TECHNICAL NOTES
WESTERN QUEENSLAND BEST PRACTICE GUIDELINES

Queensland Government
Department of Main Roads
Road System & Engineering

WQ43

EROSION CONTROL IN WESTERN QUEENSLAND

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1 Introduction

In Western Queensland, a large proportion of the soil's organic matter and nutrient content lies within the surface layers. Following erosion, the productivity of these soils is seriously reduced. This can have a significant impact on the regeneration of vegetation within the road reserve.

Erosion can also result in turbid water washing into creeks and rivers resulting in siltation and water quality problems. In addition, wind blown erosion resulting in transportation of dust can present significant air pollution problems. Denuding areas of vegetation during construction will exacerbate these problems.

This note discusses erosion mechanisms, factors that influence soil erosion and specific measures to control erosion in the roadside environment.

2 Mechanics of Soil Erosion

The basic mechanics of the "erosion process" consists of three parts: soil detachment, soil transportation and soil deposition. It is essential to have a good understanding of these basic processes, as successful control of erosion and sedimentation requires these processes to be carefully managed.

When considering the planning, design, construction and maintenance of roads and highways in Western Queensland, the principal transportation agents involved in the erosion process are water and wind.

2.1 Water Induced Soil Erosion

2.1.1 Soil Detachment

Soil detachment occurs when the erosive forces of raindrop impact and flowing water exceeds the soils resistance to erosion.

Soil detachment due to raindrop impact is caused by the kinetic energy, and the hydraulic effect, of a falling raindrop as it strikes the soil surface. This typically occurs on exposed areas subject to sheet flow, such as the face of cut and fill slopes, unsealed pavements and shoulders.

In the North Western District, the erosive nature of raindrop impact is exacerbated by the high intensity monsoonal and cyclonic storms that typically occur during the summer "wet" season.

Soil detachment also occurs when the extractive force of flowing water exceeds the soils inherent resistance to erosion. This typically occurs in areas of concentrated flows such as table drains and channels.

Soil detachment, by either raindrop impact or flowing water, is the critical factor that initiates the erosion process. Minimising soil detachment from the outset will minimise all subsequent problems. The easiest way to minimise soil detachment is to retain or place a protective cover over the soil surface. This important aspect of erosion control is discussed further in Section 3, Factors that Influence Soil Erosion in Western Queensland.

2.1.2 Soil Transportation

Once the soil particles have been detached, the next step in the erosion process is the transportation of these particles from one place to another. As with soil detachment, soil transportation can also occur due to raindrop impact or flowing water.

The impact of a single raindrop on a soil surface causes individual particles to be thrown into the air. If this occurs on a slope then some particles will move up-slope, but the net effect due to gravity will cause splashed particles to move down-slope.

When rainfall intensity exceeds the infiltration rate of soil and the capacity of the available surface detention, excess water moves down-slope, transporting soil particles previously detached by raindrop impact and/or scour. Increased velocity and turbulence will subsequently entrain and move soil particles from one place to another.

2.1.3 Soil Deposition

Sedimentation is the deposition of the eroded soil particles which have been transported by either raindrop splash or flowing water. Sedimentation occurs when the energy levels, and turbulence, in the water can no longer keep the soil particles in suspension causing them to settle out under gravity.

2.2 Wind Erosion

Erosion by wind is relatively widespread in the semi-arid and arid regions of Western Queensland. The problem is exacerbated in areas of light textured soils. Unless controlled, wind blown sediments (dust) can also be a significant form of air pollution caused by construction activities.

3 Factors that Influence Soil Erosion in Western Queensland

3.1 Climatic Influences

The three critical climatic variables effecting erosion are rainfall, wind and temperature. In Western Queensland these factors are characterised by extremes, but with a bias towards dry, hot conditions. Under these conditions soil particles would be more susceptible to detachment by both wind and water, as dry soils can be easily pulverised, especially since vegetation cover is sparse.

Research in northern NSW has shown that the most erosive storm in any given year accounts for about 26% of all erosion in that year (Armstrong, 1989). In addition, summer storms tend to be more erosive than those in the winter. This is particularly relevant to Western and Northern Queensland where the majority of rainfall occurs during summer (see WQ30).

After drought or toward the end of the dry season, high intensity storms can cause considerable problems on what are normally bare and unprotected surfaces. These events need to be taken into consideration when determining timing of construction, maintenance and site rehabilitation activities.

3.2 Soil Erodibility

Soil erodibility is defined as the susceptibility of a soil to detachment and transportation of soil particles by erosive agents (Chapman and Murphy, 2000). It is based solely on soil properties.

To put it simply, the forces of soil erosion work to detach and move soil particles. For example, if the particles from which the soil is made are too large to be transported, no erosion will take place. Soil detachment and transportation will also be reduced where a soil is cohesive enough to hold together and resist detachment, or where the soil particles stick together in clods large enough not to be washed or blown away.

Therefore, a soil's ability to resist erosion primarily depends upon its cohesiveness and texture. That is, the strength of the physical, chemical and biological bonds between the soil particles and the size of the soil particles. Erodible soils lack these properties; the soil particles are easily detached and are small enough to be transported relatively easily by water and wind.

Soil cohesion is mostly derived from clays and organic matter that act as bonding agents and stick to each other and to larger particles such as silt, sand and gravel. In general terms the following rules of thumb apply:

- Sandy soils lack cohesion and have particles that are easily detached. However, they tend to be highly permeable and infiltrate a lot of rainfall that would otherwise produce runoff in less permeable soils. The relatively large size of the particles also inhibits transportation by wind and water to a large degree.

- Clay soils in general are more cohesive and have better structure that makes them more resistant to detachment. However, some clay soils are highly dispersive and become unstable when wet, literally dissolving when they come in contact with water.

- Once the fine clay particles are detached and mobilised they can be easily transported over large distances. The suspended colloidal particles result in turbid water, which is difficult to treat. Turbid water has the potential to cause environmental (water quality) problems.

- Silts and soils with a high percentage of fine sands tend to be the most highly erodible because of the small particle size and the weak bonds between particles. Accordingly, they are easily detached by raindrop impact or flowing water. Unlike the coarser grained sands, the permeability of these soils is generally lower so that the likelihood of runoff occurring is greater.

3.3 Topographic Influences

Erosion potential rises with an increase in slope length and steepness. The most vulnerable part of a slope is the area closest to the bottom, as this is where the volume and velocity of runoff it potentially at its greatest. The shape of a slope can also affect the location and time at which runoff is concentrated at any one point. Accordingly, convex slopes are more prone to erosion than concave slopes.

Disturbance of footslopes and lower sideslopes should be avoided because of this increased erosion risk. Assessment of the existing topography will also minimise the total amount of earthworks (hence total area of disturbance) and should be a key factor in road alignment planning.

3.4 Soil Surface Cover

Soil surface cover includes vegetation or any other surface treatment, such as mulches or armouring, which protect the soil surface from the erosive forces of raindrop impact, flowing water or wind.

In many areas of Queensland, vegetation can be successfully used as a primary form of erosion control. When vegetation is used for this purpose, the goal is to achieve 100% soil surface cover, however a minimum of 70% cover is required in order to keep soil loss rates to manageable and reasonably sustainable levels

A thick vegetative cover will reduce the number of runoff events, lower the storm yield and minimise the total amount of runoff and soil loss. Vegetation also reduces wind velocity, thereby minimising wind erosion. Obviously this will only apply to areas where rainfall, soil moisture and soil fertility is sufficient to sustain a vegetative cover greater than 70%.

The hot and dry conditions in most of Western Queensland makes it very difficult to establish and maintain this protective sward. Accordingly, soil surface protection in critical areas such as steep batters, drains, abutments and floodways, can best be achieved by mulching the soil surface with gravel or rock.

As vegetation establishment can be difficult in Western Queensland, it is good practice (and common sense) to minimise the extent of disturbance to existing vegetation during clearing and construction activities. It is easier and cheaper to minimise disturbance in the first place, than to try and revegetate denuded areas at the end of a project.

3.5 Soil Surface Condition

As previously mentioned, soil surface cover directly protects the soil surface from erosive forces of wind and water. However, soil surface condition, or roughness, will also influence the rate of soil detachment and transportation. A roughened surface will act to reduce the velocity of both flowing water and wind, thereby reducing potential soil loss.

Hard smooth surfaces offer little resistance with corresponding high rates of runoff and/or wind velocity. On the other hand, a roughened surface will increase infiltration, reduce runoff, and act to trap migrating soil particles.

A roughened soil surface will also assist with natural revegetation as it will trap wind blown seed and provide a better moisture regime for growing plants when it rains.

4. Management of Roadside Erosion in Western Queensland

Many of the standard principles, techniques and management practices commonly used in other parts of Queensland may not be appropriate in many areas of Western Queensland. The hot and dry climate and the distinctive geology and geomorphology, together with the remoteness of many locations, can affect the applicability and cost effectiveness of erosion control procedures in western districts. This particularly applies to revegatation.

In general, revegetation is an important component of Main Roads activities as it has the potential to protect the road asset by significantly reducing erosion of shoulders, cut and fill slopes and drains. However, as noted in section 3.4, hot and dry conditions in most of Western Queensland makes it very difficult to establish and maintain this protective sward. Accordingly, vegetation cannot be relied upon to provide the primary source of erosion control.

In this section, erosion control methods as they apply to shoulders, slopes, table drains, culverts, bridges and sidetracks are discussed.

4.1 Shoulders

Unsealed shoulders are prone to erosion because of water flowing off the road and the occasional vehicle straying off the road.

The most erosion prone shoulder materials are those containing non-plastic fines and few larger stones (Andrews, 1976).

In order for the shoulder material to resist erosion, it is important that there is a fine plastic component to bind the material together and some stone content to provide armouring to protect the material from erosion and provide some support for wheel loads (Andrews, 1976).

Andrews (1976) recommends the following requirements:

- Maximum stone size of 25mm for ease of compaction;
- Linear shrinkage of between 4 and 10% to ensure wet and dry stability;
- 20% coarser than 2.36mm to provide armouring; and
- A fines ratio (percent passing 0.075mm / percent passing 2.36mm) between 0.2 and 0.4 to provide stability and low permeability.

Shoulder materials satisfying the above requirements will have better than average resistance to erosion. However, a more effective way to prevent erosion is to seal the shoulder.

Sealed shoulders make for a safer road by allowing more manoeuvrability to drivers and providing a safe haven in the case of vehicle breakdown.

However, if shoulders are sealed it is important that they be well maintained. This involves sealing of cracks and resealing where necessary.

It is worth noting that even when shoulders are sealed it is still desirable to use shoulder materials similar to those proposed by Andrews (1976) since they restrict water movements under the road, thus providing a more stable pavement. In this situation, these materials will also be the materials exposed on the batters and are likely to be more resistant to erosion than standard base materials.

4.2 Batter Slopes

Batter slopes are particularly prone to erosion due to increased water velocities.

The most effective way to reduce erosion of the batter slopes is to flatten the batters. Ideally, the batter slopes should be between 1:4 and 1:6 and be traversable so that maintenance work can be carried out.

In addition, the batter slopes should be concave at the toe, rather than convex, to counter the tendency for water velocities to gather pace further down the slope, since the sloping face is also collecting rainwater.

The effect of batter slopes on erosion was clearly observed at Gaven Way, Queensland where embankment slopes ranged from 1:1 to 1:5 (Waters, 1985). In this case the embankments were made up of select fill material, a material not dissimilar to that used in western areas of Queensland.

It was observed that the flatter the embankment slope the less the erosion. When the embankment slope was 1:4 or flatter, erosion was minor but when the slope was 1:1 the erosion was severe.

It was found that a major reason for the more stable flatter slopes was the increased compaction levels for embankments with flatter slopes. In addition water flow rates would be less on these flatter slopes.

The increased level of compaction would assist the shoulder/embankment material to support a seal.

Extending the seal down slope will further aid in the prevention of erosion. The flatter batters are more likely to support a stable seal than steep batters. The added bonus of embankments with flat batters is that they are safer, resulting in less roll over accidents.

4.3 Table Drains

Works associated with road construction and operations can lead to the concentration of water flows. Concentrated flows are highly erosive on the fragile soils of Western Queensland and care must be taken not to exacerbate erosion prone areas. Any design should ensure that concentrated water velocity is minimised or reduced through the use of low gradient drains, check dams, lining of table drains and diversion drains.

Mathematic models are available to estimate soil loss and sediment transport, but they are outside the scope of this Technical Note. However, it is worth mentioning some basic characteristics of flowing water. In general terms, a doubling of water velocity can lead to a four-fold increase in the rate of scouring and an eight-fold increase in sediment carrying capacity.

Accordingly every effort should be made to reduce water velocity especially in erosive Western Queensland landscapes.

Table drains usually have a “V” shaped profile because they are quick and easy to construct and maintain with a grader. However, V-shaped drains are extremely prone to erosion along the invert as all the tractive forces generated by the flowing water are concentrated along a narrow corridor. Accordingly, V drains are very hard to stabilise without some form of hard armour such as rock or concrete.

Wherever practicable, table drains should be constructed with either a parabolic or trapezoidal cross-section. These profiles allow the flow of water to spread over a broader invert with a shallower depth of flow and are therefore much less prone to erosion.

In some situations where the natural contours of the ground allows free drainage, it may be possible to eliminate table drains altogether or at least limit their use. This would be ideal since it involves minimum disturbance to the soil and natural vegetation.

In the "*Roadside Landcare*" document it is stated that table drains can often be eliminated on the downhill side of the road (Herbert and Evans, 1994).

As a general guide, if table drains are omitted, the surface of the road should be at least 500mm above the surrounding countryside in order to prevent flooding or "irrigation" of the road.

Another way of reducing erosion from table drains is to divert water onto neighbouring properties using diversionary drains. Apart from preventing erosion , these diversionary drains can provide much needed water to property owners. A detailed discussion of diversionary drains is given in the "*Roadside Landcare"* document.

4.4 Culverts and Bridges

A significant risk of erosion occurs where man-made structures are constructed within natural channels. It is imperative that the hydraulics and hydrology of the associated watercourse and floodplain are assessed and appropriately sized bridges and culverts are constructed. Locating bridge piers in areas that will minimise turbulence and bed and bank erosion during periods of flow is also recommended.

Siltation of culverts and floodways is a common problem in many of the annual and perennial watercourses in Western Queensland due to the highly depositional nature of the landscape. Accordingly, most watercourses carry large bed loads and the cross sectional areas of culverts must be designed with sufficient additional capacity to allow these bed-loads to pass through, without reducing the design waterway capacity.

Selection of culvert invert RL also requires additional consideration. Care must be taken to ensure the invert RL is at the actual bed level of the watercourse, and has not been determined from a point in a pool, on a riffle or on top of a sand slug.

In cases when the streams contains fish, it is recommended that culverts be countersunk approximately 200mm into the streambed to allow movement of native fish. If the culvert is installed at level to the streambed, erosion processes and heaving of the culvert over time may cause it to perch, effectively limiting upstream movement of native fish.

The Queensland Department of Primary Industries Guidelines, *Fish Passage in Streams-Fisheries Guidelines for Design of Stream Crossings*, recommends countersinking culverts to avoid perching and placing natural streambed material on the floor of the culvert to reduce velocities within the culvert (Cotterell, 1998). Larger diameter culverts may be required to accommodate reduced capacity.

Consideration should also be given to installing culverts on piers, where a typical pier would be 1.4m deep by 0.5m wide by 10m long. If fish movements were expected the concrete floor could be omitted in favour of natural streambed material. Culverts constructed on piers have the added bonus of being less susceptible too heave thus reducing the bumps often associated with culverts, resulting in a safer and more pleasant driving experience.

4.5 Sidetracks

The construction, operation, removal and rehabilitation of sidetracks is an issue that has been, and will continue to be, a subject of much debate and discussion. Sidetracks are commonly used in Western Queensland, but none-the-less have the potential to create a myriad of problems. In many cases the sidetrack has exposed or denuded an area far greater than the project area itself, yet they are not generally included in the design.

When sidetracks are absolutely necessary, they must be designed and supported by site-specific stabilisation and rehabilitation specifications.

5. Author

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