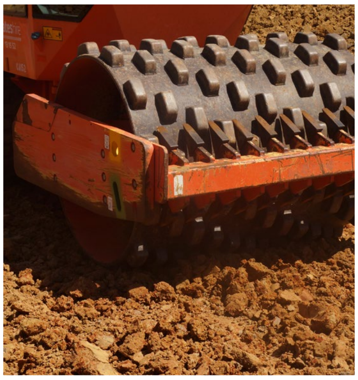

FEEDLOT DESIGN AND CONSTRUCTION

8. Bulk earthworks

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Introduction

Bulk earthworks create pens, runoff and drainage control, drains, roads, silage pits, buildings, sedimentation structures and holding ponds. They also prepare for the foundations of buildings and structures that are to be erected including site offices, grain storages, feedmill, workshop and cattle handling facilities and the levelling of areas for the road network.

Earthworks carry a significant initial capital cost and it is therefore important to get this design right from the start; mistakes will be difficult and expensive to correct once work has commenced.

Pens, runoff control and effluent storage are the largest component of the earthworks. Bulk earthworks for these are usually undertaken using materials from within the site. If suitable materials are not available from within the site they can be brought in from off site, but at a higher cost. Bulk earthworks must be executed in conjunction with other processes including, but not limited to, surface and subsurface drainage works, underground services and environmental control measures.

Bulk earthworks start with dozers...

...and scrapers.

Design objectives

Pens, runoff control systems and effluent storage earthworks should be designed to

- drain downslope from the feed apron towards the runoff control and storage elements
- provide a comfortable pen surface for cattle while lying or standing
- provide a durable and stable pen surface that is resistant to rainfall erosion and cattle damage
- provide a stable pen surface for cleaning and other equipment
- provide a pen surface that does not degrade the value of manure by admixing
- facilitate low ongoing maintenance costs
- ensure that the engineering works perform in accordance with their design capacities or capabilities
- ensure that structures containing and controlling runoff maintain their integrity and compliance with specified design criteria
- prevent adverse impacts on groundwater and surface waters.

Mandatory requirements

Compliance with

- National Guidelines for Beef Cattle Feedlots in Australia (MLA, 2012a)
- National Beef Cattle Feedlot Environmental Code of Practice (MLA, 2012b)
- relevant Commonwealth, state and local authority codes, regulations and relevant Australian standards as applicable to the feedlot development.

The National Guidelines for Beef Cattle Feedlots (MLA, 2012a) state that

- If a groundwater assessment indicates a high potential for contamination of underground water resources because of leaching of nutrients through permeable, underlying rock strata, an impermeable barrier will be needed between the contaminant and the groundwater. This is required if the permeability of underlying soil/rock strata exceeds 0.1 mm/day.
- Clay liners should have a maximum permeability of 1×10^{-9} m/s (~0.1 mm/day) for distilled water with 1 m of pressure head.
- Catch and main drains, the sedimentation system and holding ponds should be underlain by at least 300 mm of clay or other suitable compacted soil or a synthetic liner able to provide a design permeability of $<1 \times 10^{-9}$ m/s (~0.1 mm/day).

Design steps

Typically, bulk earthworks will include the following steps

- setout
- clearing vegetation
- removing topsoil
- removing and replacing any unsuitable material
- cuttings and embankment construction
- any spoil or borrow activities
- any additional processing of selected material for the selected material zone.

Staged construction

Operational requirements, funding limitations and other considerations may dictate that construction of expanded or new facilities is undertaken in a staged manner. Stages are tailored to match operational requirements and required market levels, with the basic philosophy being able to ensure that maximum use is made of existing infrastructure in subsequent development stages.

Therefore, it is important to consider the requirements for the earthworks of the full development at the start of the project if further stages are likely. A staged earthwork plan can reduce double handling and other inefficiencies. For example, it is usually more cost effective to prepare a larger surface area utilising cut and fill quantities. The location of initial borrow areas and stockpiles may also impact on future development areas. Similarly, the construction of effluent storage ponds should cater for the full development as these structures are difficult to extend.

Setting out of earthworks

The design information must be transferred from design to the field with precision and detail. This may occur by either

- the traditional approach – physically position and detail the extent of all cuttings and embankments shown on the drawings as well as transitions from cuttings to embankments using pegs and batter profiles or equivalent. Once the bulk material is removed, additional survey pegs are then required for the trimming of each pen. Additional features such as drains will also require survey pegging.

Step 1. Setting out earthworks

Effective erosion control measures should be installed to protect the working area and newly formed surfaces.

Step 2. Clearing vegetation

- GPS machine control – design information can be loaded into the construction machinery, enabling the operator to view real-time cut and fill values and horizontal and vertical data across the construction site. Traditional set-out pegs are no longer required.

The benefits of GPS-guided plant include independent operation and less survey pegging resulting in significant cost benefits, improved accuracy, easy design updates, the inclusion of unplanned works and increased safety.

Before starting earthworks, the levels of the existing natural surface should be verified by the construction contractor. This approach may prevent later disputes on earthwork quantities from a variation between design data and existing ground levels.

Protection of earthworks

Effective erosion and sedimentation control measures should be installed to protect the working area as well as the surrounding environment. Drainage should ensure run-off water does not scour the working area. Water should not be allowed to pond in the working area resulting in wetting up of the foundation material.

A sediment and erosion control plan (SECP) which outlines the sediment and erosion control measures for the works may need to be prepared.

Should earthworks material become over-wet (above the specified moisture content for compaction), the material will need to be left to dry out. Earthworks material should not be allowed to dry out to the point where excessive shrinkage occurs and the surface is pulverised by traffic generating excessive dust. Dust control is critical not only from an environmental impact perspective but from an animal welfare perspective during expansion or redevelopment construction works.

Clearing and grubbing

Clearing is carried out in advance of any earthwork operations both from within the boundaries of areas affected by earthworks or other areas to be cleared as designated on the approved design drawings. Clearing consists of cutting, taking down, removing and disposing of everything above ground level, except where such trees, vegetation, structures or specific sites are designated to remain. The material to be cleared shall include, but not be limited to, trees, stumps (parts above ground), logs, bushes, undergrowth, long grasses, crops, vegetation, large rocks, abandoned services and structures.

Grubbing consists of the removal and disposal of surface vegetation, the bases of stumps, roots, the underground parts of structures and other obstructions to the depth specified in the earthworks specifications. Typically these are removed to a depth of not less than 300 mm below the subgrade level in areas where future earthworks will be required. Grubbed holes should be backfilled and well compacted with the foundation material.

Removal of topsoil

Topsoil is surface soil which is normally high in organic material and contaminated by residual grass seed and grass roots and reasonably free from subsoil, refuse, clay lumps and large stones.

In most cases, topsoil is unsuitable for use as foundation material for bulk earthworks due to the high organic matter and contamination by other materials e.g. rocks and timber.

Topsoil can only be removed once clearing and grubbing and disposal of materials has been completed and sediment and erosion control measures have been implemented on that section of the works.

Topsoil should be stockpiled separately clear of the work area with care taken to avoid contamination by other materials. The topsoil stockpile should also be accessible for later use for covering finished embankments and re-establishment of site vegetation once works have been completed.

The depth of topsoil to be removed will be indicated on the engineering plans. Typically the depth of topsoil removed is not less than 150 mm. However, the actual depth is usually assessed on site during excavation.

Step 3. Removing topsoil

Topsoil stockpile sites

Topsoil should be stockpiled in dedicated stockpile sites. These sites are usually nominated on the approved design drawings. Stockpile sites are located to minimise damage to natural vegetation, and maintain the existing surface drainage such that material from the stockpiles does not enter drainage lines or watercourses. They are located so that the stockpiled material is accessible for carting away at any time.

Typically, the maximum height of stockpiles is about 2.5 m and a maximum batter slope of 2H to 1V. Slope and batter is expressed in rise over run— for every 1 metre of rise (vertical) there is a 2 metre of run (horizontal). To minimise erosion, stockpile batters are usually track rolled or stabilised by other acceptable means.

Temporary erosion and sedimentation control measures to protect the stockpiles should be installed and maintained.

Problems may arise during construction earthworks. Groundwater encountered will need appropriate drainage.

Cuttings

All excavation needs to be carried out to the required lengths, breadths, depths, inclinations and curvatures as required for the construction of the permanent works, in whatever material that may be found.

Groundwater may be encountered when material is removed during cuts. This will be most likely from underground streams and springs in areas with cohesionless (sandy or gravelly) soil or water-yielding rock. In this case, the area may need dewatering with mechanical equipment (i.e. pumps) or subsoil drainage may need to be installed using suitable slotted-pipe drainage pipe.

Unsuitable material

The suitability of material for construction is assessed on the basis of its geotechnical qualities. Soil testing during site investigations determines the nature of the material on the proposed feedlot site. The results of these tests will identify whether material is suitable for construction. Refer to *Section 7 – Site investigations* for more detail on soils investigation.

Even though soil investigations may indicate that materials are suitable for construction, unsuitable materials may still be encountered below the design level of cuttings and below the nominated depth for stripping topsoil beneath embankments.

Unsuitable material may include

- cohesive soils having a liquid limit in excess of 90% or plasticity index in excess of 65%; any material containing topsoil, wood, peat or waterlogged substances
- any material containing biodegradable or organic material (more than 5%); any material containing scrap metal
- material from contaminated sites
- material which by virtue of its particle size or shape cannot be properly and effectively compacted e.g. sand
- large rocks.

Unsuitable material such as large rocks should be excluded from earthworks.

The construction contractor and lot feeder may need to locate a borrow pit to obtain suitable construction material. If large enough, this borrow pit may be used in the future as a source of material for pen maintenance. Alternatively, the borrow pit could be the location of future runoff storage structures.

Materials that are soft or unusable merely because they are too wet or too dry for effective compaction are not usually classified as unsuitable, unless otherwise defined by the earthworks specifications.

Unsuitable material should be excavated and disposed of as directed to spoil or as fill in areas in which it would be deemed suitable. The unsuitable material which has been removed must be replaced with suitable material from cuttings, or with material borrowed from elsewhere on or off the site.

Suitable material

Typically, the construction contractor will be required to have visited and examined the site to ascertain its general nature and the kinds of materials to be excavated prior to the submission of the tender.

Soils may need to be mixed or engineered to produce a material that meets the foundation, sub-base or lining specifications. The parameters of interest include permeability (for protecting groundwater) and strength (for trafficability). The performance criteria required to be met for the material used for pen and road surfaces, and manure stockpiling/composting areas can be found in *Section 17* and the material performance criteria for clay liners for holding ponds is found in *Section 12*.

If significant earthworks are required to create suitable slopes, a borrow pit will be needed to source suitable additional material for pen and road surface construction. The location of this borrow pit should be determined during the site investigation stage where material samples from several locations are tested for suitability. From an economic viewpoint, the borrow pit should be sited as short a haul distance as possible from the construction area to avoid expensive long material hauls. Borrow sites should have cut batter slopes not steeper than 4H to 1V.

Permeability

The National Guidelines for Beef Cattle (MLA, 2012a) provide guidance on the selection of the materials suitable for use as clay lining and pen surfacing. State guidelines may also outline material specifications.

Table 1. Specifications for clay liner materials

Soil characteristic	Acceptability criterion	Test method
Percentage fines	More than 25% passing a 75 µm sieve	AS 1289 3.6
	More than 15% passing a 2 µm sieve	
Liquid Limit	Less than 70	AS 1289 3.1.1
Plasticity Index	More than 15	AS 1289 3.3.1
Emerson Class Number	5 to 6	AS 1289 3.8.1

More detail on the material specifications for clay liners in holding ponds can be found in *Section 12*.

The finished surface of the clay liner or pen should be trafficable for cattle and equipment. The minimum depth recommended for the clay liner is 300 mm after compaction.

The design pen surface levels may include an allowance for a sacrificial or wearing layer to ensure that the integrity of the liner is maintained. The depth of the wearing layer and liner should be sufficient to ensure that equipment does not damage the liner during harvesting of manure, although periodic repair of the pen surface will be necessary due to the wear and tear associated with cattle traffic and normal cleaning operations. A supply of suitable material should be identified on site.

Strength

To measure the soil's ability to handle a load, the mechanical strength of the material is typically determined by the California Bearing Ratio (CBR). The CBR test is used in the design and analysis of both rigid and flexible road pavements.

CBR is a strength test that compares the bearing capacity of a material with that of a well-graded crushed stone (thus, a high quality crushed stone material should have a CBR ~ 100%). It is primarily intended for, but not limited to, evaluating the strength of cohesive materials having maximum particle sizes less than 19 mm.

Though CBR is apparently a ratio of forces, in reality it is a stiffness ratio, since it gives the ratio of forces required for a given penetration. Table 2 shows the typical range of CBR values for various unified soil classification types. (See also Table 1 in *Section 17*).

Field testing soil strength

Bulking and shrinkage (cut to fill ratio)

Bulking occurs when soil is excavated. One cubic metre of in situ material expands and does not always translate into one cubic metre of fill when placed and compacted on the site. Bulking can have a significant effect on the balance of cut and fill volumes and hence the cost of the earthworks. To allow for this, the earthworks

Soil fill in earthworks must be compacted. This sheepsfoot compactor combines high speed and capacity compaction control.

specifications must state the measure of volume for the material. For example, a 'bank cubic metre' represents the volume of soil in the ground before it was excavated and an 'excavated cubic metre' represents the volume of soil after it is excavated.

Table 2. Typical range of CBR values (Fahey 2009)

General soil type	USCS Soil Type*	CBR Range %
Coarse-grained soils (>75 μm)	GW	40 – 80
	GP	30 – 60
	GM	20 – 60
	GC	20 – 40
	SW	20 – 40
	SP	10 – 40
	SM	10 – 40
	SC	5 – 20
Fine-grained soils (<75 μm)	ML	15 or less
	CL L <50%	15 or less
	OL	5 or less
	MH	10 or less
	CH L >50%	15 or less
	OH	5 or less

**USCS soil types are detailed in Section 7 – Site Investigations.*
The National Guidelines for Beef Cattle (MLA, 2012a) state a minimum standard for CBR wet and dry of 20% for pen surfaces.

When the material is compacted, its volume decreases. This is referred to as shrinkage.

Disputes over bulking factors (cut to fill ratio) and shrinkage are common between construction contractors and the project manager or lot feeder.

Filling (embankment)

Filling must be carried out to the lines, levels and grades required to complete the design surface. Filling or embankment construction includes

- all operations associated with the preparation of the foundation areas on which fill material is to be placed
- the placing and compacting of approved material within areas from which unsuitable material has been removed
- the placing and compacting of fill material and of materials of specified quality in nominated zones throughout the works
- all other activities required to produce embankments as specified to the alignment, grading and dimensions shown on the drawings.
- any pre-treatment such as breaking down or blending material, wetting or drying out material containing excess moisture.

Typically, material for filling is obtained from the excavations within the site (Figure 1), supplemented by borrow material if necessary. The material must be free of tree stumps and roots and be capable of being compacted in accordance with the earthworks specification. (See *Section 12* for more detail on material specification for clay liners in holding ponds.)

In general, fill materials will be well-graded suitable material as stated in the earthworks specifications.

Foundations will need to be prepared on which fill will be placed. Typically, foundations are prepared after removing topsoil and unsuitable material, by loosening the exposed material to a depth of not less than 200 mm, adjusting the moisture content of the loosened material and compacting to the levels specified in the earthworks specifications.

It is critical that the methods of excavation, transport, depositing and spreading of the fill material are selected to ensure that the placed material is uniformly mixed.

In embankments other than pond embankments, rock material may be broken down and evenly distributed through the fill material, and sufficient fine material placed around the larger material as it is deposited to fill the voids and produce a dense, compact embankment.

Fill materials are generally placed in layers and uniformly compacted to the design (dry density at optimum moisture content) specification before the next layer is applied. The loose thickness of each layer should not be greater than 300–400 mm depending on the type of compaction machinery.

Each layer of fill must be processed as necessary to bring its moisture content to a uniform level throughout the material suitable for compaction. The optimum moisture content as determined by the laboratory compaction test is used as a guide in determining the proper moisture content at which each soil type needs to be compacted. Compaction should not be carried out when the fill is too dry or too wet as the degree of compaction will be unsatisfactory. In the case of dry fill, the moisture content needs to be increased by spraying with water using water trucks (or similar) as the compaction proceeds. In wet fill, material shall be aerated and dried to adjust the moisture content to obtain the required density.

The National Guidelines for Beef Cattle Feedlots state that clay lining material should be placed in layers of 150mm (±50mm). Each layer should be tined, wetted to ±2% of optimum moisture content and compacted to the required compaction (relative to the Maximum Dry Density) that is needed to achieve the required permeability of 1 mm/day. The minimum depth recommended for the clay liner is 300 mm after compaction.

The contractor should be required to carry out compliance field tests to check the degree of compaction attained on site is in accordance with the earthworks specifications.

Slope (or batter) stability

Some natural slopes exist in a state of marginal stability and relatively minor works such as trenching, excavation, removal of scrub and vegetation, or the erection of buildings, can lead to failure. Signs of instability include

- cracked surfaces
- crescent-shaped depressions
- crooked fences
- trees or power poles leaning uphill or downhill

Dry surfaces may need spraying with water to allow the required degree of compaction.

Optimum moisture level of soil permits a strong cast formed from sheepsfoot roller compaction.

Field testing soil compaction

Acceptable limits for cut and fill slopes depend on soil type and strength, geology of the site and saturation.

This unsaturated embankment has drainage pipes that direct water from trough overflow and pen cleaning away from the embankment to the runoff control system

- uneven surfaces, or wet ground in elevated positions
- plants such as rushes growing on a slope
- water seeping from the ground.

In most cases, it is unnecessary or impracticable to measure quantitatively the factor of safety of a slope against shear failure. Maximum slopes of cuts and fills may be determined by the geotechnical engineer from experience and from observation of slopes in the vicinity which have a long-standing history of stability, are of similar height to the proposed slope and are of apparently similar geological formation.

Where necessary or where a precedent is not available, a special soils engineering investigation should be carried out by the geotechnical engineer to determine acceptable limits to cut and fill slopes. In assessing slope stability, account should be taken of possible future changes in ground water level or other conditions. Groundwater is the major cause of slope failures.

Slopes of embankments must be stable under all conditions of construction and operation. Figures 1 to 4 illustrate typical embankment types that may be found at a feedlot. These include above-ground water and effluent storages such as turkey's nest, ring tanks and holding pond (Figure 3), above-ground road and pen embankments (Figures 1 and 2) and structures with no embankment height (i.e. below ground water and/or effluent storages) (Figure 4).

Figure 1 shows a typical balanced cut and fill earthworks. This approach is used on relatively flat sites to minimise the volume of earthworks.

Often embankment slopes are chosen on more practical issues such as the ability to place and retain a topsoil cover or the ability to undertake bank maintenance.

Figure 1. Balanced cut and fill

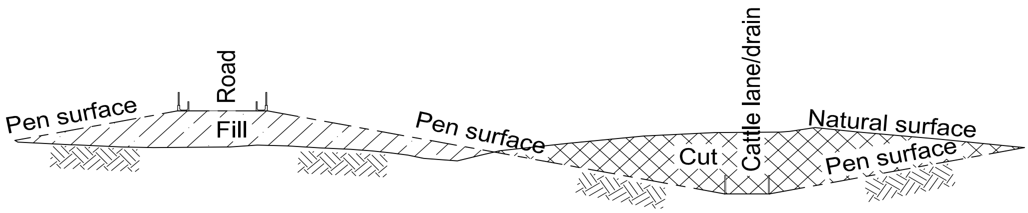


Figure 2 illustrates a bench cut. This approach is used on sites where sufficient natural fall is available for the pen slope and a cutting is required to obtain the required grade for the feed road.

Figure 2. Bench cut

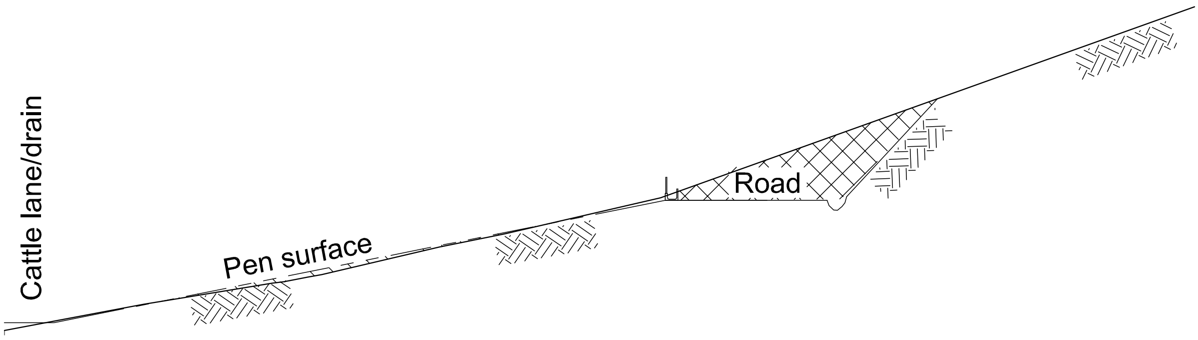


Figure 3. Above-ground earthen storage

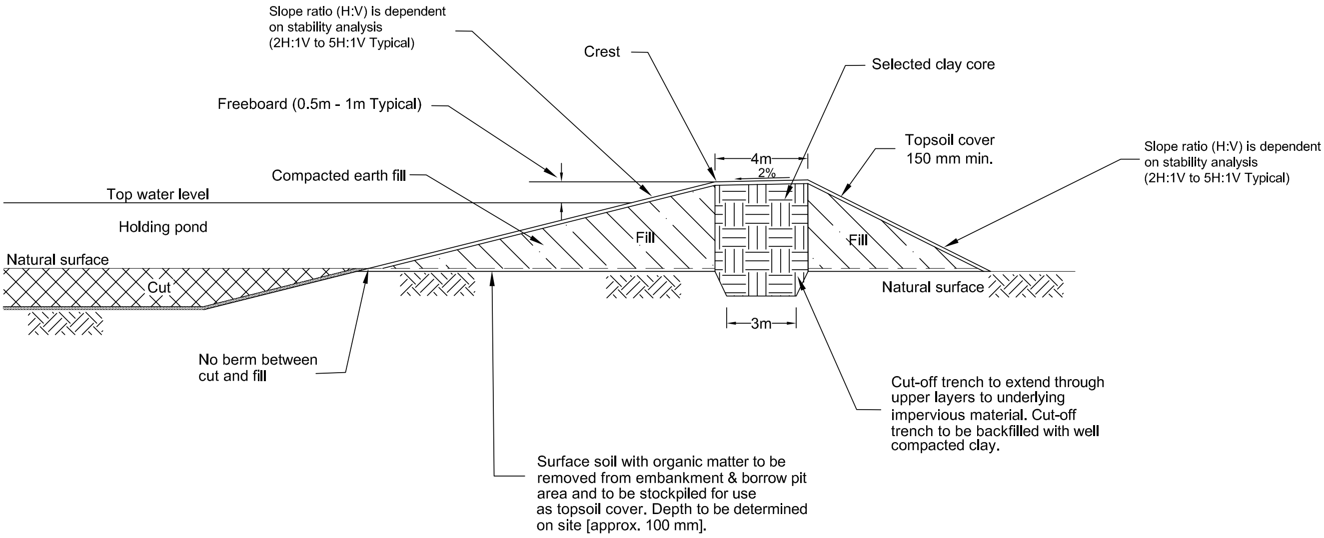
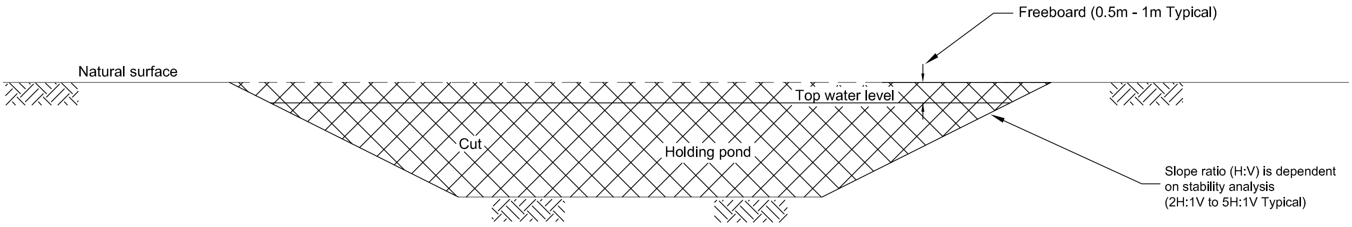


Figure 4. Below-ground storage



The stability of an embankment is determined by its ability to reduce shear stresses, which can cause failure by inducing sliding along a shear surface. Shear stresses result from externally applied loads (such as water or traffic) and internal forces caused by the weight of the soil and embankment slopes.

The design slope chosen will depend on the following parameters

- soil types and strength parameters
- soil layering – changes in geology of the site e.g. soft layers
- saturation – variation in groundwater levels, perched water, potential for rapid drawdown and effects of irrigation
- external loads – e.g. long-term (buildings) versus short loading (e.g. roads)
- construction – the construction technique, schedule and any safety issues
- erosion control – particularly where sand, non-plastic silt and dispersive clays are used as embankment fill materials or found in cut slopes
- maintenance considerations.

The most critical post-construction condition for the stability of an embankment slope is the saturation condition and the drawdown rate after a period of saturation.

For example, embankment slopes on downstream sides of structures adjacent to areas subject to flooding may require a flatter slope than would otherwise be needed if a rapid lowering of the water level (drawdown) could occur (i.e. rise and fall of floodwaters). This is to prevent rapid drawdown failure.

Smoothing embankments with a grader

Batters that are too steep for the soil type and strength will collapse.

Slope stability analysis should be carried out by a qualified and experienced designer (usually a geotechnical engineer).

Spoil

Spoil is surplus material from excavations which is not required to complete the earthworks as specified or material from excavations whose quality is deemed to be unacceptable for incorporation into the earthworks.

Consideration should be given as to where this material can be utilised, stockpiled or disposed of on site. For example, surplus material may be used to flatten batter slopes on embankments which have not been commenced, and/or directed to uniformly widen embankments.

Trimming and finishing of surfaces

Unless otherwise specified, all areas within the limits of clearing and outside the limits of earthworks should be graded to an even surface. Ridges should be trimmed and depressions filled as necessary to produce a surface which will drain freely and is suitable for the operation of maintenance equipment.

Tolerances

Tolerances are specified to allow reasonable leeway for imperfections and inherent variability in the earthworks without compromising performance.

Tolerances may be specified on completion of cutting, filling and all incidental operations and before the placement of covering materials. Tolerances will be specified on finished surfaces.

Tolerances in level and shape will be itemised in the earthworks specifications.

Quality assurance

Quality assurance is an important aspect of earthworks. Earthworks certification and compliance may be required prior to, and during, earthworks. Site inspections and testing activities (e.g. compaction and CBR) are usually carried out as part of the certification and compliance process.

Graders are used for excavation, batters and precision finishing in the final shaping of surfaces (e.g. roads, pens, building foundations).

Site inspections and testing activities are usually conducted by accredited third parties in accordance with Australian Standard 3798: Guidelines on earthworks for commercial and residential developments.

Site inspections and testing activities ensure that the earthworks specifications (and any Development Permit requirements) are complied with. This includes

- verifying the setout and site constraints
- ensuring foundations have been suitably prepared. For example, vegetation has been cleared, topsoil has been stripped and the area cleared of organic and foreign material if required
- that unsuitable materials are not used as fill

- that the methods of excavation, transport, depositing and spreading of the suitable material ensure that the material is uniformly mixed and placed according to specifications
- that all fill layers are uniformly compacted to not less than the relative compaction specified before the next layer is commenced
- that surface and percolating water will not undermine the stability of the excavation and nearby ground through the process of ground loss, consolidation and/or increase in lateral earth loading
- that requirements under Development Application permits are in place. For example, sediment and erosion control plans, stormwater management plans, pond lining testing and rehabilitation plans
- that non-compliant earthworks are rectified
- minimising disputes over earthwork activities and quantities
- verifying where payment can be made for activities associated with completing all or sections of the earthworks.

Smooth-drum rollers are used to compact the high spots until the surface is smooth—usually after a grader has levelled the surface.

Building foundations

Typically, the bulk earthworks for building structures (e.g. offices, commodity/machinery/cattle handling facilities, silos, feed preparation and shade structures) and pens and drainage areas are similar. However, building structures may need additional ground improvements to obtain a suitable foundation.

The type of foundation depends on the type of rock or soil and how that type is influenced by changes in moisture, temperature and imposed loads from the structure above. Foundations are usually classified as either reactive or non-reactive to changes in their moisture content.

Reactive soils are typically clay soils but also include the 'black soil' and 'black earth' found in Queensland, South Australia and Western New South Wales. All of these are plastic soils that shrink and swell rapidly as their moisture content decreases or increases. For these soils, linear shrinkage is used to correlate soil volume change.

Non-reactive soils are soils such as rock, gravel, shale, phyllite or sand, where their volume does not increase or decrease with changes in the moisture content.

A geotechnical survey to determine the soil profile of a building area should be conducted in accordance with the Australian Standards AS2870-1996: Residential Slabs and Footings - Construction and AS1726-1993: Geotechnical site investigations. (See *Section 7 – Site investigations*).

The design of building structures needs an appreciation of many factors including foundation design and therefore must be carried out by a suitably qualified and experienced designer (usually a structural engineer).

Suitability of material for construction should be assessed on its geotechnical qualities.

Erosion and sediment controls should be implemented downstream of working areas to prevent off-site impacts.

Erosion and sediment control measures

Earthworks activities may increase the risk of the disturbed soils being eroded – mostly by water. The loss of soil can result in the earthworks failing with consequent repair costs, or impacts upon the receiving environment.

Erosion and sediment control measures should be implemented to effectively manage erosion and sediment control issues. An approved Erosion and Sediment Control Strategy or Plan may be a mandatory requirement for the earthworks under state legislation or local authorities planning schemes.

Typically, erosion and sedimentation control measures include

- installing diversion and drainage structures before removing topsoil and starting the earthworks
- stabilising diversion and catch drains to prevent uncontaminated runoff from outside the disturbed areas entering the site
- providing contour and diversion drains across exposed areas before, during and immediately after clearing and re-establishing and maintaining these drains during soil removal and earthworks operations
- providing sediment filtering or sediment traps, in advance of and in conjunction with earthworks operations, to prevent contaminated water leaving the site
- limiting areas of erodible material exposed at any time to those areas being actively worked
- minimising sediment loss during construction of embankments by means such as constructing berms (raised barrier separating two areas) along the edge of the formation leading to temporary batter flumes and short-term sediment traps
- progressive vegetation of the site as work proceeds
- adequate protection of stockpile sites from erosion and contamination of the surrounding area.

Quick tips

- Mark up site plans to show major site and building staging requirements (e.g. topsoil piles, fill piles, parking areas, material storage areas, layout locations). These may highlight practical difficulties and contractual problems that could occur.
- Ensure the construction contractor verifies levels of the existing natural surface. This may prevent disputes on earthwork quantities from a variation between design and existing natural surface levels.
- Dispose of unsuitable or excess excavation material in locations that will not cause water quality or other environmental impacts.
- Ensure setout pegs and benchmarks are placed so that they are not disturbed during earthworks.
- Use balanced cut and fill construction where practical to minimise earthworks.
- Confirm suitability of material with geotechnical testing of material.
- Disputes over bulking factors are common, and specialist advice should be obtained.
- Specialist advice should be obtained for maximum slopes of cuts and fills.
- Flatter cut slopes are required in coarse granular and unconsolidated soils, in wet areas and in soft or clay-rich soils.
- Consider dust, erosion and sediment control measures to minimise impacts on the receiving environment.
- Engage the services of a suitably qualified and experienced person for the design of building structures.

Further reading

Standards Australia, AS2870-1996: "Residential Slabs and Footings - Construction" and AS1726-1993: "Geotechnical site investigations".

Standards Australia, AS3798-1996, AS3798 – Guidelines on Earthworks for commercial and residential buildings.