to 31.4 multiplied by the square of the depth in feet.

THICKNESS OF DAM.

The width of the dam on top will depend on its height and whether a roadway is to be constructed on top. The width of the dam on top should never be less than six feet and it is recommended that a width of twelve feet with a roadway on top be used. A good rule to follow is to make the top width of the dam at least equal to the height. A slope of 1 vertical to 2
horizontal should be used on the upstream face and 1 to 2 on the lower face. This would make a thickness at the bottom of a dam 10 feet high with a 12-foot width on top of 57 feet. If the top width of the dam is made equal to the height the slopes may be made a little steeper.
A good form of riprapping is to smooth off the bank to be riprapped to the form that is desired. Lay flat rocks or boulders all over the prepared ground as close together as they can be laid, then flush a wet mixture of concrete (about one of cement, two of sharp sand, and two of fine gravel) over the surface of the rocks fairly well. This will then be a cheaply built rock wall with the spaces filled with concrete.

Another form of riprapping that has been used to advantage in spill-ways is a mixture of rock and willows. Small willows an inch in diameter or less are cut, leaving all branches and leaves on, tied in bunches about six or eight inches in diameter with binding twine to make them easier to handle, and laid lengthwise of the spill-way with the butts down stream so the water will drop over them and hold them in place, then lapping about half or more with another layer of willows and rocks, and continuing this process until all the surface is covered.

If the water side of the dam is well riprapped with rock it is generally enough. Willows tied in bunches laid in the dam with the butts out give good service. Russian thistles, manure, hay and straw held down with woven wire have been used for this purpose. A log boom well anchored close to the dam will
break the wave action and protect the dam to a large extent. The lower slope may be seeded to grass to prevent washing from rain.

**SPILL-WAY.**

For earthen dams this is one of the most important features of construction. An earthen dam should never be overtopped by water and the spill-way should be large enough to pass safely the greatest flood flow that will come. The crest of the spill-way should be far enough below the top of the dam so that with the greatest flood passing, the water surface will be safely below the top of the dam. The bottom of the spillway should be at least three feet below the top of the dam.

The size of the spill-way necessary will depend upon the size, shape and contour of the drainage area above the dam. The amount and character of the rainfall during storms is about the same throughout the state as far as it affects the runoff. Figuring the maximum depth of water at 1 1/2 feet on the spill-way, the width of spillway should be 20 feet for one section of land and about 50 feet for five sections of drainage area.

One of the best and easiest spill-ways to construct and use is a natural saddle in one of the ridges bordering the reservoir. If this natural spill-way is heavily sodded and quite wide, usually no riprapping will be necessary. It is not possible to get a natural spill-way in every reservoir and where this is the case special precautions have to be taken to let the excess water back to the coulee level again. If this spill-way has to be made in the center of the dam or within the dam anywhere it should be reinforced with concrete. It is possible in most cases to have the spill-way at one end of the dam and drop the water on a more or less gentle slope down the side of the hill over the natural sod. If the slope is steep or not heavily sodded, all the ground that the water runs over should be riprapped.

**BUILDING THE OUTLET.**

The best outlet for a reservoir is vitrified sewer tile with the joints set in cement mortar, with one or two collars of reinforced concrete six or eight inches thick and about four to six feet in diameter.

Reinforced concrete, either square or round, makes a good outlet. This may be made by cutting a trench in the earth below
where the dam is to be built, filling the bottom with concrete and reinforcing it well with iron rods or barb wire, placing boards on both sides, spacing them so there is about six inches between them and each bank and filling these spaces with concrete. Short rods should be placed in the sides letting them stick out four or five inches to insure good connection with the upper layer. After these forms are taken out a board is cut so that it will fit loosely in the trough that has been made. This is put on legs so that it will be held up even with the top edge of the trough and a six-inch layer of concrete poured over the top. When it has set sufficiently the legs may be knocked out by shoving a narrow plank through, and the board pulled out. A square solid box of reinforced concrete is thus made with very little expense for forms. A stove pipe may be used for forms, a round pipe being the result. The stove pipe will rust out in a year or so leaving the clear concrete pipe. Many of these are in satisfactory use.

Cast iron soil pipe as used in sewers is very good and the same precautions should be taken as for vitrified clay.

Iron well casing if it is tarred well makes a satisfactory outlet conduit. In no case should wood be used in the body of a dam as it is very short lived and unsatisfactory.

Controlling gates should be put on the water side of the dam, and a platform built out to them. They should be regulated from the top with a threaded rod or pipe. The best gate is a cast iron valve the size of the pipe or conduit through the dam, but several different home-made gates have given efficient service. The home-made gates should be made of steel or reinforced concrete, the notches or slides should be lined with angle iron to insure a smooth running surface and the gate should have a rod or pipe welded or riveted to it for control. The rod or pipe will reach to the platform and be threaded on top and regulated by turning a nut or wheel, the rod working up or down through it. This gate should be very substantial as it will be hard to get at if anything goes wrong with it when the reservoir is full. By placing the gate on the water side of the dam the trouble with getting the pipe filled with mud or trash is eliminated, also the trouble with having the pipe full of ice when winter comes.
USE OF SPILL-WATER.

The water that goes through the spill-way after the dam is full may be diked up on the land below it if this land does not slope more than a foot in a hundred. This water can be used on higher land than that stored in the reservoir. By constructing a system of contour dikes, running the ends into the hill, a series of shallow lakes will result. The tops of the dikes should be built a foot higher than the outlet at the end. If they are built right this system will work automatically and all the land will get one good soaking in the spring when the water runs.

If land in Montana is soaked to the four-foot level a crop that year is almost a certainty. It is better than any summer fallowing that can be done and has proved a success on hundreds of places in northern Montana. One good irrigation in the spring before the crop is planted is generally enough and this might just as well be real early when there is so much runoff water going to waste.

Diversion Dams

The purpose of a diversion dam is to raise the water surface in a stream so that water can be forced into a ditch to be led away from the bed of the stream.

A wing dam is one that extends only part way across the stream and is built so as to direct part of the current through a head gate to a ditch or canal.

A diversion dam may be a very elaborate and expensive structure or it may be simple and easily constructed by the farmer. Diversion dams have been built largely in perennial streams, but there is opportunity in many places in our dry land sections where diversions dams can well be built across ordinarily dry coulees to divert the flood flow onto land that has been diked and prepared to hold the water for irrigation. It is with the idea of assisting such farmers as wish to construct their own diversion dams of a simple type that this is written.

Figure 6 shows the head of a flood water irrigation ditch leading from a coulee. The diversion dam in this case is only the lower bank of the ditch extending across the coulee. The ditch is made large enough to carry the flood water that comes
down the coulee. The view shows the coulee coming down between the hills in the distance and also a portion of the drainage area which furnished the runoff for the ditch.

BRUSH DAMS.

Figure 7 is a view of a brush dam across Teton River. It has been in 15 years without being washed out. Brush dams,
however, are frequently washed out in places and need repair every few years. The dam is made by holding down layers of brush, usually willows and cottonwood, with rocks and gravel, or piles driven into the stream bed. The usual method of construction is to cut brush to a convenient length and bind them together in bundles called “facines” about 4 or 6 inches in diameter then to drive stakes across the stream and attach a layer of these bundles to the stakes in the stream bed with tops upstream and weighted down with gravel and rocks. Another layer of brush is then placed on top of this one overlapping the upper end about half the length of the brush, and rocks and gravel added to hold it down. This method of placing alternate layers of brush and rocks is continued until the required height is reached which may be four to six feet. This makes a dam that is rather inexpensive, aside from labor, that has given satisfaction.

ROCK DAMS.

Figure 8 shows a diversion dam made of rocks across a dry coulee. This raises the water high enough to divert it into an irrigation ditch at the end of the dam. Usually loose rock fill dams should be faced with compact clay to hold the water. The body of the dam must be massive enough to hold the water back and prevent washing out.
WOODEN DAMS.

Timber crib dams are sometimes used, and, when properly constructed and the timber is not exposed to frequent wetting and drying they give good service. Crib weirs consist of a frame filled with rocks and gravel to keep them in place. They are fixed to the foundation by bolting to the solid rock where there is bed rock, or by sinking a number of cribs, one on top of the other, to a considerable depth in the ground. They may consist of separate cribs built side by side across the stream and fastened firmly together or they may be built as one continuous weir.

A satisfactory type where the coulee banks are steep and not far apart consists of square crib work abutments built into the banks and sunk below the river bed for end supports of the dam. Timbers are then bolted to the upper faces of these abutments so as to close the channel.

Contour Dikes

The object of contour dikes is to catch the runoff and hold it on the land to be irrigated. The first requisite for a successful diking system is a comparatively level field with a slope not greater than one foot in a hundred. Most of our farms have at least a few acres of this kind of land.

The next requisite is a draw or coulee from which the water can be run directly or by ditch onto this land. If a storage reservoir has been constructed the water running over the spill-way can be run onto this land while the stored water can be used on rougher land if necessary. To irrigate rough land requires an irrigator to tend the water, while it is not so essential to have an attendant where the system of checks formed by contour dikes is used.

If the draw runs through the land to be diked the first thing to do it to throw up a good strong dike along the bank of the draw to keep the water from running back into the draw and for the ends of the contour dikes to run into. This should be thrown up about two feet high. Figure 9 shows an ideal condition for this system of irrigation. In the foreground can be seen the border dike on the edge of the coulee.

The contour dikes must be run on a level so that the water will stand at the same height all along their length. These must
be run out with some sort of a level. Their distance apart is governed by the slope of the land, the kind of soil, and the size of the drainage area supplying the flood water. Dikes on the average should be 18 inches high although lower dikes are often used. The 18-inch dikes will hold water 12 inches deep, and if the soil is such that it is desired to hold the water 6 inches deep
on the shallow side this would make it necessary to put the dikes 50 feet apart for a slope of 1 foot in 100 feet, and to put them 100 feet apart for a slope of \( \frac{1}{2} \) foot in 100 feet. If this makes the checks too large for the water to get over the entire check rapidly enough with the flow available the dikes can be put closer together. For sandy soils the checks should be small to prevent excessive seepage loss.

The contour dikes extend across the flat from the dike along the bank of the coulee into the hill. Figures 9, 10 and 11 show how the contour dikes run from the border dike along the coulee to the hill where they run out. The outlet for passing the water from a check to the next one lower down is cut in the dike at the end near the hill and the dike protected so it will not cut out, or the water may be allowed to pass over the sod beyond the end of the dike. For such crops as hay or pasture where the dikes can be made permanent and sodded they can be made lower and broader with a rounded top so they will hold water to their full height, and when they get full the water will "brim" over the dike for its entire length. This gives an ideal distribution of the water.

If there is danger of getting too much water on the upper checks, boxes can be built through the dikes to drain the water.
into the lower ones. If one flood does not irrigate all the checks the water from the next flood can be led to the lower checks first.

By these methods of utilizing the flood waters of the state thousands of Montana dry farms can be developed into real homes. Many of those already abandoned can be brought back into productivity, and the destructiveness of the high water along the lower valleys of the large rivers will be greatly lessened.

Figure 12, Dikes for a Check.