Water for the World

Constructing Small Dams
Technical Note No. RWS. 1.C.5

The construction of small earth dams and water impoundments requires great care and skill. Poorly constructed dams are dangerous because they may break and cause flooding. A dam construction project should never be attempted without expert technical advice and some skilled labor. In attempting to build a dam, be sure to follow carefully the design prepared by the project designer (see "Designing Small Dams," RWS.1.D.5).

This technical note discusses the construction of small earth dams and outlines the construction steps to follow. Follow each step carefully to ensure that the dam is well built and strong.

Materials Needed

Before construction begins, the project designer should give you the following items:

1. A map of the area, including the location of the dam, access roads, the watershed area and nearby communities and houses. Figure 1 gives an example of the type of location map needed.

2. A list of all labor, and materials and tools needed as shown in Table 1. Ensure that all needed materials are available and at the work site before work begins. Make sure that adequate quantities of materials are available to prevent construction delays.

3. A cross-section of the dam to be built with slope and sample dimensions as shown in Figure 2. Dimensions other than the sample shown should be in line ratios.

Useful Definitions

ANTI-SEEPAGE COLLAR - Metal disks attached to steel pipe installed in a dam embankment. They prevent any flow of water in the space between the outside of the pipe and the embankment and thus prevent erosion and dam failure.

EROSION - The wearing away of soil, rock or other material by the flow of water.

PERCOLATION - Movement of water downward through the pores of the soil.

RESERVOIR - A natural or artificial lake where water is stored for use.

RIP-RAP - A covering of large stones or rock on the water side of a dam or on the banks to prevent erosion by waves or currents.

SILT - Sediment made up of fine particles carried or laid down by moving water.

SPILLWAY - A channel built to control flood water in a reservoir; it causes flood water to spill around the ends of a dam rather than over its top.

WATERSHED - The area of ground over which rainfall flows into bodies of surface water.

Table 1. Sample Materials List for a Small Dam

Item	Description	Quantity	Estimated Cost
Labor	Foreman Laborers		
Supplies	Clay soil Flat rocks Grass seed Stakes Rope Steel pipe		
Tools	Surveying equipment Digging tools A small tractor or backhoe (if possible) Soil compaction device Levels Earth moving equipment		

Total Estimated Cost = _____

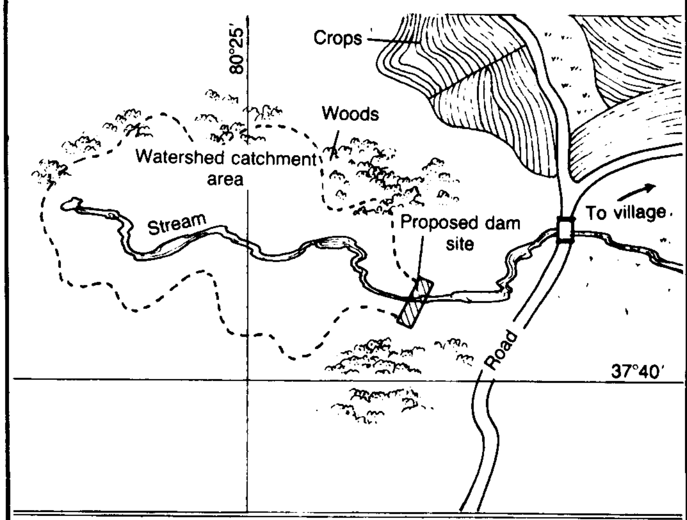

Figure 1. Location Map

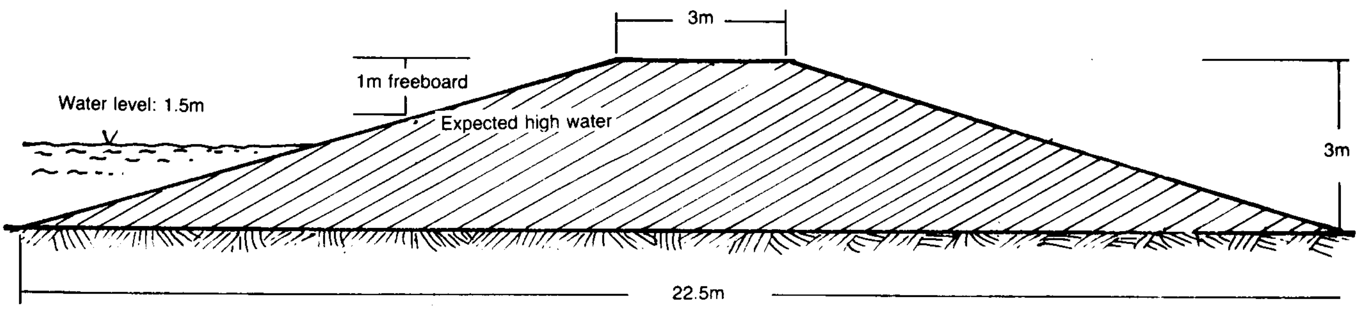

Figure 2. Clay Dam Cross-Section

General Construction Steps

Follow the construction steps below. Refer to the figures noted during the construction process.

1. Divert the flow of water away from the dam construction site. Two methods are available. The first and best method is to install a large diameter steel pipe in the stream as shown in Figure 3. Place the opening of the pipe beyond the furthest extension upstream of the dam embankment. Lay enough pipe so that the entire length extends past the furthest downstream extension of the embankment. Channel all flow into this pipe, if possible.

Before laying the pipe, attach anti-seepage collars to it. Each collar should be welded to the pipe and separated by a distance of 7m. The entire length of the installed pipe for the sample dam described in this technical note should be approximately 25 or 26m in order to extend beyond both sides of the embankment.

If the volume of stream flow is great, difficulties may arise in channeling all water flow into the pipe. A diversion ditch that leads water around the dam may have to be built. The construction of the ditch is very tedious and time-consuming if work is done by hand. In fast flowing streams, a combination of both methods can be used since the pipe should be installed to drain water from the reservoir during times of flooding.

No matter how the water is diverted, the job may be easier if the dam can be built during the dry season since less water will need to be diverted.

2. Mark out the dam site with stakes and rope as shown in Figure 4. Mark the proposed water lines using a hand level. The string across the valley should mark the high point of the dam. Be sure that the line is level before starting the other construction steps.

3. Clear all trees, dead leaves, branches, logs, stumps, roots and other debris from the area that will be covered by water. Special care must be taken to clear out all roots and debris at the site of the dam itself so that percolation and possible embankment leakage and failure do not occur. Before proceeding with further constuction steps, check the area well to be sure that no debris is left in the area.

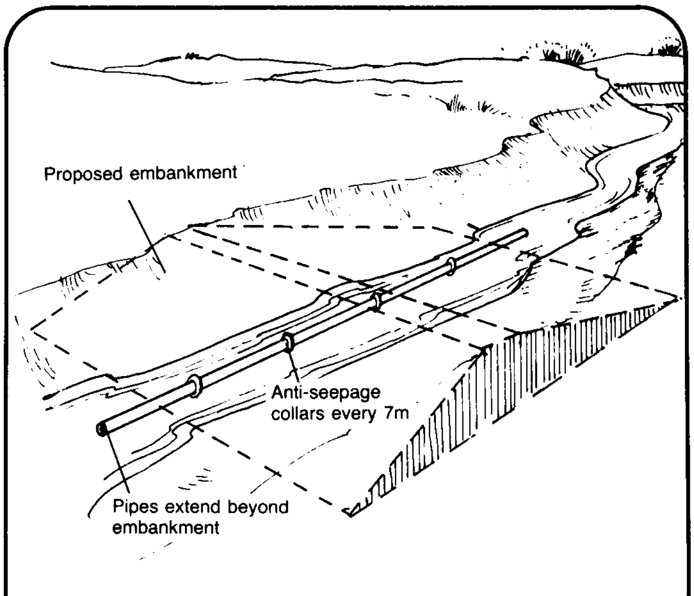

Figure 3. Drain Pipe

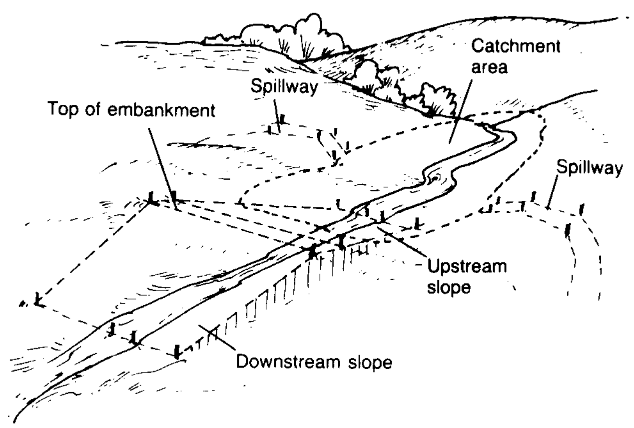

Figure 4. Staking Dam Site and Spillways

Embankment

The first step in the construction of the dam is to determine the width of the embankment. First, find the width of the embankment at its widest point. The widest point is also the lowest point of the reservoir. Refer to "Designing Small Dams," RWS.1.D.5, when determining the base width.

Dam width is equal to the height of the dam times the upstream slope added to the height of the dam times the downstream slope (a typical earth dam has a 3.5:1 upstream slope and a 3:1 downstream slope) added to the top width. For example, for a dam 3.0m in height with a 3.0m top width and 3.5:1 and 3:1 bank slopes, the width of the base is:

(height x upstream slope) + (height x downstream slope) + top width

(3.0m x 3.5m) + (3.0m x 3m) + 3.0m = 10.5m + 9.0m + 3.0m = 22.5m

The width of the dam should be checked continually to ensure proper slopes and width. For example, if 0.5m of the dam is completed, a new calculation can be done. This time, instead of using the number 3.0m as the height, use only 2.5m. The width of the dam after 0.5m of the fill height is completed should be 19.25m. See Table 2 for the proper widths of dam embankments at various fill levels.

Before beginning to build the embankment with soil, mark its width with rope and pegs to ensure accuracy.

Table 2. Widths of Dam Embankments at Different Fill Heights

Fill Height Above Ground	Embankment Width
Base	22.5m
0.5	19.25m
1.0	16.0m
1.5	12.75m
2.0	9.5m
2.5	6.25m
3.0 (top width)	3.0m

Dig out the pegged area until solid ground is reached. Then dig out another 0.3m of earth to ensure that the structure is well bonded to the ground surface. If the bottom is rough and irregular, the bond to the ground will be better but there should not be any stumps, roots or other debris around the bottom or ends of the dam.

To begin embankment constuction, be sure that adequate quantities of soil are at hand. Try to obtain good soil from the nearest possible site. Soil from spillway and reservoir excavation should meet most needs. Use a clay soil containing some silt and sand. If only clay is used, the embankment may crack. If too much sand is used, water may percolate through. In the construction process, use uniform material. If the quality of any of the material is questionable, use it only on the downstream side of the embankment. If there is any doubt about the suitability of embankment material, consult a soils expert or geologist, or send soil samples to the nearest soils laboratory for analysis.

To ensure the strength of the dam, the following guidelines should be followed in constructing the embankment. First, the fill material should be spread in continuous layers across the entire length of the dam. See Figure 5. Each layer should be between 100-150mm thick. Compact each layer carefully and thoroughly before adding the next layer. If the dam is being constructed without machinery, have the laborers dump their baskets of earth in lines from one end of the dam to the other. The workers should walk over the deposited soil to compact it well. Another method that can be used to compact the soil is to drive cattle from one end of the dam to the other after each day's work.

If the soil contains the correct level of moisture, sufficient compaction occurs from having the laborers tread on the fill and from using a simple pounding device as shown in Figure 6. The soil should be moist enough so that a foot mark will show. Dry soil should be wetted to reach the correct level of moisture. These steps are very important since the water tightness and strength of the dam depends on compaction.

If construction takes place in the wet season, precautions should be taken to ensure that water does not stay on the surface of the fill material. To allow water to drain, build up the center line of the dam and keep it a little higher than the sides so that rain runs off both the upstream and downstream sides. No part of the dam should be more than about 0.9m above any other part.

Continue to build the dam up layer by layer until the desired height and dimensions are reached. No dam holding more than 2.5m of water should be

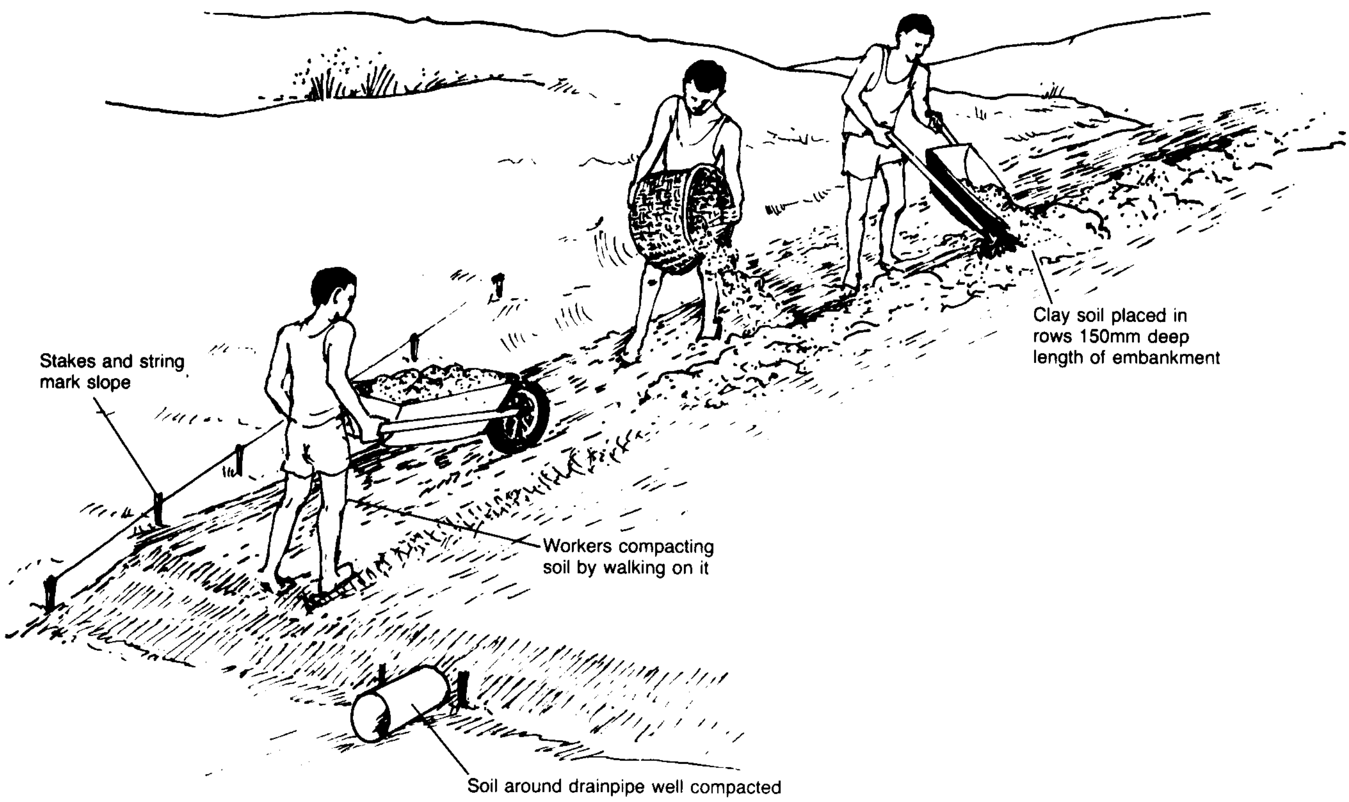

Figure 5. Constructing Embankment

attempted without expert advice. Usually, a small dam should not be more than 3m high. The design dimensions for dams are easily calculated. See "Designing Small Dams," RWS.1.D.5 for specific design information.

When building the embankment, make sure that the soil is well-compacted around the drain pipe. The soil should be as well bonded to the pipe as possible to prevent any flow of water along the pipe. The anti-seepage collars are installed specifically to prevent the wearing away of soil from around the pipe.

Once the embankment is completed, precautions against erosion should be taken. Rainfall may wash away soil from the exposed parts of the embankment. To prevent this, grass--preferably a creeping grass--should be planted on the downstream slope, the crest and the upper part of the upstream slope not covered by water.

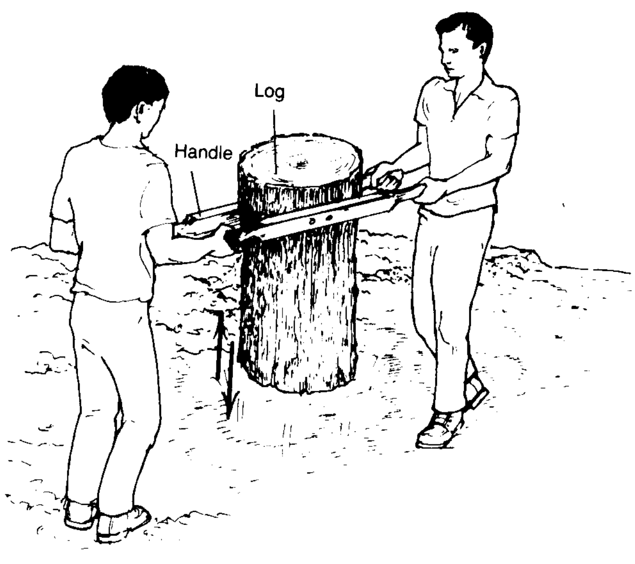

Figure 6. Manually Compacting Soil

Before planting, cover the embankment surface with a mixture of top soil and fertilizer, compost or animal manure. Plant the grass in horizontal rows for best results.

On the upstream side, erosion may be caused by the wave action of the water in the reservoir. To prevent this, pave the upstream slope with large rough stones to a point about 0.6m above the top water level as shown in Figure 7. Fill in the spaces between the large rocks with smaller flintstones so that few spaces are exposed to the water. This protective covering is called "rip-rap." Once the embankment is completed, install a cut-off valve at the downstream side of the drainage pipe. The valve can be used if there is a need to drain the reservoir or if there is flooding and danger of overtopping. An elbow joint and short vertical extension can be installed at the upstream side of the pipe. This is useful but not essential.

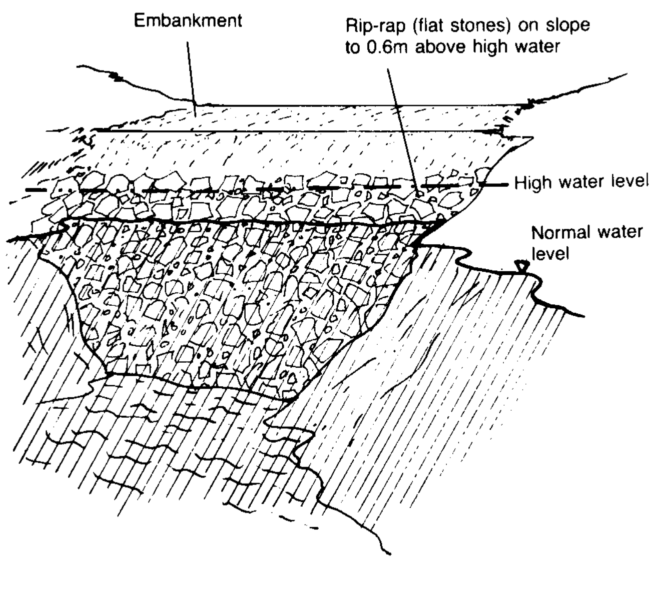

Figure 7. Placement of Rip-rap on Upstream Slope of Dam

Spillways

Spillways are one of the most important parts of the dam structure. They channel water away from the dam during periods of high water and protect the dam from overtopping. For extra safety, two spillways are recommended. Generally, one is placed higher than the other to act as a backup and extra precaution.

Dig the spillways in solid ground, clear of the ends of the dam. They should be continued past the downstream edge of the base to prevent erosion. The earth excavated from the spillway channels provides fill materials for the embankment, and should be used in construction.

To detemine the dimensions of the spillway, use local information and field observation to make good estimates. From evidence of debris on banks, water marks on rocks and the knowledge of local people, the level to which water rises during typical flood times can be determined.

Find out how high the stream rises during the wettest season of the year. Estimate the width of the stream if it were running with a depth of 0.6m and then double the number to allow for any heavy flooding. This figure should be the minimum width of the spillway.

The calculated width is the width of the spillway at the highest point or crest, which is generally in line with the dam. Line the spillway crest with stone to prevent erosion. There is no need to line the channels leading in and out of the spillway crest. For best results, the channel below the crest should be widened a little and the first part of the channel made steep but smooth. Downstream, the channel should flatten out and lead into the stream below the dam. See Figure 8 for details.

Reservoir

Deepen all edges of the reservoir by approximately 0.6m to prevent the growth of vegetation and weeds and the breeding of mosquitoes and snails. The soil excavated from the edge of the reservoir may also be suitable as fill material for the dam embankment.

Summary

The construction of a small dam must be done carefully to ensure that the dam does not fail. Whenever possible, an expert should be consulted before and during the construction process. Poor construction can cause dam leakage and breakage, resulting in physical and economic loss. Careful construction using the advice of experts will ensure that the dam lasts for many years.

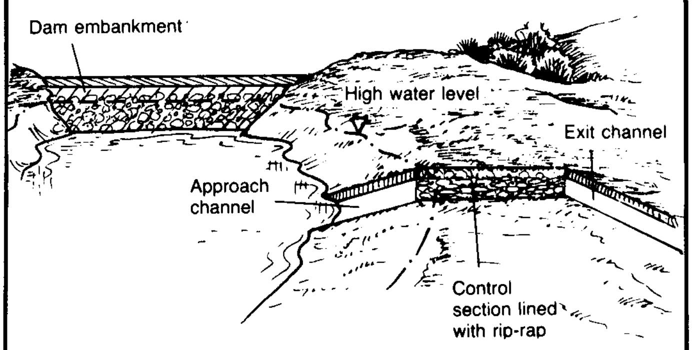

Figure 8. Spillway Design