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Preliminary investigations for small dams

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INTRODUCTION

Australians spend about US$30 million each year on the construction of small dams for scattered rural communities. Unhappily, our experience is that much of this money is wasted because about 25 per cent of these dams fail. The solution to this problem lies in more thorough investigation and improved standards of design and construction. Unfortunately such proposals are often regarded with scepticism because in many peoples' minds higher standards mean higher costs. This need not be the case.

The combined cost of field investigation and design usually represents only 5 to 10 per cent of the total capital cost of the dam. Furthermore, if the dam is constructed to a well-designed plan many cost-saving features can be incorporated. So we may well ask ourselves "Can we afford the extravagance of a cheap dam?"

SITE INVESTIGATION

The aim of this investigation is to find the most economical site for the dam. For a gully dam (i.e. an earth embankment built across a gully, stream or depression) this means the smallest embankment which provides the required storage. To compute the volumes of earth in the embankment and water in the storage, a survey must be carried out; in conjunction with this survey a sub-surface exploration is undertaken. The main considerations are:

- Reservoir site
- Foundation of dam
- Availability of suitable dam building material.

Reservoir Site

When choosing a gully site, the following topographical features should be borne in mind:

- the storage should be located in a wide valley just upstream of a narrow gorge. This will provide maximum storage for minimum earthworks.
- it should be located on the flat slope of a stream (site A) rather than on the steep slope (site B); this provides a larger capacity of stored water for any given height of dam (Figure 1).

Figure 1

One problem sometimes associated with site A is that there may be substantial depths of pervious materials (say three metres); this could mean a deep cutoff excavation for the dam. The presence of pervious materials could also result in more expensive de-watering problems during excavations.

A good reservoir should fulfil three main conditions:

- seepage losses must be low
- sides must be stable
- sedimentation must not be excessive.

Seepage Losses

These losses are affected more by the prevailing groundwater conditions than by pervious soils. For example, if an excavation is cut into sandy soil which lies well above the water-table, water will tend to seep out of the excavation (Figure 2)

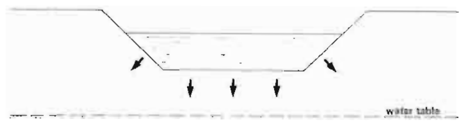


Figure 2

On the other hand if the water-table is higher than the floor of the excavation, then obviously water will seep in (Figure 3)

Figure 3

However, because most storages are built well above the water-table, sands and gravels are likely to be sources of seepage.

If the site is doubtful, there is a test that can be useful (ref. 1). During the site exploration, to be discussed later, several soil-sampling test holes will be put down in the borrow pit areas (i.e. areas from which soil is taken to build the earth embankment). These holes usually have a diameter of 100mm and are about three metres deep. Three or four of these holes can be selected for the seepage tests. The following procedure should be adopted:

1. Presoak each three-metre hole to a two metre depth for at least one hour before starting the test (Figure 4).

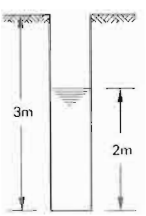


Figure 4

2. Maintain each hole at the two-metre level (i.e. one metre below ground level). The amount of water which has to be added to keep the water level constant should be recorded.
3. Continue the test for one day.

If the water added is less than 50 millilitres per minute (3 litres per hour) the site should be satisfactory. If the rate exceeds 500 millilitres per minute (30 litres per hour) the site is too permeable for a dam. For rates below these two figures (i.e. 50-500 millilitres per minute) the site should be regarded as doubtful. This indicates the need for further tests. If figures above 50 millilitres per minute are confirmed then other factors must be considered before proceeding with the project. These would include the purpose of the water supply scheme, the availability of water for the dam and the likely cost of treating the seepage area.

If it is necessary to support the sides of the test hole it can be done by packing gravel around a PVC slotted pipe.

Like sands and gravels, some rocks, too, are permeable and encourage seepage. Dams have failed due to sink-holes developing in the reservoir floor. This usually occurs when limestone underlies the soil. Water from the reservoir dissolves the rock to form vertical holes, which in turn lead to underground cavities and springs. One Australian farmer I know lost his entire water storage overnight in this way (Figure 5).

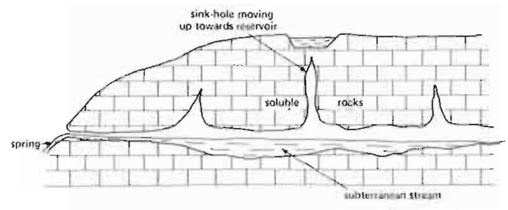


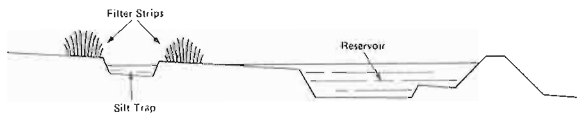
Figure 5

Stability of Reservoir Sides

As the level of stored water rises, so does the water-table in the sides of the reservoir. Soils and rocks which are quite stable when dry may become weak when saturated. This could cause a landslip which, in turn, will reduce the capacity of the storage. Frequently this problem is aggravated by cutting the borrow pits too close to the reservoir sides.

Sedimentation in Reservoirs

Sedimentation is a problem which occurs in catchments with active soil erosion. In these cases, advice should be sought from a soil conservationist. Sometimes it is possible to remedy the problem at its source; if not, it may be necessary to resort to silt traps and filter strips (Figure 6).



FILTER STRIPS AND SILT TRAP

Figure 6

Filter strips are dense stands of stiff, long-stemmed plants intermingled with grass; these strips reduce the velocity of the water and so cause silt to be deposited.

Foundations of Dams

Foundations must be capable of supporting the weight of the dam and must be sufficiently watertight to prevent seepage under the dam.

Springs, soaks or landslips indicate unstable soil conditions and should be avoided. The three main kinds of foundation material are:

- clay
- rock
- sand and gravel.

Clay

Clay foundations are usually satisfactory, provided that they are of the same material as that placed in the earth bank. However, if they are soft and saturated it may become necessary to remove them or place additional stabilising fills.

Rock

Most rock can support the weight of the dam but care must be taken to ensure that:

- seepage does not occur between the rock foundation and the earth-fill dam
- weathering of the rock does not lead to weakening of the foundation
- permeable zones are not created by joints and faults.

Sands and Gravels

The problem with this type of foundation is high seepage losses. While it is possible to build dams with these materials the cost is frequently prohibitive. Such sites are best avoided and an alternative location found.

AVAILABILITY OF SUITABLE DAM BUILDING MATERIAL

Soils placed in dams must fulfil two conditions; they must be sufficiently impervious to keep the seepage at a safe rate and they must be sufficiently stable to ensure firm side slopes.

There are three kinds of gully dams: homogeneous, zoned, and diaphragm. (Figure 7) The homogeneous dam is built from one type of soil and is the most common kind in Australia. A zoned bank consists of a centre clay core with pervious material on either side; it is considered the most stable form of farm dam. The diaphragm is built when there is only a limited amount of clay available at the site; the bulk of the bank is constructed from relatively pervious material with a thin layer (that is a diaphragm) of clay on the upstream slope. This layer varies from 0.6 to 1.0 metre thick, depending on the height of the dam.

Good impervious material contains about 25 percent clay with the balance made up of silt, sand and some gravel. Too much clay results in the embankment being weak and prone to expand and contract with changes of moisture. Insufficient clay can cause excessive seepage through the bank.

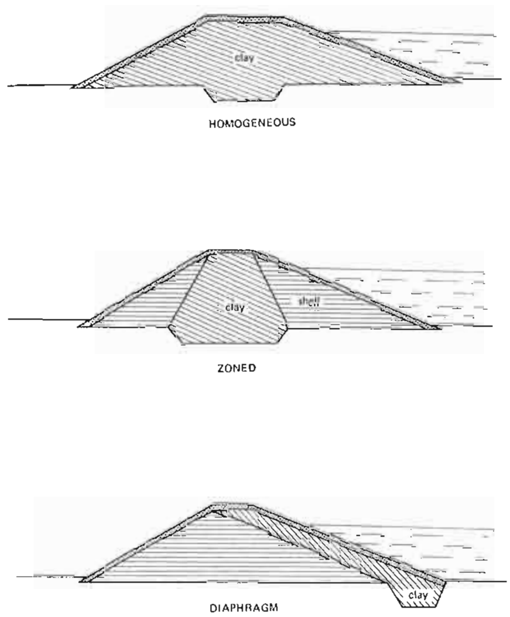
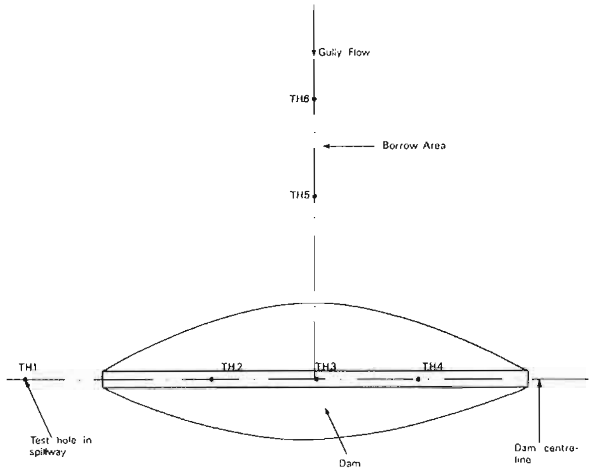


Figure 7

The usual method for exploring the area of material is hand auger boring. This is the cheapest, but it is very hard work for the operator. It is advisable to sink a test pit or trench so that the soil can be examined in its natural state.

Dam sites are tested on a fixed pattern. Small dams (up to three metres high) have a minimum of six test holes, four in the centre-line (including one on the spillway) and at least two in the borrow pit area. (Figure 8) For larger farm dams the number of test holes is increased, with holes at 20 metre intervals in borrow pits where sites are steep or complicated. This spacing can be increased to a 70 metre by 100 metre grid when the site is flat or uncomplicated. The test holes on the centre-line of larger dams are spaced at about 30 metre intervals. The test holes in the borrow pits are sunk to about 3 metres or to rock, while those in the dam centre-line are put down to at least three-quarters of the dam height or to rock (ref. 2).

When the exploration has been completed, all test holes and pits should be carefully filled to prevent human and stock injury.



TH1-Test hole No 1

Test Hole Plan For Small Gully Dam

Figure 8

CONCLUSION

Most of the element of risk can be eliminated from the building of a small dam by careful attention to four basic requirements. The builder should ensure that:

- the site selected is the most economical
- the reservoir has low seepage losses, stable sides and does not silt up
- the foundations are watertight and capable of supporting the dam
- there is sufficient dam-building material.

The cost and effort expended on making sure that these conditions are met will, in the long run, save the builder both time and money. Remember the military adage "Time spent in reconnaissance is never wasted".

REFERENCES

1. U.S. BUREAU OF RECLAMATION. Earth Manual, 1974. (A book)

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