Appendix F

Soil Conservation Service (2013) *Erosion and Sedimentation Management Report Realignment of Princes Highway at Dignams Creek, 20 km south of Narooma, NSW.*
EROSION AND SEDIMENTATION MANAGEMENT REPORT
Realignment of Princes Highway at Dignams Creek, 20 km south of Narooma, NSW
For NSW Roads and Maritime Services

prepared by
Soil Conservation Service
May 2013
TABLE OF CONTENTS

1 INTRODUCTION 3

2 PROJECT DESCRIPTION 3

3 DESCRIPTION OF EXISTING ENVIRONMENT 6
   Site Context 6
   3.1 Site inspection and assessment of local environment 6
      Soil Assessment 6
      Steep Slope 8
      Rainfall Intensity 8
   3.2 Potential impact of proposal on local environment 8
      Revised Universal Soil Loss Equation (RUSLE) analysis 8
      Slope analysis 10
      Rainfall Erosivity analysis 10
   3.3 Site Constraints 12
      Steep slopes immediately after site clearing and grubbing 12
      Potential for large bare areas as a result of the footprint of the fills at
      Clearing and grubbing 12
      Steep Slopes 13
      Constrained Sites 14

4 MITIGATION MEASURES 15
   4.1 Principles to guide site erosion and sediment control
       assessment 15
   4.2 Sediment Basin Design 16
      Determination of sediment type 17
      Sediment Basin Design 17
      Determination of 5 day 80th & 85th rainfall depths 17
   4.3 Cross Drainage design 20
      Clean Water Diversion – lined diversion channel 20
      Clean upslope runoff calculations 21
   4.4 Soil Conservation Recommendations 22
      Erosion Control – via use of C factor 23
      Erosion Control – via the LS factor 24
      Erosion Control – via the P factor 25

5 REVEGETATION REQUIREMENTS 26
   Cover crop and native species 26
   Mulch 27

6 RECOMMENDATIONS 28

7 CONCLUSION 30
   REFERENCES 31

APPENDIX 1 SOIL TEST RESULTS 32

APPENDIX 2 GENERAL ARRANGEMENTS OF SEDIMENT BASINS 33

APPENDIX 3 Drawing 1: New online Culvert 50

Author: David Thompson
Reviewer: Guy Van Owen
Signature: ____________________________
Signature: ____________________________
Date: 10/05/2013
Date: ________________________________
1 INTRODUCTION

The Roads and Maritime Services (RMS) has commissioned the NSW Soil Conservation Service (SCS) to prepare an Erosion and Sedimentation Management Report (ESMR) for the Realignment of the Princes Highway at Dignams Creek, Ch 94750 to 97850 south of Bateman’s Bay in accordance with RTA Policy PN 143.

The project route has been identified by RMS as a potentially high risk site for erosion and sediment control (as per RMS Preliminary Erosion and Sedimentation Assessment procedure defined in ‘Managing Urban Stormwater, Soils and Construction, Vol1’, Section 4.4.1 Assessment of Erosion Hazard).

This ESMR details the SCS erosion and sedimentation assessment of the Realignment of the Princes Highway at Dignams Creek proposal. Specifically this report details:

- Identification of site constraints including slope, soil erosion hazard and sedimentation potential, and aspects for revegetation response;
- Collection of soil samples and analysis to determine the sediment type to guide sediment basin design and soil amelioration requirements to maximise site revegetation potential;
- The design procedure for locating and sizing sedimentation basins in accordance with the Blue Book Vol 2D and determination of standard and sensitive receiving waters;
- Recommendations to eliminate site risks arising from site constraints; and
- Provide guidance in the design of measures to control site risks that cannot be eliminated.

This ESMR is guided by a set of erosion and sediment control principles as set out in ‘Managing Urban Stormwater, Soils and Construction, Vol 2D’. These erosion and sediment control principles are to be incorporated into the construction Primary Erosion and Sediment Control Plan (Primary ESCP) and subordinate Progressive Erosion and Sediment Control Plans. Upon commencement of construction activities, progressive ESCPs should be developed by RMS to provide more detailed and up-to-date information relating to specific areas and control measures. These will be regularly updated to reflect the evolution of site conditions as the project proceeds.

The main reference documents used in the production of this ESMR are listed at the end of this report.

2 PROJECT DESCRIPTION

The proposal involves the upgrading and re-alignment of 3.7 km of the Princes Highway where the highway crosses Dignams Creek approximately 20 km south of Narooma, NSW (Figure 1). The key features of the project would be to:

- Construct a new highway built to modern road alignment standards
- Construct a new bridge over Dignams Creek replacing the existing bridge
- Construct a new junction at the Princes Highway and Dignams Creek Road
- Upgrade an existing southbound overtaking lane.

1. for the remainder of this document ‘Managing Urban Stormwater, Soils and Construction, Vol1’ is referred to as the Blue Book Vol 1.
2. For the remainder of this document ‘Managing Urban Stormwater, Soils and Construction, Vol 2D’ is referred to as the Blue Book Vol 2D.
The RMS has split the project into two stages (Figure 1). Stage One consists of a realignment to the north, a new bridge for a 100km/h speed environment and providing a road safety treatment in the south. The road safety treatment will utilise the existing alignment and consist of widening the northbound shoulders and providing a central painted median.

Stage two consists of a realignment of the southern portion of the project that was not realigned in stage one to bring the total project up to a 100km/h speed environment. Stage one is expected to be developed first with stage two being set aside for future development. Figure 1 shows the location of the two stages. This report provides details on the location of sediment basins and drainage issues across both stages. In relation to the soils of the project the report covers issues for Stage One and Two.

![Figure 1 – Location of the Dignams Creek Realignment proposal – yellow line indicates location of project](image)

Stage One has a length of 2.1 km, including a 2km realignment and 1.1km road safety treatment while Stage One and Two combined equals 3.7km. The slopes of the Stage One route range from 1 percent along the floodplain of Dignams Creek to localised sections with slopes of up to 30 percent in the forested areas of Kooraban National Park. The existing slopes in the section north of the first Highway crossing range from 4.9 to 9.5 percent with a localised section of 25 percent just below the existing Highway above the floodplain. The slopes encountered along the proposed route in the Kooraban National Park range from 10 to 30 percent, and an average cross slope of 10 percent, with significant cross slopes of up to 50 percent in the middle section of Stage 2.

The final design slopes for the re-alignment range from one to six and a half percent, with the cut and fill batters slopes defined as two horizontal to one vertical.
The final drainage design was still being finalised at the time of writing this report. It is assumed that drainage points exist at approximately Ch 94780, 95180, 95460, 95580, 96565 and 97000 and 97820. A new bridge across Dignams Creek is located between Ch 95850 and 95920.

To aid the presentation of report findings the proposed route has been divided into four zones that correspond to the basic cut and fill configuration. The zones also have common drainage catchments and topographical features and construction issues. Figure 2 shows the location of the zones with basic dimensions for length, slopes at clearing and grubbing and at final levels, and disturbed areas.

The Southern ‘Tie In’ zone will be re-constructed when Stage Two commences. The route of Stage Two (See Figure 1) will take the new highway into Kooraban National Park and cut through the western edge of the highest point on the current Highway route. As the Southern ‘Tie In’ Zone involves minor raising of the current Highway pavement the issues involved will be dealt with in the notes on the Southern Zone.

Figure 2: Location of Stage One and zones used in this report.
3 DESCRIPTION OF EXISTING ENVIRONMENT

A number of key erosion and sedimentation assessments were undertaken. These included a soils, slope and rainfall assessment to determine the likely impact of soil erodibility, steep slopes and rainfall erosivity on the local environment. This information was then used to identify the site constraints that would potentially interact negatively with the construction zone.

Site Context

The project is located within the catchment of Dignams Creek, a tributary of Wallaga Lake, north of Bermagui on the south coast of NSW. As such the project is located in a highly sensitive coastal environment with the potential for the project to impact on the water quality and environment of the Wallaga Lake catchment.

This project is less than 5 km in length. It is not subject to license conditions provided in an Environment Protection Licence (EPL) issued under the Protection of the Environment Operations Act, 1997. Usually on projects such as this the parameters and limits to be monitored in the management of sediment basins correspond to the Water Quality Parameters listed in Table 1. These parameters are required to be achieved usually within 5 days of a rainfall event. Table 1 outlines typical water quality parameters commonly imposed by an EPL.

Table 1 – Water Quality Parameters:

<table>
<thead>
<tr>
<th>WATER QUALITY PARAMETER</th>
<th>LIMIT IMPOSED BY EPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>&lt;50 mg/l</td>
</tr>
<tr>
<td>Ph</td>
<td>6.5 to 8.5</td>
</tr>
<tr>
<td>Oil &amp; grease</td>
<td>&lt;10 mg/l</td>
</tr>
</tbody>
</table>

Source Bluebook Vol 1, Section 6.3.3 (d) (ii) and Vol 2 Appendix B

3.1 Site Inspection and assessment of local environment

The proposed route was inspected to determine the direction of runoff, location of safe water disposal areas, degree of ground cover, scale of site constraints and to collect soil samples. The information collected has guided the design of the erosion and sediment control measures.

Soils assessment

The SCS collected five soil samples from along the route. The soil sampling covered the whole length of Stage One and Two. The results are listed in Appendix A. A summary of the results are presented in Table 2.

At each sample site a 150 mm auger was used to collect soil from the topsoil horizon and the top 500 mm of the subsoil horizons. Two sample sites were analysed for revegetation potential, with three sites sampled for subsoil erodibility analysis. The soil erodibility test results enabled an accurate Revised Universal Soil Loss Equation (RUSLE) assessment, for the determination of sediment type and guidance of sediment basin design. The Emerson Aggregate Test (EAT) also provided an indication of soil material reaction to the presence of water, the potential to disperse and/or slake, and therefore the potential for sediment generation.
Table 2: Summary of site specific soil tests (see Appendix 1 for full Soil Test Report)

<table>
<thead>
<tr>
<th>Soil erodibility(1)</th>
<th>Emerson Aggregate Test(2)</th>
<th>Dispersion Percentage(3)</th>
<th>Organic Carbon percent(4)</th>
<th>Organic Matter(5)</th>
<th>Sediment type(6)</th>
<th>pH (CaCl₂)</th>
<th>Topsoil texture</th>
<th>Fertility (CEC)(7)</th>
<th>Phosphorus (mg/kg)(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.038</td>
<td>Moderate</td>
<td>2(1)</td>
<td>Slakes</td>
<td>33%</td>
<td>Moderate</td>
<td>0.88%</td>
<td>Moderate</td>
<td>1.54%</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.03</td>
<td>Moderate</td>
<td>3(1)</td>
<td>Dispersion</td>
<td>32%</td>
<td>Moderate</td>
<td>0.8%</td>
<td>Moderate</td>
<td>1.4%</td>
<td>0.54%</td>
</tr>
<tr>
<td>0.026-0.031</td>
<td>Moderate</td>
<td>2(1)</td>
<td>Slakes</td>
<td>55%</td>
<td>High</td>
<td>0.54%</td>
<td>Moderate</td>
<td>0.95%</td>
<td></td>
</tr>
</tbody>
</table>

Notes
1. This is the soil erodibility, ‘k factor’, in the Revised Universal Soil Loss Equation. Soil tests usually range from 0.01 (very low) to 0.075 (extreme) and provide an indication of the soils ability to resist the erosive power of flowing water or wind.
2. An Emerson Aggregate Test (EAT) result of 3 in the topsoils indicates that the topsoil will disperse in the presence of water, while a result of 2 and 3 in the subsoils shows that the subsoil will slake and disperse in the presence of water. This indicates that these soils will readily release sediment when in the presence of water. Slaking is the breakdown of a lump of soil into smaller fragments on wetting. It is caused when clay swells and the trapped air bursts out. Organic matter reduces slaking by binding mineral particles and by slowing the rate of wetting.
3. The Dispersion percentage provides an indication of how easily the soil particles will detach and be transported.
4. Measure the amount of carbon in plant and animal remains in the soil. This includes the level of humus in the soil. The estimate of Organic matter in the soil is the Organic Carbon percentage multiplied by 1.755. Organic Matter gives an indication of soil fertility and stability. Levels of 0.5-1.0 % are considered very low.
5. Type C sediment is dominated by the fine and course sand fractions in the Particle Size Analysis testing. Type D sediment refers to dispersible soils that contribute sediment to flowing water. This type of sediment remains in suspension indefinitely. A flocculant is required to settle this sediment out of the water column before discharge from site. Type F sediment is often associated with soils that slake in the presence of water. The collapsed soil crumb breaks down into its individual soil particles – these smaller particles are then available for transport off site.
6. Cation Exchange Capacity (CEC) measures soils ability to store and release cations and provides an indication of a soils relative fertility. A reading of <6 is very low and 6 to 12 is low, while 12 to 25 is moderate.
7. Phosphorus levels give an indication of soil fertility, and indicate the likely response to the addition of phosphorus fertiliser. A reading of 2 mg/kg is a very low result, while a reading of 8 is low. Thus the addition of phosphorus fertiliser would result in a high response by vegetation (i.e. revegetation and erosion cover crop grass species).

The test results show that these soils are dominated by fine sand and silt in the subsoil layers, and very little clay is present in the subsoils clays. However the EAT results show that these soils will slake (see Note 2, Table 2) in the presence of water, and that working these soils in wet conditions should be avoided as the samples then underwent total dispersion on...
re-moulding. This indicates that these soils are tending towards the Type F and D sediment type.

The topsoils appear to be stable if grass cover is maintained, and should be stockpiled for revegetation. The pH levels indicate that lime could be added to the topsoil to correct the pH level as close to 6.5 for optimal revegetation. However this is considered to be unnecessary as the mulch and topsoil mix should provide conditions as near to the original forest soils to aid the desired natural revegetation. These soils have low fertility. See Section 6 Revegetation Notes and Appendix 1 Soil Test Results for more details.

**Steep slopes**

The northern and southern sections of the 3.7 km proposed route are a highly constrained road corridor that traverses steep hilly country with excessive side slopes. The road passes through relatively uncleared forested vegetation. The middle section crosses a broad floodplain valley of Dignams Creek. The existing road has a steep road grade of up to approximately ten percent. During construction bare slopes of up to 20 percent with a length of 200 metres will be created just after clearing and grubbing.

**Rainfall Intensity**

The potential for high intensity rainfall at this site represents the greatest threat to the project meeting the water quality objectives. The Intensity Frequency Duration table for this site (sourced from Bureau of Meteorology website) shows there is a high probability that this project site will encounter rainfall intensities of up to 125 mm/hr for a five minute period within the next two years. The combination of these rainfall intensities, slopes and soil types have the potential to cause significant soil movement from this project.

### 3.2 Potential impact of proposal on the local environment

The level of soil erosion hazard at a site is an interaction between soil erodibility, rainfall erosivity and slope. An increase in the slope at a site can exacerbate the impact of rainfall erosivity on the soils erodibility. The combination of steep slopes and high intensity rainfall could lead to a severe to extreme soil loss potential for sections of the proposal. The following RUSLE analysis provides an indication of the potential impact if soil erosion is not controlled on this proposal.

**Revised Universal Soil Loss Equation [RUSLE] analysis**

The Revised Universal Soil Loss Equation [RUSLE] was used to determine the potential soil loss from each work zone. The RUSLE is $A \text{ (tonnes/ha)} = R \times K \times LS \times C \times P$ where $R =$ rainfall erosivity, $k =$ soil erodibility, $LS =$ length and slope factor, $C =$ cover factor, and $P =$ conservation factor. See Appendix A of Bluebook Vol 1 has more detail on each factor of the equation.

An initial soil loss assessment followed the procedure presented in *Blue Book Vol1 Section 4.4.2 Management of Sites of High Erosion Hazard* (p4-10 to 4-15). See Table 3. This initial assessment assumes the worst case scenario of minimal site management and of highest soil loss potential.

The Blue Book Vol 1, Section 4.4.2(b) notes that the calculation of erosion hazard is to be based on RUSLE factors specific to the site:

- Local Rainfall Erosivity, data derived from Bureau of Meteorology data (Intensity Frequency Duration data for the ARI 2yr, 6hr rainfall event)
- Soil erodibility derived from soil test analysis
• Length and slope set at 80m slope length to enable a consistent comparison across the whole site, to enable an ‘apples with apples’ comparison
• Ground cover factor, C, is assumed to be 1.0 due to the site being bare
• Site conservation factor, P, assumed to be 1.3 as the site will be hard and compacted under construction.

Table 3 Revised Universal Soil Loss Equation soil loss classes

<table>
<thead>
<tr>
<th>Soil Loss Class</th>
<th>Calculated soil loss (tonnes/ha/yr)</th>
<th>Erosion Hazard</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-150</td>
<td>Very low</td>
</tr>
<tr>
<td>2</td>
<td>151-225</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>22-350</td>
<td>Low-moderate</td>
</tr>
<tr>
<td>4</td>
<td>351-500</td>
<td>Moderate</td>
</tr>
<tr>
<td>5</td>
<td>501-750</td>
<td>High</td>
</tr>
<tr>
<td>6</td>
<td>751-1500</td>
<td>Very high</td>
</tr>
<tr>
<td>7</td>
<td>&gt;1501</td>
<td>Extremely high</td>
</tr>
</tbody>
</table>

Table 4 lists the relevant values for each of the RUSLE factors read from Appendix A Blue Book Vol 1.

Table 4 – Results of the RUSLE calculations for each Work Zone

<table>
<thead>
<tr>
<th>Zone</th>
<th>Middle zone</th>
<th>South End</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbed Catch Area</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Particle Size Analysis</td>
<td>Subsoil</td>
<td>Subsoil</td>
<td>Subsoil</td>
</tr>
<tr>
<td></td>
<td>sample</td>
<td>sample</td>
<td>Data from Soil TestResult-see Appendix A this report</td>
</tr>
<tr>
<td>% gravel (fraction &gt;2mm)</td>
<td>12</td>
<td>41</td>
<td>45</td>
</tr>
<tr>
<td>% sand (fraction 0.02-2mm)</td>
<td>60</td>
<td>39</td>
<td>32</td>
</tr>
<tr>
<td>% silt (fraction 0.002-0.02mm)</td>
<td>14</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>% clay (fraction &lt;0.002mm)</td>
<td>14</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Dispersion Percentage</td>
<td>33</td>
<td>32</td>
<td>43</td>
</tr>
<tr>
<td>% of whole sample dispersible</td>
<td>6.93</td>
<td>4.96</td>
<td>6.88</td>
</tr>
<tr>
<td>Sediment Type</td>
<td>C</td>
<td>D</td>
<td>F</td>
</tr>
<tr>
<td>Rainfall Intensity (mm/hr) of 2yr, 6hr storm</td>
<td>12.5</td>
<td>12.5</td>
<td>12.5 Source: Bureau of Meteorology – Intensity Frequency Duration table for Dignams Creek</td>
</tr>
<tr>
<td>Rainfall Erosivity, R</td>
<td>3350</td>
<td>3350</td>
<td>3350 Units: (mm/ha/hr/yr) Source: BB Vol1 Appendix A2</td>
</tr>
<tr>
<td>Soil Erodibility, k</td>
<td>0.031</td>
<td>0.03</td>
<td>0.026 Units: (t/ha x ha/MJ x h/mm) Source: BB Vol1 App A3</td>
</tr>
<tr>
<td>Slope length (m)</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Slope Gradient %</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Length Slope factor, LS</td>
<td>2.81</td>
<td>2.81</td>
<td>2.81 See Table A1, p A-9, BB Vol1, App A4</td>
</tr>
<tr>
<td>Conservation factor, P</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3 See Table A2, p A-11, BB Vol1, App A5. Assume maximum value as per RMS default value.</td>
</tr>
<tr>
<td>Cover factor, C</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0 See Figure A5, p A-12, BB Vol1, App A6. Assumed maximum value as per RMS default value.</td>
</tr>
<tr>
<td>Soil Loss (t/ha/yr)</td>
<td>379</td>
<td>367</td>
<td>318</td>
</tr>
<tr>
<td>Soil Loss Class</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 4 shows that the proposed route is a moderate erosion hazard site. However, this assessment represents a worst case scenario where the site has maximum exposed slope lengths (80 metres) and 100 per cent bare ground (C factor of 1.0) and no erosion controls in place.
Section 3 Mitigation Measures will highlight the need to employ various erosion control techniques to minimise the potential generation of sediment and impact on the Wallaga Lake catchment area.

**Slope analysis**

Figure 4.8 Blue Book Vol1, Section 4.4.2 *Management of Sites of High Erosion Hazard* gives guidance to the maximum length of slope that a batter can have before rill erosion will become a significant factor in producing sediment and hinder revegetation. Table 4 shows that this site has a rainfall erosivity (R) value of 3350 and a soil erodibility (k) ranging between 0.026 and 0.031.

![Image of slope analysis graph](image)

Figure 3 – Copy of Figure 4.8 Blue Book Vol1, Section 4.4.2 *Management of Sites of High Erosion Hazard* that shows the maximum distance allowed between control structures on batters of various grades. Table 5 indicates the slope lengths that should not be exceeded in each work zone. The 3:1 grade would apply to the land just after clearing and grubbing and is a guide to the distance between slope cross banks. See Photo 4.

<table>
<thead>
<tr>
<th>Batter Grade</th>
<th>Northern section (k=0.031)</th>
<th>Middle section (k=0.03)</th>
<th>Southern section (k=0.026)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:1</td>
<td>17</td>
<td>18</td>
<td>24</td>
</tr>
<tr>
<td>3:1</td>
<td>27</td>
<td>28</td>
<td>35</td>
</tr>
</tbody>
</table>

**Rainfall erosivity analysis**

Rainfall erosivity is a measure of the power of rainfall to cause erosion. It is a combination of the energy applied to the soil by rainfall intensity. It is related to the time of year that the rainfall is occurring. For example the energy delivered by an intense summer storm could
potentially be higher than the energy delivered by a weeklong low intensity rain event in winter. Research cited in the Blue Book Vol 1 indicates that there is a high correlation between monthly rainfall and the monthly erosivity for a site.

Using the Erosivity Classification procedure outlined in Blue Book Vol1 Section 4.2.2 and Table 6.2 a very high correlation between annual rainfall and the site’s erosivity can be seen. The Dignams Creek proposal occurs in a rainfall zone that has a very high rainfall erosivity index potential. Figures 4a and 4b indicate that approximately 60 per cent of the potential erosion at this site will occur in the February to April period in an average rainfall year. The red area and lines show that 60 per cent of the EI greater than five per cent (yellow line) each month at Dignams Creek occurs between February and late April.

Figure 4a – Annual Erosion Index for Dignams Creek. The ‘y axis’ represents the percentage proportion of the yearly erosion. 
Source: Fig 4.9 & Table 6.2, Section 6.3, Blue Book Vol 1, 2004.

Figure 4b Annual Narooma Rainfall

Therefore, a major site management option on the control of potential erosion from this site is to schedule the construction of the project so that major earthworks occur in months other than the February to April period. As this is not necessarily feasible then it is essential that an emphasis on erosion control must be implemented across all seasons of the year to minimise the potential for sediment generation.
3.3 Site Constraints

The RUSLE and rainfall erosivity analysis have both indicated that the combination of the soil erodibility on site and the high intensity rainfall in the area have the potential to cause excessive erosion and generate large quantities of sediment. The soil loss data presented in Table 4 highlights the possibility that the potential volumes of soil loss generated would have a highly detrimental effect on the local environment if allowed to leave the construction site in an uncontrolled fashion. The soils and climate information presented will be used to guide the development of control measures that are presented later in this report.

In addition to the above the following site constraints have been identified as having the potential to exacerbate the soil loss from the construction site. Photos one to five and notes are based on the RMS Conjola Realignment Project and demonstrate the potential issues identified at Dignams Creek:

- **Steep slopes immediately after site clearing and grubbing**

![Photo 1](image1.jpg)

Photo 1- Shows the Conjola Project just after clearing and grubbing. Note the large amount of loose soil material that could be transported off site. These slopes are similar to those encountered at Dignams Creek.

- **Potential for large bare areas as a result of the footprint of the fills at clearing and grubbing**

![Photo 2](image2.jpg)

Photo 2 – Highlights the area of bare ground required to commence construction. Note the combination of long lengths of steep slopes which will increase the potential for soil loss. The period of time between clearing and grubbing and the establishment of the final drainage paths is a critical management issue. It is recommended that no clearing and grubbing occur until all cross drainage and up slope clean water diversions are established.
Figure 3 and Table 5 show the maximum distance between controls on these types of slopes in order to minimise the potential for erosion to occur.

- **Steep cross slopes**

Photo 3 and 4 – Photo 3 is typical of the cross slopes encountered at Dignams Creek, while Photo 4 (taken at Conjola) shows the potential cross slopes to be encountered in the southern section of Stage One at Dignams Creek. Note the scale of the exposed area required for construction as well as the potential soil loss that would result from this combination of soil erodibility, district rainfall erosivity and the resultant increase in slope and length of slope.

Table 6 provides a sensitivity analysis of the various slope and length combinations that can be found in the steepest slopes of the northern and southern sections of Stage One if no cross slope controls (i.e. Diversion banks and diversion drains) are installed during construction. The calculations are based on the slopes just after clearing and grubbing when the slopes are most exposed.

**Table 6 – Sensitivity Analysis of the impact of various combinations of unprotected slopes and slope lengths on resulting Soil Loss**

<table>
<thead>
<tr>
<th>Zone</th>
<th>North End Ch 95200-95460</th>
<th>South End (see Photo 2 &amp; 4) Ch 96450-96500</th>
<th>South End (see Photo 2 &amp; 4) Ch 95520-95640</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disturbed Catch Area (ha)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Rainfall Erosivity, R</td>
<td>3350</td>
<td>3350</td>
<td>3350</td>
</tr>
<tr>
<td>Soil Erodibility, k</td>
<td>0.031</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Slope length (m)</td>
<td>240</td>
<td>50</td>
<td>120</td>
</tr>
<tr>
<td>Slope Gradient %</td>
<td>10</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>Length Slope factor, LS</td>
<td>5.75</td>
<td>7.99</td>
<td>11.92</td>
</tr>
<tr>
<td>Conservation factor, P</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Cover factor, C</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Soil Loss (t/ha/yr)</td>
<td>578</td>
<td>1044</td>
<td>1557</td>
</tr>
<tr>
<td>Soil Loss Class</td>
<td>5 High erosion hazard</td>
<td>6 Very High erosion hazard</td>
<td>7 Extremely High erosion hazard</td>
</tr>
</tbody>
</table>

When these Soil Loss figures are compared with those presented in Table 4 it can be seen that a significant increase in potential soil loss will result. The management of these areas is critical to the projects ability to successfully control soil movement off site into the surrounding environment.
• **Constrained Site**

The proposed route through the Kooraban National Park at the southern end of Stage One will traverse a steep and narrow road corridor. Therefore the use of conventional erosion and sediment control measures is considered problematic. The southern end of Stage One in particular does not have any locations for sediment basin as designed in this report. It is highly likely that the sediment storage capacity in this area will have to be made up of a number of smaller structures with a combined volume equal to the design volume. Photo 5 from Conjola gives an indication of the constraint impact of having a forested environment adjacent to the project. The clearing restrictions severely limit the ability of the project to install designed sediment basin. Also once sediment has entered the forested zone it is virtually impossible to collect the sediment that has moved off site. It is critical to minimise erosion from these zones in order to meet water quality objectives.

![Photo 5](image) – An example of a constrained site ( Conjola Project) highlighting the restrictions imposed by forested areas.

From the above discussion it can be seen that the length of slopes, cross slopes and exposed areas will lead to a significant potential soil loss from site. It is critical that sediment is prevented from moving off site into local watercourses.

The *Blue Book Vol2D* p14 provides advice on erosion and sediment control in constricted and sensitive sites. It states in part that constricted and sensitive sites require enhanced erosion control as a pollution prevention strategy, given the limited opportunities for pollution control through sediment basin installation. The *Blue Book Vol 2D* p14 also recommends that the site be independently audited at least fortnightly by an accredited erosion and sediment control specialist.

The *Blue Book Vol2D* p 14 and 15 advises on the following to aid erosion control in constrained and sensitive sites:

- Where sediment control options are restricted by space (i.e. for sediment basins) then enhance the erosion controls installed and stage clearing to minimise bare areas
- Ensure that bare areas are covered with a ‘product’ (i.e. a soil binder) that reduces
the c-factor value to at least 0.05 the equivalent of 70 percent ground cover

- Consider the use of geofabric and/or a soil binder to provide day to day cover (i.e. geofabric) and cover over a longer period (i.e. soil binder)
- Use of Bureau of Meteorology forecasts and rainfall radar images to assess the likelihood and severity of rainfall for the site. If moderate to heavy rainfall is forecast then additional erosion controls should be used
- Undertake construction activities when the erosion potential of the local rainfall is lowest. Table 6.2, *Blue Book Vol 1* shows that the February to April period represents the highest erosion potential for this area. See Figure 4a and 4b of this report.

### 4.0 MITIGATION MEASURES

A number of mitigation measures should be used to control erosion and sediment generated on site. These include:

- Site management principles that guide the development of erosion and sediment control plans and day to day site management
- Sediment basins
- Cross drainage to transfer pavement runoff through construction zones
- Use of geofabric and soil binder products as temporary ground covers
- Use of mulch bunds, batter chutes, velocity checks
- Use of revegetation, mulches and landscaping to achieve permanent ground cover

The following sections will provide detail on how the recommended mitigation measures should be designed and how the techniques will reduce the soil loss potential highlighted in section 3.2 above.

### 4.1 Principles to guide site Erosion and Sediment Control assessment

The principles that follow are based on the principles for erosion and sediment control listed in the *Managing Urban Stormwater, Soils and Construction Vol 2D, Main Road Construction*.

**PRINCIPLE 1 Minimise the extent and duration of disturbance**

To minimise sheet erosion of disturbed areas, construction should aim to:

- Minimise forward clearing. Areas around flow lines, drainage lines and watercourses should particularly remain in their natural state until the installation of drainage works (e.g. culverts) commences.
- Where practicable or when specified, stage construction activities so that land disturbance is confined to the minimum area possible.
- Complete work and stabilise disturbed areas quickly and progressively.

**PRINCIPLE 2 Control stormwater flows onto, through and from the site**

To reduce erosion and runoff volumes requiring treatment, and to maximise the efficiency of sediment control measures, aim to:

- Intercept, divert and safely dispose of ‘clean’ run-on water from undisturbed areas so that it does not flow onto the works.
- Pass ‘clean’ water through the site without mixing it with ‘dirty’ sediment contaminated run-off from the works. This may require temporary solutions, such as temporary flexible pipes to convey water across a site when the site is being worked.
- Break up slope lengths and minimise catchment areas within the work area, to reduce run-off volume and velocities to manageable levels.
PRINCIPLE 3  Use erosion control measures to prevent on-site damage
To minimise erosion of disturbed areas and unlined drains:
• Protect the soil surface from raindrop impact.
• Convey run-off in a non-erosive manner.

PRINCIPLE 4  Use sediment control measures to prevent off-site damage
To minimise the off-site transport of eroded sediment:
• Slow the velocity of ‘dirty’ water so that soil particles can settle out by gravity.
• Chemically treat sediment laden water to remove very fine suspended soil particles.
• Locate control measures as close to the sediment source as possible, whilst not impeding construction or maintenance activities

PRINCIPLE 5  Stabilise disturbed areas quickly
To minimise sheet erosion of disturbed areas, aim to:
• Strip and save site topsoil material early in the construction phase for reuse in the restoration/stabilisation phase.
• Progressively stabilise or revegetate the site immediately following completion of earthworks so that land disturbance is confined to the minimum area possible.
• If permanent stabilisation is delayed by construction activities or unsuitable site conditions, use temporary measures such as a quick growing cover crop, temporary mulch or hydraulic soil stabiliser (e.g. geobinder).

PRINCIPLE 6  Inspect and maintain control measures
The effectiveness of erosion and sediment controls is related to both the selection of appropriate techniques and the maintenance of these measures. It is therefore important to:
• Inspect, maintain and/or modify control measures regularly (e.g. after storms and weekly) to ensure their effective operation.
• Maintain control measures until the project is completed and the site has been stabilised or rehabilitated.
• Remove temporary control measures once an area has been stabilised.

4.2  Sediment Basin Design
The design of the Sediment Basins described below follows the procedures set out in Bluebook Vol 1, Section 6.3 and Appendix L, and Bluebook Vol 2, p 27, Table 6.1 (reproduced as Table 7 in this report). The design parameters outlined in Table 7 enable sediment basin design to satisfy Environment Protection Licence (EPL) water quality parameters if an EPL was imposed on this proposal.

The following data and information sources and design procedures were used in the sediment basin design:
• Annual rainfall data was derived from the Bureau of Meteorology website
• The recommended minimum design criteria for temporary erosion and sediment control measures and determination of standard and sensitive receiving waters was derived from Bluebook Vol 2, Table 6.1, p27 (See Table 7 in this report)
• Soil erodibility (k-factor for Universal Soil Loss Equation), soil hydrologic group and sediment type data were determined by soil sampling and soil analysis by the Scone Soil Research Centre and Bluebook Vol1 Appendix C
Volumetric Runoff (Cv) for runoff from disturbed catchments and Peak Flow Coefficients (C10) of Runoff for design rainfall intensities were attained from Table F2 and F3, Appendix F, Bluebook Vol 1.

The Sediment Basin Design Calculation excel spreadsheet program in Appendix L, Bluebook Vol1 was used to provide detailed sediment basin design.

The construction period is assumed to be one to two years in length (See Table 7).

The receiving waters below the proposal are considered to be ‘sensitive’ to degraded water quality and hence the need to use the ‘sensitive’ design criteria to protect Wallaga Lake catchment (See Footnote 1 in Table 7 for an explanation of ‘sensitive receiving water’).

Details on sediment basin location and dimensions are also provided. The approximate locations are shown in Appendix 2 and will be drawn onto RMS drainage plans.

**Determination of sediment type**

The proposal site is located on soils that produce Type C, D and F sediment (See Table 2). The results of the Particle Size Analysis (see Appendix A) from the soil analysis was inserted into the excel spreadsheet in Appendix L, Sediment Basin Design, Blue Book Vol 1. The soil analysis report indicates that the majority of these soils will slake (collapse into smaller particles) and/or disperse. Even though all sediment types are present, the majority of the site is dominated by type F and D sediment and therefore it has been decided to design for Type D basins.

**Sediment Basin Design**

The following is a brief outline of the design of sediment basins as set out in the Bluebook Vol1, Section 6.4.3. The basic formula for a Sediment Basin is:

\[
\text{Sediment Basin Volume, } SB_{\text{volume}} = Volume_{\text{settling zone}} + Volume_{\text{sediment storage}}
\]

Where,

- **Settling Zone** designed to capture most sediment produced by the nominated rainfall event at a specified discharge quality, and

- **Sediment Zone** deposited sediment is stored until basin is cleaned out.

Table 8 presents the results of the calculations undertaken to determine the size of sediment basins required along the project route. The procedure for calculating their sizes is set out in the Excel spreadsheets calculators in Bluebook Vol 1 Appendix J.

The sediment basin design is likely to achieve significant removal of coarse sediment, although reductions in turbidity may be low. Therefore it is critical to invest in erosion control to minimise sediment generation and use of flocculants in order to meet the water quality parameters for this proposal (as per the guidance in Blue Book Vol 2D, p14 and repeated in section 3.3 Constrained Sites of this report).

**Determination of 5 day 80th & 85th percentile rainfall depths**

Bluebook Vol 1, Section 6.3.4(h) sets out a procedure to determine the 5 day 80th and 85th percentile rainfall depth for any specific site if the annual rainfall for the site is known. (See Figure 5) Narooma has an average rainfall of 914 mm/yr (Tulau, 2002, p.4). Table 7 highlights the minimum design criteria to be used in sediment basin design. (Sourced from Table 6.1, Bluebook Vol.2).
Table 7: Recommended minimum design criteria for temporary erosion and sediment control measures for main road construction. Note the red highlighted area around the design parameters for Type D sediment basins. (Copy of Table 6.1 from Bluebook Vol 2D Main Road Construction)

<table>
<thead>
<tr>
<th>Duration of disturbance</th>
<th>6-12 months</th>
<th>&lt; 6 months</th>
<th>&lt; 3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity of receiving environment (standard or ‘sensitive’)?</td>
<td>standard</td>
<td>sensitive</td>
<td>standard</td>
</tr>
<tr>
<td>Temporary drainage control measures</td>
<td>2 yrs</td>
<td>5 yrs</td>
<td>10 yrs</td>
</tr>
<tr>
<td>Type C sediment control basin</td>
<td>2 yrs</td>
<td>5 yrs</td>
<td>10 yrs</td>
</tr>
<tr>
<td>Type D sediment control basin</td>
<td>0.5 x 1 yr</td>
<td>1 yr</td>
<td>2 yrs</td>
</tr>
<tr>
<td>Embankment and spillway designed to be structurally sound</td>
<td>10 yrs</td>
<td>20 yrs</td>
<td>50 yrs</td>
</tr>
<tr>
<td>Type F or D Sediment retention basin</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
</tr>
<tr>
<td>Embankment and spillway designed to be structurally sound</td>
<td>10 yrs</td>
<td>20 yrs</td>
<td>50 yrs</td>
</tr>
</tbody>
</table>

1. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
2. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
3. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
4. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
5. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
6. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
7. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
8. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
9. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
10. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
11. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
12. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
13. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
14. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
15. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
16. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
17. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
18. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
19. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
20. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
21. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
22. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
23. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
24. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
25. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
26. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
27. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
28. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
29. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
30. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
31. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
32. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
33. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
34. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
35. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
36. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
37. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
38. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
39. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
40. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
41. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
42. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
43. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
44. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
45. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
46. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
47. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
48. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
49. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
50. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
51. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
52. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
53. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
54. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
55. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
56. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
57. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
58. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
59. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
60. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
61. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
62. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
63. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
64. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
65. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
66. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
67. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
68. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
69. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
70. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
71. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
72. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
73. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
74. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
75. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
76. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
77. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
78. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
79. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
80. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
81. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
82. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
83. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
84. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
85. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
86. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
87. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
88. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
89. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
90. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
91. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
92. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
93. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
94. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
95. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
96. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
97. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
98. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
99. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
100. A sediment control measure designed to have a non-erosive hydraulic capacity to convey.
Table 7 highlights the minimum design criteria to be used in sediment basin design. In summary, the design criteria from Table 7 are noted as follows:

- **Sediment Basins** that control Type D sediment must be designed for a 5 day 80\(^{th}\) and 85\(^{th}\) percentile rainfall depth event in a catchment defined as ‘a sensitive’ receiving water
- **Diversion Banks and catchment drains** are to be designed to capture and convey a 1 in 10 year (standard receiving water) and 1 in 20 year ARI (sensitive receiving water) rainfall event.

The Sediment Basin must be able to contain a 5 day rainfall depth event within the sediment basin, until such time as the water in the sediment basin can be flocculated to a desired water quality level before discharge.

![Annual mean rainfall vs. 5-day rainfall](image)

Figure 5 – Determination of the 5 day, 80\(^{th}\)% and 85\(^{th}\) rainfall depths for Narooma

From Figure 5 ‘Annual mean rainfall vs. 5 day rainfall’ the 5 day 80\(^{th}\)% percentile rainfall depth of 31.5 mm and the 85\(^{th}\)% percentile depth of 38mm can be extrapolated for the Dignams Creek site. Sediment basin volumes were determined using the excel spreadsheet in Appendix L of Blue Book Vol 1. Table 8 is a summary of the calculations for Type F and D sediment basins for a 5 day rainfall depth for each zone. The drainage lines flowing out of the northern zone are considered to be sensitive because they flowed to tributaries of Dignams Creek, and the drainage from the middle and southern zones are direct to Dignams Creek and Koorablan National Park. If drainage in the northern section is controlled internally then the lower R figure can be used. The higher figure is used in the Southern section because of the steep side slopes that will deliver flows very quickly to the tributaries.
Table 8: Type D sediment basin calculations and dimensions – summary of Blue Book Vol 1 Appendix L excel spreadsheet design.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Cv</th>
<th>Rx-day, y %ile</th>
<th>Total catchment area (ha)</th>
<th>Total settling zone volume (m³)</th>
<th>Sediment storage volume (m³)</th>
<th>Total basin volume (m³)</th>
<th>Dimensions (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>Northern</td>
<td>0.90</td>
<td>31.5</td>
<td>1</td>
<td>283.5</td>
<td>50</td>
<td>333</td>
<td>25</td>
</tr>
<tr>
<td>Middle</td>
<td>0.90</td>
<td>38</td>
<td>1</td>
<td>340</td>
<td>48</td>
<td>390</td>
<td>28</td>
</tr>
<tr>
<td>Southern</td>
<td>0.90</td>
<td>38</td>
<td>1</td>
<td>340</td>
<td>61</td>
<td>400</td>
<td>30</td>
</tr>
</tbody>
</table>

Note: Assumptions used in the design of the sediment basins include: slope lengths of between 80 and 200 metres and 10 percent slope (a worst case scenario encountered just after clearing and grubbing); a two month storage volume to ensure site management removes accumulated sediment from the sediment basin; and calculating a multiplication factor based on a disturbed area of one hectare so that a simple calculation can be made. For example if a 0.4 hectare disturbed area is located in the southern zone then the sediment basin volume would be $0.4 \text{ ha} \times 400 \text{ m}^3/\text{ha} = 160 \text{ m}^3$.

Ideally each work zone requires a sediment basin to enable water quality to be managed. However, the steep topography of the southern work zones and lack of space, presents difficulties in the construction of sediment basins. Sediment basin locations are shown in Appendix 2 General Arrangement – Sediment Basins. Table 14 of Appendix 2 provides design data for 20 sediment basins. However, a number of these basins (SB 10, 11, 12, 14 and 20) have not been included on the General Arrangement sheets in Appendix 2 due to the constrained site (steep slopes). It is not possible to build these basins. The required site management response to this issue is dealt with in Constrained Sites on page 14. This section provides guidance on the required site management to control erosion in order to minimise potential sediment generation.

4.3 Cross Drainage Design

The proposed construction zones will receive significant volumes of water from the existing road pavement and upslope areas. This runoff is considered ‘clean’ and must be kept separate from the construction zone water in order to satisfy Principle 2 Control stormwater flows. The runoff volumes to be diverted by clean water diversion have been calculated according to the 1 in 10 yr Annual Recurrence Interval (ARI) design rainfall event as required by Bluebook Vol1 Section 5.4.3 (b) and highlighted in Table 7 of this report.

Clean Water Diversion – lined diversion channel and pipes

For each culvert construction zone it is proposed to use a plastic or geofabric lined channel to direct upslope flows around the culvert construction zone. The channel lining can be laid out across the work zones when wet weather is imminent and over night and for shut down periods. The channel dimensions have been calculated to carry this design flow See Table 10. See Photo 6 and 7 for examples of a constructed clean water diversion. See Appendix 3 for a guide to a typical layout of a Clean Water Diversion.
Photos 6 and 7: show two temporary clean water diversion channels constructed to divert water around the culvert construction zones. The channels have been designed to convey a 1 in 10 ARI design storm around the construction. More detailed design guidance is provided in the RMS Technical Guideline 11.068 Temporary stormwater drainage for road construction. See Appendix 3.

Clean upslope runoff calculations

To calculate the 1 in 10 year ARI peak flow volume the Rational Formula is used:

\[ Q_{yr} = 0.00278 \times C_{10} \times F_{yr} \times I_{yr, tc} \times A \]

Where:
- \( Q_{yr} \) is peak flow rate (m\(^3\)/sec) of average recurrence interval (ARI) of ‘y’ years
- \( C_{10} \) is the runoff coefficient (dimensionless) for ARI of 10 years. Values source from Australian Rainfall and Runoff, Vol1, Book VIII.
- \( F_{yr} \) is a frequency factor for ‘y’ years. Values derived from Australian Rainfall and Runoff, Vol 1, Book IV.
- \( I_{yr, tc} \) is the average rainfall intensity (mm/hr) for an ARI of ‘y’ years and a design duration of \( t_c \) (minutes or hours). I values for Dignams Creek sourced from Bureau of Meteorology website.
- \( t_c \) Time of Concentration, \( t_c = 0.76 \times (A/100)^{0.38} \) hrs, and refers to the time for runoff to move from the furthest point in a catchment to the outlet, and represents the time when all points in the catchment contribute to runoff.

Peak flows for each culvert construction site are presented in Table 9. Intensity Frequency Duration data for the relevant time of concentrations for each zone are presented.
Table 9: Peak Flow Calculations

<table>
<thead>
<tr>
<th>Site</th>
<th>A (ha)</th>
<th>tc (mins)</th>
<th>Rainfall intensity, I, mm/hr</th>
<th>C_{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td>95180</td>
<td>1</td>
<td>8</td>
<td>81</td>
<td>136</td>
</tr>
<tr>
<td>95460</td>
<td>1</td>
<td>8</td>
<td>81</td>
<td>136</td>
</tr>
<tr>
<td>95580</td>
<td>50</td>
<td>35</td>
<td>42.3</td>
<td>72.2</td>
</tr>
<tr>
<td>96580</td>
<td>1.5</td>
<td>9</td>
<td>77</td>
<td>129</td>
</tr>
<tr>
<td>96640</td>
<td>1</td>
<td>8</td>
<td>81</td>
<td>136</td>
</tr>
</tbody>
</table>

The Soil Conservation Service Design Manual No. 5 was used to convert the 1 in 10 year ARI peak flows into channel dimensions. Table 10 shows the channel dimensions that will pass the peak flows for each of the design requirements.

Table 10 – channel dimensions for a Clean Water Diversion

<table>
<thead>
<tr>
<th>Peak Flow (m$^3$/s)</th>
<th>Base width (m)</th>
<th>Depth (m)</th>
<th>Velocity (m/s)</th>
<th>Channel Slope (%)</th>
<th>Sill length (m)</th>
<th>Bank Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.19</td>
<td>2.3</td>
<td>0.5</td>
<td>1.4</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>1.5</td>
<td>0.27</td>
<td>2.3</td>
<td>0.5</td>
<td>1.4</td>
<td>1</td>
<td>3.5</td>
</tr>
<tr>
<td>50</td>
<td>5.09</td>
<td>12.5</td>
<td>0.5</td>
<td>1.0</td>
<td>0.47</td>
<td>18.8</td>
</tr>
</tbody>
</table>

4.4 Soil Conservation Recommendations

The level of soil loss from a site is a result of the level of unmanaged soil disturbance at any point in the construction phase. The key to controlling sediment generation is to minimise the potential for erosion to occur. The key to minimising soil loss is the result of site management of the components represented in the RUSLE (A=R x k x LS x C x P). It is obvious that site management has no control over how rainfall arrives (R factor) on site or on the soils inherent erodibility (k factor). However, site management can adhere to simple erosion and sediment control principles that manipulate the remaining controls to minimise the area of exposed ground and the length of slopes between controls.

The following section is designed to show how using a combination of controls can minimise erosion and generation of sediment from site. The principle controls available in the RUSLE are the C factor (ground cover), LS factor (the impact of length and grade of site slopes) and the P factor (the use of velocity checks and drainage controls).
Notes on erosion and sediment control techniques

**Erosion Control – via use of C factor**

The manipulation of the C factor will have maximum influence on the soil loss on site. A number of control techniques have been identified to enable site management to use the RUSLE concept to control soil loss.

A C factor of 0.05 is the equivalent of 70 per cent ground cover, a ground cover percentage where soil loss on relatively flat ground is minimised. The use of temporary ground cover with low C factors will enable site management to minimise soil loss. Table A3, Appendix A, Blue Book Vol1 provides various C factor values for different ground cover techniques. Table 11 presents the C factor values for various erosion control techniques that have been chosen for this project.

Table 11 Recommended erosion control techniques for each zone

<table>
<thead>
<tr>
<th>Erosion Control Technique used on 2:1 batters &gt;15m long</th>
<th>C factor</th>
<th>Work Zone</th>
<th>Construction phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood chip @ 50-75 mm deep @ 56 t/ha</td>
<td>0.02</td>
<td>All zones</td>
<td>Revegetation and landscaping</td>
</tr>
<tr>
<td>Soil Binder</td>
<td>0.1</td>
<td>All zones</td>
<td>Construction</td>
</tr>
<tr>
<td>Geofabric</td>
<td>0.1</td>
<td>All zones</td>
<td>Construction</td>
</tr>
<tr>
<td>Erosion Control Mat</td>
<td>0.1</td>
<td>All zones</td>
<td>Revegetation and landscaping</td>
</tr>
</tbody>
</table>

Table 12 shows how site management can have a major impact on the final soil loss values for the site. This is critical to meeting the water quality parameters outlined in section 3 and Table 1. It is stressed that these figures are a guide to the possible minimising of soil loss that can be achieved. To achieve these soil loss values it is essential to take all opportunities to maximise erosion control in order to minimise the potential sediment generation.

Table 12 New Soil Loss values after the above Erosion Control techniques are applied to Southern Zone

Revised Universal Soil Loss Equation – used to determine Soil Loss Class & Erosion Hazard

\[ A (t/ha/yr) = R \times k \times LS \times C \times P \]

<table>
<thead>
<tr>
<th>Work Zone</th>
<th>Southern Zone without ground cover</th>
<th>Southern Zone with a ground cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall Erosivity, R</td>
<td>3350</td>
<td>3350</td>
</tr>
<tr>
<td>Soil Erodibility, k</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>Slope length (m)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Slope Gradient %</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Length Slope factor, LS</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Conservation factor, P</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>Cover factor, C (using soil binder or geofabric)</td>
<td>1.0</td>
<td>0.1 (soil binder or mulch)</td>
</tr>
<tr>
<td>Disturbed Area (ha)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Soil Loss (t/ha/yr)</td>
<td>405</td>
<td>39</td>
</tr>
<tr>
<td>Soil Loss Class</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
Use of soil binder

The bare areas in each work zone can be stabilised with the regular use of a soil binder product on completed fill batter faces. The slopes involved in these zones will enable the soil binder product to achieve a cover factor of 0.05 if applied regularly. Soil binder maintains a crust for up to three months if it is not disturbed by machinery or people walking on it. Inspection of the surface integrity of the binder would be part of regular site inspections. The ongoing maintenance of the binder would be an inspection item. Combined with the use of a mulch bund, sediment traps and a sediment basin per work zone, this approach should result in minimal sediment movement off site.

It is critical that site management aims to minimise disturbance in areas sprayed with soil binder when construction is not occurring in those areas. It is also critical that the binder be reapplied after each construction period, and/or when rainfall is predicted. This will decrease the potential sediment generation from these work zones to a manageable volume.

Use of geofabric

The culvert construction zones will require the use of geofabric to cover the work zone, and sediment fencing placed around the headwall to capture any sediment generated. The geofabric can be installed when wet weather is predicted and for periods of shut down. The RMS Technical Guideline RMS 11.068, Temporary stormwater drainage for road construction provides guidance in relation to culvert construction and minimisation of potential sediment production.

Erosion control – via the LS factor

The slopes on site are already set by the slopes of the existing landscape. The control of erosion by manipulation of the LS factor can have a significant impact on the resultant soil loss from a site. For example, if construction slopes have an 80 to 200 metre length of run on 20 percent slopes (possible scenario between Ch 96570 and 96700) then the LS factor will range from 7.32 to 14.84, with a soil loss potentially reaching 1940 t/ha/yr. The length of these slopes and their impact on soil loss can be controlled by site management using cross slope drains to shorten the length of slope.

Use of cross slope drains

Photos 8 and 9 shows lined cross slope drains on a similar construction scenario at the Conjola Mountain Realignment. The drains are approximately 30 metres apart. The LS factor here was 3, and resulted in a significant reduction in soil loss.
**Use of velocity checks – at toe of batters and within channels**

It is recommended that as each section of the batter achieves its final shape a small sediment trap of geofabric wrapped rock or sand bag wall be installed to collect and slow runoff that comes off the finished batter slope. See Photos 10 and 11. Alternatives include sand bag sediment traps and coir logs. Wrapping them in geofabric will enhance the sediment trapping efficiency. An interval of 30m between sediment traps will enable a significant reduction in runoff velocity. These need to be installed so flows pass through the spillway to avoid outflanking the structure. It is critical that these structures are regularly emptied to ensure maximum collection volume is maintained. More structures can be installed in the 30 metre space if it is obvious that sediment is passing through the site. Site control will be enhanced with the use of velocity controls such as rock sediment traps and/or sand bag check dams.

Photos 10 and 11 – Rock velocity control in a drainage line also acting as a sediment trap. Sand bag and coir logs are an alternative.

**Erosion control – via the P factor**

It is assumed that the P factor will offer minimal control options as the site will often be compacted and smooth during construction. Most controls will be located on the edge of the construction zone. Two P factor controls proposed include mulch bunds at the toe of fill batters and temporary batter chutes. See Photos 12 and 13. The use of cross drainage channels and pipes to divert runoff through the site will minimise the impact of upslope flows on the construction zone.

Photos 12 and 13 – show mulch bunds placed at the toe of embankments to collect sediment and batter chutes to transfer runoff between different construction levels in a controlled manner.
Some notes on soil fertility for revegetation are provided below:

- The soil tests results in Appendix 1 indicate that the topsoil on site is of a low fertility, highlighted by the low Cation Exchange Capacity and low organic matter content. The soil fertility analysis indicate that the cations recorded readings considered below balanced levels.
- The base saturation levels range from 39 percent in the forested areas to 80 percent from the sample taken from the Dairy Farm (See Table 2). This shows that the forested soils are highly leached (nutrients washed through the profile by rainfall over time) and therefore low in available nutrients, while the dairy based soils will readily release nutrients for revegetation purposes. The forested soils should be augmented with mulch or erosion control mats to ensure erosion is minimised while revegetation of cut and fill batters is established.
- pH levels range from 4.6 (strongly acidic in forested areas) to 5.3 (slightly acidic on dairy flats). The forested soils will not require liming as mulching will be the main ground cover used, with native plant tubestock or native seed sown into the mulch. The dairy flats will require about 1 tonnes/ha of lime to raise the pH to 6.5 to aid the cover crop revegetation of the batters in the Middle Section.
- The recorded Aluminium levels in the forest are high and may ‘tie up’ any applied fertiliser. The use of a slow release fertiliser with little or no Phosphorus plus mulch will aid the nutrient requirements for native revegetation in the forested areas.
- The levels of Phosphorus and Nitrogen (recorded as Organic Matter) are very low and this reflects the highly leached soils due to the high rainfall and forested area that the road is located in.
- The low exchangeable Sodium reading and balanced Calcium : Magnesium ratios indicate that the soils are not Sodic. However, the Emerson Aggregate Test readings of 2(1) and 3(1) indicate a significant slaking and dispersion problem particularly if these soils are worked when the site is wet after rainfall. It is recommended that gypsum should be applied to the topsoil stockpiles at a rate of 5 tonnes/ha. On the dairy flats in the Middle Section the lime and gypsum can be applied as a ‘50/50’ split at stripping. Once respread the gypsum in the topsoil will provide a degree of stability to raindrop impact while revegetation establishes. The soils should be fairly stable if cover can be established and maintained.
- The soils are not saline.

**Covercrop on the Dairy Flats and native species for the forested areas**

The revegetation species in Table 13 is a reproduction of ‘Table 11 Cover crop and native seed application rates, page 34 of RMS Landscape Guidelines (2008)’ and provides details of cover crop and native species applicable to this area of the south coast. As each construction area is completed it is critical to progressively revegetate the bare area in order to achieve 70 percent ground cover. Additional watering of revegetated areas should be considered.

---

3. Soils with an exchangeable sodium percentage greater than six percent of the total exchangeable cations are called ‘Sodic’. Sodic soils will disperse.

4. Slaking is the breakdown of a lump of soil into smaller fragments on wetting. It is caused when clay swells and the trapped air bursts out. Organic matter reduces slaking by binding mineral particles and by slowing the rate of wetting.
Cover crop and native seed application rates for south coast

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Japanese Millet (Sep-Ma)</td>
<td>@35 kg/ha (NOT IN THE NATIONAL PARK)</td>
</tr>
<tr>
<td>Rye Corn (Apr-Aug)</td>
<td>@35 kg/ha</td>
</tr>
<tr>
<td>Eclipse Rye</td>
<td>@25 kg/ha</td>
</tr>
<tr>
<td>Couch</td>
<td>@ 7 kg/ha</td>
</tr>
<tr>
<td>Red Clover</td>
<td>@ 5 kg/ha</td>
</tr>
<tr>
<td>Austrodanthonia richardsonii var Hume</td>
<td>@ 2 kg/ha</td>
</tr>
<tr>
<td>Microlaena stipoides var Griffin</td>
<td>@ 2 kg/ha</td>
</tr>
<tr>
<td>Themeda triandra var Tangara</td>
<td>@ 1 kg/ha</td>
</tr>
<tr>
<td>Native seeds – comprising selected local acacia species (25% of the mix), hardwood shrubs (45%) and ground covers (30%)</td>
<td>@ 5 kg/ha</td>
</tr>
<tr>
<td>Organic Fertiliser – slow release N, P, K</td>
<td>@ 250 kg/ha</td>
</tr>
</tbody>
</table>

Temporary erosion and sediment controls should not be removed until 90 per cent of any finished area has at least the equivalent of 70 per cent ground cover. The use of mulches and compost can help in the establishment of the final ground cover.

**Mulch**

After topsoil is respread over the batters it is recommended that mulch derived from the clearing phase be used to provide ground cover in the landscaping phase. This will help achieve the required ground cover rate of 70 percent (C factor = 0.05) within 10 days (as per the requirements of Table 7.1, page 7-3, Blue Book Vol 1). Mulch applied at 56 t/ha (50 to 75 millimetres thick) will achieve a C factor of 0.02. Native species (as tubestock, virocells etc) can then be planted directly through the mulch into the topsoil below. See Photos 14 and 15.

Photos 14 and 15 – showing use of mulch respread on batter faces to provide quick equivalent ground cover of greater than 70 percent.

If mulch is not available then the use of erosion control mat (ECM) should be considered for provision of ground cover until the revegetation has established. See Photo 16.
Photo 16 – shows use of ECM on a fill batter on the Kings Highway five kilometres west of Bateman's Bay, NSW. Note the revegetation starting to grow through the ECM. The grass will eventually replace the ECM as the principal erosion control with the decaying ECM acting as mulch for the established vegetation.

6 RECOMMENDATIONS

The following is a summary of the recommendations found within the report.

6.1 Slope and Rainfall Erosivity Analysis

A major site management option on the control of potential erosion from this site is to schedule the construction of the project so that major earthworks occur in months other than the February to April period. As this is not necessarily feasible then it is essential that an emphasis on erosion control must be implemented across all seasons of the year to minimise the potential for sediment generation.

6.2 Site Constraints

From the Site Constraint discussion it can be seen that the length of slopes, cross slopes and exposed areas will lead to a significant potential soil loss from site. It is critical that sediment is prevented from moving off site into local watercourses.

The Blue Book Vol2D p14 provides advice on erosion and sediment control in constricted and sensitive sites. It states that:

- Constricted and sensitive sites require enhanced erosion control as a pollution prevention strategy, given the limited opportunities for pollution control through sediment basin installation.
- The site is independently audited at least fortnightly by an accredited erosion and sediment control specialist.
- Where sediment control options are restricted by space (i.e. for sediment basins) then enhance the erosion controls installed and stage clearing to minimise bare areas.
- Ensure that bare areas are covered with a ‘product’ (i.e. a soil binder) that reduces the c-factor value to at least 0.05 the equivalent of 70 percent ground cover.
- Consider the use of geofabric and/or a soil binder to provide day to day cover (i.e. geofabric) and cover over a longer period (i.e. soil binder).
- Use of Bureau of Meteorology forecasts and rainfall radar images to assess the likelihood and severity of rainfall for the site. If moderate to heavy rainfall is forecast then additional erosion controls should be used.
- Undertake construction activities when the erosion potential of the local rainfall is lowest. Table 6.2, Blue Book Vol 1 shows that the February to April period represents the highest erosion potential for this area. See Figure 4a and 4b of this report.
6.3 Mitigation Measures

6.3.1 Principles
The following six principles for erosion and sediment control listed in the Managing Urban Stormwater, Soils and Construction Vol 2D, *Main Road Construction* are to be used to guide the development of all Erosion and Sediment Control Plans:

**PRINCIPLE 1** *Minimise the extent and duration of disturbance*

**PRINCIPLE 2** *Control stormwater flows onto, through and from the site*

**PRINCIPLE 3** *Use erosion control measures to prevent on-site damage*

**PRINCIPLE 4** *Use sediment control measures to prevent off-site damage*

**PRINCIPLE 5** *Stabilise disturbed areas quickly*

**PRINCIPLE 6** *Inspect and maintain control measures*

6.3.2 Sediment Basin and Cross Drainage Design

The minimum design criteria for sediment basin and cross drainage design are:

- *Sediment Basins* that control Type D sediment must be designed for a 5 day 80th and 85th percentile rainfall depth event in a catchment defined as ‘a sensitive’ receiving water
- *Diversion Banks and catchment drains* are to be designed to capture and convey a 1 in 10 -20 year ARI rainfall event.

<table>
<thead>
<tr>
<th>Zone</th>
<th>$C_v$</th>
<th>$R_{5\text{day}, y%-ile}$</th>
<th>Total catchment area (ha)</th>
<th>Settling zone volume (m³)</th>
<th>Sediment storage volume (m³)</th>
<th>Total basin volume (m³)</th>
<th>Dimensions (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Length Width Depth Batter slopes</td>
</tr>
<tr>
<td>Northern</td>
<td>0.90</td>
<td>31.5</td>
<td>1</td>
<td>283.5</td>
<td>50</td>
<td>333</td>
<td>25 15 1.5 3</td>
</tr>
<tr>
<td>Middle</td>
<td>0.90</td>
<td>38</td>
<td>1</td>
<td>340</td>
<td>48</td>
<td>390</td>
<td>28 15 1.5 3</td>
</tr>
<tr>
<td>Southern</td>
<td>0.90</td>
<td>38</td>
<td>1</td>
<td>340</td>
<td>61</td>
<td>400</td>
<td>30 15 1.5 3</td>
</tr>
</tbody>
</table>

*Clean Water Diversion – lined diversion channel and pipes*

For each culvert construction zone it is proposed to use a plastic or geofabric lined channel to direct upslope flows around the culvert construction zone. The channel lining can be laid out across the work zones when wet weather is imminent and over night and for shut down periods. The channel dimensions have been calculated to carry this design flow

<table>
<thead>
<tr>
<th>Peak Flow (m³/s)</th>
<th>Base width (m)</th>
<th>Depth (m)</th>
<th>Velocity (m/s)</th>
<th>Channel Slope (%)</th>
<th>Sill length (m)</th>
<th>Bank Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>0.19</td>
<td>2.3</td>
<td>0.5</td>
<td>1.4</td>
<td>3.5</td>
<td>0.9</td>
</tr>
<tr>
<td>1.5</td>
<td>0.27</td>
<td>2.3</td>
<td>0.5</td>
<td>1.4</td>
<td>3.5</td>
<td>0.9</td>
</tr>
<tr>
<td>50</td>
<td>5.09</td>
<td>12.5</td>
<td>0.5</td>
<td>1.0</td>
<td>0.47</td>
<td>18.8</td>
</tr>
</tbody>
</table>

6.4 Soil Conservation Recommendations

The key to controlling sediment generation is to minimise the potential for erosion to occur. The key to minimising soil loss is the result of site management of the components represented in the RUSLE (A=R x k x LS x C x P). It is obvious that site management has no control over how rainfall arrives (R factor) on site or on the soils inherent erodibility (k factor).
However, site management can adhere to simple erosion and sediment control principles that manipulate the remaining controls to minimise the area of exposed ground and the length of slopes between controls. To achieve these soil loss values it is essential to take all opportunities to maximise erosion control in order to minimise the potential sediment generation.

**Erosion Control – via use of C factor**

The manipulation of the C factor will have maximum influence on the soil loss on site. A number of control techniques have been identified to enable site management to use the RUSLE concept to control soil loss. A C factor of 0.05 is the equivalent of 70 per cent ground cover, a ground cover percentage where soil loss on relatively flat ground is minimised. The use of temporary ground cover with low C factors will enable site management to minimise soil loss. Table A3, Appendix A, Blue Book Vol1 provides various C factor values for different ground cover techniques. Table 11 presents the C factor values for various erosion control techniques that have been chosen for this project.

**Erosion control – via the LS factor**

*Use of velocity checks – at toe of batters and within channels.* It is recommended that as each section of the batter achieves its final shape a small sediment trap of geofabric wrapped rock or sand bag wall be installed to collect and slow runoff that comes off the finished batter slope.

6.5 **Revegetation Requirements**

- The forested soils should be augmented with mulch or erosion control mats to ensure erosion is minimised while revegetation of cut and fill batters is established
- If over time it is found that the site does not revegetate adequately from the seed stored in the mulch then supplementary revegetation must be used.

7 **CONCLUSION**

This report outlines the site constraints, hazards and strategies to control the erosion and sediment potential of this site. The control strategies identified in this report will fulfil the principles of sound soil conservation practice required by the Bluebook Vol 1 and Vol 2D and the water quality parameters that normally would be imposed by an Environmental Protection Licence. It is critical to the success of this project in relation to water quality that a proactive and preventative philosophy be adopted in the design of the erosion and sediment control plans for the project.

This project has a number of constraints that contribute to the sites high erosion risk. These are the narrow road corridor, steep slopes and soils with an inherently high level of soil erodibility. These constraints should be at the forefront in any decision made in relation to erosion and sediment control. This decision making should include the following recommendations of Bluebook Vol 1, Section 6.3.4(g) as a minimum. Applied to this project these recommendations can be interpreted as follows:

- Ensuring that the site does not have a high erosion hazard rating in the period of the year where rain erosivity is highest. This corresponds to the February to April period of the year
- The C-factor in the Revised Universal Soil Loss Equation is no higher than 0.1. This is the equivalent of achieving 60% ground cover by the use of vegetation, geofabric for smaller areas or the application of a soil stabiliser on larger exposed areas
A C-factor of 0.05, or the equivalent of 70 per cent ground cover, needs to be achieved on all finished areas within 10 days of completion. The quick application of compost and mulch will help achieve this goal.

The protection of concentrated flow lines to minimise the scouring of the channel invert. The use of channel linings such as geofabric, plastic or establishing the final channel lining (jute matting or rock) will minimise the delivery of sediment to the sediment basins and potentially offsite.

Due to the very difficult terrain, the unstable nature of the soils, the high rainfall intensities and the duration of the construction period anticipated for this project, it is strongly recommended that regular independent audits of the site be undertaken. It is crucial that the Primary and progressive Erosion and Sediment Control Plans developed be followed, and that identified corrective actions be identified early, so that resultant improvements to the plans and their implementation are made in a timely manner.

It is recommended that training of site personnel be undertaken before construction commences to ensure that all aspects of the site constraints and hazards and identified control techniques be understood and implemented by the construction contractor. Timely follow up training and regular toolbox talks should also be encouraged.

REFERENCES:


Best Practice Erosion and Sediment Control, 2008, International Erosion Control Association


RMS Landscape Guideline: Landscape design and maintenance guidelines to improve the quality, safety and cost effectiveness of road corridor planting and seeding (RMS, 2008)


SKM Report, April 2013: Upgrade of the Princes Highway – Dignams Creek: Operational Water Quality Basins
APPENDIX 1 SOIL TEST RESULTS

Analysis of seven soil samples – Dignams Creek Project

The Soil Conservation Service, Scone Laboratory analysed seven soil samples from the Dignams Creek project area for:

- Particle Size Analysis and Organic Carbon to determine the soil erodibility factor (k factor from the Revised Universal Soil Loss Equation). The soil surface was assumed to be medium granular and profile permeability was slow to moderate
- Soil fertility for revegetation purposes

K factor readings

<table>
<thead>
<tr>
<th>Lab No</th>
<th>Sample Id</th>
<th>K factor</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Site 1 Bag 1 15-30</td>
<td>0.031</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>Site 1 Bag 2 30-65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Site 4 15-50</td>
<td>0.030</td>
<td>Moderate</td>
</tr>
<tr>
<td>6</td>
<td>Site 6 10-40</td>
<td>0.038</td>
<td>Moderate</td>
</tr>
<tr>
<td>7</td>
<td>Site 7 10-50</td>
<td>0.026</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

Particle Size Analysis, Dispersion Percentage, Emersons Agg Test, and Organic Carbon Percentage

<table>
<thead>
<tr>
<th>Lab No</th>
<th>Method</th>
<th>P7B/2 Particle Size Analysis (%)</th>
<th>P8A/2</th>
<th>P9B/2</th>
<th>C6A/2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Clay</td>
<td>Silt</td>
<td>F sand</td>
<td>C sand</td>
</tr>
<tr>
<td>1</td>
<td>Site 1 Bag 1 15-30</td>
<td>14</td>
<td>15</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Site 1 Bag 2 30-65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Site 4 15-50</td>
<td>11</td>
<td>9</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Site 6 10-40</td>
<td>14</td>
<td>14</td>
<td>27</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>Site 7 10-50</td>
<td>9</td>
<td>14</td>
<td>21</td>
<td>11</td>
</tr>
</tbody>
</table>

Soil fertility

<table>
<thead>
<tr>
<th>Lab No</th>
<th>Method</th>
<th>C1A/4</th>
<th>C2A/3</th>
<th>C2B/3</th>
<th>C5A/3 (me/100g)</th>
<th>CEC &amp; exchangeable cations</th>
<th>C8A/2</th>
<th>C9B/2</th>
<th>P (mg/kg)</th>
<th>EAT</th>
<th>Texture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>EC (dS/m)</td>
<td>pH</td>
<td>DH/Cl(CaCl2)</td>
<td>CEC</td>
<td>Na</td>
<td>K</td>
<td>Ca</td>
<td>Mg</td>
<td>Al</td>
<td>P</td>
</tr>
<tr>
<td>2</td>
<td>Site 2 0-25</td>
<td>0.02</td>
<td>5.7</td>
<td>4.6</td>
<td>9.5</td>
<td>0.4</td>
<td>0.6</td>
<td>1.5</td>
<td>1.2</td>
<td>1.8</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Site 3 0-20</td>
<td>0.04</td>
<td>5.8</td>
<td>4.6</td>
<td>7.8</td>
<td>0.3</td>
<td>0.7</td>
<td>0.7</td>
<td>2.7</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Site 5 0-25</td>
<td>0.05</td>
<td>6.5</td>
<td>5.3</td>
<td>13.6</td>
<td>0.3</td>
<td>1.5</td>
<td>6.6</td>
<td>2.6</td>
<td>0.4</td>
<td>8</td>
</tr>
</tbody>
</table>
APPENDIX 2   GENERAL ARRANGEMENT OF SEDIMENT BASINS

DIGNAM’S CK UPGRADE PROJECT - PROPOSED LOCATION OF SEDIMENT BASINS

Disclaimer: The plans that follow are concept only and provide a basic indication of the size and location of the required sediment basins. It is up to the Contractor to design and manage the ultimate Erosion and Sediment Controls used on this project.

The use of cover (be it vegetation, mulch, or use of a geofabric or erosion control mating) is going to be critical to controlling the level of sediment generated by the construction. The use of sediment basins as the sole control is not recommended – the sediment basins should be seen as the last line of defence and other erosion controls on slopes and internal drainage paths are required to be installed to ensure that erosion is minimised and therefore the potential for the generation of sediment minimised as well. The ideas presented below have also incorporated the use of diversion banks and reducing the catchment size where ever possible. It is critical to emphasise the site management requirements outlined on page 14 and 15 of the Blue Book Vol 2D, and the note on page 20 of this report.

Table 14 provides the required design volume for each sediment basin site. However, Sediment Basins 10, 11, 12, 14 and 20 have been found to be not possible to build due to the site constraints (steep slopes) outlined in the report on page 14 of this report.

Table 14   Sediment Basin design volumes and volumes achieved on General Arrangement Plans

<table>
<thead>
<tr>
<th>Sediment Basin STAGE 1</th>
<th>Area (ha)</th>
<th>Multiplication factor (m³/ha)</th>
<th>Required Volume m³ (2)</th>
<th>Volumes achieved on digitised drawings (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(B95.45L)’’</td>
<td>0.18</td>
<td>333</td>
<td>619</td>
<td>655</td>
</tr>
<tr>
<td>2(Temporary)</td>
<td>0.09</td>
<td>333</td>
<td>300</td>
<td>327</td>
</tr>
<tr>
<td>3(T)</td>
<td>0.09</td>
<td>333</td>
<td>300</td>
<td>326</td>
</tr>
<tr>
<td>4</td>
<td>0.06</td>
<td>390</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>5(B95.93L)</td>
<td>0.07</td>
<td>390</td>
<td>663</td>
<td>203</td>
</tr>
<tr>
<td>6(T)(B96.45L)</td>
<td>0.10</td>
<td>400</td>
<td>400</td>
<td>535</td>
</tr>
<tr>
<td>7(T)(B96.16R)</td>
<td>0.13</td>
<td>400</td>
<td>190</td>
<td>535</td>
</tr>
<tr>
<td>8(T)(B96.52R)</td>
<td>0.15</td>
<td>400</td>
<td>536</td>
<td>332</td>
</tr>
<tr>
<td>STAGE 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9(T)(B96.70R)</td>
<td>0.20</td>
<td>400</td>
<td>400</td>
<td>457</td>
</tr>
<tr>
<td>10(T)</td>
<td>0.21</td>
<td>400</td>
<td>400</td>
<td>457</td>
</tr>
<tr>
<td>11(T)</td>
<td>0.08</td>
<td>400</td>
<td>224</td>
<td>115</td>
</tr>
<tr>
<td>12(T)</td>
<td>0.10</td>
<td>400</td>
<td>250</td>
<td>130</td>
</tr>
<tr>
<td>13(T)(B97.70L)</td>
<td>0.13</td>
<td>400</td>
<td>260</td>
<td>130</td>
</tr>
<tr>
<td>14(T)</td>
<td>0.09</td>
<td>400</td>
<td>120</td>
<td>130</td>
</tr>
<tr>
<td>15(T)</td>
<td>0.06</td>
<td>400</td>
<td>140</td>
<td>138</td>
</tr>
</tbody>
</table>

Note 1 – The notation in brackets refers to the use of the construction sediment basin as an Operational Water Quality Basin – refer to Upgrade of the Princes Highway – Dignams Creek Operational Water Quality Basins April 2013, SKM.

Note 2 – Some of the sediment basins are smaller than 150m³ due to the small size of the contributing catchment not because the soil loss is less than 150m³/ha.

Note 3 – The volumes achieved on the digitised drawings are the best volumes available after site constraints are taken into account. As a result some volumes are below the required volume and this will mean that site management must emphasise a higher level of erosion control in the catchment areas of the sediment basin so as to minimise the level of sediment generated.
SECTION 1-5
BASIN 4
BED LEVEL RL 6.2
WATER LEVEL RL 7.7
CREST RL 8.5

SECTION 2-5 CAPACITY TABLE

LEGEND

REJECTED (IN 1 CM AS SHOWN)
EST. BATTED IN 1 CM AS SHOWN

PLAN

ROADS AND MARITIME SERVICES
HRV - PRINCES HIGHWAY - DIGNAMS CREEK
CONTOUR PLAN AND PROPOSED HIGHWAY DEVIATION
BASIN 4
PLAN AND SECTIONS

PREPARED BY
ROADS AND MARITIME SERVICES
0 4 8 12 16 20
NSW Soil Conservation Service
MOBILE: 0411 522162
FAX: (02) 9481 4814

A1 ORIGINAL THIS SHEET MAY BE PREPARED USING COLOUR AND MAY BE INCOMPLETE IF COPIED
COORDINATE SYSTEM: MGA ZONE 55
HEIGHT DATUM: A.H.D.

REVIEWED
D. VAN OWEN
D. THOMPSON

ADVANCED NAVIGATION SYSTEMS

FILE No.
DRAWING
RTA PLAN NO.
Printed Date
Sheet No.
DB13_010.Dwg
20/05/2013
005

NO. AMENDMENT DESCRIPTION INITIALS DATE
NOMINAL SCALE RATIO: 1:200 (A1)
NOMINAL SCALE RATIO: 1:125 (A1)

CONTOUR PLAN AND PROPOSED HIGHWAY DEVIATION

CAPACITY TABLE

<table>
<thead>
<tr>
<th>CONTINUOUS LENGTH</th>
<th>AREA</th>
<th>NET</th>
<th>VOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.20</td>
<td>30.50</td>
<td>6.50</td>
<td>6.50</td>
</tr>
<tr>
<td>6.20</td>
<td>15.90</td>
<td>8.90</td>
<td>8.50</td>
</tr>
<tr>
<td>6.50</td>
<td>6.50</td>
<td>8.90</td>
<td>8.50</td>
</tr>
<tr>
<td>6.50</td>
<td>7.70</td>
<td>9.70</td>
<td>9.70</td>
</tr>
<tr>
<td>6.70</td>
<td>7.70</td>
<td>7.70</td>
<td>7.70</td>
</tr>
<tr>
<td>6.60</td>
<td>7.80</td>
<td>7.00</td>
<td>7.00</td>
</tr>
<tr>
<td>6.90</td>
<td>8.20</td>
<td>7.70</td>
<td>7.70</td>
</tr>
<tr>
<td>7.00</td>
<td>8.60</td>
<td>7.60</td>
<td>7.60</td>
</tr>
<tr>
<td>7.20</td>
<td>10.30</td>
<td>9.00</td>
<td>9.00</td>
</tr>
<tr>
<td>7.20</td>
<td>10.30</td>
<td>9.70</td>
<td>9.70</td>
</tr>
<tr>
<td>7.40</td>
<td>12.20</td>
<td>12.50</td>
<td>12.50</td>
</tr>
<tr>
<td>7.40</td>
<td>12.20</td>
<td>12.50</td>
<td>12.50</td>
</tr>
<tr>
<td>7.60</td>
<td>14.60</td>
<td>15.70</td>
<td>15.70</td>
</tr>
<tr>
<td>7.60</td>
<td>14.60</td>
<td>15.70</td>
<td>15.70</td>
</tr>
</tbody>
</table>
SECTION 1-8
BASIN 7
BED LEVEL RL 21.5
WATER LEVEL RL 23.0
CREST LEVEL RL 23.8

CAPACITY TABLE

SECTION 2-8

LEGEND

PLAN

ROADS AND MARITIME SERVICES
HWY - PRINCES HIGHWAY - DIGNAMS CREEK
CONTOUR PLAN AND PROPOSED HIGHWAY DEVIATION
BASIN 7
PLAN AND SECTIONS

PREPARED BY
ROADS AND MARITIME SERVICES
NSW
Soil Conservation
GOVERNMENT

FILE No. DRAWING PRINTED DATE SHEET No.
0 4 8 12 16 20
NSW
Soil Conservation
GOVERNMENT

RTA PLAN NO.
008
SECTION 1-10
BASIN 9
BED LEVEL RL 66.7
WATER LEVEL RL 68.2
CREST LEVEL RL 69.0

SECTION 2-10
CAPACITY TABLE

<table>
<thead>
<tr>
<th>PLAN</th>
<th>LEGEND</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>FILL RATER (7 MM TO 28 MM)</td>
</tr>
<tr>
<td>CTA</td>
<td>CUTTING (13 MM TO 25 MM)</td>
</tr>
<tr>
<td>VAC</td>
<td>VAPE</td>
</tr>
<tr>
<td>SBC</td>
<td>SOCKET BACKfill</td>
</tr>
<tr>
<td>CSM</td>
<td>CURRENT Sketch MAPPING INUse I NAL HIGHWAY DEVIATION</td>
</tr>
</tbody>
</table>

PREPARED BY
ROADS AND MARITIME SERVICES
NOMINAL SCALE RATIO 1:200 (A1)

RTA PLAN NO.
010
## General Sheet

| DATUM 79 | \n|---|---|
| DESIGN | \n| SURFACE HEIGHT | \n| OFFSET | \n| EXISTING SURFACE HEIGHT | \n| OFFSET | \n
| BASIN 10 | \n|---|---|
| BED LEVEL RL 92.0 | \n| WATER LEVEL RL 93.5 | \n| CREST LEVEL RL 94.3 | \n
| DATUM 81 | \n|---|---|
| DESIGN | \n| SURFACE HEIGHT | \n| OFFSET | \n| EXISTING SURFACE HEIGHT | \n| OFFSET | \n
## Section 1-14

**Capacity Table**

<table>
<thead>
<tr>
<th>Contour</th>
<th>Area</th>
<th>Later Vol</th>
<th>Net Vol</th>
</tr>
</thead>
<tbody>
<tr>
<td>91.00</td>
<td>202.12</td>
<td>5.03</td>
<td>4.98</td>
</tr>
<tr>
<td>92.00</td>
<td>203.30</td>
<td>19.06</td>
<td>19.06</td>
</tr>
<tr>
<td>93.00</td>
<td>204.58</td>
<td>32.30</td>
<td>32.30</td>
</tr>
<tr>
<td>94.00</td>
<td>205.86</td>
<td>46.62</td>
<td>46.62</td>
</tr>
<tr>
<td>95.00</td>
<td>207.14</td>
<td>60.94</td>
<td>60.94</td>
</tr>
<tr>
<td>96.00</td>
<td>208.42</td>
<td>75.26</td>
<td>75.26</td>
</tr>
<tr>
<td>97.00</td>
<td>209.70</td>
<td>89.58</td>
<td>89.58</td>
</tr>
<tr>
<td>98.00</td>
<td>210.98</td>
<td>103.90</td>
<td>103.90</td>
</tr>
<tr>
<td>99.00</td>
<td>212.26</td>
<td>118.22</td>
<td>118.22</td>
</tr>
</tbody>
</table>

## Section 2-14
### Basin 12

**Bed Level RL**: 117.0

**Water Level RL**: 118.5

**Crest Level RL**: 119.3

### Capacity Table

<table>
<thead>
<tr>
<th>Contour</th>
<th>Area</th>
<th>Layer Vol</th>
<th>Ht Vol</th>
</tr>
</thead>
<tbody>
<tr>
<td>177.00</td>
<td>38.75</td>
<td>9.54</td>
<td>2.30</td>
</tr>
<tr>
<td>177.50</td>
<td>33.05</td>
<td>9.43</td>
<td>2.29</td>
</tr>
<tr>
<td>178.00</td>
<td>25.00</td>
<td>5.46</td>
<td>2.16</td>
</tr>
<tr>
<td>178.50</td>
<td>25.00</td>
<td>5.46</td>
<td>2.16</td>
</tr>
<tr>
<td>179.00</td>
<td>25.00</td>
<td>5.46</td>
<td>2.16</td>
</tr>
<tr>
<td>179.50</td>
<td>25.00</td>
<td>5.46</td>
<td>2.16</td>
</tr>
</tbody>
</table>

### Legend

- **Sol Survey**: Unstabilised Sol
- **Silt/sand**: Unstabilised Silt/Sand
- **Surf/Gravel**: Surfaced/Gravelled
- **Segmen. Main Agricat.**: Segment Main Agricat.
- **Segmen. Main Agricat. Silt/Sand Mbldg**: Segment Main Agricat Silt/Sand Mbldg

---

**Design by**: Roads and Maritime Services

**Prepared by**: Mobile: 0411 522162

**Fax**: (02) 9481 4814

---

**Roads and Maritime Services**

HR1 - PRINCES HIGHWAY - DIGNAMS CREEK

CONTOUR PLAN AND PROPOSED HIGHWAY DEVIATION

BASIN 12

PLAN AND SECTIONS

FILE No.: D813_010

DRAWING PRINTED DATE SHEET No.: 013

RTA PLAN NO. 013