5 – DAM CONSTRUCTION

5.1 Types of Construction Equipment

There is a range of equipment available to excavate, shift and place material in farm dams. Each type of equipment has been developed to suit particular requirements such as short haul distances or deep and narrow excavations. The cost per cubic metre of excavation varies depending on the efficiency of excavation and movement. Short haul distances are always least costly. Shallow excavations and tasks where efficient haul routes can be employed are also cheaper. Table 5-1 shows the range of equipment available and approximate earthworks costs.

TABLE 5-1 – APPROXIMATE COSTS OF DIFFERENT TYPES OF EARTHMOVING EQUIPMENT

Type of Equipment	Comment	Approximate cost per m^3
Bulldozer	Short hauls (<50 m) Low compaction	$ 0.80
Elevating Scraper	Confined site/Small volumes	$ 2.00
	Large volumes with hauls up to 400 m round trip.	$ 1.00
	Extra cost per extra 200 m round trip distance	$ 0.10
Sheepsfoot roller		$ 0.30
Excavator	Excavate and place beside excavation	$2.00
Excavator and truck	Excavate and place in truck and move 2 km	$4.00
Land Clearing	Light Heavy	$500/ha $1500/ha

Note: Costs can vary significantly. A contractor should be consulted to determine accurate costs.

PHOTOGRAPH 5-1 – ELEVATING SCRAPERS IN BORROW PIT

5.2 Compaction of Soils

To achieve low permeability and high strength, soils need to be compacted when they are placed in an embankment. Appendix E describes standard laboratory (Proctor) compaction tests. Maximum compaction is achieved for least compactive effort if the material is placed at 'optimum' moisture content. It is for this reason that all specifications require that the material to be placed in an embankment is at, or close to, 'optimum' moisture content.

Specifications usually require that at least 95% standard compaction be achieved (see Appendix E). Some contractors claim that adequate compaction can be achieved using bulldozers. This is not correct. Bulldozers are specifically designed so that they have a low ground-bearing pressure (see Table 5-2). Larger fully-loaded elevating scrapers (ie larger than Caterpillar 631 series) can achieve 95% standard compaction but only if the material is placed in thin layers (200 mm or less). A laser bucket working in tandem with the scrapers can maintain the thin layers required.

Sheepsfoot rollers are the recommended method for compacting farm dams. Compaction by this method can add 10% to 30% onto the construction cost of a dam but the reduction in risk failure is worthwhile. Sheepsfoot rollers have two beneficial features for dam construction - firstly, a high ground bearing pressure (see Table 5-2) and secondly, the shape of the sheepsfoot which 'punches' into the clay material to break down clods and form a homogeneous embankment. Scrapers only tend to squeeze the clods together. On a roller, the length of each foot should be at least 175 mm from the outside surface of the drum (see Photograph 5-2).

When using a sheepsfoot roller, a general guide that adequate compaction has been achieved is when the roller starts to "walk out". This is when the feet cease pushing into the clay and start to walk across the compacted surface.

TABLE 5-2 – GROUND-BEARING PRESSURE OF EARTHMOVING EQUIPMENT

Type of Equipment	Bearing Pressure (kPa)
Bulldozer	60
Wheeled tractor	180
Loaded elevating scraper	300
Sheepsfoot roller	1750

PHOTOGRAPH 5-2 – CLOSE UP OF SHEEPSFOOT ROLLER

5.3 Site Preparation

Site preparation can occur well before a contractor has been chosen. Depending on circumstances, it may be necessary to relocate powerlines, telephone cables, irrigation mains or farm roads.

The most important site preparation task is management of borrow pit moisture content. To achieve adequate compaction of material in the embankment, the material should be at optimum moisture content (see Appendix E). It is possible to add water during construction but large volumes are required and this can be costly. There is also the question of uniformity of water application. In most cases, water trucks are considered as an unnecessary expense.

Fortunately soil with a full profile of moisture (i.e. at the drained upper limit) is generally close to optimum moisture content. Therefore moisture control of the borrow pits areas can be managed well before construction commences by allowing a full profile of moisture to accumulate. This can be done by removing all vegetation from the area and deep ripping to encourage rainfall to permeate into the profile.

Growing a crop on a borrow pit area immediately before construction simply removes valuable moisture.

5.4 Diversion drains

In some cases, it is desirable to construct diversion drains or banks to protect the borrow pits and embankment areas from runoff during construction. Inundation of borrow pits can cause costly delays.

5.5 Site Clearing and Topsoil Stripping

The area to be covered by the embankment, borrow pits and bywash should be stripped of topsoil (100-150 mm), timber and deep roots. With prudent site management, stripped topsoil can be placed directly on completed sections of the embankment – thus reducing the extra cost of double handling. Borrow pits should only be stripped immediately prior to excavation to maintain moisture. Stump holes under the embankment should be carefully backfilled with compacted clay.

Care should be taken **NOT** to strip bywash return slopes and any other area where vegetation management is important. The bywash return slope should be pegged and all construction traffic excluded.

For large storages, full clearing of trees within the storage area is at the discretion of the landholder. Some landholders are concerned that sticks and other debris can get lodged in pipes and pumps. However, if trees are not pushed and raked, experience indicates that there are few problems with trash. Other landholders leave trees as habitat areas for water birds and fish (see Appendix F). Trees within and beside a storage also provide wind breaks that reduce wave erosion of embankments.

5.6 Setting Out

The location of cut-off trenches, batter toes and borrow pits needs to be pegged before construction commences. Colour coding pegs is useful (red tops for cut-off, yellow tops for embankment toes). Set-out is usually based on bench marks established during the design stage. Care should be taken not to destroy bench marks during construction. Judicious placement and clear identification of bench marks (away from possible construction zones) helps to ensure that bench marks are not destroyed.

5.7 Cutoff Excavation

A cutoff trench should be excavated along the whole length of the embankment. To avoid double handling, the material excavated from the cutoff trench can be placed directly in outside batters. The cutoff should extend through permeable zones and at least 0.5 m into good clay material or down to a solid rock foundation. Fractured rock should be partially excavated so that the embankment forms a solid connection with the foundations.

Site investigations (test pits) prior to construction should give an indication of the depth of the cutoff trench required and can eliminate unexpected surprises (e.g. water seepage into the cutoff trench).

Cutoff trenches should not have vertical side batters as it is difficult to connect the backfill tightly to a vertical side wall.

PHOTOGRAPH 5-3 – DEEP CUT-OFF TRENCH WITH SEEPAGE IN BED

5.8 Cutoff Backfill

The bed of the cutoff trench should be scarified and watered prior to backfilling. Backfill material should be good quality clay that will be used to form the core of the embankment. The material should be placed in thin layers and compacted as per the embankment (see next section).

PHOTOGRAPH 5-4 – COMPACTION OF CUT-OFF TRENCH WITH ROLLER

5.9 Embankment Construction

The embankment is constructed in horizontal layers. Care must be taken to join the embankment with the cutoff trench backfill. The core (zoned embankment) or the diaphragm (diaphragm embankment) should be a homogenous extension of the cutoff backfill and should extend to the top of the embankment. The best, non-dispersive clay material should be selected for this zone.

Material should be placed in thin layers (no more than 200 mm) at the correct moisture content and correctly compacted. As a guide in the field, if a clay is at optimum moisture content, it can be rolled into a 4 mm diameter pencil. If the thread begins to crumble before this diameter is reached, the material is too dry.

The outer zones of a zoned embankment are generally constructed with poorer material with the worst material placed in the outside batter. Outer zones should also be compacted.

Each time a new section of bank is started (e.g. after a weekend break), the surface of the older embankment should be stripped and scarified so that new compacted material will bond to the existing embankment without leaving a dry seam. This is very important, as an embankment is only as good as its weakest seam.

5.10 Compaction Testing

Most specifications require that the material is to be placed in the embankment at, or near, optimum moisture content and at least 95% standard compaction is to be achieved. These terms are defined in Appendix E. "Walking out" by rollers is often a sign that adequate compaction has been achieved. However, this is a subjective assessment and field testing of compaction is preferred.

In the field, there are different methods of measuring field dry density and moisture content. They include the sand-replacement test, core cutter methods and densometers (see Photograph 5-5).

Continual compaction testing throughout the construction period is usually cost-prohibitive for farm dams. However, it is often very helpful to do some compaction testing in the earliest stages of the work. In this way, the contractor and the landholder both become aware of the correct moisture content and the amount of compactive effort required to achieve satisfactory results.

PHOTOGRAPH 5-5 – COMPACTION TESTING USING A DENSOMETER

5.11 Trimming

When the embankment is finished, it should be trimmed to achieve a uniform appearance. Articulated graders are adept at finishing embankment, roads and drains (see Photograph 5-6)

The crest of the embankment should be graded with a 2% cross fall to the inside (water side) to encourage runoff away from the steeper, outside batters.

5.12 Topsoil Cover

Topsoil should be spread evenly in a smooth uncompacted layer not less than 150 mm deep over the embankment batters. It is often desirable not to place topsoil on the embankment crest. Vegetation growth on the crest can dry out the narrowest section of the embankment causing cracking and makes vehicular movement difficult if not controlled.

PHOTOGRAPH 5-6 – GRADER TRIMMING EMBANKMENT

PHOTOGRAPH 5-7 - POORLY DISTRIBUTED TOPSOIL COVER

5.13 Bywashes

During construction, machinery should be kept away from the bywash return slopes. Vegetation growth on this area should be encouraged. The bywash must be excavated to a smooth, level finish to ensure uniform flow. Material excavated from the bywash area should be used in the outer zones of the embankment. Small diversion banks should be placed above the bywash excavation batters to prevent local runoff from eroding the bywash batters and return slope.

5.14 Pipelines

Seepage along pipelines is probably the most common cause of embankment failure. Hence, great care should be taken in the installation of pipelines. This is the main reason for installing pipelines over an embankment rather than through the bank (see Photograph 5-8). The disadvantage of pipelines over an embankment is the additional pump priming equipment that may be required.

PHOTOGRAPH 5-8 – PIPELINE OVER THE EMBANKMENT

All pipelines under embankments should be designed by an experienced engineer and should conform to relevant Australian Standards.

All pipelines should have at least three baffles installed around the pipeline to prevent seepage along the pipeline trench. The baffles should extend at least 500 mm into undisturbed material around the pipe.

Installation should carefully follow the plans, in particular bedding type, pipe class, baffles and trench backfill. The area where the pipeline is to be installed should be built up so that there will be at least 600 mm cover over the top of the pipe after the trench has been backfilled. The trench width should be the minimum that will allow proper compaction around and under the pipe. The trench walls should be vertical and all workplace health and safety issues (e.g. shoring of the trench) should be understood. The bed of the trench should be smooth and uniform in grade so that all pipe joints are aligned and individual pipe lengths rest on a uniform bed.

For large socket-jointed pipes, a smooth excavation should be made under each socket so that the weight of the pipe is not loaded onto the socket joint. Once the pipe has been laid, backfilling can commence. Selected clay material should be placed in thin layers at the correct moisture content and compacted to 95% standard compaction. Hand held plate vibrators (Wacker packers) are useful in achieving adequate compaction.

PHOTOGRAPH 5-9 – INSTALLATION OF PIPELINE UNDER EMBANKMENT

"Watering in" of pipes is a procedure where the pipe is laid in the trench and partially backfilled with loose material. The trench is then flooded and the saturated material is vibrated around the pipe. This achieves a good contact of saturated clay around the pipe but it is not recommended. Little compaction of the backfill occurs and post-construction settling within the pipeline trench is a possibility. The saturated material also provides little support to the pipe when construction equipment passes over the trench as the embankment is finished off.