Nebraska Estate, St Georges Basin

Integrated Water Cycle Assessment

Project No.: 1619
Date: March 2017

Prepared for: Shoalhaven City Council

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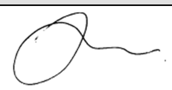
Document and Distribution Status									
Author(s)			Reviewer(s)			Signatures			
Stephanie Noble/Ashley Bond			Ashley Bond						
Revision No.	Status	Release Date	Document Distribution						
			Eric Hollinger						
1	DRAFT	06/01/17	PDF						
2	FINAL	02/03/17	PDF						

Distribution Types: F = Fax, H = Hard Copy, P = PDF, E = Other Electronic Document. Digits indicate number of copies.

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EXECUTIVE SUMMARY

The Nebraska Estate Planning Proposal was submitted to the NSW Department of Planning and Environment (DPE) in late 2014. The Planning Proposal seeks to eventually amend SLEP 2014 to rezone the land in conjunction with a reduction in the minimum lot size requirement where housing is proposed to be allowed, albeit with a reduction in the overall number of allotments due to constraints including bush fire, ecology and flooding.

Legislative planning controls and policies applying to development of the subject site all have similar objectives with regard to ensuring stormwater runoff resulting from development has no net impact on the receiving environment. These objectives are similar to the Neutral of Beneficial Effect (NORBE) approach that applies to new development in the Sydney Water Catchment (SEPP 58) and therefore this approach has been adopted to assess impacts for the redevelopment of Nebraska Estate.

Shoalhaven Council has prepared a Planning Proposal which considers the site constraints as required under the NSW planning framework. As a result some land which currently has a forest land use will be cleared for residential development. This proposed increase in development density could, if left unmanaged, lead to a decline in the health of the receiving waters downstream of the site. The main purpose of this report is to determine the impact on water quality and quantity and development a treatment strategy to prevent this from occurring.

In order to assess the impact of the development on water quality comprehensive computer modelling was undertaken using MUSIC in order to estimate how the proposed changes in land use together with any treatment measures used to mitigate impacts associated with the development proposal will affect water quality and quantity.

In addition to a predevelopment model which provided present day baseline results, two post development scenarios were modelled as follows;

- Unsealed Roads – a combination of unsealed and sealed roads with the extent of sealed roads adopted from the concept subdivision and development plan shown in the concept subdivision and development plan prepared by Council as part of the Planning Proposal.
- Sealed Roads – sealing of all proposed roads within the estate.

Both of the above scenarios were also assessed with and without roadside treatment.

The MUSIC model was configured to enable water quality impacts to be considered separately for the roads and the allotments as well as for the Estate as a whole.

Stormwater treatment measures to be employed on the site consist of roadside bio-retention swales for the treatment of road runoff and rainwater tanks and infiltration trenches for the treatment of roof runoff.

The results of the pre and post development modelling are summarised in Table 1 and show that;

i. The combination of change in land use within the lots and improvements in the road network alone (i.e. without treatment) is expected to significantly improve current TSS loads (by up to 48%), however the change in land use and increase in effective impervious area both on the lots and within the road corridors is expected to result in an increase in nutrient loads (by up to 17%).

ii. For both the unsealed and sealed roads scenarios with roadside treatment the proposed stormwater treatment train is predicted to result in a marked improvement in water quality when compared to the current situation.

iii. When roadside treatment is included very similar improvements in water quality are expected compared to the current situation regardless of whether roads are to be unsealed or sealed. Sealed roads expected to result in a change of plus or minus 2% in pollutant loads compared to unsealed roads.

Table 1 - Comparison of Results

Parameter	Pre-Development Load	Without Roadside Treatment				With Roadside Treatment			
		Unsealed Roads		Sealed Roads		Unsealed Roads		Sealed Roads	
		Load	%	Load	%	Load	%	Load	%
Flow (ML/yr)	103	108	-5	110	-7	100	3	102	1
TSS (kg/yr)	21,000	15,500	26	10,800	48	4,600	78	4,400	79
TP (kg/yr)	19.2	21.1	-10	22.2	-16	12.4	35	12.8	33
TN (kg/yr)	148	171	-15	174	-17	133	10	133	10

% = percentage reduction in mean annual flow/load from the predevelopment state. Where expressed as a negative it indicates an increase in mean annual flow/load.

The modelling also demonstrated that the existing flow regime for each of the post development scenarios was very similar to the current situation, with sealed roads producing marginally more runoff than the predevelopment model.

Modelling of lot based controls, consisting of a rainwater tanks and infiltration trench, was also undertaken to develop site controls for each lot. Minimum sizes for trenches have been recommended and are based on the need to maintain existing hydrological regimes.

The results of the lot scale water quality modelling are shown in Table 2.

Table 2 - Lot Scale Water Quality Modelling Results

Parameter	Predevelopment (rural residential)	Post Development (rural residential)
Flow (ML/yr)	0.097	0.092
Total Suspended Solids (kg/yr)	10.5	1.9
Total Phosphorus (kg/yr)	0.024	0.013
Total Nitrogen (kg/yr)	0.20	0.20

Controls and performance standards have been recommended, at both allotment and subdivision scale, in order to mitigate any potential adverse environmental impacts resulting from the redevelopment as well as to ensure that the development is controlled and managed in a practical manner. Recommended lot based controls include rainwater tanks and infiltration trenches. At subdivision scale, grassed roadside bio-retention swales are recommended.

The report demonstrates that the proposed rezoning and development of Nebraska Estate can achieve a long term beneficial effect on water quality, water quantity and the receiving environment subject to implementation of the recommended controls and performance standards outlined in the report.

Further the modelling undertaken demonstrates that there is very little difference in net pollutant loads between sealed and unsealed roads if coupled with bio-retention swales. Sealing of the public road network is therefore not considered necessary from a water quality perspective. However, sealing of the roads will significantly reduce the sediment loads on the bio-retention swales and thus maintenance burdens.

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd (*Footprint*) has been engaged by Shoalhaven City Council to prepare an Integrated Water Cycle and Stormwater Management Plan for the subject site in order to:

i. assess any downstream impacts associated with the proposed redevelopment of the subject site;
ii. incorporate water sensitive urban design (WSUD) principles into the proposal to ensure the downstream environment is protected.

1.1. Scope of Work

The scope of works associated with preparation of the Integrated Water Cycle and Stormwater Management Plan was identified in the consultants brief and is included below;

1) Identify and collect any necessary field information, soil testing etc.
2) Undertake modelling using MUSIC V.5 or similar, and use available soil and water quality information, digital elevation data.
3) Model the predicted surface water hydrology and water quality (TSS, TP & TN) from the subject land with the aid of the available soil, water quality and other relevant site specific information for;
    a) current condition ('pre-development').
    b) post development, without stormwater treatment.
    c) post development, with stormwater treatment.
4) Prepare a conceptual stormwater management plan that:
    a) Protects the environmental values of the proposed E2 – Environmental Conservation areas; and
    b) protects water quality within the receiving body.
5) Specify the design flows (ARI) to be adopted for the proposed stormwater treatment measures based on the modelling results and analysis.
6) Provide advice on the location of any 'pit and pipe' measures considered necessary to safely convey stormwater.
7) Provide a preliminary life cycle cost assessment for the recommended stormwater treatment measures to be provided on Council land.
8) Prepare a soil and water management plan that provides management strategies for the 1) construction of subdivision infrastructure and 2) development of individual lots. Appropriate strategies should be addressed such as;
    a) minimising the extent of soil disturbance and prevent soil erosion;
    b) controlling stormwater runoff and sedimentation using appropriate measures for the site;

c) stabilising disturbed areas, and;

d) inspection and maintenance.

9) Identify controls and performance standards (at both subdivision and allotment scales) that are consistent with the objectives of the Planning Proposal. These will be included in a site-specific development control plan (DCP) chapter for the subject land. (The DCP Chapter will be prepared in conjunction with the Planning Proposal). In respect of the individual lots, a template Erosion and Sediment Control Plan specific to Nebraska Estate is required.

2.0 SITE DESCRIPTION

2.1. Location of Subject Site

Nebraska Estate is located approximately 24km south of Nowra and 2km east of St Georges Basin, adjacent to the intersection of Grange Road and The Wool Road as shown in Figure 1.

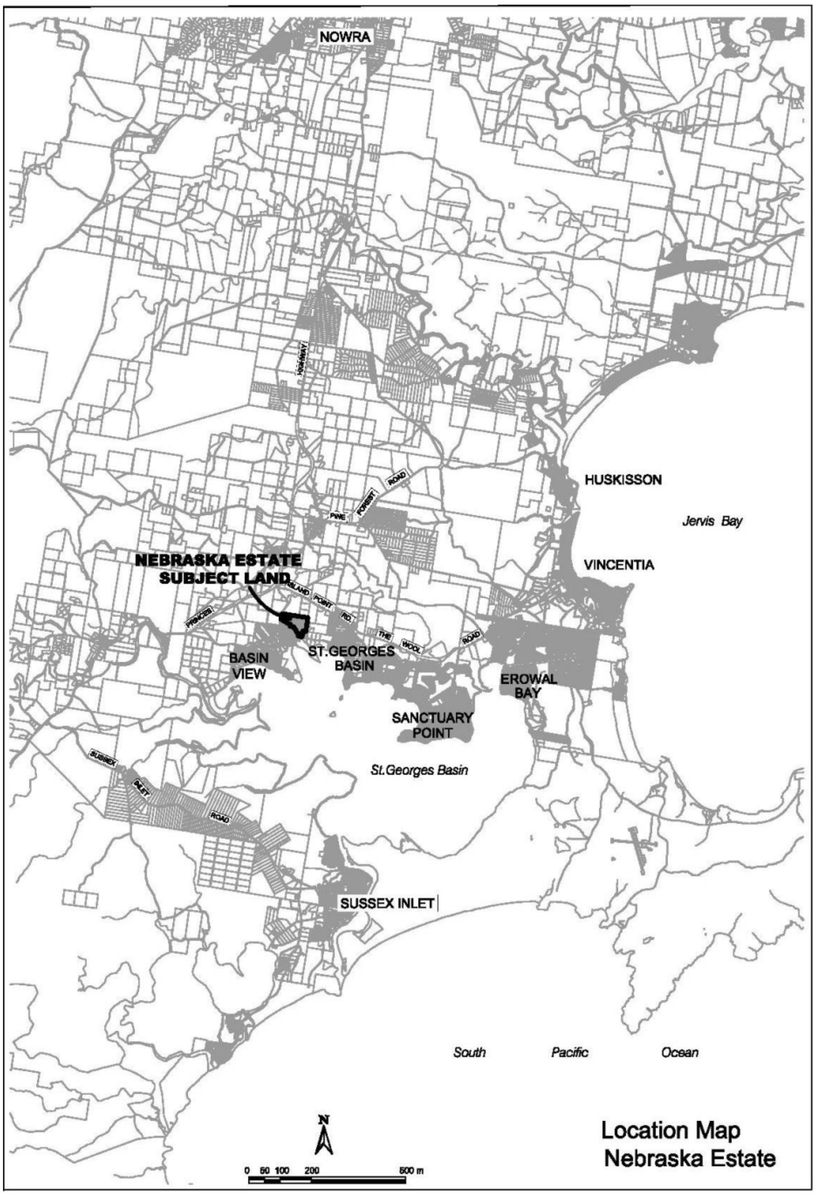

Figure 1 - Location of Subject Land (source SCC Planning Proposal)

2.2. Background

The Nebraska Estate subdivision was registered in 1919. Apart from the southern fringe of the estate where some development has occurred, the land remained undeveloped when land use zoning was introduced in 1964. At that time most of the estate was zoned 'non-urban' generally precluding development of the individual lots due to their size.

In 1992 Council resolved to prepare a draft local environmental plan over that part of the estate that was zoned rural, for the purpose of allowing low density residential development. In 1994 Council resolved to deal separately with lots located along Park Road due to this area being less constrained than the remainder of the estate.

Rezoning investigations for the remainder to the estate where suspended in 1999, pending completion of the Jervis Bay Settlement Strategy (JBSS). Council recommenced a thorough investigation of the constraints and land capability in 2006, which showed that substantial areas of the subject land where affected by one or more significant constraints including flooding, acid sulphate soils, threatened biodiversity, bushfire and Aboriginal archaeology.

The Nebraska Estate Planning Proposal aims to create a total of 23 new residential allotments located in three separate sectors across three separate zoning areas (R5 – large lot residential, E2 – Environmental Conservation and E4 – Environmental Living). The land that is unsuitable for development is proposed to be zoned E2. Reticulated sewer (low pressure) and water is proposed to be provided to all sectors.

The subject land has been disturbed to varying degrees and some lots have been under-scrubbed or totally cleared. The vegetation was significantly disturbed in the 1970s and much of the existing understorey vegetation is advanced regrowth. There are three existing approved dwellings and an approved shed along with several unauthorised structures that will need to either be regularised or removed.

Road reserves currently comprise a mix of maintained gravel pavements, unmaintained vehicle tracks and bushland. It is proposed to upgrade the existing roads, some of which are unmaintained and construct rights of way and a perimeter fire trail to provide the necessary access and bush fire protection to each allotment.

This proposed increase in development density could, if left unmanaged, lead to a decline in the health of the receiving waters downstream of the site. The main purpose of this report is to determine the impact on water quality and quantity and development a treatment strategy to prevent this from occurring.

A Land Capability Assessment undertaken by Morse McVey and Associates in 1994 identified that soils on the site had high erodibility and where moderately dispersive which is a good indication of the high potential of the soils on this site to suffer from erosion and is an issue which will need to be carefully managed into the future.

Figure 2 - Boundary of Subject Land (source SCC Planning Proposal)

2.3. Catchment and Topography Description

The subject land is characterised by undulating slopes and three broad drainage depressions, draining to St Georges Basin at Home Bay via three unnamed watercourses, as shown in Figure 3. The total catchment area to St Georges Basin is approximately 284 ha, with the subject site being 32.77 ha, or 11.5% of the total catchment area.

The south western and south eastern edge of the site are bounded by unnamed water courses, with the third water course running through the centre from north east to south west. The entire site thus comprises of four main sub-catchments separated by one ridge orientated north to south, and another orientated north east to south west.

The land is generally gently inclined with slope ranges of between 0-5˚ and elevations on ranging between 2 and 22 metres AHD.

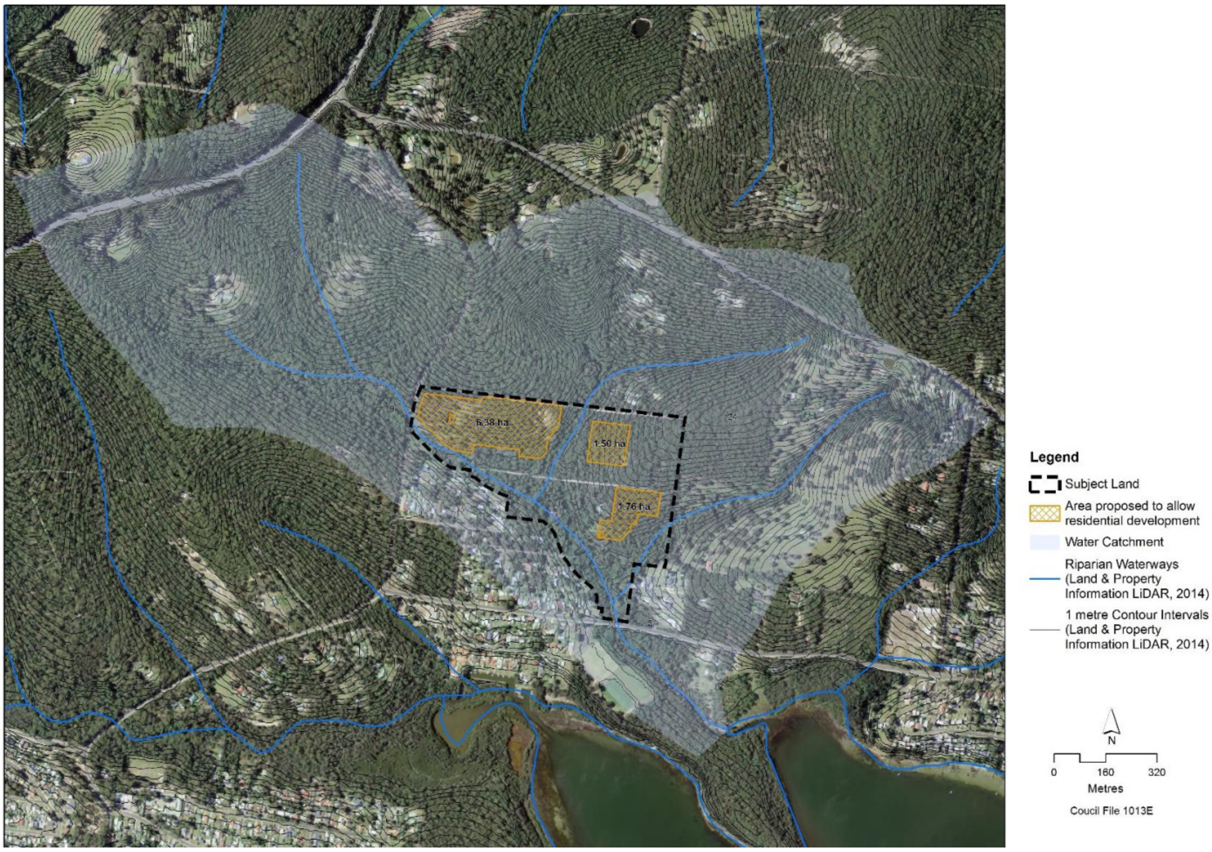

Figure 3 - Location of Subject Land within the wider catchment (source SCC Project Brief)

2.4. Flooding

The modelled extent of stormwater inundation in Nebraska Estate is shown in Figure 4, This figure displays the results from several flood studies:

- 'St Georges Basin Flood Study', Webb, McKeown and Associates P/L, 2001
- 'St Georges Basin Floodplain Risk Management Study and Plan Climate Change Assessment', WMA Water 2013
- A site specific draft preliminary catchment analysis prepared from airborne laser scanning (ALS) survey over Nebraska Estate by Shoalhaven City Council, 2006.

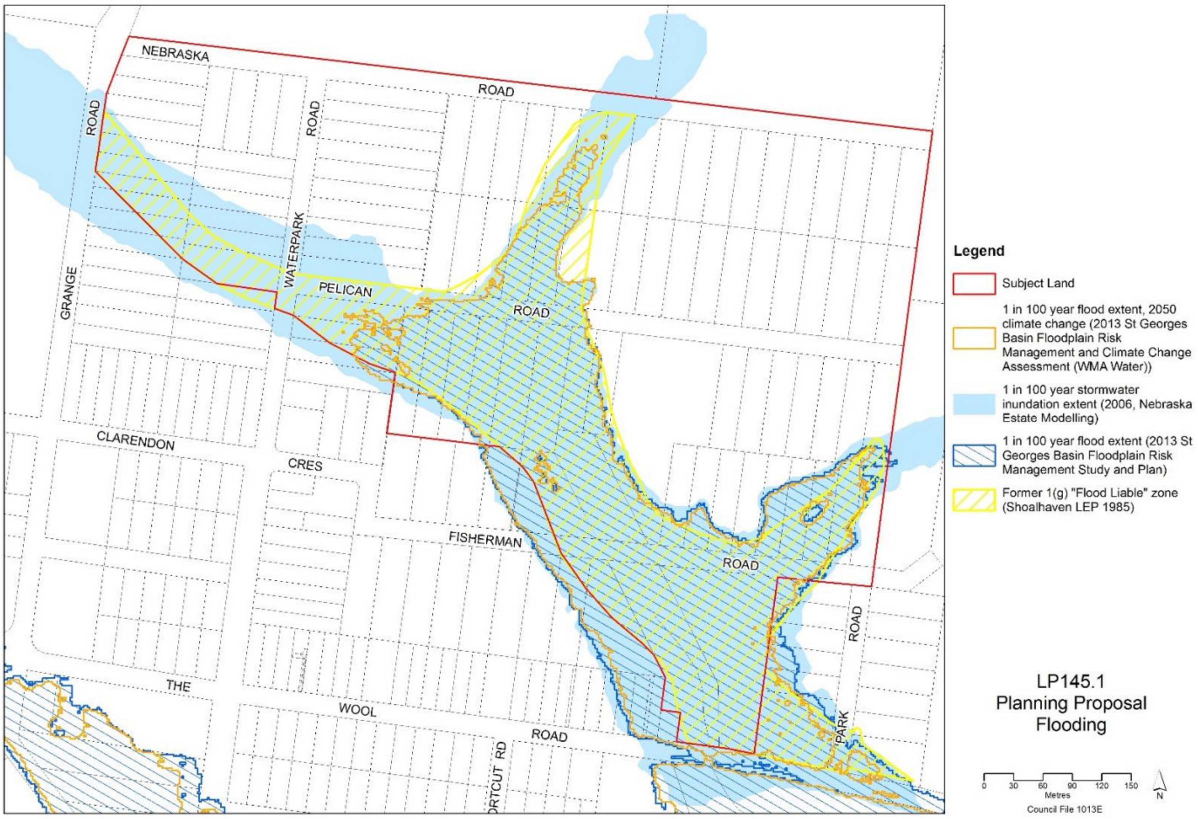

Figure 4 – Flood-related information (source SCC Project Brief)

2.5. Soils and Geology

The geology of the area is dominated by Shoalhaven Group (Permian sedimentary formations) with the exception of Quaternary alluvial deposits in lower areas and creek lines.

The Land Capability Assessment conducted by Morse McVey & Associates Pty Ltd in 1994 identified two soil landscapes:

- Wandrawandian – occurs on crests and side slopes. Duplex (textural contrast) soils (typically clay loam topsoil over light-medium clay subsoil). Topsoil limitations include high erodibility, low fertility and strong acidity. Subsoil limitations include moderate to high erodibility, low fertility, strong acidity, potential aluminium toxicity and poor drainage.
- Tomerong Creek soil landscape – occurs on the lower lying land associated with the un-named watercourses. Characterised by low slopes (<5%) and high clay and silt content with high reactivity (large shrink-swell characteristics), low fertility, strong acidity, and potential aluminium toxicity.

Significant soil constraints were identified and include:

- High soil erodibility (values of 0.026 and 0.046 used in the universal soil loss equation – USLE), and;

- Moderately dispersive subsoil, meaning that the clay particles can be more readily eroded and transported to the downstream environment. As noted in the report, the risk to water quality can be minimised through best practice design, construction and management techniques.

Acid Sulfate Soils

The lower reaches of the flood prone land were identified by the Huskisson Acid Sulfate Soils Risk map as having a high probability of Acid Sulfate Soils (ASS) occurring within one metre of the ground surface. This land is identified as 'Class 2' on the Acid Sulfate Soils map that forms part of Shoalhaven LEP 2014, to which clause 7.1 applies.

The affected area is encompassed within the area that is proposed to be zoned E2 – Environmental Conservation, where no additional residential development is proposed. Appropriate investigations, including preparation of an ASS management plan, would be required to be undertaken prior to commencing any works associated with upgrading of Fisherman Road or excavation for the purpose of providing water or sewerage services.

In 2001, Environmental and Earth Sciences P/L undertook an ASS investigation along the path of the proposed sewerage line for Park Road, Nebraska Estate. This investigation involved soil and groundwater testing at the southern end of the subject land. The results of the investigation are summarised below:

- There was negligible PASS. A borehole within the main watercourse contained low concentrations of soil sulphides but these were considered non-reactive.
- As a cautionary measure, it was recommended that any soil excavated from the watercourse, should be mixed with 4 kg of lime per ton of soil.
- Groundwater should be monitored if dewatering is undertaken for periods exceeding one week.
- Any concrete or metallic structures placed between the banks of the watercourse should have a buffer of at least 150 mm of sand mixed with lime at a ratio of 5 kg per ton of sand.

2.6. Flora and Fauna

The subject site is home to a number of endangered, threatened or protected plant species. Swamp Sclerophyll Forest, is categorised as an endangered ecological community (EEC) under the NSW Threatened Species Conservation Act (BES, 2009). This EEC broadly corresponds to the flood prone land area, which also contains a population of protected Biconvex Paperbark (Melaleuca biconvexa). The north east corner of the subject land also contains a large number of threatened orchid species, one of which (Pterostylis ventricosa) was actually discovered in Nebraska Estate in 2000.

2.7. Aboriginal Cultural Heritage

Archaeological studies were undertaken in Nebraska Estate in 1994, 1995 and 2001. The first of these identified two small scatters of stone artefacts and one isolated artefact within the drainage lines. All three Aboriginal sites are located within the proposed E2 zone and no further residential development is proposed on the affected land. Some ground disturbance will be necessary for the construction of infrastructure and if these works uncover any additional artefacts the necessary requirements will be undertaken in order to comply with the NSW National Parks and Wildlife Act and regulations.

2.8. Existing Development

Three approved dwellings and an approved shed are currently present on the subject site along with several unauthorised structures on approximately 6 lots as shown in Figure 6.

Existing road reserves within the estate currently comprise a mix of maintained gravel pavements, unmaintained vehicle tracks and bushland. Despite signage indicating that roads within the estate are not regularly inspected or maintained by Council the existing formed gravel roads within the estate are generally well constructed with only a few signs of surface erosion in isolated locations. It is understood however that the western half of Pelican Road was recently reconstructed by Council following significant erosion resulting from high velocity flood water flowing down the road.

Plates 1 to 8 demonstrate the current condition of roads and vehicle tracks within the estate.

Plate 1: Waterpark Road (looking north from Pelican Road intersection)

Plate 2: Table Drain Erosion – Water Park Road

 Plate 3: Nebraska Road (western end looking east)	 Plate 4: Nebraska Road (eastern end looking east)
 Plate 5: Informal vehicle track between Nebraska Road and Pelican Road	 Plate 6: Pelican Road (eastern end looking west)
 Plate 7: Pelican Road (western end looking east)	 Plate 8: Fisherman Road (looking east)

3.0 PLANNING PROPOSAL

The Nebraska Estate Planning Proposal was submitted to the NSW Department of Planning and Environment (DPE) in late 2014. Key elements of the Planning Proposal included the proposed zoning and lot size maps.

The Planning Proposal included one lower density option and two variations of the higher density residential subdivision option for the north western sector. Conceptual subdivision and development maps providing an indication of how the land could be developed under each zoning option. In each option the Planning Proposal proposes four (4) low impact dwellings in both the eastern sector and the north eastern sector to protect sensitive environmental values in these locations.

As a result of community consultation the low density option (Option 1) from the Planning Proposal was adopted and amended slightly to reflect feedback received during the consultation process. The Zoning and Conceptual Subdivision and Development plans adopted following the consultation process are shown in Figure 5 and Figure 6 respectively.

Within all sectors reticulated water and pressure sewer is proposed, with the latter minimising the risk to downstream water quality.

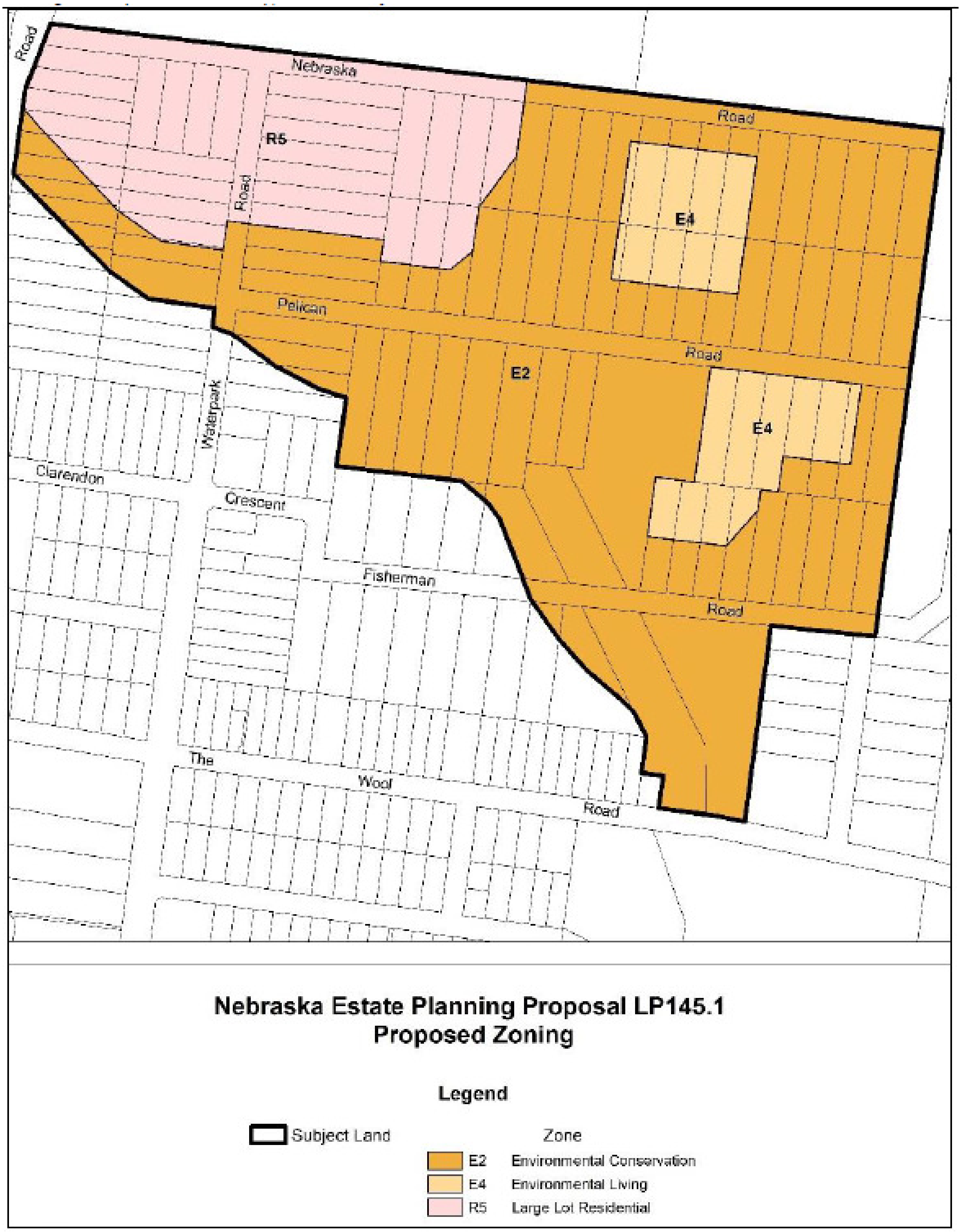

Figure 5 - Planning Proposal Zoning (Source SCC Project Brief)

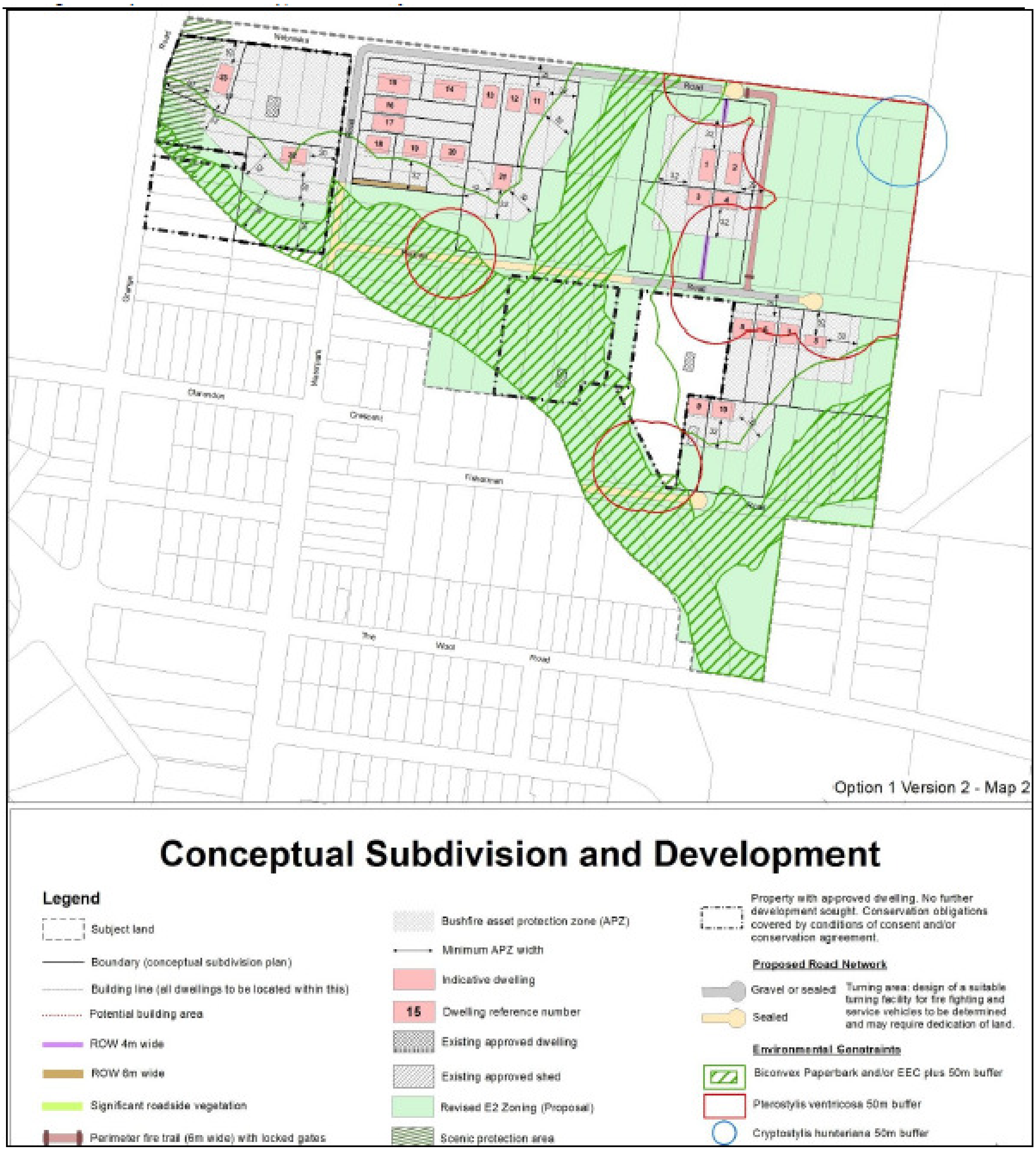

Figure 6 – Concept Subdivision and Development Plan (source SCC Project Brief)

4.0 LEGISLATIVE AND POLICY FRAMEWORK

The following plans and policies set the legislative framework for the subject site with regard to the management and disposal of stormwater from development sites.

4.1. Shoalhaven Local Environment Plan 2014 (SLEP 2014)

Under Shoalhaven Local Environmental Plan (LEP) 2014, the subject land is zoned RU2 - Rural Landscape. The minimum lot size required for dwellings is 40 ha effectively preventing development of the individual lots.

Clause 7.1 of the Shoalhaven Local Environmental Plan 2014 (SLEP 2014) relates to acid sulphate soils.

7.1 Acid Sulfate Soils

(1) The objective of this clause is to ensure that development does not disturb, expose or drain acid sulfate soils and cause environmental damage.

(2) Development consent is required for the carrying out of works described in the Table to this subclause on land shown on the Acid Sulfate Soils Map as being of the class specified for those works.

Class of land	Works
1	Any works.
2	Works below the natural ground surface. Works by which the watertable is likely to be lowered.
3	Works more than 1 metre below the natural ground surface. Works by which the watertable is likely to be lowered more than 1 metre below the natural ground surface.
4	Works more than 2 metres below the natural ground surface. Works by which the watertable is likely to be lowered more than 2 metres below the natural ground surface.
5	Works within 500 metres of adjacent Class 1, 2, 3 or 4 land that is below 5 metres Australian Height Datum and by which the watertable is likely to be lowered below 1 metre Australian Height Datum on adjacent Class 1, 2, 3 or 4 land.

(3) Development consent must not be granted under this clause for the carrying out of works unless an acid sulfate soils management plan has been prepared for the proposed works in accordance with the Acid Sulfate Soils Manual and has been provided to the consent authority.

(4) Despite subclause (2), development consent is not required under this clause for the carrying out of works if:

(a) a preliminary assessment of the proposed works prepared in accordance with the Acid Sulfate Soils Manual indicates that an acid sulfate soils management plan is not required for the works, and
(b) the preliminary assessment has been provided to the consent authority and the consent authority has confirmed the assessment by notice in writing to the person proposing to carry out the works.

(5) Despite subclause (2), development consent is not required under this clause for the carrying out of any of the following works by a public authority (including ancillary work such as excavation, construction of access ways or the supply of power):

(a) emergency work, being the repair or replacement of the works of the public authority, required to be carried out urgently because the works have been damaged, have ceased to function or pose a risk to the environment or to public health and safety,
(b) routine maintenance work, being the periodic inspection, cleaning, repair or replacement of the works of the public authority (other than work that involves the disturbance of more than 1 tonne of soil),
(c) minor work, being work that costs less than $20,000 (other than drainage work).

(6) Despite subclause (2), development consent is not required under this clause to carry out any works if:

(a) the works involve the disturbance of less than 1 tonne of soil, and
(b) the works are not likely to lower the watertable.

Most of the subject land is mapped as 'Class 5' land apart from an area of 'Class 2' land that occurs within the lower part of the main watercourse (and which is also identified as flood liable). Clause 7.1 may be triggered within the Class 2 land, and potentially adjacent land that is less than 5m AHD. This may be relevant in respect of infrastructure construction at Fisherman Road, and the low-lying section of Pelican Road

Clause 7.6 of the Shoalhaven Local Environmental Plan 2014 (SLEP 2014) relate to water quality and riparian land management.

Clause 7.6 – Riparian land and watercourses

The objective of this clause is to protect and maintain the following:

(a) water quality within watercourses,

(b) the stability of the bed and banks of watercourses,

(c) aquatic and riparian habitats,

(d) ecological processes within watercourses and riparian areas.

(2) This clause applies to all of the following:

(a) land identified as "Riparian Land" on the Riparian Lands and Watercourses Map,

(b) land identified as "Watercourse Category 1", "Watercourse Category 2" or "Watercourse Category 3" on that map,

(c) all land that is within 50 metres of the top of the bank of each watercourse on land identified as "Watercourse Category 1", "Watercourse Category 2" or "Watercourse Category 3" on that map.

(3) Before determining a development application for development on land to which this clause applies, the consent authority must consider:

(a) whether or not the development is likely to have any adverse impact on the following:

(i) the water quality and flows within the watercourse,

(ii) aquatic and riparian species, habitats and ecosystems of the watercourse,

(iii) the stability of the bed and banks of the watercourse,

(iv) the free passage of fish and other aquatic organisms within or along the watercourse,

(v) any future rehabilitation of the watercourse and its riparian areas, and

(b) whether or not the development is likely to increase water extraction from the watercourse, and

(c) any appropriate measures proposed to avoid, minimise or mitigate the impacts of the development.

(4) Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that:

(a) the development is designed, sited and will be managed to avoid any significant adverse environmental impact, or

(b) if that impact cannot be reasonably avoided—the development is designed, sited and will be managed to minimise that impact, or

(c) if that impact cannot be minimised—the development will be managed to mitigate that impact.

(5) For the purpose of this clause:

bank means the limit of the bed of a watercourse.

bed, of a watercourse, means the whole of the soil of the channel in which the watercourse flows, including the portion that is alternatively covered and left bare with an increase or diminution in the supply of water and that is adequate to contain the watercourse at its average or mean stage without reference to extraordinary freshets in the time of flood or to extreme droughts.

4.2. Jervis Bay Settlement Strategy

The Jervis Bay Settlement Strategy (JBSS) 2003 identifies the Nebraska Estate as an opportunity for rural residential settlement, and states that:

'The development potential for rural residential development will be investigated through a review of lot sizes and configuration in order to accommodate on site effluent management and meet the guiding principles and policy actions of this Strategy'

Section 9.1 of the JBSS addresses water quality and flow. The object of this section is "*to ensure that the water quality and flow of waterways and their aquatic, marine and estuarine ecosystems is not detrimentally affected as a result of new settlement in the region.*"

Actions of Section 9.1 include:

i. All development will meet the statutory requirements of the Jervis Bay Regional Environmental Plan 1996 in respect of clause 11 – Catchment Protection.
ii. New development will be located and designed so as to avoid detrimental impacts on waterbodies and watercourses, including groundwater. Where there are manageable impacts, erosion and sediment control measures and means to mitigate nutrient and other pollutants should be provided on the development site and be excluded from areas set aside for the protection of natural or cultural attributes (eg riparian areas, habitat corridors, Aboriginal places/sites and so on).
iii. New development will be designed so that domestic effluent management does not have a detrimental impact on water quality and flow, meets the Interim Environmental Objectives for the Jervis Bay Catchment (EPA, 1999, and is consistent with the relevant State government guidelines.
iv. New development, including infrastructure (e.g. stormwater controls), will be located, designed and constructed in a manner that does not degrade land based or aquatic ecosystems or processes.
v. Infrastructure works will not have a detrimental impact on the water quality of receiving waters in the region. In order to achieve this outcome, best practice soil and water management will be implemented when constructing various infrastructure, and the number of artificial barriers to flow and impediments to movements of aquatic biota will be minimised.

Section 9.9 of the JBSS addresses urban stormwater management. The objective of this section is "*to ensure the protection of life and property and water quality, by providing best practice stormwater management in new and existing development in the region*"

Actions of Section 9.9 include:

i. A hierarchy of sizes and types of stormwater infrastructure will be provided. This infrastructure should, as far as practicable, be contained within the developable area and excluded from areas set aside for protection of the environmental and cultural attributes (eg. riparian areas, habitat corridors etc).
ii. Stormwater infrastructure associated with new development in the region should be designed and constructed in a manner that does not degrade existing natural land-based or aquatic ecosystems or processes. Wherever possible, stormwater should be treated as close to the source as possible prior to any proposed discharges to natural systems.
iii. Monitoring programs to investigate and assess the effectiveness of stormwater controls will be considered and, where appropriate, implemented in association the new development in the region. A community education campaign targeted at improving attitudes and practices in relation to stormwater will also be developed and implemented as per the Shoalhaven Urban Stormwater Management Plan.
iv. The provisions of the Shoalhaven Urban Stormwater Management Plan will be incorporated into relevant planning instruments, works and development processes.

4.3. Illawarra-Shoalhaven Regional Plan

The Illawarra-Shoalhaven Regional Strategy (ISRS) lists St Georges Basin as a sensitive estuary and the NSW Government, through the ISRS, is committed to protecting sensitive estuaries from inappropriate development that affects water quality and ecological function (Action 5.4.1).

4.4. Shoalhaven Development Control Plan 2014

Chapter G2 of the Shoalhaven DCP 2014 relates to sustainable stormwater management and erosion and sediment control.

The objectives of this Chapter are to:

i. Manage stormwater flow paths and systems to ensure the safety of people and property.
ii. Protect and enhance natural watercourses and their associated ecosystems and ecological processes.
iii. Maintain, protect and/or rehabilitate modified watercourses and their associated ecosystems and ecological processes towards a natural state.
iv. Mitigate the impacts of development on water quality and quantity.
v. Encourage the reuse of stormwater.
vi. Integrate water cycle management measures into the landscape and urban design to maximise amenity.
vii. Minimise soil erosion and sedimentation resulting from site disturbing activities.
viii. Minimise the potential impacts of development and other associated activities on the aesthetic, recreational and ecological values of receiving water.
ix. Ensure the principles of ecologically sustainable development are applied in consideration of economic, social and environmental values in water cycle management.
x. Ensure stormwater systems and infrastructure are designed, installed and maintained so as not to increase the risk to life or safety or people.
xi. Provide Green and Golden Bell Frog (GGBF) friendly stormwater detention ponds in areas where GGBF are present.

In relation to stormwater quality the DCP nominates the following post development average annual load reductions.

Pollutant	Post Development Average Annual Load Reduction
Gross Pollutants (GP)	90%
Total Suspended Solids (TSS)	85%
Total Phosphorous (TP)	65%
Total Nitrogen (TN)	45%
Total Hydrocarbons	90%

A site specific chapter will be prepared for Nebraska Estate and will include stormwater management provisions derived from this report.

4.5. Summary

The above plans and policies all have similar requirements to ensure that stormwater runoff from development has no net impact on the environment and these requirements can be summarised as follows;

i. maintain or improve water quality
ii. maintain the natural flow regime.

The above objectives are similar to the "Neutral or Beneficial Effect" (NORBE) approach that applies to new development in the Sydney Water Catchments (SEPP 58) – in other words the proposed development must achieve a neutral or beneficial effect on receiving waters.

An overview of this approach is provided in Section 5.0.

5.0 OVERVIEW OF WSUD AND RECOMMENDED TREATMENT MEASURES

5.1. The Water Sensitive Urban Design (WSUD) Philosophy

WSUD is an holistic approach to the planning and design of urban development that aims to minimise the negative impacts on the natural water cycle and protect the health of aquatic ecosystems. It promotes the integration of stormwater, water supply and sewage management at the development scale. It represents a fundamental change in the way urban development is conceived, planned, designed and built. Rather than using traditional approaches to impose a single form of urban development across all locations, WSUD considers ways in which urban infrastructure and the built form can be integrated with a site's natural features. In addition, WSUD seeks to optimise the use of water as a resource.

One of the major benefits of implementing WSUD is that it enables the management of not only water quality, but of the hydrology of the catchment in which it is applied. Typically when urban development occurs in an area that was previously dominated by vegetation, increases in both hard surfaces, and the efficiency of the drainage system are usually a result. This leads to not only increased flows, but also for more rapid delivery of those flows and the associated pollutants into the receiving environment. The WSUD approach seeks to sever the connection between the hard surfaces and the drainage system, leading to both a reduction in flow volumes through increased infiltration and/or retention, and also a slowing down of water travelling to the drainage system. This in turn results in a reduction of flow velocities and provides opportunities for settlement and biological removal of pollutants.

The key principles of WSUD are to:

- Protect existing natural hydrological and ecological processes.
- Maintain the natural hydrological behaviour of catchments.
- Protect water quality of surface and ground waters.
- Minimise the demand on the reticulated water supply system.
- Minimise sewerage discharges to the natural environment.
- Integrate water into the landscape to enhance visual, social, cultural and ecological values.

In a rural residential context , development is not normally connected to a formal drainage system and traditional approaches typically incorporate the use of infiltration trenches to accept overflows from rainwater tanks and the use of roadside swales (in the absence of pits and pipes). Thus it is arguable that WSUD is an extension of good rural practice into an urban context.

5.2. Overview of Recommended Treatment Measures

The following treatment measures have been recommended for implementation as part of the development of Nebraska Estate. Their application within the development and further information is contained with Section 6.0.

5.2.1. Bio-retention Swales (Bio-Swales)

Bio-retention swales provide both flow conveyance and storage in the swale and water quality treatment through the bio-retention area in the base of the swale. The bio-retention area provides maximum water quality treatment efficiencies for small to modest flow rates. Limited flow detention capacity may also be provided if the cross section of the swale is large, relative to the flow rate.

Typical bio-retention swales are created with longitudinal slopes between 1% and 4% in order to maintain flow capacity without creating high velocities, potential erosion of the bio-retention or swale surface and safety hazard. Rock check dams can be used in steeper areas to flatten the longitudinal hydraulic grade.

The amount of pollutant removal in a bio-retention swale is dependent on the filter media, landscape planting species and the hydraulic detention time of the system. Pollutant removal is achieved through sedimentation, filtration of water through the filtration media and through biological processes.

5.2.2. Rainwater Tanks

The core WSUD roles of using rainwater tanks are to conserve water through substituting potable water supply, protect urban streams by reducing stormwater runoff volumes (particularly for small, frequent storms) and reducing the loads of some stormwater pollutants entering the waterways by loss of water through consumption.

The consumption of water from rainwater tanks also reduces the hydraulic loading on downstream stormwater treatment devices, potentially making them more efficient. The maximum benefits of rainwater tanks are realised when the collected water is regularly used.

5.2.3. Infiltration Trenches

Stormwater infiltration systems encourage stormwater to infiltrate into surrounding soils. Their performance is dependent on local soil characteristics and they are generally best suited to sandy-loam soils with deep groundwater, though can be successfully implemented on soils of lower permeability and sites with shallower groundwater subject to appropriate design. The soils within Nebraska Estate have relatively low permeability and this was taken into account during the sizing and design of infiltration trenches for this development.

Stormwater infiltration systems can reduce the volume and magnitude of peak discharges from impervious areas, particularly for small storms.

Pre-treatment to remove sediments is a vital component to prevent to prevent the deterioration of infiltration effectiveness over time due to clogging. Rainwater tanks are considered adequate pre-treatment for roof runoff however if the infiltration trench is receiving runoff from ground level hardstand areas then a dedicated pre-treatment device will be required.

6.0 STORMWATER QUALITY MODELLING

6.1. The Neutral or Beneficial Effect Approach

Sydney Catchment Authority (2011) describes a neutral or beneficial effect (NORBE) on water quality being satisfied if a development:

a) has no identifiable potential impact on water quality, or
b) will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or
c) will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.

Further a proposed development (or activity) will be found to have a neutral of beneficial effect on water quality if it complies with and demonstrates one or more of the following;

1. There are no factors involved that have any potential to impact on water quality.

   There will be no changes to site conditions and/or the nature and location of development that could:

   a) directly change pollutant loads by introducing or increasing substances into the water cycle (such as waste flows, increase erosion, nutrient and sediments), or
   b) indirectly change the quality of water in the hydrological system by changing the bio-physical characteristics of the site in any way that reduces, or significantly threatens to reduce, the capacity of the site and related hydrological/ecological components to assimilate, treat and otherwise produce water of at least equal quality to the existing systems. Changes relate to the environmental values of the system, and may include:
      - significant changes to water flows (reductions or increases in flows)
      - clearing or degradation of watercourses or of riparian corridors, or
      - changing the path of water flows through these assimilative systems.
2. The development will not adversely affect water quality off-site because:
   a) Pollutant loads from the development/activity can be transported to acceptable downstream treatment and disposal facilities without adverse off-site water quality impacts, or
   b) Any water quality issues can be effectively managed on-site so that there are no adverse water quality impacts off-site, or
   c) There are no indirect adverse impacts on water quality caused, or likely to be caused, by changes to factors that currently affect water quality off-site such as treatment, assimilation of pollutants, or the hydrological cycle (such as changes in flow or flow paths, water courses or riparian corridors).

6.2. Modelling Approach

In order to determine if the Nebraska Estate development proposal will achieve a neutral or beneficial effect on the receiving waters it is necessary to estimate how the proposed changes in land use together with any treatment measures used to mitigate impacts associated with the development proposal will affect water quality and quantity.

A wide range of stormwater treatment measures are available to improve water quality runoff from new and existing developments. Computer modelling is used to assist in selecting the most effective combination of treatment measures for a given situation.

It then becomes necessary to assess if the proposed land use changes and the beneficial treatment provided by the stormwater treatment measures will lead to a neutral or beneficial effect on water quality. The configuration of a stormwater treatment train and assessment of impacts on hydrology and water quality is complex. The industry has adopted the use of water quality modelling as means of assessing the impact of proposed developments on water quality and quantity and effectiveness of any proposed treatment measures.

The model adopted on this project is MUSIC Version 6 (the Model for Urban Stormwater Improvement Conceptualisation) which has been developed by the Cooperative Research Centre for Catchment Hydrology. MUSIC uses a continuous simulation approach to model water quality and is suitable for simulating catchment areas of up to 100 km^2.

By simulating the performance of stormwater management systems, MUSIC can be used to determine if these proposed systems and changes to land use are appropriate for their catchments and are capable of meeting specified water quality objectives (CRCCH, 2004). The water quality constituents modelled in MUSIC of relevance to this report include Total Suspended Solids, Total Phosphorus and Total Nitrogen (TSS, TP & TN).

MUSIC allows hydrology (hydrographs and cumulative flow) and water quality (TSS, TN and TP loads) to be compared under different land use and stormwater treatment scenarios. It enables decision makers to determine if the proposed development is likely to result in a NORBE.

6.3. Model Inputs

MUSIC simulates catchment processes of rainfall, storage of rainfall in the soil, seepage and evapotranspiration from the soil to emulate the rainfall runoff process. Therefore it is necessary to use appropriate data on rainfall, evapotranspiration and soils before you can simulate the rainfall runoff process with any rigour. Using localised data helps to minimise the assumptions made and maximise rigour and accuracy of the modelling process. The following sections describe the assumptions made and sources of data used to construct the MUSIC models.

6.3.1. Rainfall Data

A total of three pluviograph (rainfall measured every 6 minutes) rainfall data stations exist in the vicinity of the subject site as depicted in Figure 7.

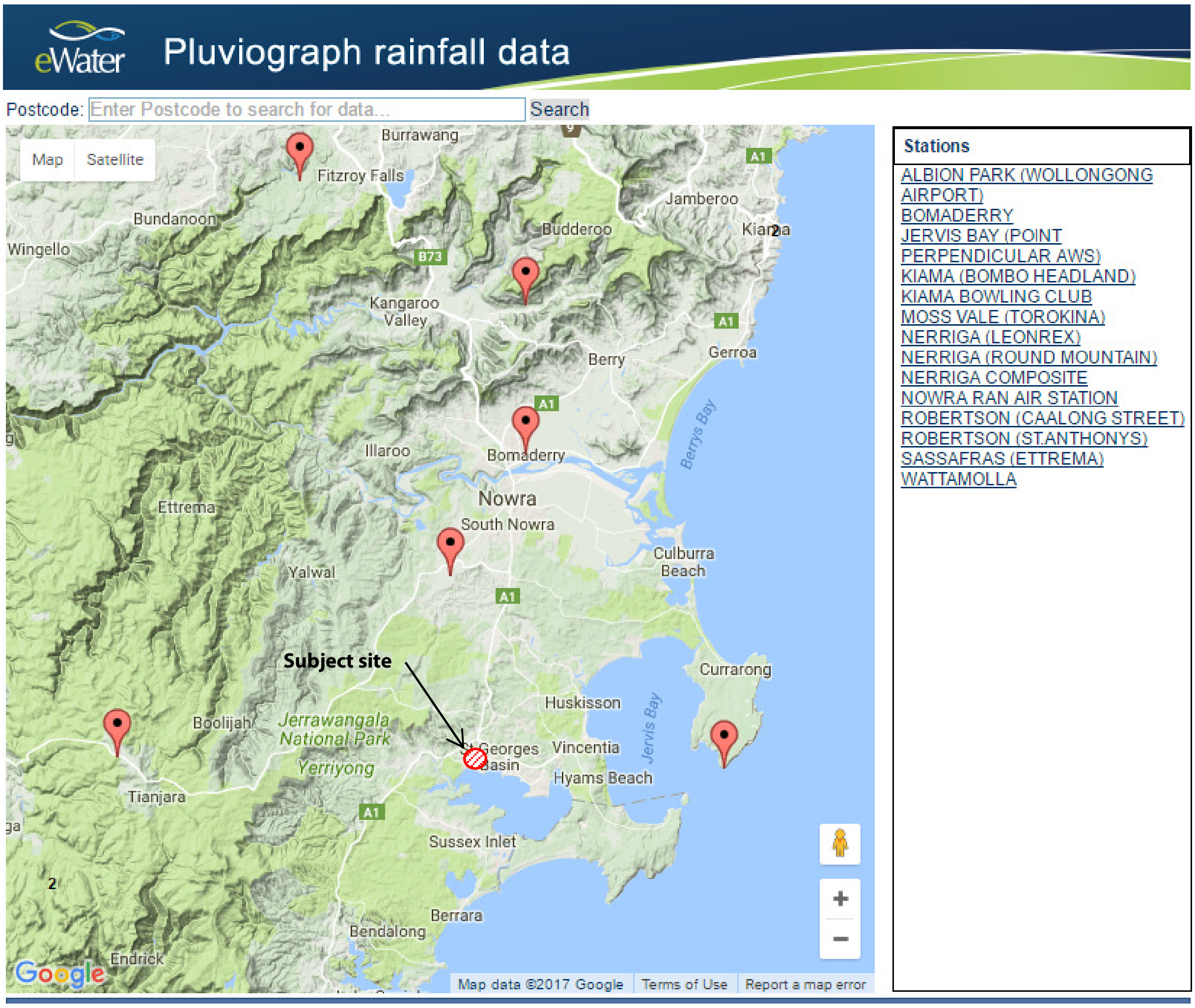

Figure 7 - Pluviograph Rainfall Data Stations

The data available from each station is summarised in Table 3.

Table 3 - Summary of Nearby Pluviograph Rainfall Data Stations

Station No.	Station Name	Distance and Orientation from Subject Site	Period of Data Set
068076	Nowra RAN Air Station	14km NNW	08/1964 – 12/1997
068151	Jervis Bay (Point Perpendicular AWS)	18km ESE	10/2001 – 05/2008
068136	Bomaderry	23km N	01/1969 – 10/1972

The Nowra RAN Air Station was adopted as it has the longest period of available data and is situated closest to, and in a similar microclimate to the subject site.

The historical statistics for the Nowra RAN Air Station are provided in Table 4.

Table 4 – Rainfall Statistics

Rainfall Statistic	Annual Rainfall Depth (mm)
Mean	1133.1
5th percentile	549.9
10th percentile	592.8
90th percentile	1750.7
95th percentile	1925.3

The period 1966 – 1975 (10 years) was used for modelling. This period has an average annual rainfall depth of 1128.9mm which compares favourably to the mean rainfall depth for the station. Further the data period contains both a very dry year (1968 – 463mm which is the lowest on record) and a very wet year (1974 – 1928mm which closely approximates a 95th percentile rainfall depth).

This period of data was reviewed for completeness and found to contain a minor period of missing data. The annual average rainfall depth for the 10 year long 6 minute rainfall template used in the MUSIC model for modelling is 1098mm/annum. In comparison to the rainfall statistics shown in Table 4 the MUSIC rainfall template has an average rainfall depth equal to 97% of the mean annual rainfall depth. Given the length of the record to be used and the nature of the “comparative” assessment to be undertaken (i.e. using the same rainfall template to assess both pre and post development scenarios) the data is considered to be of suitable quality and integrity.

6.3.2. Potential Areal Evapotranspiration

Pan evaporation data was provided by Shoalhaven Council from information obtained from the Bureau of Meteorology (Station 068076 – Nowra RAN Air Station).

Analysis of this data showed an annual total pan evaporation of 1200mm/year. This was compared to the National potential evapotranspiration (PET) atlas available from the Bureau of Meteorology which showed annual Areal PET to be in the order of 1200mm/year. Given that Areal PET is approximately equal to pan evaporation there is no need to convert the pan data and it can be used as Areal PET data for the purposes of modelling in MUSIC.

The Areal PET data adopted is shown in Figure 8.

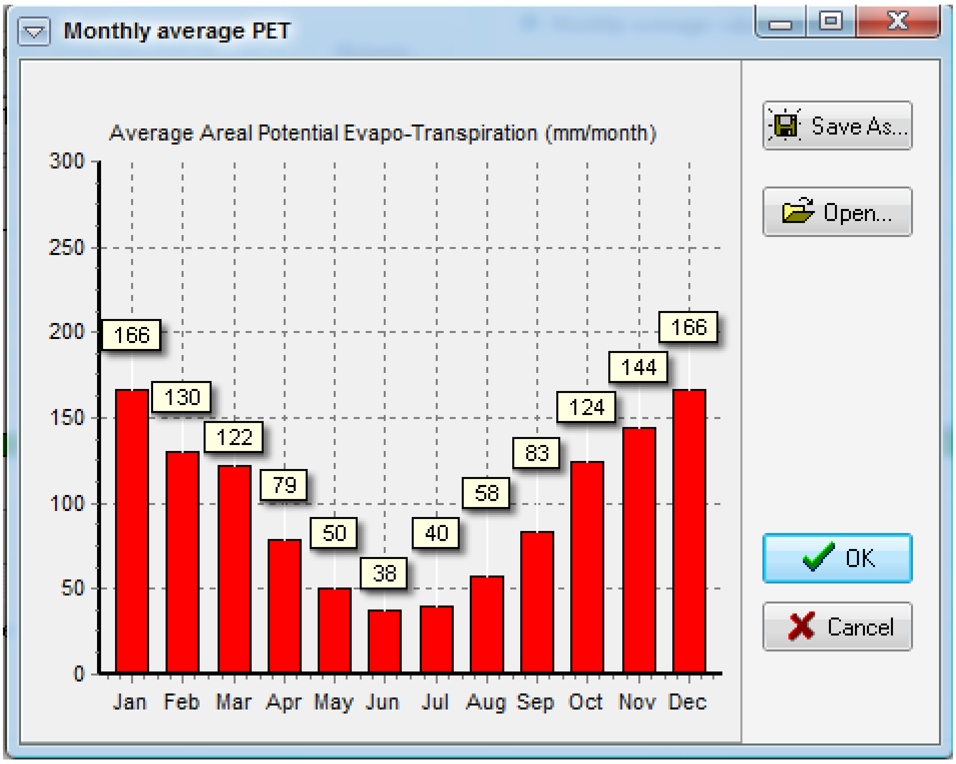

Figure 8 - Graph of Areal PET data adopted

6.3.3. Hydrological Parameters

MUSIC uses a watershed model similar in nature to the tipping bucket type model developed originally by Boughton. The following values were adopted for use in the model:

Table 5 - Values of Hydrological Parameters Adopted in MUSIC

Parameter	Value Adopted	Justification or source of data
Rainfall threshold	0.3mm 1.0mm	Value adopted for roofs based on Table 3.6 – Sydney Metro Catchment Management Authority (SMCMA) (2010) Value adopted for all other source nodes based on Table 3.6 (SMCMA, 2010)
Depth of soil	1.0m	Adopted based on soil investigations by Morse McVey (1994) where test pits revealed depth of soils in excess of 0.75m across the entire estate.
Soil storage capacity	144mm/m	Average value calculated based on the procedure outlined in Section 3.6.4.3 - SMCMA (2010) based on soil profiles contained in Morse McVey 1994. Range over the five test pits varied between 140mm/m and 147mm/m
Field Capacity	122mm/m	Average value calculated based on the procedure outlined in Section 3.6.4.3 - SMCMA (2010) based on soil profiles contained in Morse McVey 1994. Range over the five test pits varied between 119mm/m and 128mm/m
Daily baseflow rate	10%	Typical Value for Clays (B Horizon) from Table 3.8 (SMCMA, 2010)
Daily Groundwater recharge rate	10%	Typical Value for Clays (B Horizon) from Table 3.8 (SMCMA, 2010).
Daily deep seepage rate	0%	Typical Value from Table 3.8 (SMCMA, 2010).
Infiltration parameter a	200mm/d	Default Value adopted in the absence of reliable site specific information.
Infiltration parameter b	3.0	Typical Value for Sandy Clay Loams and Light-Medium Clays based on Table 3.8 - SMCMA (2010).

6.3.4. Pollutant Load Rates

Pollutant concentrations (in the form of event mean concentrations (EMC's) for the range of land uses on the site are based on typical values obtained from the SMCMA (2010) which in turn are based on Fletcher et al (2004).

The adopted values are shown in Table 6 and Table 7 for base flow and storm flow concentrations respectively.

Table 6 – Adopted Base Flow Concentration Parameters

Landuse:	Concentration (mg/L-$\log_{10}$)					
	TSS		TP		TN	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Rural Residential	1.15	0.17	-1.22	0.19	-0.05	0.12
Roofs	N/A	N/A	N/A	N/A	N/A	N/A
Forest/E2 Zoned Land	0.78	0.13	-1.52	0.13	-0.52	0.13
Unsealed Roads	1.20	0.17	-0.85	0.19	0.11	0.12
Sealed Roads[1]	1.20	0.17	-0.85	0.19	0.11	0.12

[1] Values apply where sealed roads contain a pervious fraction (e.g. verge), otherwise N/A

Table 7 – Adopted Storm Flow Concentration Parameters

Landuse:	Concentration (mg/L-$\log_{10}$)					
	TSS		TP		TN	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Rural Residential	1.95	0.32	-0.66	0.25	0.30	0.19
Roofs	1.30	0.32	-0.30	0.25	0.30	0.19
Forest/E2 Zoned Land	1.60	0.20	-1.10	0.22	-0.05	0.24
Unsealed Roads	3.00	0.32	-0.30	0.25	0.34	0.19
Sealed Roads	2.43	0.32	-0.30	0.25	0.34	0.19

6.3.5. Effective Impervious Area

Effective Impervious Area (EIA) factors for the different land use/surface types present on the subject site have been adopted from Table 3-5 SMCMA (2010) and are shown in Table 8.

It should be noted that the definition of an effective impervious area in MUSIC is one that is directly connected to the stormwater system and is a measure of the area of land that is effective in generating runoff that flows directly to the stormwater drainage system. In the context of the proposed rural residential development it is worth understanding there is minimal stormwater drainage in place.

Table 8 - Surface Type EIA Factors

Surface Type	EIA Factor
Roofs	1.0 x TA
Sealed Road Corridors[1]	0.3 x TA
Unsealed Road Corridors[2]	0.15 x TA
Rural Residential Land (R5/E4)	0.05 x TA
Forest/E2 Zoned Land	0 x TA

TA = Total Site/Catchment/Surface Area.

[1]The EIA factor of 0.3 applies to the entire road corridor with a width of 20m. The sealed road width was assumed to be 6m (having unsealed shoulders), therefore making up 30% of the TA. The sealed fraction would have an EIA of 1.0, resulting in an overall EIA for the road corridor of 0.3 x 1 =0.3, as the corridor verges have been assumed pervious (EIA 0).

[2]As with sealed roads, the EIA factor of 0.15 applies only to the entire road corridor. The EIA of the 6m road width for unsealed roads is 0.5. As the road width make up 30% of the corridor area, an overall EIA is 0.3 x 0.5 = 0.15.

6.4. Landuse Assumptions

The current state of each existing allotment was determined using a combination of an assessment of current aerial photography (six maps) and a visual inspection of each lot from the road only (25 October 2016).

Each existing allotment was typically either classified as a 'rural residential' lot or a 'forest' lot based on analysis of the above information. In some instances and where disturbance appeared to be limited to only part of the allotment, a rural residential classification was only applied over that disturbed part of the lot. Typically rural residential lots included those with a reasonable degree of disturbance (e.g. existing structures, under scrubbing, earthworks) whereas forest lots where those with little or no evidence of disturbance.

Post development land use categories were defined based on the planning proposal zoning maps. Building envelopes and surrounding APZ areas (i.e. R5 and E4 zoned areas) were classified as 'rural' residential' which is reflective on the more intense use and required under scrubbing within these areas.

Environmental conservation areas outside proposed building envelopes (i.e. proposed E2 zoning) were classified as forest. This approach reflects the retention and/or conversion of these areas back to natural forest, which will be imposed on the development through proposed planning controls.

The change in land use (including roads) resulting from the proposed development is shown in Figure 9 (for the unsealed road scenario) and forms the basis of generating pre and post development land use categorisation for the purposes of water quality modelling.

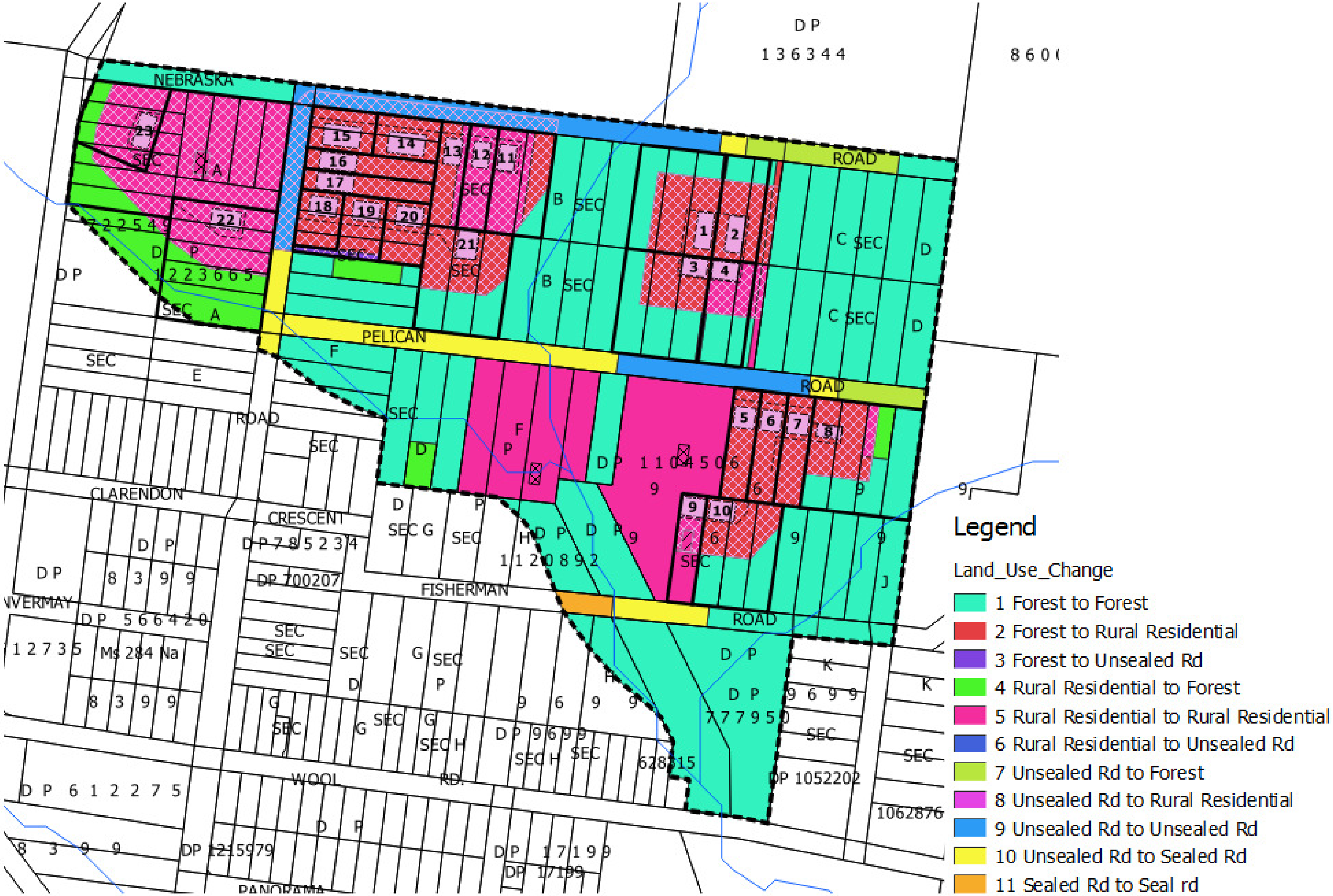

Figure 9 - Landuse Change Plan – Unsealed Road Scenario

6.5. Pre-Development Modelling

6.5.1. Model Configuration

The configuration of the pre-development MUSIC model is shown in Figure 10. As can be seen from the configuration the model consists of lot based source nodes (to the right) and road based source nodes (to the left). The model clearly shows the lots and roads being routed through separate junctions prior to the receiving node such that any change in water quality resulting from a change in land use could be assessed for roads and lots independently of each other.

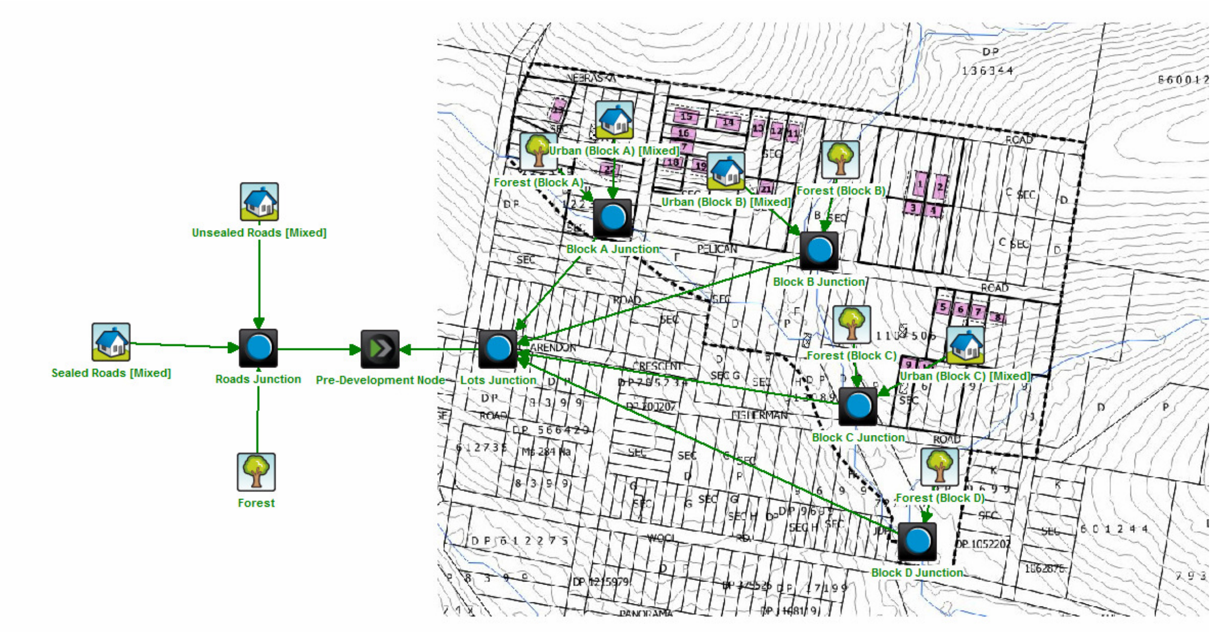

Figure 10 - Pre-Development MUSIC Model Configuration

6.5.2. Results

The results of the pre-development modelling, expressed as mean annual loads, are summarised in Table 9.

Table 9 - Pre-Development Results (summed for the whole site)

Parameter	Lots	Roads	Total
Flow (ML/yr)	87.5	15.2	103
TSS (kg/yr)	5,430	15,600	21,000
TP (kg/yr)	11.8	7.4	19.2
TN (kg/yr)	116	32	148

The results show that the roads account for approximately 75% of the annual TSS load yet account for only 12% of the total site area. The modelling predicts that TSS loading from existing road areas is predicted to be in the order of 3,700 kg/ha/yr. In comparison TSS loading from the lots is predicted to be in the order of 180 kg/ha/yr.

In contrast nutrient (TP and TN) loads are predicted to be higher for lots than roads with lots generating 60% and 77% of TP and TN loads respectively.

6.6. Post Development Modelling

6.6.1. Overview

Two post development scenarios were modelled as described below:

- Unsealed Roads – a combination of unsealed and sealed roads with the extent of sealed roads adopted from the concept subdivision and development plan shown in Figure 6. It is understood that the delineation of the sealed road network shown in Figure 6 is to limit the potential for road erosion resulting from overland flooding which is understood to have previously caused significant damage along the western portion of Pelican Road. In other words, this scenario represents the minimum extent of road sealing.
- Sealed Roads – sealing of all proposed roads within the estate.

Both of the above scenarios were also assessed with and without roadside treatment.

6.6.2. Model Configuration

The configuration of the post development MUSIC model is shown in Figure 11. Once again the model consists of lot based source nodes and treatment (to the right) and road based source nodes and treatment (to the left).

Roadside treatment was assumed to consist of vegetated bio-retention swales (bio-swales). With the exception of Waterpark Road which typically runs perpendicular to the slope the bio-swales were assumed to be located on only one side (the low side) of the road. The reasoning for this approach is such that cut off drains can be formed on the upslope side of each road to divert 'clean' water away from the road and the road would be graded with one way crossfall towards a bio-swale on the downslope side thereby reducing the hydraulic loading on the bio-swale and improving treatment performance. For bio-swales on both sides of the road a swale base width of 0.5m was adopted whilst for bio-swales on only one side of the road, a base width of 1.0m was adopted.

Rainwater tanks and infiltration trenches where applied to roof runoff from each new dwelling consistent with Section 6.10.

Vegetated buffers where applied as treatment to all rural residential source nodes to represent the treatment associated with dispersed stormwater flows over vegetated APZ areas from remaining ground surface impervious surfaces.

The MUSIC input values adopted for bio-swales and buffer strips are shown in Table 10 and Table 11 respectively. For modelling assumptions for rainwater tanks and infiltration measures refer to Section 6.10.

Table 10- Adopted Bio-Swale Parameters

Parameter	Value Adopted	Justification or source of data
Low Flow Bypass	Varies 0.10– .89m^3/s	Determined from Manning's capacity of each swale , based on cross sectional area and grade.
Extended Detention Depth	0.05m	Average value adopted assuming maximum depth of ponding of 100mm achieved using rock check dams or similar.
Surface Area	Varies 10-305m^2	Determined by multiplying base width of swale x length of swale
Filter Area	Varies 6-92m^2	Determined by multiplying swale length x 0.3m wide bio-retention strip.
Saturated Hydraulic Conductivity	100mm/hr	Typical value for sandy loam
Filter Depth	0.3m	Assumed media depth above subsoil pipe
TN Content of Media	800mg/kg	MUSIC Default
Orthophosphate Content of Media	55	MUSIC Default
Base Lined	No	
Vegetated with Effective Nutrient Removal Plants	Yes	Recent studies have shown that turf is effective for nutrient removal, with performance better than or equal to species commonly used in bio-retention systems.
Underdrain Present	Yes	Subsoil drainage present
Submerged Zone with Carbon Present	No	

Table 11 - Adopted Buffer Strip Parameters

Parameter	**Value Adopted**	**Justification or source of data**
Percentage of upstream area buffered	100%	APZ encompass all building envelopes and therefore will treat 100% of the upstream area
Buffer Area (% of upstream impervious area)	50%	
Exfiltration Rate	0.1mm/hr	Recommended value from Section 3.8.1.2 (SMCMA, 2010).

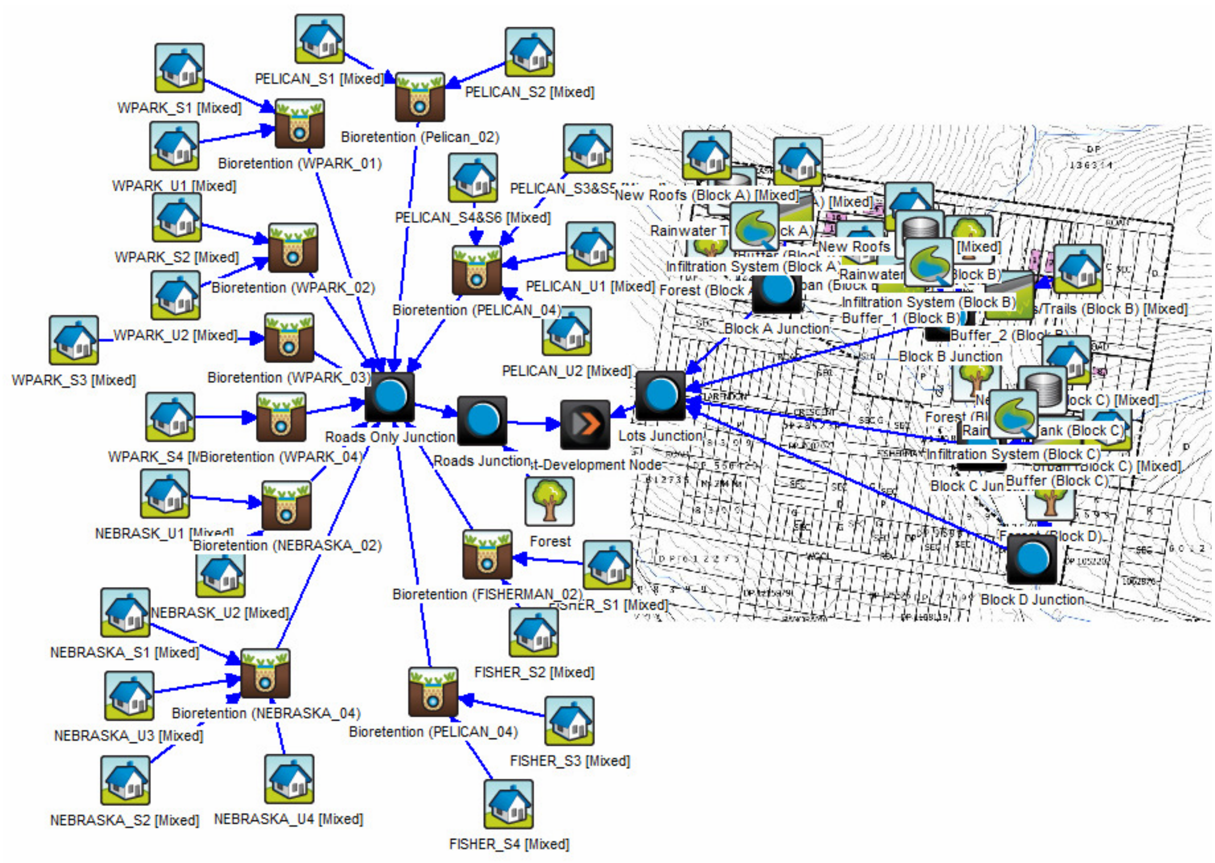

Figure 11 - Post Development Model Configuration

6.6.3. Results

The results of the Post development modelling are included in Table 12 to Table 14 with;

- Table 12 providing a comparison of pre and post development results for changes in landuse within the lots only.
- Table 13 providing a comparison of pre and post development results for roads only for unsealed and sealed road scenarios both with and without roadside treatment.

- Table 14 providing a comparison of pre and post development results across the entire estate (i.e. total loads from both lots and roads) for unsealed and sealed road scenarios both with and without roadside treatment.

Table 12 – Comparison of Pre and Post Development Results for Lots Only

Parameter	Pre-development Load	Post Development Load Untreated	%	Post Development Load Treated	%
Flow (ML/yr)	87.5	92.2	-5	86.7	1
TSS (kg/yr)	5,430	6,020	-11	3,990	26
TP (kg/yr)	11.8	14	-19	10.7	9
TN (kg/yr)	116	138	-19	116	0

% = percentage reduction in mean annual flow/load from the predevelopment state. Where expressed as a negative it indicates an increase in mean annual flow/load.

The results in Table 12 show that the change in land use within the lots if left untreated is predicted to result in an increase in pollutant loads of up to 20%, whilst when treatment is applied is predicted to result in a decrease in TSS and TP loads of 26% and 9% respectively, whilst TN is expected to remain constant.

Table 13 – Comparison of Pre and Post Development Result for Roads Only

Parameter	Pre-Development Load	Without Roadside Treatment				With Roadside Treatment			
		Unsealed Roads		Sealed Roads		Unsealed Roads		Sealed Roads	
		Load	%	Load	%	Load	%	Load	%
Flow (ML/yr)	15.2	16	-5	17.5	-15	13.8	9	15.2	0
TSS (kg/yr)	15,100	9,450	37	4,800	68	572	96	390	97
TP (kg/yr)	7.4	7.2	3	8.2	-10	1.9	74	2.1	72
TN (kg/yr)	32	32	0	36	-13	16	50	17	47

% = percentage reduction in mean annual flow/load from the predevelopment state. Where expressed as a negative it indicates an increase in mean annual flow/load.

The results in Table 13 show that:

i. In the absence of roadside treatment nutrient loads are expected to slightly reduce or remain constant for the unsealed scenario whilst for the sealed road scenario these loads are expected to increase in the order of 10%.
ii. The addition of roadside swales to the public road network results in an overall reduction of all pollutants. For unsealed roads the swales are predicted to retain an additional 59% of the pre-development TSS load, 71% of the TP load and 16% of the TN load. For sealed roads these numbers are 60%, 82% and 60% respectively.
iii. TN & TP loads are slightly higher for sealed roads compared to unsealed roads. However, TSS loads for sealed roads are approximately half that of unsealed roads.

iv. Improvements to the road network and the construction of roadside swales, is expected to reduce TSS loads by 68% for unsealed roads and 97% for sealed roads compared to the current situation.
v. For both scenarios the pollutant load reduction resulting from the roadside bio-swales exceeds the retention targets in DCP Chapter 12 of 85% TSS, 65% TP and 45% TN. Reductions of 96% TSS, 78% TP and 57% TN are predicted to be achieved for the unsealed road scenario and reductions of 95% TSS, 78% TP and 58% TN are predicted to be achieved for the sealed road scenario.

Table 14 – Comparison of Pre and Post Development Result for Entire Site

Parameter	Pre-Development Load	Without Roadside Treatment				With Roadside Treatment			
		Unsealed Roads		Sealed Roads		Unsealed Roads		Sealed Roads	
		Load	%	Load	%	Load	%	Load	%
Flow (ML/yr)	103	108	-5	110	-7	100	3	102	1
TSS (kg/yr)	21,000	15,500	26	10,800	48	4,600	78	4,400	79
TP (kg/yr)	19.2	21.1	-10	22.2	-16	12.4	35	12.8	33
TN (kg/yr)	148	171	-15	174	-17	133	10	133	10

% = percentage reduction in mean annual flow/load from the predevelopment state. Where expressed as a negative it indicates an increase in mean annual flow/load.

The results in Table 14 show that:

i. The combination of change in land use within the lots and improvements in the road network alone (i.e. without treatment) is expected to significantly improve current TSS loads (by up to 48%), but result in an increase in nutrient loads (by up to 17%).
ii. For both the unsealed and seal roads scenarios with roadside treatment the proposed stormwater treatment train is predicted to result in a marked improvement in water quality when compared to the current situation.
iii. Overall improvements in water quality are expected regardless of whether roads are to be unsealed or sealed when roadside treatment is included (plus or minus 2%).

Further discussion on the results is included in Section 6.8.

6.7. Impact of Development on Surface Hydrology

Cumulative flow frequency curves for the pre-development and the two post development with treatment models are included in Appendix B and demonstrate that the frequency of flows generated will remain relatively unchanged. The curves have been generated by MUSIC and included all flow data at the receiving node.

Interrogation of the curves shows that the 98th percentile flow rate to be approximately 0.006m^3/s for the pre-development and both post development scenarios.

The results indicate that the proposed treatment measures are effective in mitigating against any impact resulting from an increase in surface runoff quantity.

6.8. Results Discussion

The reduction in water quality resulting from the change in land use within the lots without treatment is best described with reference to Table 15 which shows that an overall change in land use of 13% is to occur as a result of the proposed redevelopment. That is, a 13% decrease in forest land and a corresponding 13% increase in rural residential land compared to the current situation. Lower pollutant loads are generated from forested land compared with rural residential land as a result of both a lower effective impervious area (refer to Table 8), resulting in lower runoff volumes, and lower pollutant concentrations (refer to Table 6 & Table 7). Therefore a decrease in forested land will naturally result in an increase in pollutant loads as documented.

Table 15 – Change in Land Use Comparison (Lots Only)

Model	**Land Use Type**			
	Forest		**Rural Residential**	
	Area (Ha)	**(%)**	**Area (Ha)**	**(%)**
Pre Development	20.30	70	8.54	30
Post Development	16.33	57	12.51	43
Change	-3.97	-13%	+3.97	+13%

The treatment train adopted for lot based controls counters these increases in pollutant loads largely through extracting water (and entrained pollutants) from the system through water re-use and infiltration. This is clearly demonstrated by the increase in runoff volume in the absence of treatment measures (87.5 to 92.2ML/yr) and a corresponding reduction back to slightly lower than the predevelopment rate in the presence of treatment. With the exception of TN, which is predicted to remain constant, the proposed lot based measures result in an overall reduction in pollutant loads.

For the roads, the TSS load is anticipated to significantly reduce in both post development scenarios, even in the absence of roadside treatment. This is due to two factors;

- Firstly, a reduction in the area of the road network due to road closures (i.e. from unsealed road to forest)
- Secondly, as a result of sealing roads. Whilst sealing of the road network results in an increase in effective impervious area (see Table 16) they generate almost 50% less TSS than unsealed roads (refer to Table 7) as a result of the binding of the road surface, with the net effect being a reduction in pollutant load.

Table 16 - Effective Impervious Area Comparison

Model	Total Area (Ha)	Effective Impervious Area (Ha)	Effective Impervious Percentage
Pre Development	32.92	0.86	2.6%
Post Development – Unsealed	32.92	1.31	4.0%
Post Development – Sealed	32.92	1.53	4.6%

Ultimately sealing of that part of the road network shown to be unsealed in the Concept Subdivision and Development plan in Figure 6 results in very little difference to water quality in the presence of roadside treatment (less than 2%) and therefore the decision to seal the unsealed sections of road will need to be made on the basis of cost, community expectation and maintenance rather than from a water quality perspective.

With reference to Table 13, TSS retention for in bio-swales for the unsealed road scenario is about 9,500kg/yr, whilst for the sealed road scenario is about 4,800kg/yr. This demonstrates that maintenance requirements for bio-swales on unsealed roads will be approximately twice that of sealed roads due to the higher generation of TSS loads associated with unsealed roads.

6.9. Preliminary Life Cycle Cost Assessment

A preliminary life cycle cost assessment of the road side treatment measures was undertaken using MUSIC in accordance with the scope of works. It must be noted that the proposed roadside bio-swales form a critical part of the drainage infrastructure for the site and as such they fulfil dual functions of drainage and water quality management.

Maintenance of the bio-swales would include periodic reseeding, removal of mass sediment accumulation following large events or following an episode of erosion. Some areas may need occasional reshaping. The extent of maintenance required will of course depend on the standard of the original construction. Less maintenance would be required if a high standard of construction is achieved initially.

Sealing of roads within the estate will significantly reduce the sediment load on the bio-swales and thus maintenance burdens as the average accretion rate is expected to be about halved. Effective revegetation and appropriate vegetation management practices will also help to reduce the sediment load on the bio-swales.

The assumptions in Table 17 formed part of the life cycle cost assessment.

Table 17 - Values of Parameters Adopted in MUSIC Life Cycle Costing Analysis

Parameter	**Value Adopted**	**Justification or source of data**
Span of Analysis	50 years	Recommended by MUSIC. Note that whilst one could convincingly argue the life cycle is infinite for well maintained and 're-graded' bio-swales, the span of analysis needs to be set to a finite number to enable the calculation of a life cycle cost.
Real Discount Rate	5.5%	MUSIC default
Annual Inflation Rate	2.0%	MUSIC default
Base Year	2016	
Acquisition Cost (includes design & construction costs)	MUSIC default lower quartile	Lower quartile value reflects dual function of the bio-swale for drainage and water quality management with acquisition costs shared between the two roles. Furthermore subsoil drainage would also be required for pavement drainage and therefore the cost associated with water quality would be relatively low. Value adopted equates to approximately $\$50/m^2$ **WARNING:** Bio-retention acquisition costs in MUSIC are derived from algorithms established from a very limited data set which also include swale systems rather than from a quantity take off specifically for this project. Their use should therefore be limited to a strategic planning level only and not for budgetary purposes.
Renewal Period	25 years	Recommended by MUSIC. 25 years is considered appropriate for unsealed roads based on average accretion rate of about 5mm/yr. For sealed roads with an average accretion rate of about 1mm/year renewal would not be required during a 50 year life cycle analysis.
Typical Annual Maintenance Cost	$\$5/m^2$	Value adopted from Melbourne Water (2013) which is considerably lower than even the lower quartile default value of about $20 in MUSIC and considered more realistic of the maintenance expected to be undertaken by Council.

Annual Establishment Cost	Not included	
Annualised Renewal Cost	MUSIC default expected value	Value adopted equates to approximately \$1.30/m^2/annum.
Decommissioning Costs	Not Relevant	In the context of modelling a bio-swale with infinite life the decommissioning cost is not relevant.

6.9.1. Results

The results of the preliminary life cycle analysis are reported in Table 18 and Figure 12 for real costs and Table 19 and Figure 13 for discounted real costs.

Table 18 - Preliminary Life Cycle Cost Analysis of Roadside Bio-Swales – Real Costs

Cost Type	Real Costs (\$2012)	Percentage of Discounted Real Cost
Total Acquisition Cost	\$25,000	16%
Sum of Annual Maintenance Costs	\$115,000	74%
Sum of Renewal Costs	\$15,000	10%
Life Cycle Cost	\$155,000	100%

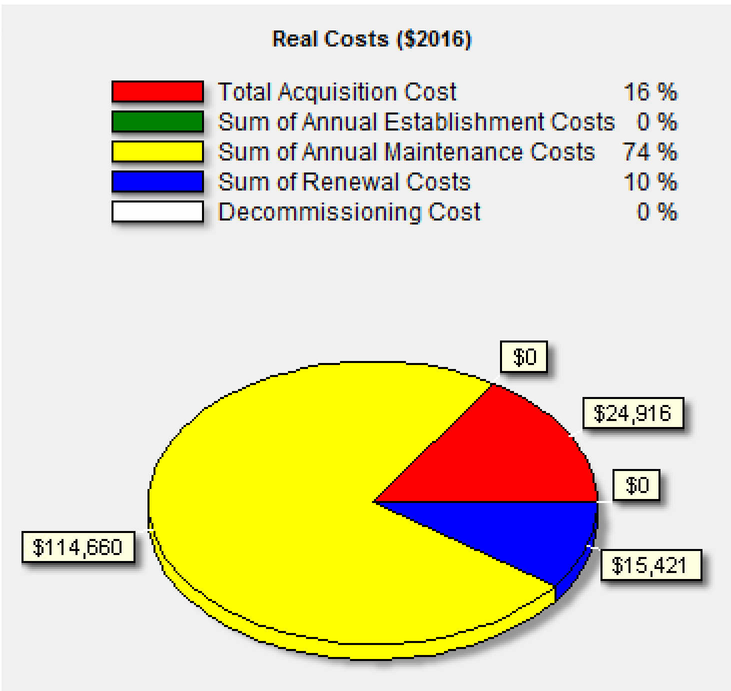

Figure 12 – Breakdown of Preliminary Life Cycle Costs (Real Costs)

Table 19 - Preliminary Life Cycle Cost Analysis of Roadside Bio-Swales – Discounted Real Cost

Cost Type	**Discounted Real Cost ($2012)**	**Percentage of Discounted Real Cost**
Total Acquisition Cost	$25,000	36%
Sum of Annual Maintenance Costs	$40,000	58%
Sum of Renewal Costs	$4,000	6%
Life Cycle Cost	$69,000	100%

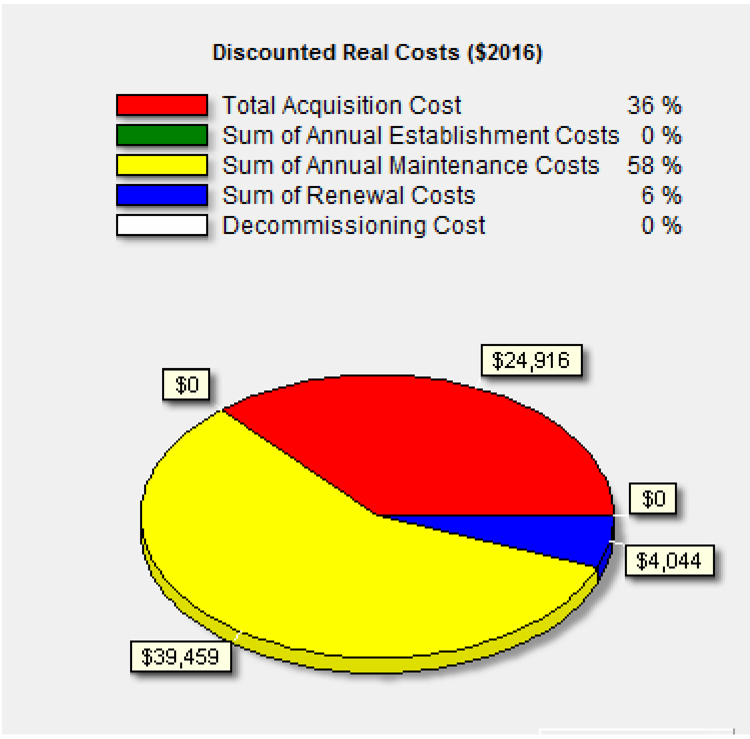

Figure 13 – Breakdown of Preliminary Life Cycle Costs (Discounted Real Costs)

6.9.2. Apportionment of Cost

Given that roadside swales are a linear treatment measure and form an integral part of the road formation, their construction cost should be incorporated into the overall cost of road construction. If this is done the costs associated with the roadside swales will be apportioned to each individual lot in the same manner as road costs are apportioned.

6.10. Modelling of Lot Based Controls

To check the performance of lot based controls a second independent MUSIC model was developed. This model included future roof areas draining to a tank which in turn drained to an infiltration trench. This model was used to develop lot based controls to be specified in the future DCP.

This model configuration is shown below in Figure 14.

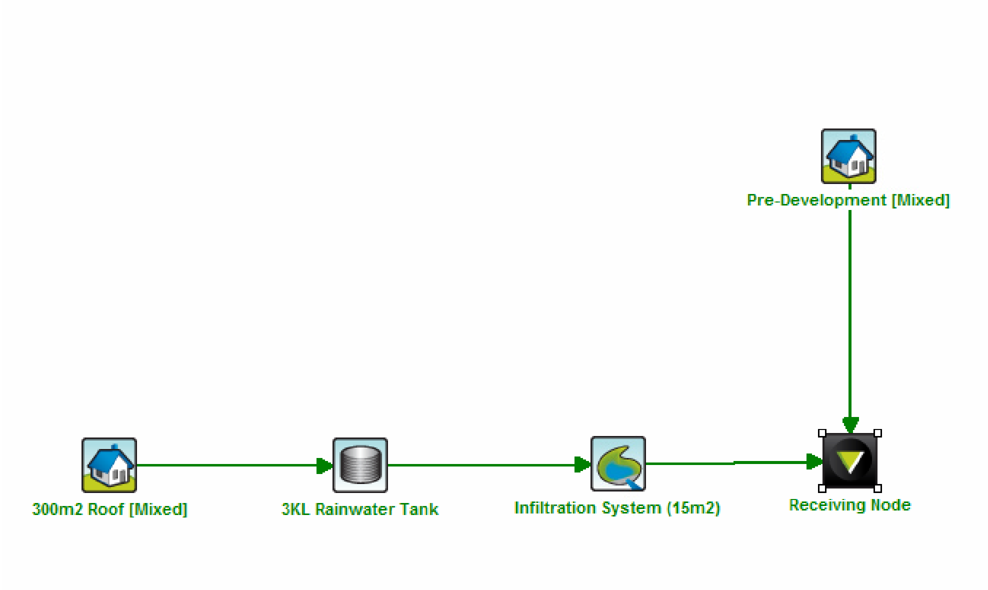

Figure 14 - Lot scale MUSIC model

The model is a comparative model – it compares the predevelopment node (300m^2 of rural residential land with 5% imperviousness) results against the post development (300m^2 roof which is 100% impervious). In the post development state the tank was assumed to be a 3 kL tank supplying a water consumption of 360 litres/day for internal household use (toilet and laundry) and 310 litres/day external use. These values accord with the values for dwellings with mains water supply for 3 occupants recommended in T3-12 of SMCMA, (2010). The tank in turn overflows to an infiltration trench. The trench was assumed to be 0.5m deep, have a surface storage depth of 200mm and be filled with gravel with a porosity of 0.35. The trench was assumed to infiltrate at a rate of 2mm/hour. This is an appropriate value to use for soils present on this site.

The climate template, soils data and pollution rates used were the same as those used for the estate scale MUSIC model and which was described in detail earlier.

The model was run and the trench surface area varied until the predevelopment and post development cumulative frequency curves were almost identical. Cumulative frequency curves measure the whole flow regime – they measure flow rate as well as flow frequency and are used to show any potential changes in flow that may in turn cause ecological impacts.

The results for a trench with a surface area of 15m^2 are shown in Figure 15.

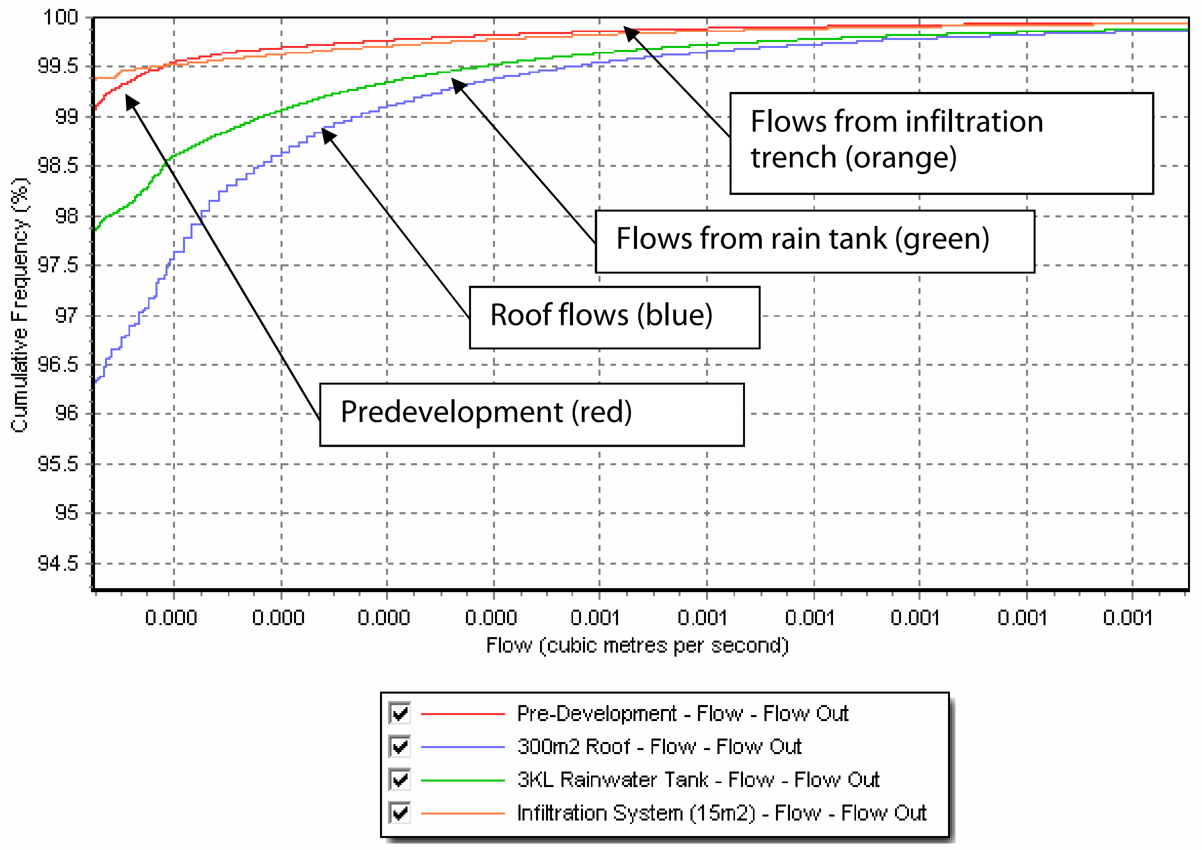

Figure 15 - Cumulative Frequency Graph comparing pre and post development lot flows with rain tank and trench.

Figure 15 shows clearly the impact of roof flows without mitigation. Flows from the 300 m^2 roof are clearly higher and more frequent than predevelopment flows. The impacts of both the rain tank and infiltration trench in reducing or pegging back the flows to predevelopment levels is also clear. As a result of the tank and trench the flow regime on each lot will not alter after development. This also assumes that other controls such as ensuring driveways are diverted to buffer strips and do not directly connect into the drainage system are put in place.

It is worth noting that the x-axis on the graph shows flows to three decimal places. Unfortunately this version of MUSIC does not allow the axis to be formatted. The units are approximately tenths of litres per second which reflects the highly sensitive nature of this assessment.

In the model a 300m^2 roof was adopted as a typical roof size however the trench size varies according to roof size so that larger roof areas require larger trenches to infiltrate the additional runoff. The results show that for every 100m^2 of roof, 5m^2 of trench is required. These development requirements are defined fully in Section 8.1.

The water quality modelling results (including total flow) are shown below in Table 20.

Table 20 - Lot Scale Water Quality Modelling Results

Parameter	Predevelopment (rural residential)	Post Development (rural residential)
Flow (ML/yr)	0.097	0.092
Total Suspended Solids (kg/yr)	10.5	1.9
Total Phosphorus (kg/yr)	0.024	0.013
Total Nitrogen (kg/yr)	0.20	0.20

7.0 CONCEPTUAL DRAINAGE DESIGN

The purpose of the conceptual drainage design is to inform Council of the likely extent and location of stormwater drainage measures that will be required to be implemented as part of the proposed redevelopment in order to satisfy Council's engineering design specifications.

The adopted conceptual drainage design approach consists of the following:

- roadside bio retention swales (for both stormwater flow conveyance and stormwater treatment) typically located on the downslope (low) side of the roadway to manage road runoff,
- open drainage swales located on the upslope (high) side where required to intercept upslope runoff and divert it away from the road surface, and
- a limited number pipes at road intersections and road low points.

This approach is very typical of rural residential developments and is considered appropriate for this site.

Property access would be achieved by way of culverts crossing over the roadside bio-swales/open drainage swales.

7.1. Council's Performance Criteria

Roadside swales and associated pipes, as described above, form part of the 'minor' drainage system. In accordance with Shoalhaven City Council's *Engineering Design Specification, D5 – Stormwater Drainage Design* the minor system design recurrence interval for a rural residential development is 5 years.

Design criteria for the minor drainage system as they relate to this development are as follows:

i. Gutter flow widths are to be limited to a maximum of 2.1m. Flows on one side of the street are to be contained by the crown of the road. *In the absence of a formal kerb and gutter it is assumed that for a rural residential situation the minor system event flow is allowed to encroach onto the roadway by 2.1m as measured from the outside edge of the shoulder.*
ii. Minimum conduit sizes are 375mm diameter for pipes and 600mm wide x 300mm high for box culverts.

7.2. Adopted Conceptual Drainage Design

Figure 1 in Appendix A shows the conceptual drainage design adopted for the site. The drawing shows the location of proposed culverts which are required to meet Council's minor system design criteria and/or provide the necessary connection across newly established roadways.

The sag points in Nebraska Road, Pelican Road and Fisherman Road drain catchment areas of approximately 62Ha, 67Ha and 130Ha respectively. Peak flows for the 5yr ARI storm event are predicated to be in the order of 7 m^3/s at Nebraska Road and Pelican Road and $13m^3/s$ at Fisherman Road. In order to convey such significant flows under the roads large culvert structures would be required to be constructed and road approaches raised to accommodate the structures. Given the current flooding, particularly at Pelican Road and Fisherman Road raising road approaches would likely lead to a change in flood behaviour and an increase in levels upstream of the structures which is not considered desirable. Rather at these locations low flow pipes and floodways are recommended to minimise any filling within the floodplain. The concept drainage design shows these structures to be nominally twin 300 x 600mm reinforced concrete box culverts however the size should be confirmed during detailed design to balance serviceability and flood impact.

Although outside the scope of this study, consideration should also be given to upgrading the culvert at Nebraska Road to convey the 100year ARI storm event and thereby create an effective emergency flood access during significant storm events.

Wherever possible, natural catchment boundaries have been maintained in order to avoid potential issues associated with an increase in additional runoff to potentially environmentally sensitive areas.

All existing and any new stormwater pipes should be constructed with appropriate scour protection at the outlet. For outlets discharging into environmentally sensitive areas small sediment retention basins should be incorporated into the outlet design to minimise the migration of sediments, and potentially weed seeds, into these areas. Further flows to these sensitive areas should be dispersed over a reasonable length (i.e. one that limits flow velocities to less than 1m/s) rather than concentrated in order to avoid potential erosion issues.

Were the longitudinal gradient of road side swales/bio-swales exceeds 4% check dams should be constructed at regular intervals across the invert of the swale to help reduce velocities and potential for scour. Check dames typically consist of low level (e.g. 100mm) rock weirs. A rule of thumb for locating check dams is for the crest of a downstream check dam to be at 4% grade from 100mm below the toe of an upstream check dam. The impact of check dams on the hydraulic capacity of the swales will need to be assessed further during preliminary and detailed design.

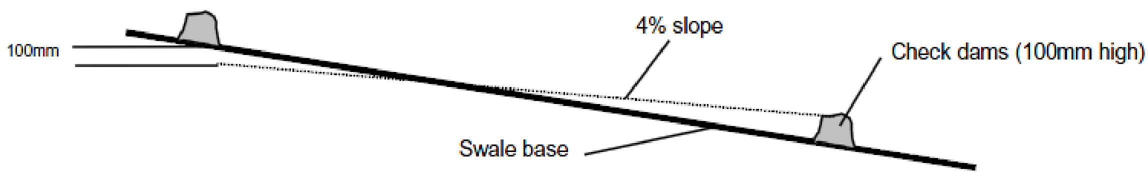

Figure 16 - Location of Check Dams (source SEQ WSUD Technical Guidelines)

Fire trails should be constructed flush with the existing surface so as not to obstruct or divert the natural flow of surface water. No drainage is therefore proposed on the proposed fire trails.

8.0 RECOMMENDED CONTROLS AND PERFORMANCE STANDARDS

The following controls and performance standards, at both allotment and subdivision scale, are recommended to be implemented in order to mitigate any potential adverse environmental impacts resulting from the development in relation to stormwater and water quality management.

8.1. Allotment Scale

8.1.1. Disconnection of Impervious Area

The direct connection of impervious areas (i.e. roofs, paving) to roadside drainage swales will not be permitted. All roof areas shall be conveyed to an on-site infiltration trench (see 8.1.3) via a rainwater tank (see 8.1.2). Any paved areas must be designed and graded such that any runoff is uniformly dispersed over the adjacent downslope land.

8.1.2. Rainwater Tanks

All roof runoff (including sheds and other outbuildings) shall be conveyed to a rainwater tank (or tanks) of sufficient capacity to satisfy BASIX requirements.

Rainwater tanks should include a suitable first flush device and shall be designed, installed and maintained in accordance with the Rainwater Tank Design and Installation Handbook (2008).

8.1.3. Infiltration Trenches

Tank overflows shall be directed to an infiltration trench with a minimum surface area of $5m^2/100m^2$ of roof area, which in combination with rainwater tanks will ensure that the frequency of run-off from roofs is approximately equal to that from pervious surfaces.

The infiltration trench shall:

- have a surface area of $5m^2$ for every $100m^2$ of roof/impervious area.
- have the capacity to store a minimum of $1.75m^3$ of stormwater for every $100m^2$ of roof/impervious area. This may be achieved in any number of ways including gravel filled tranches, reln drains, plastic cells or a combination. Clean washed aggregate (10-20mm) shall be assumed to have a void ratio of 0.35.
- have 200mm depth of storage above the surface of the trench.
- include a sediment trap on the inlet where accepting flows other than from a rainwater tank.
- be rectangular in shape with a minimum length to width ratio of 5:1and be orientated such that the long axis of the trench is parallel to the contour of the land.
- be bound by a hard landscaped edge, such as treated pine sleepers or concrete edging, in order to protect the long term integrity of the surface storage component. The downslope edge shall be level and at natural ground level in order to evenly disperse overflows onto the adjacent ground surface.

- be located downslope of the dwelling and in such a manner so as not to cause nuisance to adjacent properties.
- not be located any closer than 5m from any building or property boundary.

Figure 17 shows an example of a typical gravel filled infiltration trench.

For a dwelling with a roof area of 250m^2 an infiltration trench area of 12.5m^2 [(250/100) x 5] would be required. Based on the typical configuration shown this would result in a trench length of 6.25m (12.5/2).

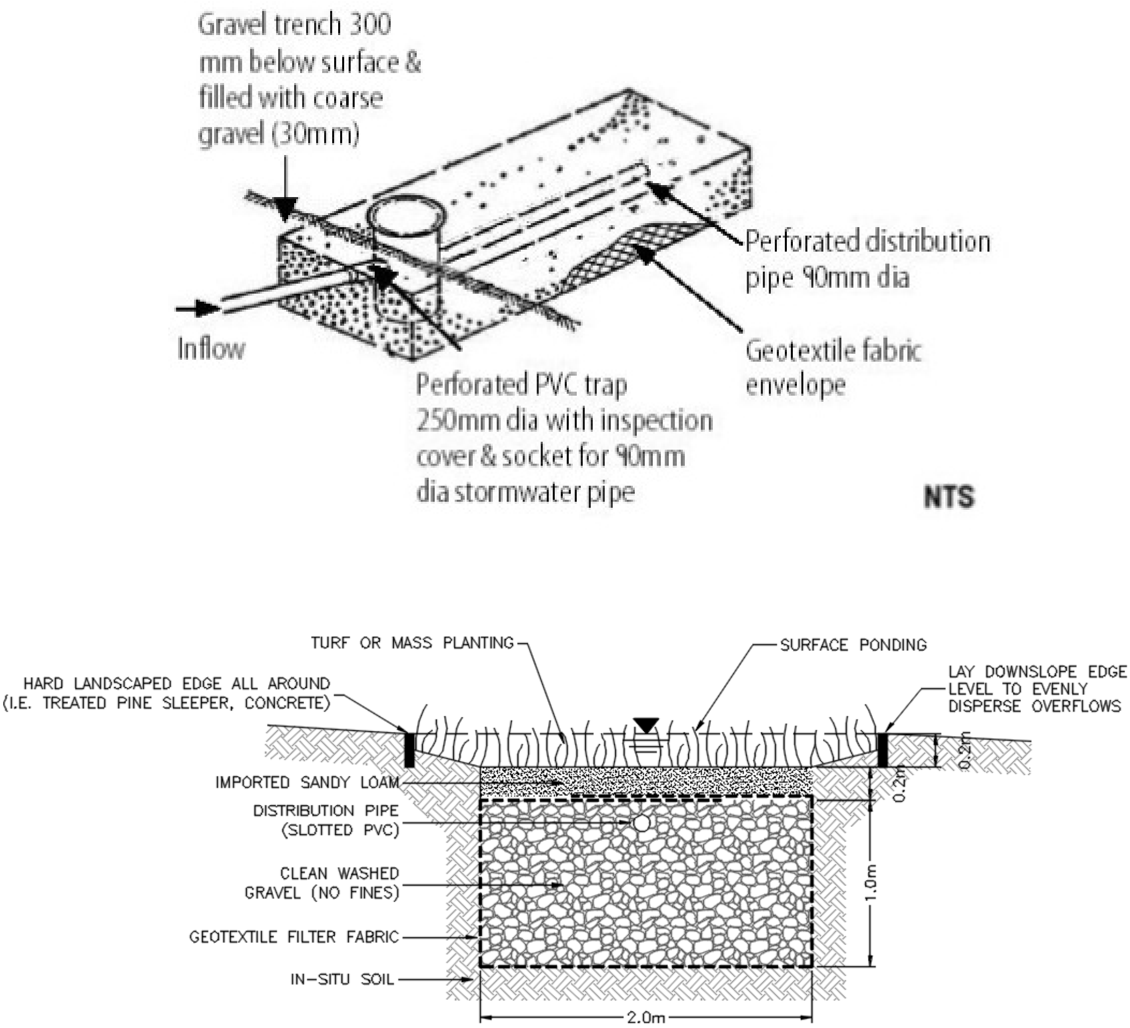

Figure 17 - Typical Infiltration Trench Detail

Infiltration trenches shall be planted with suitable native species or turf.

Details, including proposed location, material type, dimensions and elevations etc of the rainwater tank and infiltration trench must be submitted in support of a development application for any building works.

8.1.4. Driveways

Internal driveways shall comply with the following minimum requirements with respect to stormwater and water quality management:

Width	The maximum driveway width shall be limited to 3.0m unless otherwise required to provide unimpeded access for large bushfire fighting vehicles in accordance with the requirements of *Planning for Bushfire Protection, NSW RFS (2006)*.
Gradient	The desirable maximum gradient of an unsealed driveway is 5% with an absolute maximum of 10%.
Form	Due to their erodibility, the in-situ soils are not considered suitable for driveway construction. All internal driveways shall therefore be constructed with a minimum of 100mm of compacted gravel (DGB20 or similar equivalent) from an imported source.
Crossfall	Internal driveway shall incorporate minimum cross falls of 3% to facilitate drainage and minimise longitudinal flows. One way cross fall is preferable to facilitate treatment.
Water Quality Treatment	Treatment for driveways shall consist of a vegetated swale (or swales in the case of a crowned driveway) along the full length. Swales should include rock check dams were the gradient exceeds 4%. Where the driveway grades to the public road in addition to the above a small mound shall be constructed at the boundary to direct flows to a sediment basin/vegetated swale or raingarden located within the property boundary in order to limit potential sedimentation of public roads.
Driveway Crossings	Driveway crossings shall be limited to a maximum width of 7.2m in order to minimise the impact on roadside swales. (Note: 7.2m width will satisfy minimum turning path requirements for RFS tankers). The driveway culvert shall be sized to accommodate bank full flows in the swale at the proposed location, the minimum diameter shall be 375mm. The outlet of the culvert shall include appropriate scour protection sized in accordance with the requirements on Managing Urban Stormwater: Soils and Construction, Volume 1 (Section 5.4.5)

Details of the driveway must be submitted in support of a development application for any building works.

8.1.5. Erosion and Sediment Control

Construction on individual lots shall comply with the following minimum requirements with respect to the control of erosion and sediment:

- A site specific erosion and sediment control plan must be submitted in support of development applications for any works involving soil disturbance.
- The site specific erosion and sediment control plan shall be consistent with the Nebraska Estate, St Georges Basin - Primary Erosion and Sediment Control Plan – Lot Based Development (2017).

- The site specific erosion and sediment control plan must be designed, installed and maintained in accordance with *Managing Urban Stormwater; Soils and Construction* (Landcom, 2004).
- An Acid Sulfate Soils investigation if Clause 7.1 of SLEP 2014 is triggered.

A copy of the Nebraska Estate, St Georges Basin - Primary Erosion and Sediment Control Plan – Lot Based Development (2017) is included in Appendix C.

8.2. Subdivision Scale

8.2.1. Roads

Public road construction shall comply with the following minimum requirements with respect to stormwater and water quality management:

Longitudinal Gradient	Shall not exceed 10% for unsealed roads.
Pavement Materials	Pavement materials used for the construction of any unsealed public roads shall have a low erodibility potential. In-situ soils are not considered suitable for this purpose and therefore pavement material should be sourced from external sources.
Clearing Width	Clearing for road construction shall be limited to a maximum width of 2m from the edge of any construction activity.
Batter Slopes	Road batter slopes should preferably not exceed 1 in 4 and be no steeper than 1 in 3.
Cut and Fill	Cut and fill heights shall be minimised in order to limit the duration and extent of disturbance and the need for stockpiling of material.
Water Quality Treatment	Bio-swales shall be incorporated on every public road to treat road runoff. Bio-swales shall have a minimum base width of 0.5m for crowned roads and 1.0m for roads with one way cross fall. The base of the swale shall incorporate a minimum 300mm wide x 400mm deep bio-retention trench drained with a minimum 90mm diameter subsoil drainage line. Batter slopes shall not exceed 1 in 3. Where the longitudinal gradient exceeds 4% rock check dams shall be incorporated into the construction to help reduce velocities and potential for scour. Swales shall be lined with biodegradable jute mat and seeded with drought tolerant native seeds which will not invade native plant communities in the downstream receiving environment. Swales shall be maintained and regularly watered until establishment of a good coverage of grass and for at least 3 months following seeding.

Pipe Culverts	All pipe culverts shall incorporate suitable outlet scour protection in accordance with the requirements of *Managing Urban Stormwater: Soils and Construction, Volume 1* (Landcom, 2004). All outlets other than those discharging directly to roadside swales shall incorporate shallow sediment basins to maximise the retention of sediments. The sediment basins shall incorporate overflow weirs of sufficient length to uniformly disperse flows to the surrounding environment with a maximum flow velocity of 1.0m/s for the 1 in 5 year ARI design storm event.

8.2.2. Fire Trails

Fire trail construction shall comply with the following minimum requirements:

- Fire trails should be constructed flush with the existing surface so as not to obstruct or divert the natural flow of surface water.
- Suitable rock material should be incorporated into the top 200 mm of soil to provide all weather access whilst allowing a groundcover or appropriate non-invasive species to be established and maintained. Some excavation may be required to ensure the trail remains flush with the existing surface and any material removed for this purpose should preferably be B horizon soil.

8.2.3. Erosion and Sediment Control

Public road, fire trail and infrastructure construction shall comply with the following minimum requirements with respect to the control of erosion and sediment:

- Progressive erosion and sediment control plans shall be designed and implemented for all road and infrastructure works on the subject site.
- The progressive erosion and sediment control plans shall be consistent with *Nebraska Estate, St Georges Basin - Primary Erosion and Sediment Control Plan – Infrastructure Development* (Footprint, 2017) and developed in accordance with the principles contained in *Managing Urban Stormwater; Soils and Construction – Volumes 1 and 2C* (Landcom, 2004 & Landcom, 2008).
- The progressive erosion and sediment control plan/s shall detail the specific location and type of individual erosion and sediment control measures throughout the site.

8.2.4. Acid Sulfate Soil Management

The following minimum requirements shall apply with respect to the management of acid sulfate soils:

- An Acid Sulfate Soil Management Plan (ASSMP) shall be developed for the subject site prior to the commencement of works.
- The ASSMP shall be developed in accordance with the *Acid Sulfate Soil Manual* (1998) prepared by the Acid Sulfate Soil Management Advisory Committee.
- The ASSMP shall specifically address all works associated with upgrading of Fisherman Road or excavation for the purpose of providing water, sewerage or stormwater drainage services across the entire site.

9.0 CONCLUSION

This report demonstrates that the proposed rezoning and development of Nebraska Estate can achieve a long term beneficial effect on water quality, water quantity and the receiving environment subject to implementation of the recommended controls and performance standards outlined in this report. It is therefore considered to be consistent with the relevant policy and planning framework. The stormwater management system will combine lot based measures including rainwater tanks and infiltration trenches, with grassed bio-swales within the road network.

The modelling undertaken demonstrates that, by incorporating roadside bio-swales into the road formation, there is very little difference in net pollutant load between sealed and unsealed roads. Sealing of the public road network is therefore not considered necessary from a water quality perspective and actually results in a marginal increase in runoff volume compared to the predevelopment case. Sealing the roads will, however, significantly reduce the sediment load on the bio-swales and thus maintenance burdens. The choice to seal the roads may therefore be driven by life cycle costs in addition to other factors including noise and dust rather than by water quality.

The site soils are however erodible and highly dispersible and achieving a good standard during construction is critical to the outcome of this project.

Primary Erosion and Sediment Control Plans have been developed for both infrastructure and lot based development. These documents outline the intentions and fundamental principles that should be followed in planning and implementing control measures for all aspects of the project and need to be supplemented with progressive (for infrastructure development) and site specific (for lot based development) ESCPs developed by the Contractor and individual property owners. Erosion control measures for all construction works which involve the disturbance of soil must be implemented in accordance with these plans.

It is recommended that areas which are to be revegetated follow a vegetation management planning regime similar to that recommended by DWR for riparian vegetation management to ensure that the site is sealed and does not erode and thereby contribute sediment.

Finally it is noted that the roadside bio-swales will need to have a good vegetation cover to be effective. This will only happen with appropriate care (mainly regular watering) during the establishment phase of the bio-swales.

10.0 REFERENCES

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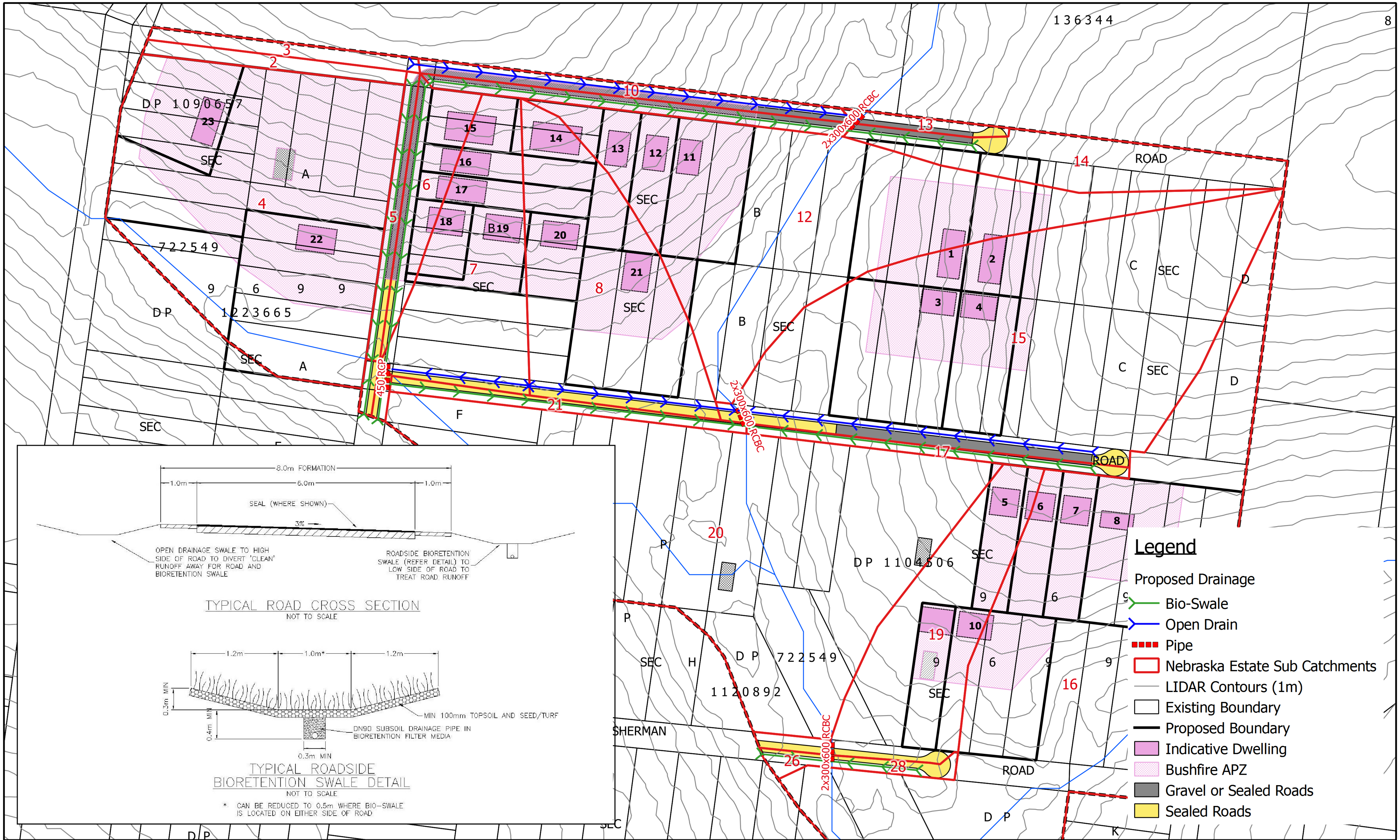
APPENDIX A

Conceptual Stormwater Drainage Plan



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Scale 1:2,500 at A3

NEBRASKA ESTATE, ST GEORGES BASIN

Integrated Water Cycle Management Plan

FIGURE 1

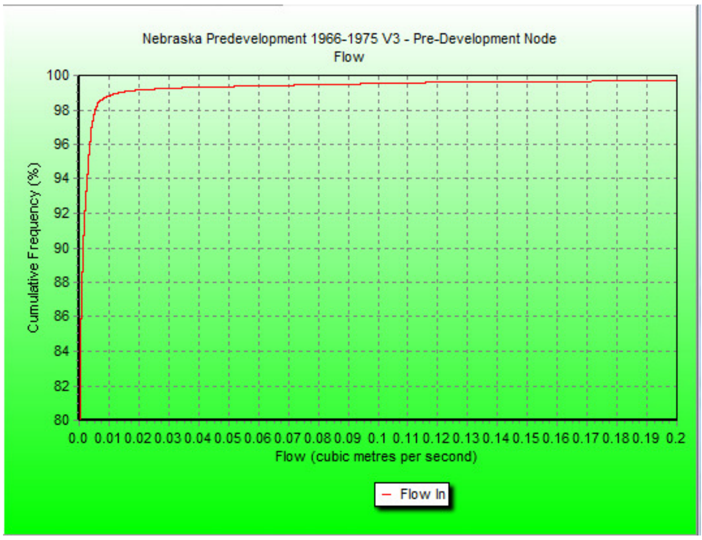
Concept Stormwater Management Plan

Rev 1 - 06 January 2017

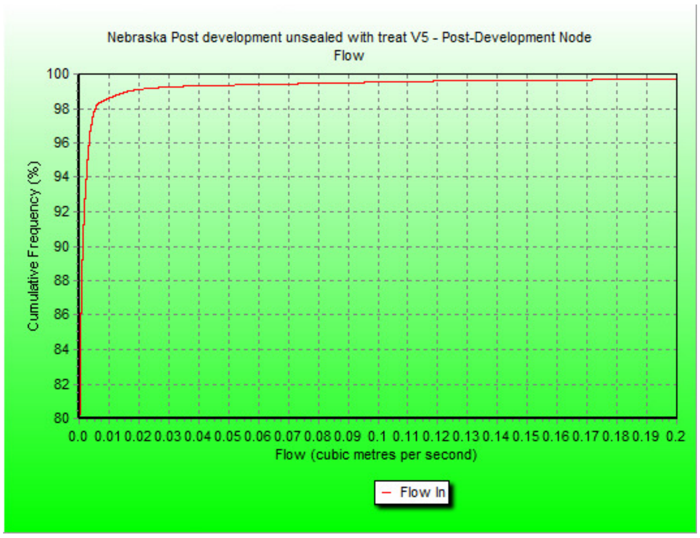
APPENDIX B

Flow Frequency Curves

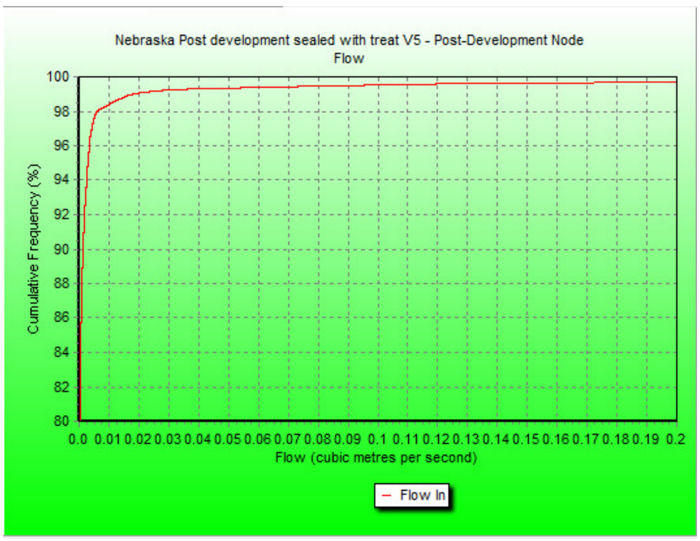
Pre-Development



Post Development - Unsealed



Post Development - Sealed



APPENDIX C

Nebraska Estate, St Georges Basin – Primary Erosion and Sediment Control Plan – Lot Based Development

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Nebraska Estate, St Georges Basin

Primary Erosion and Sediment Control Plan - Infrastructure Development

Project No. 1619
Date: March 2017

Prepared for: Shoalhaven City Council

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Document and Distribution Status								
Author(s)			Reviewer(s)		Signatures			
Ashley Bond					[signature]			
Revision No.	Status	Release Date	Document Distribution					
			Eric Hollinger					
1	DRAFT	21/02/17	PDF					
2	FINAL	02/03/17	PDF					

Distribution Types: F = Fax, H = Hard Copy, P = PDF, E = Other Electronic Document. Digits indicate number of copies.

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Standard Erosion Control Measures

1.0 INTRODUCTION

1.1. Purpose

Land that has been disturbed or cleared of vegetation is potentially subject to erosion as a result of stormwater runoff. Soil particles that are eroded in such a way are transported down-slope, usually settling in watercourses, wetlands and lakes.

Erosion and sedimentation may result in many adverse environmental impacts including:

- Reduction in water quality, increased turbidity and nutrient enrichment of water bodies,
- Damage to vegetation communities
- Disturbance to aquatic flora and fauna
- Increased potential for flooding
- Restrictions to navigation
- Reduction in recreational values
- Increased maintenance costs
- Promotion of weed growth
- Reduce agricultural, forestry and biomass production.

This plan will form the initial link in the chain to minimise on-site erosion and off-site sedimentation and therefore adverse environmental impacts.

1.2. Project Description

Nebraska Estate was a 'paper subdivision' registered in 1919 and released without any infrastructure to support its development. At the time of preparing this report, the land has very limited development potential due to the relevant planning controls. The land has generally remained undeveloped and un-serviced bushland with the exception of a few existing authorised structures.

After numerous studies and public exhibitions Council adopted a Planning Proposal based on a constrained development option that would enable up to 23 dwellings to be approved. The Planning Proposal was submitted to the Department of Planning and Infrastructure in late 2014.

The roads and service infrastructure are required to be constructed prior to the approval of individual dwellings. The costs associated with the provision of this infrastructure will be borne by the property owners.

1.3. Scope of this Plan

The purpose of this document is to serve as a broad based erosion and sediment control plan (ESCP) to outline the requirements and fundamental principles that must be followed in the planning and implementation of erosion and sediment control measures for the construction of the infrastructure works including road, drainage and fire trail construction.

A separate Primary ESCP has been developed for the management of development of lot based infrastructure on individual allotments.

This Primary ESCP will need to be supplemented with numerous Progressive ESCP's which detail the individual work areas and control measures required as construction of the project progresses. The progressive plans must be:

- Prepared by a suitably qualified practitioner with experience in the preparation of ESCP's.
- Integrated with work procedures, work method statements, activity statements and their scheduling.
- Site specific and will generally not need to repeat the information contained in this Primary ESCP and/or the Contractors EMP.
- Given a sequential number
- Controlled and distributed in accordance with the Contractors quality system procedures for document control.'

1.4. Legislative Requirements

The key environmental legislation relating to soil and water quality management includes:

- The Protection of the Environment Operations Act 1997 (POEO Act)
- The Environmental Planning and Assessment Act 1979 (EP&A Act)
- The Roads Act 1993

1.5. Supporting Documents

This document should be read in conjunction with the following supporting documents:

- Shoalhaven City Council Construction Specification Work Section 1102 – Control of Erosion and Sedimentation.
- Managing Urban Stormwater: Soils and Construction – Volume 1.
- Managing Urban Stormwater: Soils and Construction – Volume 2C, Unsealed Roads

2.0 SITE CHARACTERISTICS

2.1. Topography

The subject land is characterised by undulating slopes and three broad drainage depressions, draining to St Georges Basin at Home Bay via three unnamed watercourses and shown in Figure 1.

The south western and south eastern edge of the site are bounded by unnamed water courses, with the third water course running through the centre from north east to south west. The entire site thus comprises of four main sub-catchments separated by one ridge orientated north to south, and another orientated north east to south west.

The land is generally gently inclined with slope ranges of between 0-5˚ and elevations ranging between 2 and 22 metres AHD.

Figure 1 - Elevation of Subject Land (source SCC On-Site Effluent Disposal Assessment)

2.2. Soils and Geology

The geology of the area is dominated by Shoalhaven Group (Permian sedimentary formations) with the exception of Quaternary alluvial deposits in lower areas and creek lines.

The Land Capability Assessment conducted by Morse McVey & Associates Pty Ltd in 1994 identified two soil landscapes:

- Wandrawandian – occurs on crests and side slopes. Duplex (textural contrast) soils (typically clay loam topsoil over light-medium clay subsoil). Topsoil limitations include high erodibility, low fertility and strong acidity. Subsoil limitations include moderate to high erodibility, low fertility, strong acidity, potential aluminium toxicity and poor drainage.
- Tomerong Creek soil landscape – occurs on the lower lying land associated with the un-named watercourses. Characterised by low slopes (<5%) and high clay and silt content with high reactivity (large shrink-swell characteristics), low fertility, strong acidity, and potential aluminium toxicity.

Significant soil constraints were identified and include:

- High soil erodibility (values of 0.026 and 0.046 used in the universal soil loss equation – USLE), and;
- Moderately dispersive subsoil (with dispersion percentage ranging from 1.3 – 3.3), meaning that the clay particles can be more readily eroded and transported to the downstream environment. Soils on the site have been classified as Type F (fine textured) soils.

Acid Sulfate Soils

The lower reaches of the flood prone land were identified by the Huskisson Acid Sulfate Soils Risk map as having a high probability of Acid Sulfate Soils (ASS) occurring within one metre of the ground surface. This land is identified as 'Class 2' on the Acid Sulfate Soils map that forms part of Shoalhaven LEP 2014, to which clause 7.1 applies. Clause 7.1 can also be triggered for works within 500m of adjacent Class 1, 2, 3 and 4 land that is below 5m AHD. Refer to Clause 7.1 of SLEP 2014 for further details.

The affected area is encompassed within the area that is proposed to be zoned E2 – Environmental Conservation, where no additional residential development is proposed. Appropriate investigations, including preparation of an ASS management plan, would be required to be undertaken prior to undertaking any works associated with upgrading of Fisherman Road or excavation for the purpose of providing water or sewerage services.

In 2001, Environmental and Earth Sciences P/L undertook an ASS investigation along the path of the proposed sewerage line for Park Road, Nebraska Estate. This investigation involved soil and groundwater testing at the southern end of the subject land. The results of the investigation are summarised below:

- There was negligible PASS. A borehole within the main watercourse contained low concentrations of soil sulphides but these were considered non-reactive.
- As a cautionary measure, it was recommended that any soil excavated from the watercourse, should be mixed with 4 kg of lime per ton of soil.
- Groundwater should be monitored if dewatering is undertaken for periods exceeding one week.
- Any concrete or metallic structures placed between the banks of the watercourse should have a buffer of at least 150 mm of sand mixed with lime at a ratio of 5 kg per ton of sand.

2.3. Flooding

The modelled extent of stormwater inundation in Nebraska Estate is shown in Figure 2, This figure displays the results from several flood studies:

- 'St Georges Basin Flood Study', Webb, McKeown and Associates P/L, 2001
- 'St Georges Basin Floodplain Risk Management Study and Plan Climate Change Assessment', WMA Water 2013
- A site specific draft preliminary catchment analysis prepared from airborne laser scanning (ALS) survey over Nebraska Estate by Shoalhaven City Council, 2006.

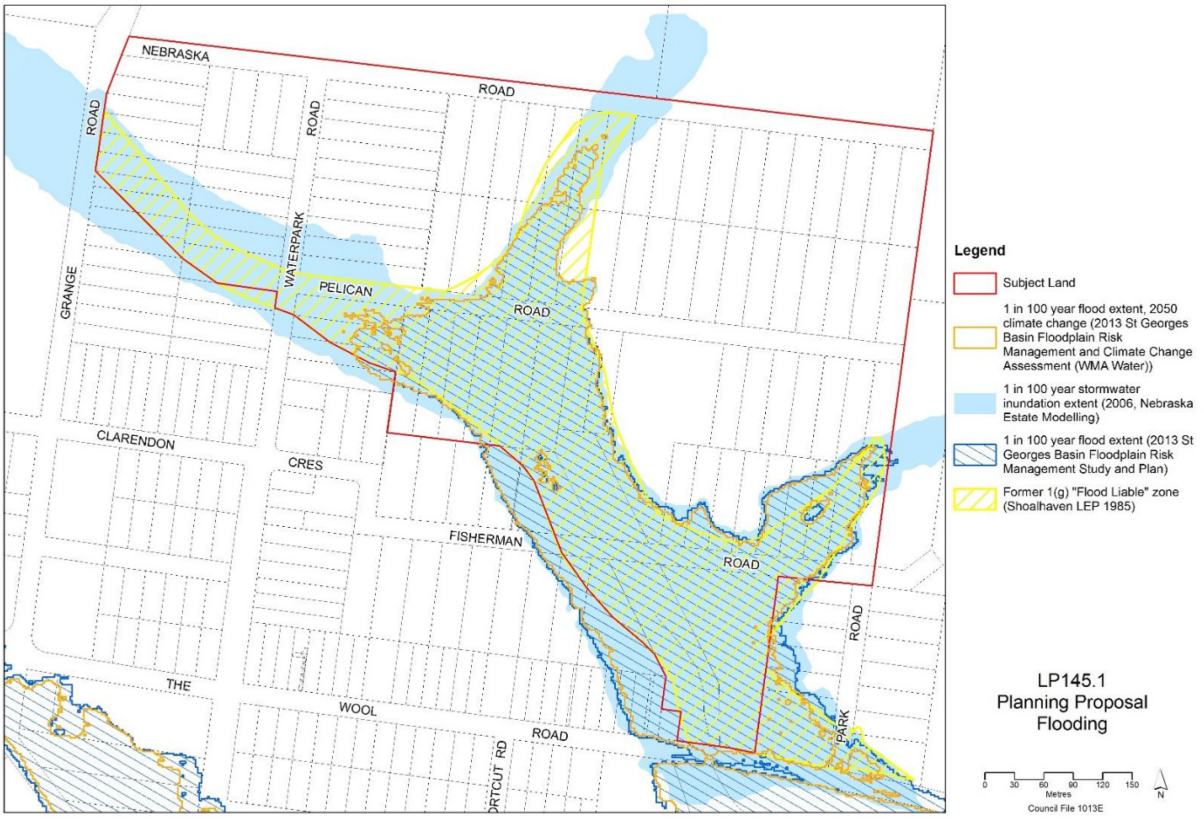


Figure 2 – Flood-related information (source SCC Project Brief)

2.4. Flora and Fauna

The subject site is home to a number of endangered, threatened or protected plant species. Swamp Sclerophyll Forest, is categorised as an endangered ecological community (EEC) under the NSW Threatened Species Conservation Act (BES, 2009). This EEC broadly corresponds to the flood prone land area, which also contains a population of protected Biconvex Paperbark (Melaleuca biconvexa). The north east corner of the subject land also contains a large number of threatened orchid species, one of which (Pterostylis ventricosa) was actually discovered in Nebraska Estate in 2000.

2.5. Aboriginal Cultural Heritage

Archaeological studies were undertaken in Nebraska Estate in 1994, 1995 and 2001. The first of these identified two small scatters of stone artefacts and one isolated artefact within the drainage lines. All three Aboriginal sites are located within the proposed E2 zone and no further residential development is proposed on the affected land. Some ground disturbance will be necessary for the construction of infrastructure and if these works uncover any additional artefacts the necessary requirements will be undertaken in order to comply with the NSW National Parks and Wildlife Act and regulations.

3.0 CALCULATED SOIL LOSS

The annual average soil loss during construction activities on the subject site has been estimated at 560 tonnes/ha/year using the Revised Universal Soil Loss Equation as defined in Managing Urban Stormwater: Soils and Construction, Volume 1 and using the values below.

Parameter	Adopted Value	Source/Comment
R – Rainfall Erosivity Factor	4,550	Morse Mcvey, 1994 (Section 2.7)
K – Soil Erodibility	0.046	Morse Mcvey, 1994 (Section 3.2) based on Tomerong Creek Soil Landscape (worst case scenario)
LS – Slope Length/Gradient Factor	2.05	Based on 8% gradient (approx. 5 degrees) and maximum 80m slope
P – Erosion Control Practice Factor	1.3	Assumed Compacted and Smooth
C – Cover Factor	1.0	Recently disturbed soil with no cover

Based on the above calculated soil loss rate the subject site is classified as having **Soil Loss Class 5** and **HIGH Erosion Hazard**.

4.0 KEY MANAGEMENT STRATEGIES

In comparison to urban development rural road construction has a number of key characteristics and differences and therefore the approach to erosion and sediment control needs to be tailored accordingly. Some of the key characteristics of rural road construction include;

- they are linear
- they cross multiple catchments and have numerous discharge points
- the road corridor is often limited in width.

With conventional subdivision, road construction occurs prior to release of the subdivision certificate thereby providing the contractor with the ability to utilise future lots for the construction of temporary sediment controls.

At Nebraska Estate, however the lots have already been subdivided and are in private ownership and therefore the ability to utilise such land for temporary sediment control is very limited. Furthermore, the land proposed to be zoned E2 is affected by one or more environmental constraints, hence the degree of disturbance should be minimised from an environmental perspective.

Given the above constraints erosion and sediment controls implemented for road construction will need to be confined to the public road corridors. Due to the limited space available within the existing road reserve the adoption of source controls in combination with sound site management practices is considered the most appropriate form of soil and erosion control.

The following site management practices and temporary and permanent treatment measures should be considered and incorporated, as deemed appropriate, into any Progressive Erosion and Sediment Control Plans prepared for construction of the public road network and service infrastructure.

4.1. General

- Ensure erosion and sediment control are installed at all sites associated with the construction activities including access roads and tracks, office and compound sites.
- Develop relevant documentation and systems for recording erosion and sediment control activities via:
  - Progressive ESCP
  - Inspection reports
  - Maintenance checklists
  - Meeting/Toolbox Talk Minutes
- Highlight the importance of soil conservation issues during site induction and continually address relevant matters at regular toolbox meetings during the course of the project.

4.2. Site Management Practises

Managing Urban Stormwater: Soils and Construction, Volume 2C – Unsealed Roads, provides guidance on appropriate site management measures that should be implemented during construction in order to ensure effective erosion and sediment control. These measures include;

- timing of construction to avoid erosive rainfall periods
- programming construction stages to minimise erosion
- minimising the extent and duration of disturbance
- conveying clean water through the site
- practicing good site housekeeping

A summary of each measure is provided below. For further information refer to Volume 2C, Section 6.2.

4.2.1. Timing of Construction

Based on the soil loss rate calculated in Section 3.0 the subject site is classified as having a Soil Loss Class 5 and therefore, in accordance with Table 4.3 *Managing Urban Stormwater: Soils and Construction, Volume 1,* works should be not be scheduled to be undertaken during either February or March.

4.2.2. Construction Sequencing

Implement construction programming that promotes good erosion and sediment control including;

- early installation of culverts and other permanent drainage works
- installation of culvert outlet and inlet protection works immediately following culvert installation
- early installation of permanent catch drains (where relevant) and lining
- constructing the bio-retention trench component of the bio-swales after sealing of the road surface and stabilisation of roadside batters. Alternatively consideration could be given to the placement of a temporary geotextile and sacrificial topsoil layer over the bio-retention trench, removing this on completion of road sealing and then placing the final topsoil layer and vegetating.
- regular watering and weeding of swales/bio-swales during the establishment period and until a good cover is achieved. This may require water tankers to be used to irrigate the swales to ensure grass survival. Drought tolerant species are to be used.
- Removal of excess sediment accumulation in swales/bio-swales during the establishment period and until the site has settled and sealed.
- progressive revegetation throughout the project
- progressive stabilisation of batters.

4.2.3. Minimising Extent of Soil Disturbance

- Clearing and grubbing shall be limited to two (2) metres from the edge of any essential engineering activity (i.e. top and toe of batters, stormwater outlet).

- Clear and grub to leave the soil surface in a reasonably rough condition with some surface vegetative cover.
- Stage construction works to minimise the extent of disturbance at any given time in order to negate the need for construction phase sediment basins. For example constructing, sealing and stabilising batters on one road/section prior to commencing construction on the road/next section. The extent of disturbance should be no more than that which limits the average annual soil loss from the total area of land disturbed to less than 150 cubic metres per year.
- Completing works and stabilising disturbed areas quickly and progressively.
- Stabilise drainage structures as soon as possible following construction

4.2.4. Control of Stormwater Runoff

- Separate clean run-on water from dirty (e.g. turbid) construction area runoff through the use of diversion banks and drains.
- Construct permanent drainage structures early in the project such as catch drains and culverts (including associated inlet and outlet protection works)
- Maximise the diversion of turbid construction runoff into sediment control devices such as sediment basins and filters.
- Divert runoff from the road formation into the stormwater drainage system as soon as practical to reduce surface flow lengths.

4.2.5. Practicing good site house keeping

Essentially good site housekeeping means keeping the site in a clean and orderly manner and includes;

- limiting the number of sediment sources by minimising the number of stockpiles. Placing material as it is excavated will help reduce the number of stockpiles. And also minimises double handling.
- removing unwanted spoil stockpiles progressively and quickly
- locate stockpiles away from heavily trafficked areas, areas prone to inundation and drainage lines.

4.2.6. Use of Erosion Control Measures

- Stockpile soil materials in low hazard areas clear of natural depressions, drainage channel or watercourses. Additional protection to be afforded with temporary vegetation, diversion banks and sediment control measures, as required.
- Construct a range of erosion controls including sediment fences, rock check dams and straw bale filters within the various road catchments to complement and increase the effectiveness and efficiency of any sediment controls in the lower areas.
- Use geotextile linings to provide temporary surface protection in areas of concentrated flows.
- Construct control measures as close as practical to the potential sediment source.
- Control the deposition of mud and soil materials onto local roads through the use of an appropriate stabilised site access.

4.2.7. Stabilisation of Disturbed Areas

- Ensure the success of the later revegetation by utilising good quality topsoil.
- Ameliorate exposed/disturbed subsoils with gypsum (or other suitable chemical ameliorant) at a rate of 2.5kg/10m^2 to reduce soil dispersion.
- Progressively and quickly revegetate disturbed areas utilising appropriate species.
- Control dust through progressive revegetation and water tankers.

4.2.8. Inspection and Maintenance

- Ensure the progressive and continual implementation and maintenance of temporary erosion and sediment controls (e.g. sediment fences, diversion banks, diversion drains, sediment traps)
- Initiate a program to ensure regular maintenance of all erosion and sediment control measures. Sediment cleaned from structures is to be deposited in a secure location where further pollution will not occur.
- Arrange regular inspections to review and update control measures. Additional inspections shall be conducted during and/or immediately following significant (i.e. >10mm/24hrs) rainfall events to monitor the functioning of controls.

4.3. Temporary Control Measures

Temporary erosion and sediment control measures considered suitable for use during road and service infrastructure construction activities include, but are not limited to the following;

- silt fences
- check dams
- excavated, straw bale or sand bag sediment traps
- temporary diversion drains
- geotextile pit inlet filters
- lining swales with biodegradable jute matting

A suite of standard erosion control measures that may be implemented on site are included in Appendix A and have been extracted from *Managing Urban Stormwater; Soils and Construction, Volume 1* (Landcom , 2004).

In determining of the most appropriate erosion and sediment control measures to incorporate into the Progressive ESCPs the designer should make reference to *Managing Urban Stormwater; Soils and Construction, Volume 1* (Landcom , 2004).

The design criteria to be adopted for the design of temporary erosion control measures should be in accordance with Table 1. The subject site is considered to be in a sensitive environment given the environmental sensitivity and constraints of the site.

Table 1 - Design Storm Event for Temporary Erosion and Sediment Control Measures (source MUS, Vol 2c)

Control Measure Description	**Standard Design**	**Sensitive Environment**[1]
Temporary drainage (erosion) control (e.g. diversion banks, perimeter banks, catch drains, level spreaders, check dams, batter drains and chutes) should be designed to have a non-erosive hydraulic capacity (excluding freeboard) sufficient to convey the nominated design storm event.	2 year ARI	5 year ARI
Temporary Sediment Control (e.g. sediment fences, stacked rock sediment traps) in small catchment were used as a 'last line of defence' (i.e. without a sediment basin down-slope) should be constructed to remain structurally sound in the nominated design storm event.	2 year ARI	5 year ARI

[1] A 'sensitive environment' is one with a high conservation value, or that supports human uses of water that are particularly sensitive to degraded water quality.

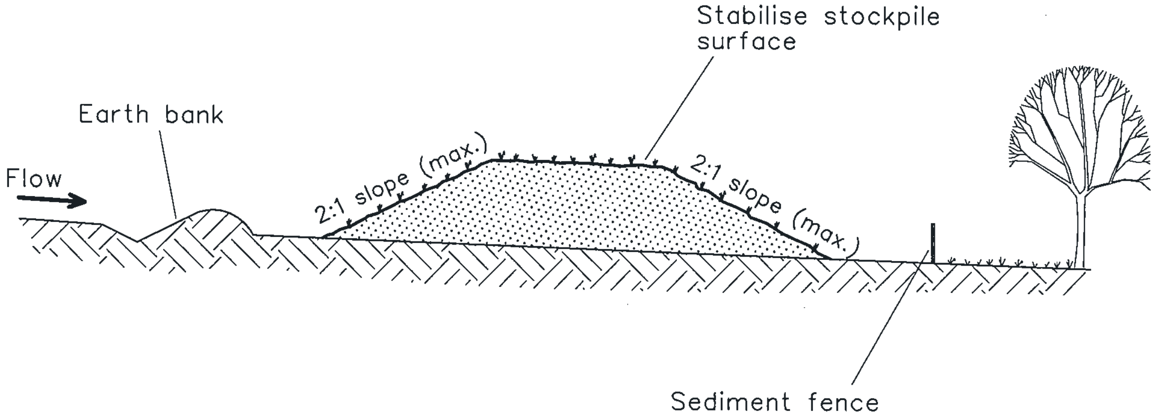
5.0 REFERENCES

Landcom (2004) *Managing Urban Stormwater; Soils and Construction – Volume 1 (4th Edition)*

Landcom (2008) *Managing Urban Stormwater; Soils and Construction – Volume 2C*

Morse McVey (1994) *Land Capability Report for Nebraska Estate, The Wool Road, St Georges Basin*, Morse McVey and Associates.

APPENDIX A
Standard Erosion Control Measures



Construction Notes

1. Place stockpiles more than 2 (preferably 5) metres from existing vegetation, concentrated water flow, roads and hazard areas.

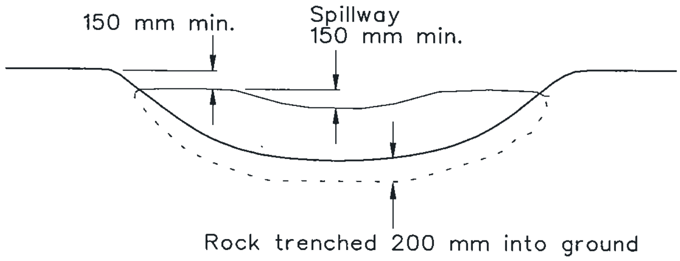
2. Construct on the contour as low, flat, elongated mounds.

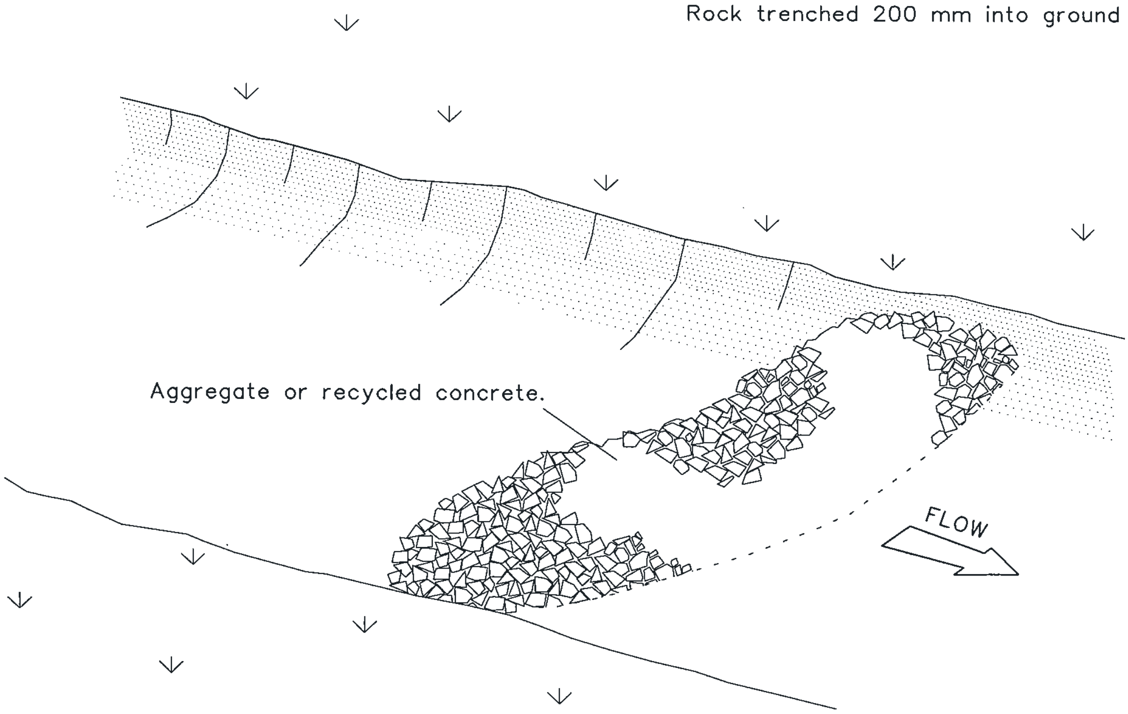
3. Where there is sufficient area, topsoil stockpiles shall be less than 2 metres in height.

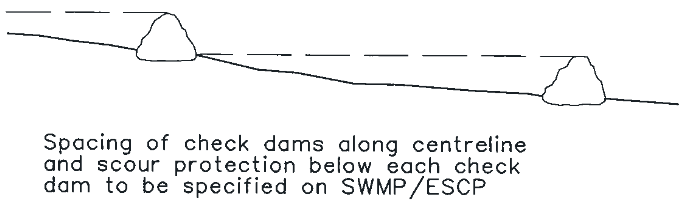
4. Where they are to be in place for more than 10 days, stabilise following the approved ESCP or SWMP to reduce the C-factor to less than 0.10.

5. Construct earth banks (Standard Drawing 5-5) on the upslope side to divert water around stockpiles and sediment fences (Standard Drawing 6-8) 1 to 2 metres downslope.

STOCKPILES **SD 4-1**







Construction Notes

1. Check dams can be built with various materials, including rocks, logs, sandbags and straw bales. The maintenance program should ensure their integrity is retained, especially where constructed with straw bales. In the case of bales, this might require their replacement each two to four months.

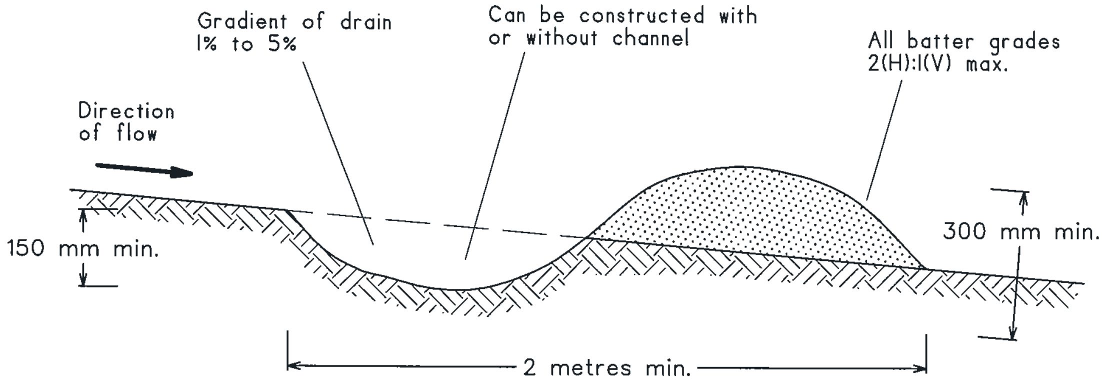
2. Trench the check dam 200 mm into the ground across its whole width. Where rock is used, fill the trenches to at least 100 mm above the ground surface to reduce the risk of undercutting.

3. Normally, their maximum height should not exceed 600 mm above the gully floor. The centre should act as a spillway, being at least 150 mm lower than the outer edges.

4. Space the dams so the toe of the upstream dam is level with the spillway of the next downstream dam.

ROCK CHECK DAM

SD 5-4



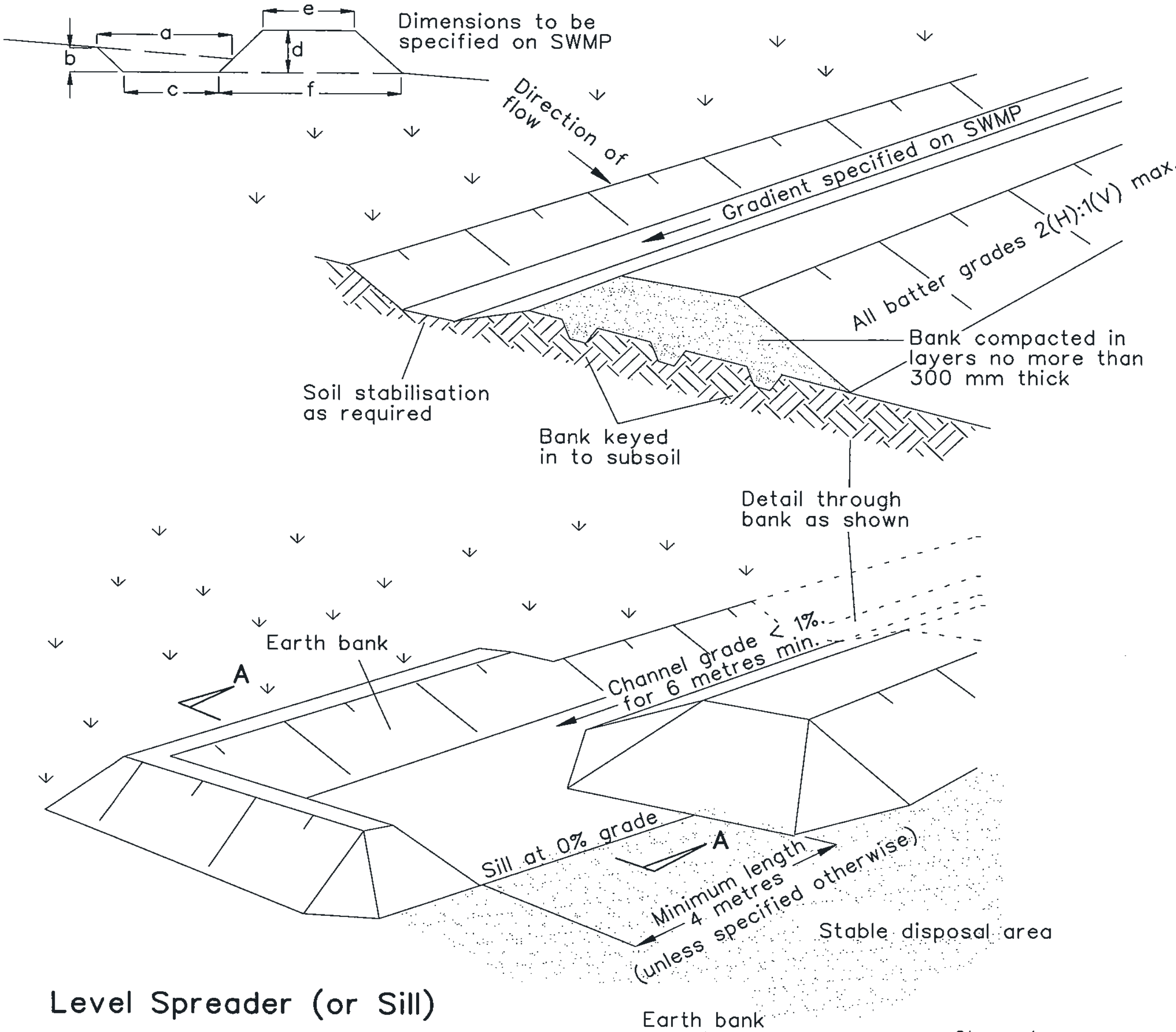
NOTE: Only to be used as temporary bank where maximum upslope length is 80 metres.

Construction Notes

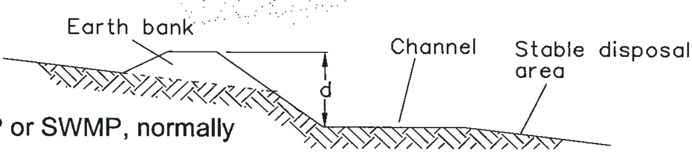
1. Build with gradients between 1 percent and 5 percent.
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V shaped.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction.

EARTH BANK (LOW FLOW)

SD 5-5



Level Spreader (or Sill)

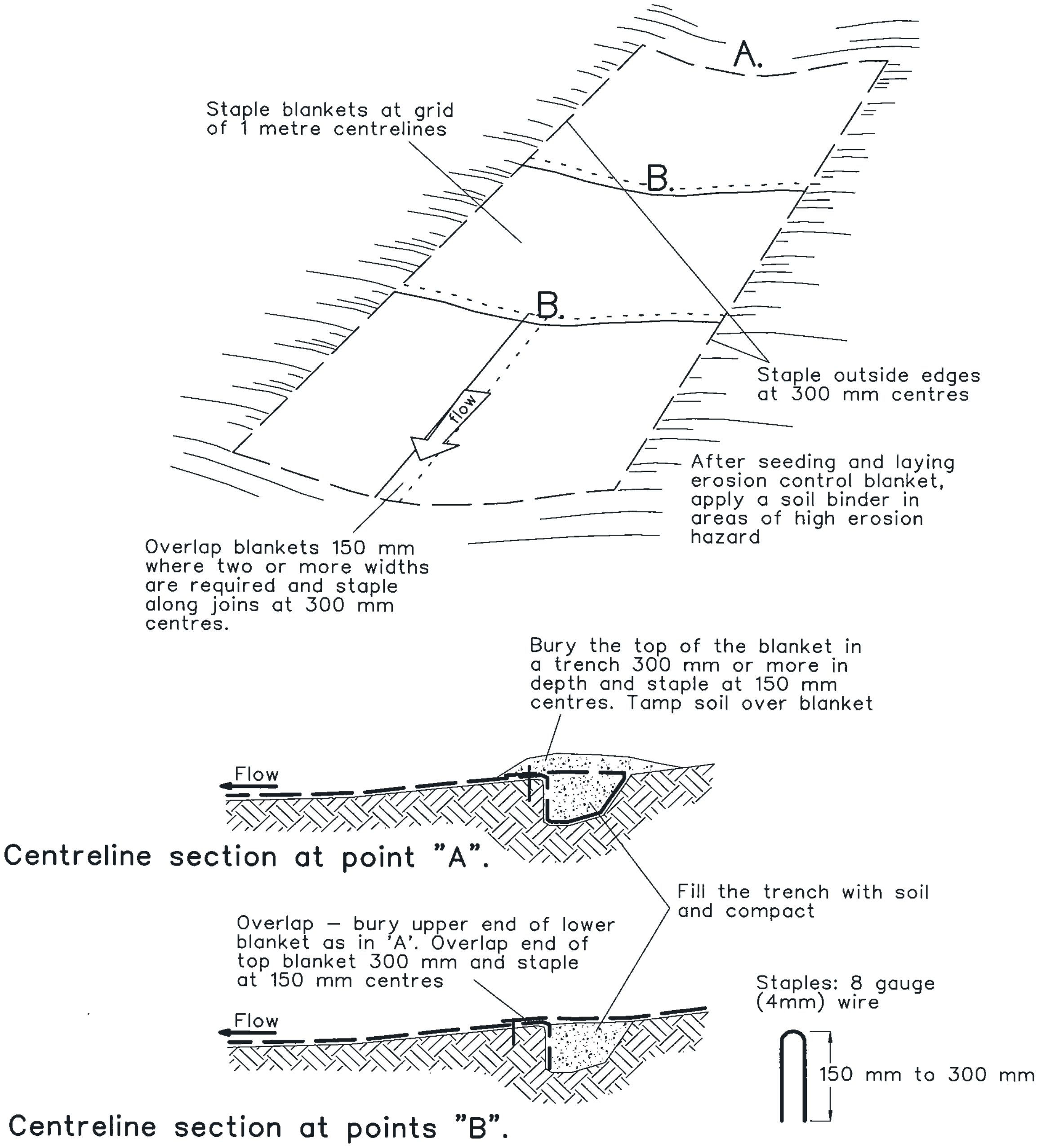


Section AA

Construction Notes

1. Construct at the gradient specified on the ESCP or SWMP, normally between 1 and 5 percent
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V-shaped, at the dimensions shown on the SWMP.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction following Table 5.2 in Landcom (2004).
7. Where discharging to erodible lands, ensure they outlet through a properly constructed level spreader.
8. Construct the level spreader at the gradient specified on the ESCP or SWMP, normally less than 1 percent or level.
9. Where possible, ensure they discharge waters onto either stabilised or undisturbed disposal sites within the same subcatchment area from which the water originated. Approval might be required to discharge into other subcatchments.

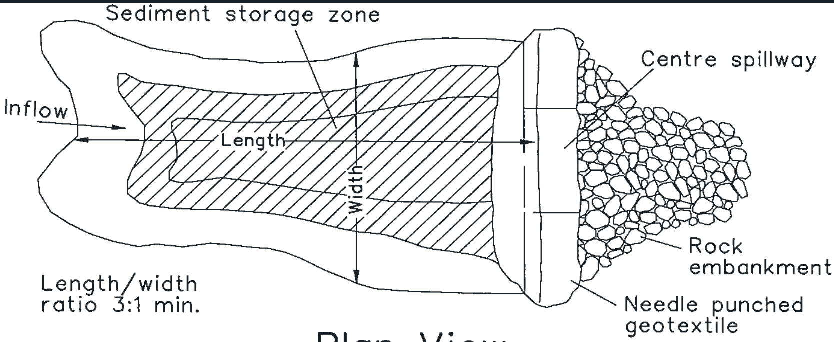
EARTH BANK (HIGH FLOWS) SD 5-6



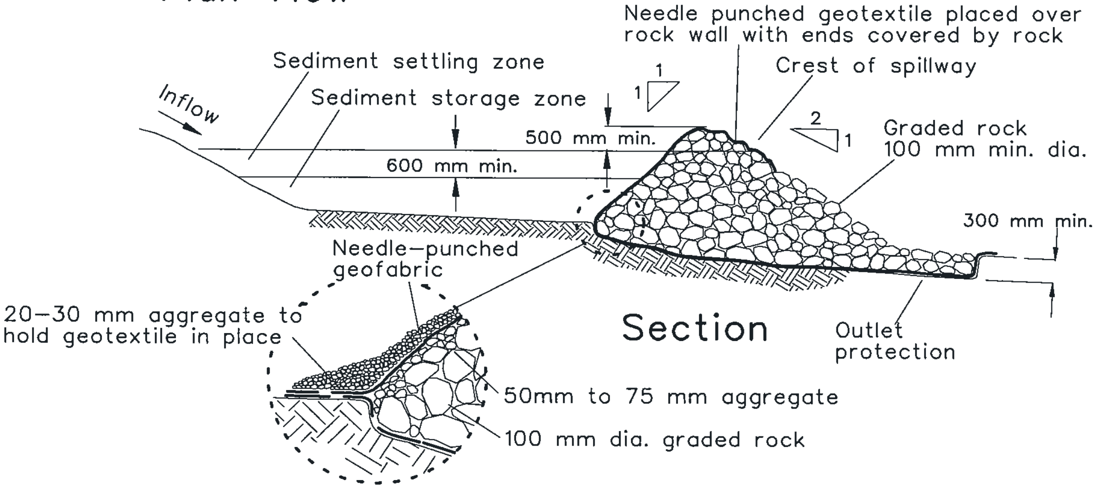
Construction Notes

1. Remove any rocks, clods, sticks or grass from the surface before laying matting
2. Ensure that topsoil is at least 75 mm deep.
3. Complete fertilising and seeding before laying the matting.
4. Ensure fabric will be continuously in contact with the soil by grading the surface carefully first.
5. Lay the fabric in "shingle-fashion", with the end of each upstream roll overlapping those downstream. Ensure each roll is anchored properly at its upslope end (Standard Drawing 5-7b).
6. Ensure that the full width of flow in the channel is covered by the matting up to the design storm event, usually in the 10-year ARI time of concentration storm event.
7. Divert water from the structure until vegetation is stabilised properly.

RECP : CONCENTRATED FLOW **SD 5-7**

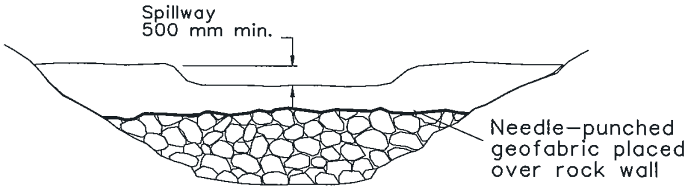


Plan View



Section

NOTE:
Spillway width and depth, wall crest width and downstream outlet protection measures to be specified on SWMP.



Downstream Elevation

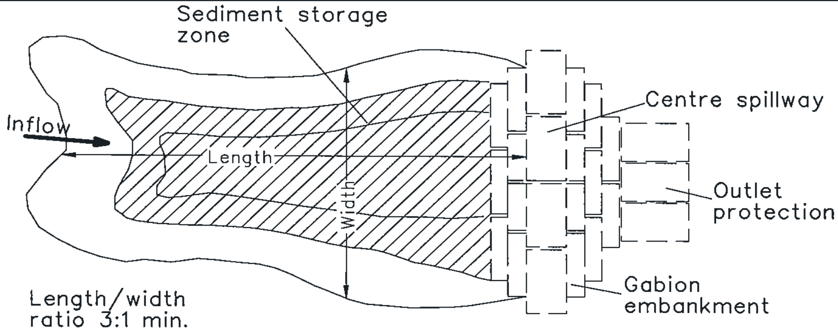
Construction Notes

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Excavate to 300 mm depth for base of the dam wall.
3. Line the excavation with a needle-punched geotextile allowing sufficient to line below the wall, and over the upstream rock and the spillway to 500 mm below the spillway exit on the downstream face.
4. Make up the wall profile and outlet protection with100 mm (min.) diameter graded rock. Spread a layer of 50 mm to 75 mm diameter aggregate over the upstream batter for a more even surface, and add 100 mm to 150 mm of 20 mm to 30 mm gravel over the 50 mm to 75 mm diameter aggregate.
5. Lay geotextile over the upstream batter and through the spillway, fixing in place with 100 mm rock.
6. Place a "Full of Sediment" marker to show when less than design capacity occurs and sediment removal is required.
7. Replace the upstream geotextile layer each time sediment is removed

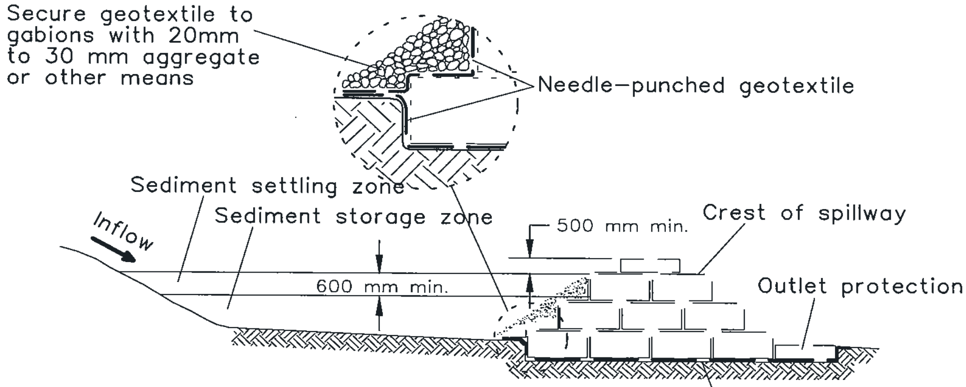
ROCK SEDIMENT BASIN

(APPLIES TO 'TYPE C' SOILS ONLY)

SD 6-1



Plan View



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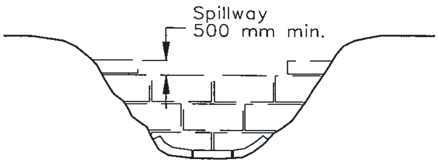


NOTE: Spillway width and depth, wall crest width and downstream outlet protection measures to be specified on SWMP.

Downstream Elevation

Construction Notes

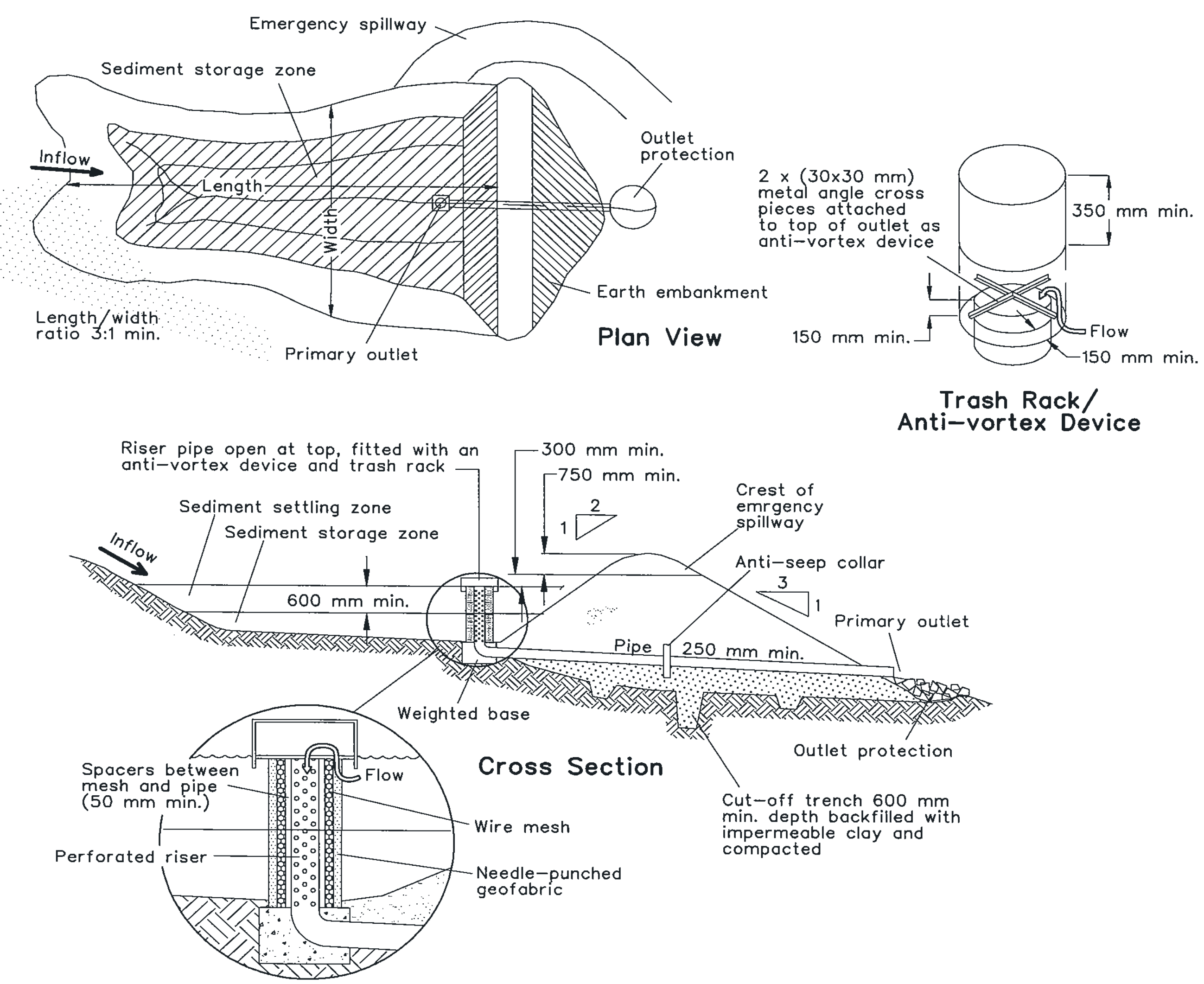
(Applies to Type C soils only)

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Excavate to 300 mm depth for the base of the dam wall and form a level platform for the gabions.
3. Line the excavation with a needle-punched geotextile allowing sufficient to line below the wall, and over the upstream gabions and spillway to 500 mm below the spillway exit on the downstream face.
4. Make up the wall profile and outlet protection with gabion units filled with graded rock as specified on the SWMP.
5. Construct a spillway 500 mm below the crest of the dam and for the width specified on the SWMP.
6. Lap the geotextile over the upstream face and through the spillway and fix it in place with the top row of gabions.
7. Cover the upstream face of the wall with 20 mm to 30 mm gravel and geotextile (Standard Drawing 6-2b)
8. Place a "Full of Sediment' marker to show when less than design capacity occurs and sediment removal is required.
9. Replace the upstream geotextile layer when sediment is removed if a dry basin is required.

GABION SEDIMENT BASIN

(APPLIES TO 'TYPE C' SOILS ONLY)

SD 6-2



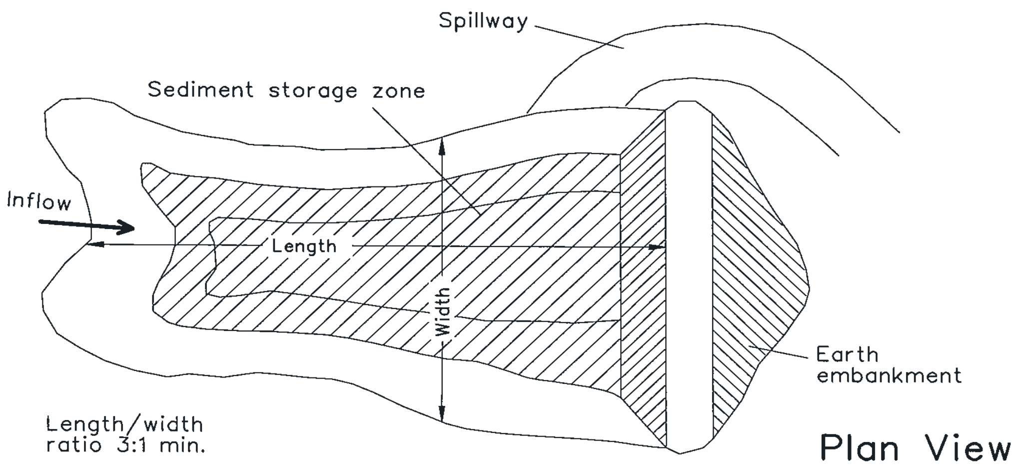
Construction Notes

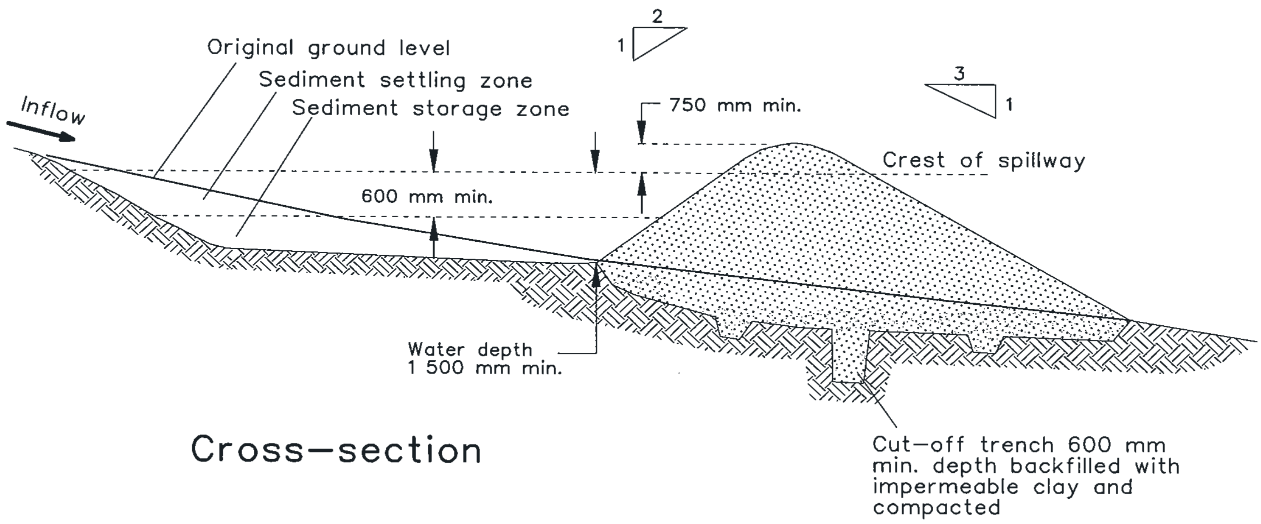
1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Form a cut off trench under the centreline of the embankment 600 mm deep and 1,200 mm wide, extending to a point on the watercourse wall above the riser sill level.
3. Maintain the trench free of water and recompact the materials with equipment as specified In the SWMP to 95 per cent Standard Proctor Density.
4. Select fill according to the SWMP that is free from roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond the compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Install the pipe outlet with seepage collars as specified in the SWMP and Standard Drawing 6-3b.
8. Form batter grades at 2(H):1(V) upstream and 3(H):1(V) downstream or as specified in the SWMP

EARTH BASIN - DRY

(APPLIES TO 'TYPE C' SOILS ONLY)

SD 6-3





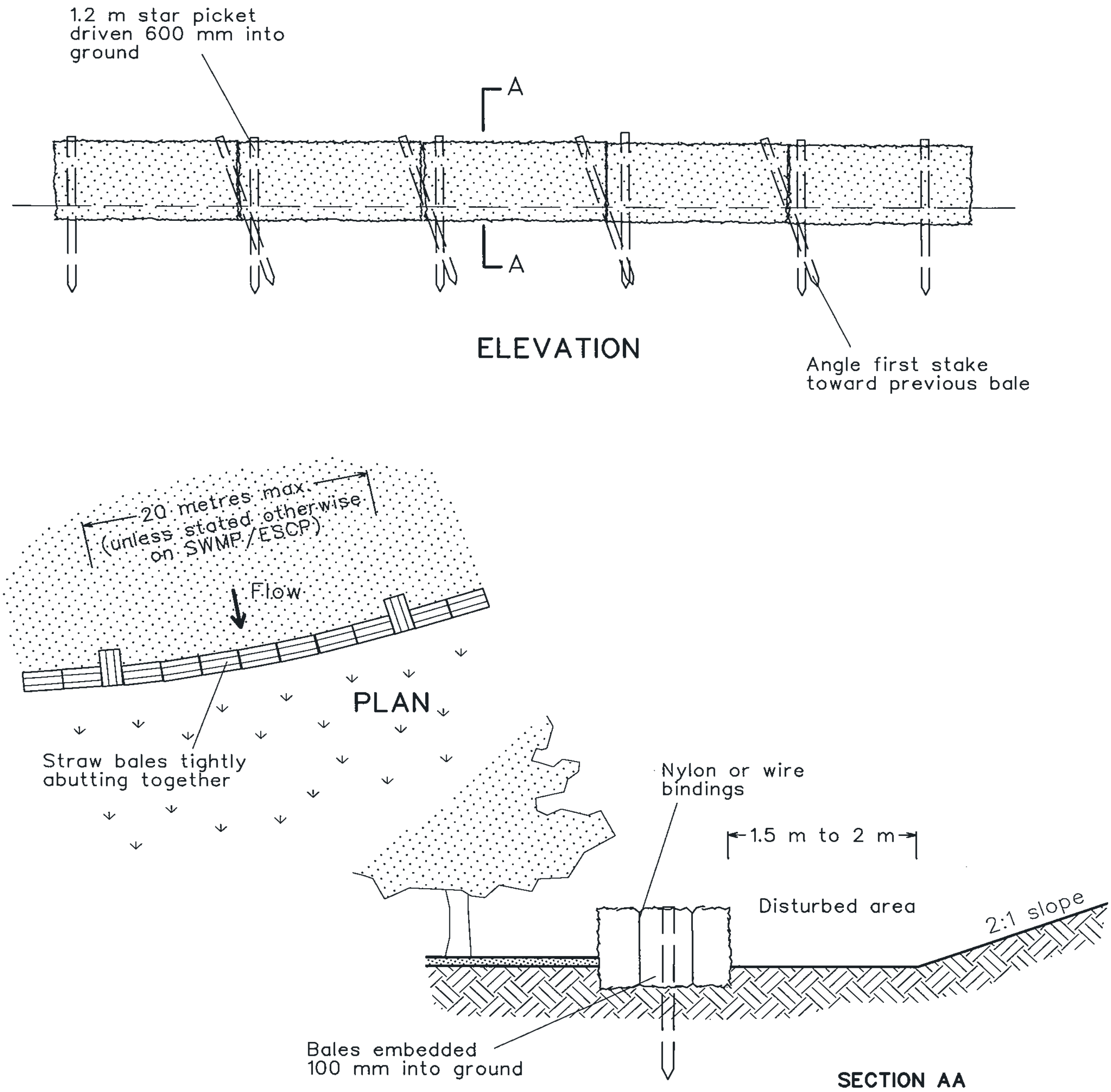
Construction Notes

1. Remove all vegetation and topsoil from under the dam wall and from within the storage area.
2. Construct a cut-off trench 500 mm deep and 1,200 mm wide along the centreline of the embankment extending to a point on the gully wall level with the riser crest.
3. Maintain the trench free of water and recompact the materials with equipment as specified in the SWMP to 95 per cent Standard Proctor Density.
4. Select fill following the SWMP that is free of roots, wood, rock, large stone or foreign material.
5. Prepare the site under the embankment by ripping to at least 100 mm to help bond compacted fill to the existing substrate.
6. Spread the fill in 100 mm to 150 mm layers and compact it at optimum moisture content following the SWMP.
7. Construct the emergency spillway.
8. Rehabilitate the structure following the SWMP.

EARTH BASIN - WET

(APPLIES TO 'TYPE D' AND 'TYPE F' SOILS ONLY)

SD 6-4

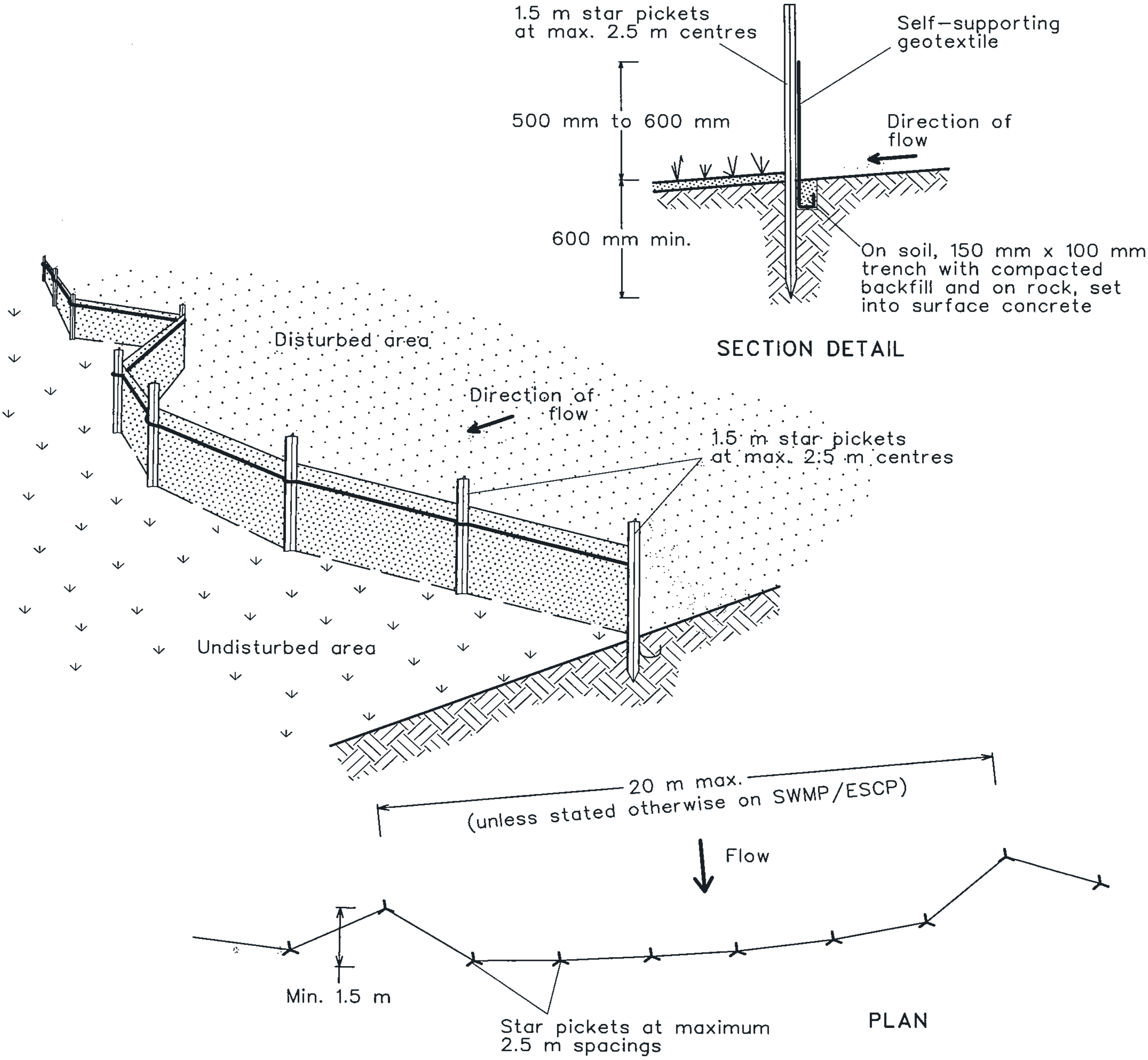


Construction Notes

1. Construct the straw bale filter as close as possible to being parallel to the contours of the site.
2. Place bales lengthwise in a row with ends tightly abutting. Use straw to fill any gaps between bales. Straws are to be placed parallel to ground.
3. Ensure that the maximum height of the filter is one bale.
4. Embed each bale in the ground 75 mm to 100 mm and anchor with two 1.2 metre star pickets or stakes. Angle the first star picket or stake in each bale towards the previously laid bale. Drive them 600 mm into the ground and, if possible, flush with the top of the bales. Where star pickets are used and they protrude above the bales, ensure they are fitted with safety caps.
5. Where a straw bale filter is constructed downslope from a disturbed batter, ensure the bales are placed 1 to 2 metres downslope from the toe.
6. Establish a maintenance program that ensures the integrity of the bales is retained - they could require replacement each two to four months.

STRAW BALE FILTER

SD 6-7



Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.

2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.

3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.

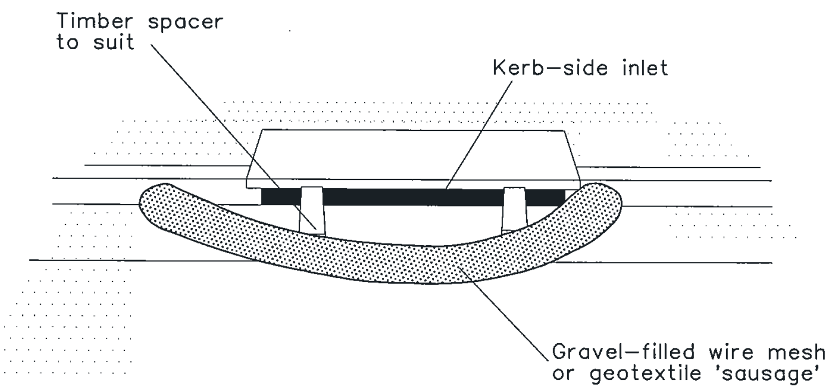
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.

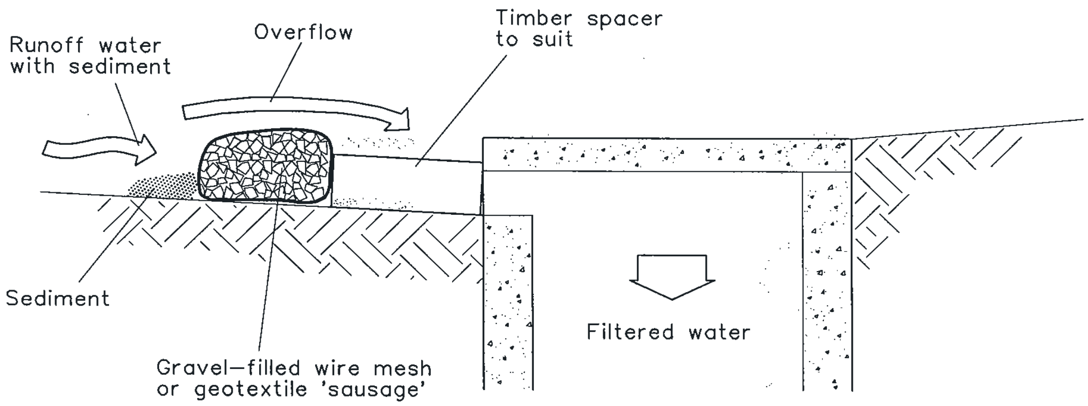
5. Join sections of fabric at a support post with a 150-mm overlap.

6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE

SD 6-8





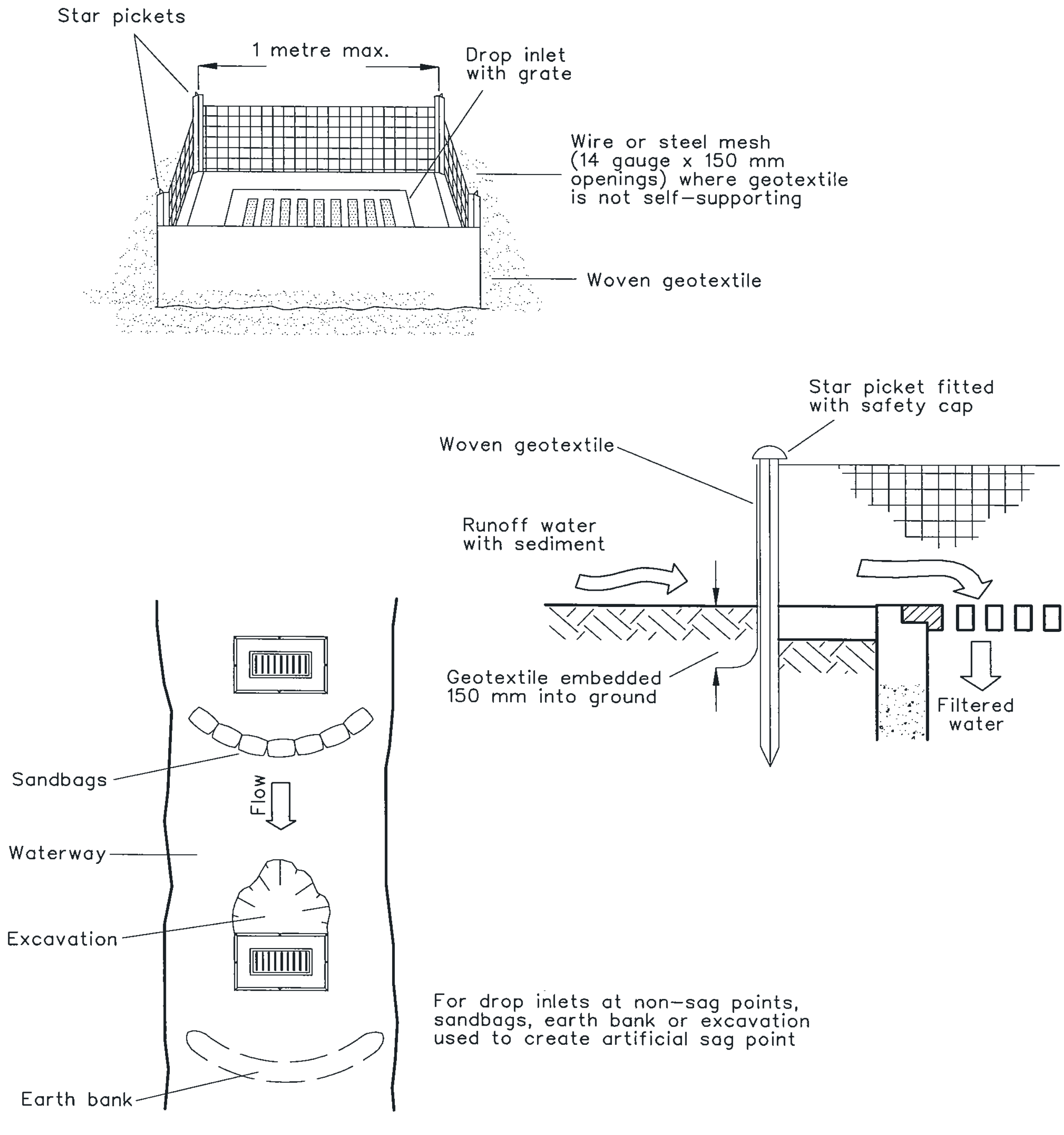
NOTE: This practice only to be used where specified in an approved SWMP/ESCP.

Construction Notes

1. Install filters to kerb inlets only at sag points.
2. Fabricate a sleeve made from geotextile or wire mesh longer than the length of the inlet pit and fill it with 25 mm to 50 mm gravel.
3. Form an elliptical cross-section about 150 mm high x 400 mm wide.
4. Place the filter at the opening leaving at least a 100-mm space between it and the kerb inlet. Maintain the opening with spacer blocks.
5. Form a seal with the kerb to prevent sediment bypassing the filter.
6. Sandbags filled with gravel can substitute for the mesh or geotextile providing they are placed so that they firmly abut each other and sediment-laden waters cannot pass between.

MESH AND GRAVEL INLET FILTER

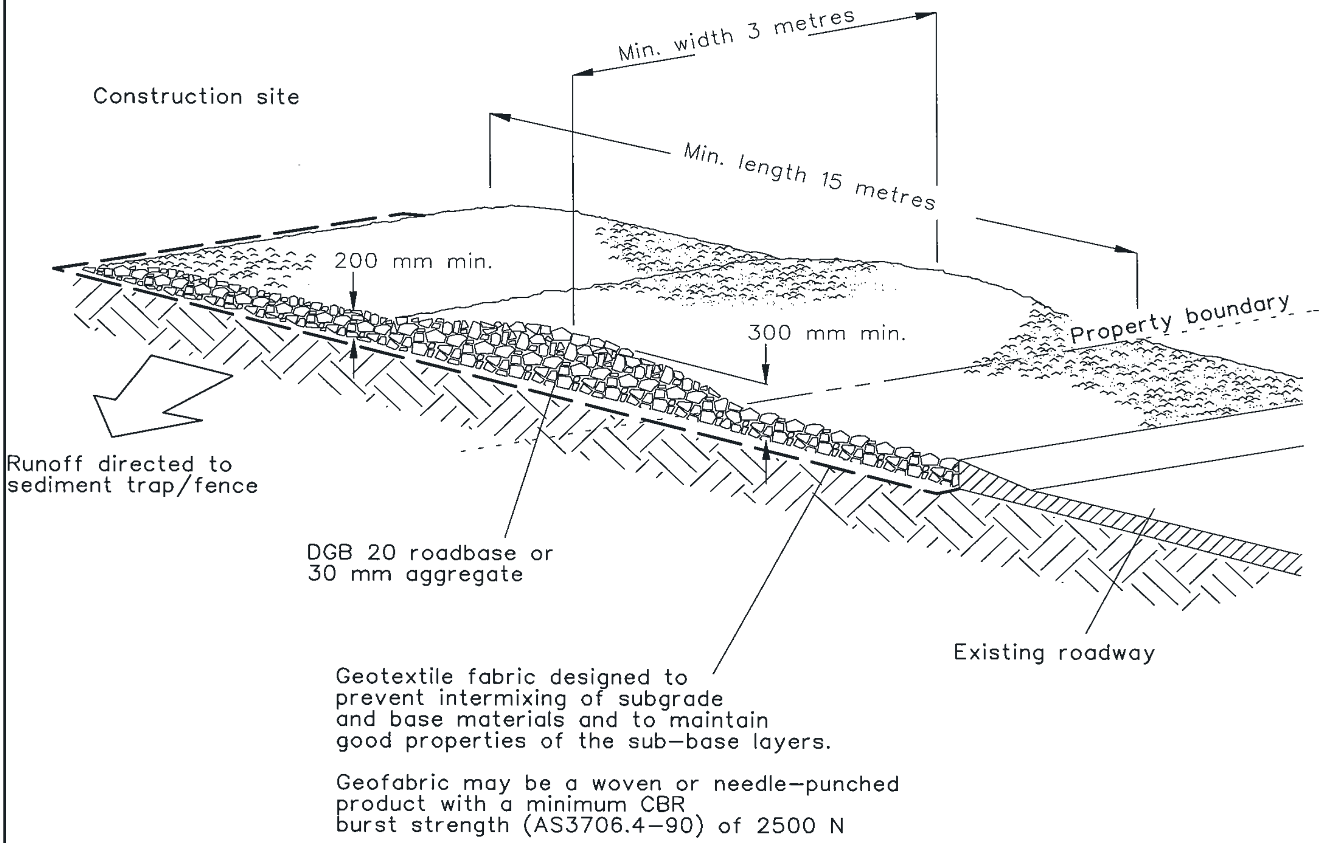
SD 6-11



Construction Notes

1. Fabricate a sediment barrier made from geotextile or straw bales.
2. Follow Standard Drawing 6-7 and Standard Drawing 6-8 for installation procedures for the straw bales or geofabric. Reduce the picket spacing to 1 metre centres.
3. In waterways, artificial sag points can be created with sandbags or earth banks as shown in the drawing.
4. Do not cover the inlet with geotextile unless the design is adequate to allow for all waters to bypass it.

GEOTEXTILE INLET FILTER **SD 6-12**



Construction Notes

1. Strip the topsoil, level the site and compact the subgrade.
2. Cover the area with needle-punched geotextile.
3. Construct a 200-mm thick pad over the geotextile using road base or 30-mm aggregate.
4. Ensure the structure is at least 15 metres long or to building alignment and at least 3 metres wide.
5. Where a sediment fence joins onto the stabilised access, construct a hump in the stabilised access to divert water to the sediment fence

STABILISED SITE ACCESS — SD 6-14

APPENDIX D

Nebraska Estate, St Georges Basin – Primary Erosion and Sediment Control Plan – Infrastructure Development

Nebraska Estate, St Georges Basin

Primary Erosion and Sediment Control Plan - Lot Based Development

Project No. 1619
Date: March 2017

Prepared for: Shoalhaven City Council

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Document and Distribution Status

Author(s)	Reviewer(s)	Signatures
Ashley Bond		

Revision No.	Status	Release Date	Document Distribution					
			Eric Hollinger					
1	DRAFT	21/02/17	PDF					
2	FINAL	02/03/17	PDF					

Distribution Types: F = Fax, H = Hard Copy, P = PDF, E = Other Electronic Document. Digits indicate number of copies.

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1.0 INTRODUCTION

1.1. Purpose

Changes in land use from rural and bushland settings to other forms have the potential to:

- cause dramatic disturbances to the soil
- destroy vegetation
- alter natural drainage pathways
- affect the environmental and amenity values adversely, not only at the site, but areas downstream of it.

To minimise the potential for this to occur all builders/developers are required to prepare an Erosion and Sediment Control Plan showing they will minimise soil erosion and trap sediment that may be eroded from the site during the construction of any works requiring a development consent that involves the disturbance of the ground. The complexity of the Plan depends upon the nature and the scale of the particular development, especially the amount of land likely to be disturbed.

This plan will form the initial link in the chain to minimise on-site erosion and off-site sedimentation and therefore adverse environmental impacts associated with lot based development within Nebraska Estate.

1.2. Project Description

Nebraska Estate was a 'paper subdivision' registered in 1919 and released without any infrastructure to support its development. At the time of preparing this report, the land has very limited development potential due to the relevant planning controls. The land has generally remained undeveloped and un-serviced bushland with the exception of a few existing authorised structures.

After numerous studies and public exhibitions Council adopted a Planning Proposal based on a constrained development option that would enable up to 23 dwellings to be approved. The Planning Proposal was submitted to the Department of Planning and Infrastructure in late 2014.

1.3. Scope of this Plan

The purpose of this document is to serve as a primary broad based erosion and sediment control plan (ESCP) to outline the requirements and fundamental principles that must be followed in the planning and implementation of erosion and sediment control measures for the construction of lot based development, including dwellings and driveways.

This Primary ESCP will need to be supplemented by a site specific erosion and sediment control plan (i.e. a drawing) prepared for each individual property by the owners builder or consultant.

1.4. Legislative Requirements

The key environmental legislation relating to soil and water quality management includes:

- The Protection of the Environment Operations Act 1997 (POEO Act)
- The Environmental Planning and Assessment Act 1979 (EP&A Act)

1.5. Supporting Documents

This document should be read in conjunction with the following supporting documents:

- Managing Urban Stormwater: Soils and Construction – Volume 1 (Landcom, 2004).
- Planning for Erosion and Sediment Control on Single Residential Allotments (http://www.environment.nsw.gov.au/resources/stormwater/ErosionSedFlyer.pdf)

2.0 SITE CHARACTERISTICS

2.1. Topography

The subject land is characterised by undulating slopes and three broad drainage depressions, draining to St Georges Basin at Home Bay via three unnamed watercourses and shown in Figure 1.

The south western and south eastern edge of the site are bounded by unnamed water courses, with the third water course running through the centre from north east to south west. The entire site thus comprises of four main sub-catchments separated by one ridge orientated north to south, and another orientated north east to south west.

The land is generally gently inclined with slope ranges of between 0-5˚ and elevations ranging between 2 and 22 metres AHD.

Figure 1 - Elevation of Subject Land (source SCC On-Site Effluent Disposal Assessment)

2.2. Soils and Geology

The geology of the area is dominated by Shoalhaven Group (Permian sedimentary formations) with the exception of Quaternary alluvial deposits in lower areas and creek lines.

The Land Capability Assessment conducted by Morse McVey & Associates Pty Ltd in 1994 identified two soil landscapes:

- Wandrawandian – occurs on crests and side slopes. Duplex (textural contrast) soils (typically clay loam topsoil over light-medium clay subsoil). Topsoil limitations include high erodibility, low fertility and strong acidity. Subsoil limitations include moderate to high erodibility, low fertility, strong acidity, potential aluminium toxicity and poor drainage.
- Tomerong Creek soil landscape – occurs on the lower lying land associated with the un-named watercourses. Characterised by low slopes (<5%) and high clay and silt content with high reactivity (large shrink-swell characteristics), low fertility, strong acidity, and potential aluminium toxicity.

Significant soil constraints were identified and include:

- High soil erodibility (values of 0.026 and 0.046 used in the universal soil loss equation – USLE), and;
- Moderately dispersive subsoil (with dispersion percentage ranging from 1.3 – 3.3), meaning that the clay particles can be more readily eroded and transported to the downstream environment. Soils on the site have been classified as Type F (fine textured) soils.

Acid Sulfate Soils

The lower reaches of the flood prone land were identified by the Huskisson Acid Sulfate Soils Risk map as having a high probability of Acid Sulfate Soils (ASS) occurring within one metre of the ground surface. This land is identified as 'Class 2' on the Acid Sulfate Soils map that forms part of Shoalhaven LEP 2014, to which clause 7.1 applies. Clause 7.1 can also be triggered for works within 500m of adjacent Class 1, 2, 3 and 4 land that is below 5m AHD. Refer to Clause 7.1 of SLEP 2014 for further details.

The affected area is encompassed within the area that is proposed to be zoned E2 – Environmental Conservation, where no additional residential development is proposed. Appropriate investigations, including preparation of an ASS management plan, would be required to be undertaken prior to undertaking any works associated with upgrading of Fisherman Road or excavation for the purpose of providing water or sewerage services.

In 2001, Environmental and Earth Sciences P/L undertook an ASS investigation along the path of the proposed sewerage line for Park Road, Nebraska Estate. This investigation involved soil and groundwater testing at the southern end of the subject land. The results of the investigation are summarised below:

- There was negligible PASS. A borehole within the main watercourse contained low concentrations of soil sulphides but these were considered non-reactive.
- As a cautionary measure, it was recommended that any soil excavated from the watercourse, should be mixed with 4 kg of lime per ton of soil.

- Groundwater should be monitored if dewatering is undertaken for periods exceeding one week.
- Any concrete or metallic structures placed between the banks of the watercourse should have a buffer of at least 150 mm of sand mixed with lime at a ratio of 5 kg per ton of sand.

2.3. Flooding

The modelled extent of stormwater inundation in Nebraska Estate is shown in Figure 2, This figure displays the results from several flood studies:

- 'St Georges Basin Flood Study', Webb, McKeown and Associates P/L, 2001
- 'St Georges Basin Floodplain Risk Management Study and Plan Climate Change Assessment', WMA Water 2013
- A site specific draft preliminary catchment analysis prepared from airborne laser scanning (ALS) survey over Nebraska Estate by Shoalhaven City Council, 2006.

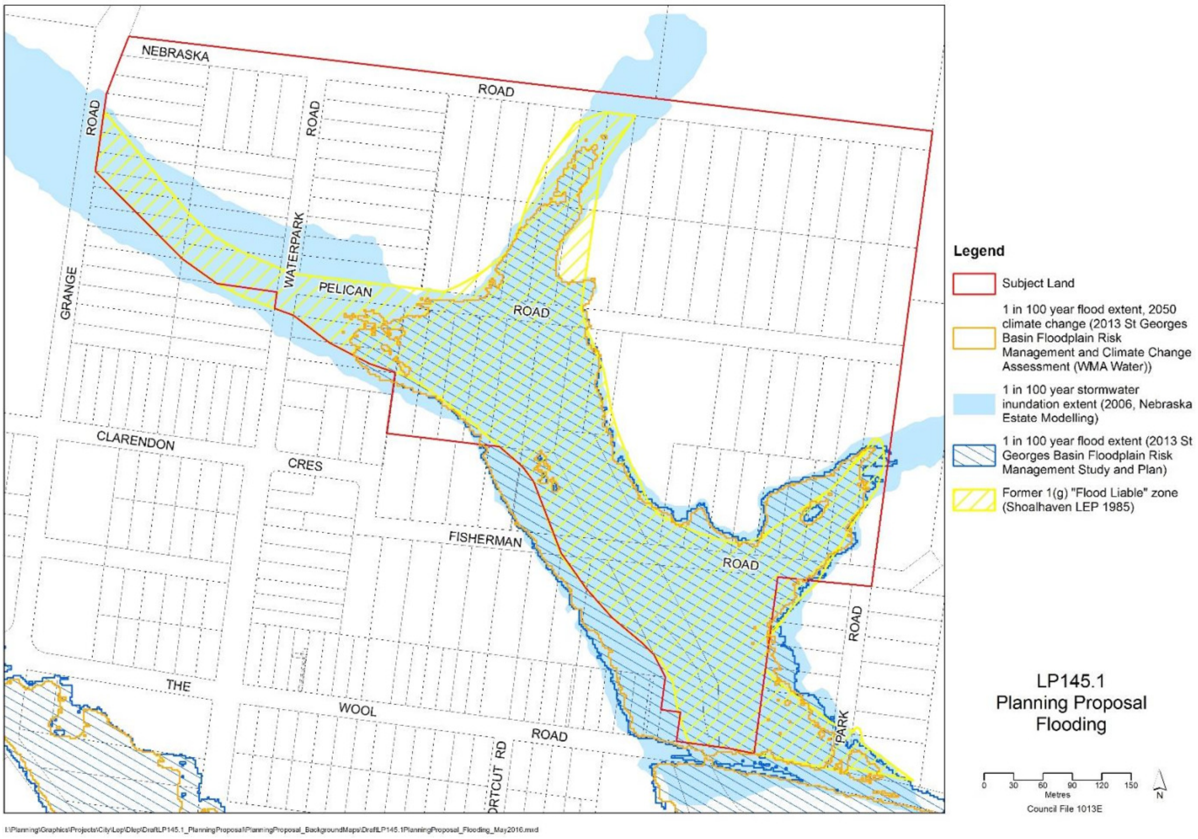


Figure 2 – Flood-related information (source SCC Project Brief)

2.4. Flora and Fauna

The subject site is home to a number of endangered, threatened or protected plant species. Swamp Sclerophyll Forest, is categorised as an endangered ecological community (EEC) under the NSW Threatened Species Conservation Act (BES, 2009). This EEC broadly corresponds to the flood prone land area, which also contains a population of protected

Biconvex Paperbark (Melaleuca biconvexa). The north east corner of the subject land also contains a large number of threatened orchid species, one of which (Pterostylis ventricosa) was actually discovered in Nebraska Estate in 2000.

2.5. Aboriginal Cultural Heritage

Archaeological studies were undertaken in Nebraska Estate in 1994, 1995 and 2001. The first of these identified two small scatters of stone artefacts and one isolated artefact within the drainage lines. All three Aboriginal sites are located within the proposed E2 zone and no further residential development is proposed on the affected land. Some ground disturbance will be necessary for the construction of infrastructure and if these works uncover any additional artefacts the necessary requirements will be undertaken in order to comply with the NSW National Parks and Wildlife Act and regulations.

3.0 CALCULATED SOIL LOSS

The annual average soil loss during construction activities on the subject site has been estimated at 560 tonnes/ha/year using the Revised Universal Soil Loss Equation as defined in Managing Urban Stormwater: Soils and Construction, Volume 1 and using the values below.

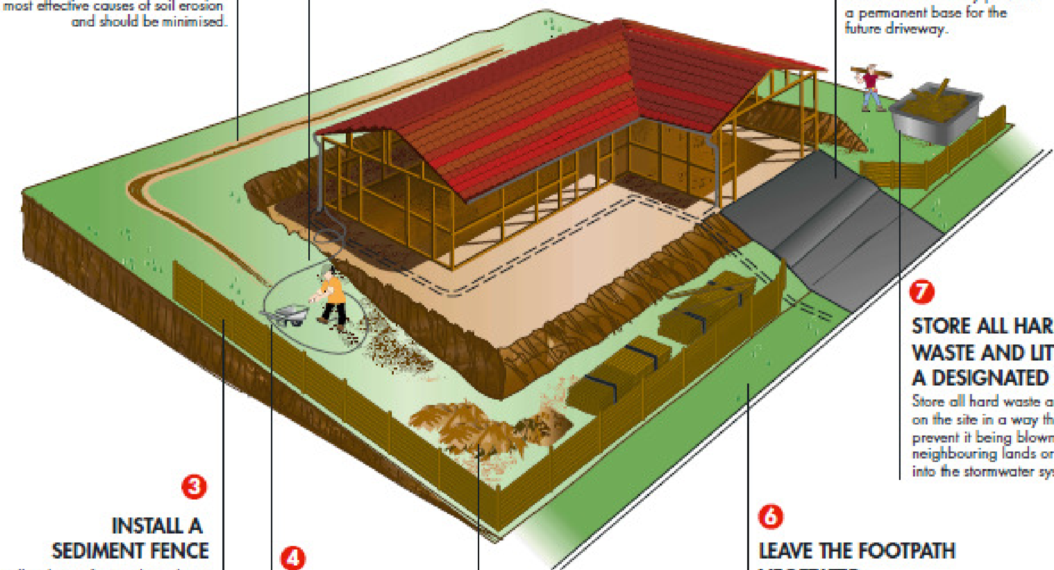
Parameter	Adopted Value	Source/Comment
R – Rainfall Erosivity Factor	4,550	Morse Mcvey, 1994 (Section 2.7)
K – Soil Erodibility	0.046	Morse Mcvey, 1994 (Section 3.2) based on Tomerong Creek Soil Landscape (worst case scenario)
LS – Slope Length/Gradient Factor	2.05	Based on 8% gradient (approx. 5 degrees) and maximum 80m slope
P – Erosion Control Practice Factor	1.3	Assumed Compacted and Smooth
C – Cover Factor	1.0	Recently disturbed soil with no cover

Based on the above calculated soil loss rate the subject site is classified as having **Soil Loss Class 5** and **HIGH Erosion Hazard**.

4.0 BASIC PRINCIPLES OF EROSION AND SEDIMENT CONTROL

The basic principles of erosion and sediment control include:

i. Making sure everyone working on the site understands how important it is not to pollute stormwater
ii. Minimising the area of soil disturbance
iii. Installation of erosion and sediment controls before starting work
iv. Maintaining erosion and sediment controls throughout the construction phase until the site is appropriately rehabilitated.



5.0 KEY MANAGEMENT STRATEGIES

The following site management practices and treatment measures should be considered and incorporated, as deemed appropriate, into any Site Specific Erosion and Sediment Control Plans prepared for construction of the lot based infrastructure.

5.1. General

- Plan the site before works commence and submit a site specific erosion and sediment control plan with the building application
- Ensure erosion and sediment control are installed at all sites associated with the construction activities including dwellings, sheds and driveways.

5.2. Construction Sequencing

Implement construction programming that promotes good erosion and sediment control including;

- early installation of permanent drainage works, including driveway culverts
- early installation of permanent catch drains (where relevant) to divert water around disturbed areas and structures.
- regular removal of excess sediment accumulation in erosion and sediment control measures
- progressive revegetation throughout the project

5.3. Minimising Extent of Soil Disturbance

- construct access driveways, including vegetated table drains, at the start of the project in order to provide a dedicated vehicle access path from the road carriageway to the building envelope to prevent unnecessary disturbance of other areas on the site
- fence off any E2 zoned land on the site at the start of the project to avoid disturbance of these more environmentally sensitive areas.
- Clear only those lands that must be disturbed by the works.
- Progressively stabilise disturbed areas on completion of sections of works rather than waiting until construction has been finished.
- Stabilise drainage structures as soon as possible following construction.

5.4. Control of Stormwater Runoff

- Construct stabilised diversion banks and drains to divert upslope water around the site
- Construct permanent drainage structures early in the project such as catch drains and culverts (including associated inlet and outlet protection works)
- Maximise the diversion of turbid construction runoff into sediment control devices such as sediment basins and filters.

- Divert runoff from the road formation into the stormwater drainage system as soon as practical to reduce surface flow lengths.

5.5. Practicing good site house keeping

Essentially good site housekeeping means keeping the site in a clean and orderly manner and includes;

- limiting the number of sediment sources by minimising the number of stockpiles. Placing material as it is excavated will help reduce the number of stockpiles and also minimises double handling.
- removing unwanted spoil stockpiles progressively and quickly
- locate stockpiles away from heavily trafficked areas, areas prone to inundation and drainage lines.

5.6. Use of Erosion Control Measures

- Stockpile soil materials in low hazard areas clear of natural depressions, drainage channel or watercourses. Additional protection to be afforded with temporary vegetation, diversion banks and sediment control measures, as required.
- Construct a range of erosion controls including sediment fences, diversion banks and drains and straw bale filters.
- Construct control measures as close as practical to the potential sediment source.
- Control the deposition of mud and soil materials onto local roads through the use of an appropriate stabilised site access.

5.7. Stabilisation of Disturbed Areas

- Ensure the success of the later revegetation by utilising good quality topsoil.
- Ameliorate exposed/disturbed subsoils with gypsum (or other suitable chemical ameliorant) at a rate of 2.5kg/10m^2 to reduce soil dispersion.
- Progressively and quickly revegetate disturbed areas utilising appropriate species.
- Control dust through progressive revegetation.

5.8. Inspection and Maintenance

- Initiate a program to ensure regular maintenance of all erosion and sediment control measures. Sediment cleaned from structures is to be deposited in a secure location where further pollution will not occur.
- Arrange regular inspections to review and update control measures. Additional inspections should be conducted during and/or immediately following significant (i.e. >10mm/24hrs) rainfall events to monitor the functioning of controls.

5.9. Temporary Control Measures

Temporary erosion and sediment control measures considered suitable for use during lot based development activities include, but are not limited to the following;

- earth banks/diversion mounds
- sediment fences
- stabilised site access

A suite of standard erosion control measures that may be implemented on site are included in Appendix A and have been extracted from *Managing Urban Stormwater; Soils and Construction, Volume 1* (Landcom , 2004).

In determining of the most appropriate erosion and sediment control measures to incorporate into the Site Specific ESCPs the designer should make reference to *Managing Urban Stormwater; Soils and Construction, Volume 1* (Landcom , 2004).

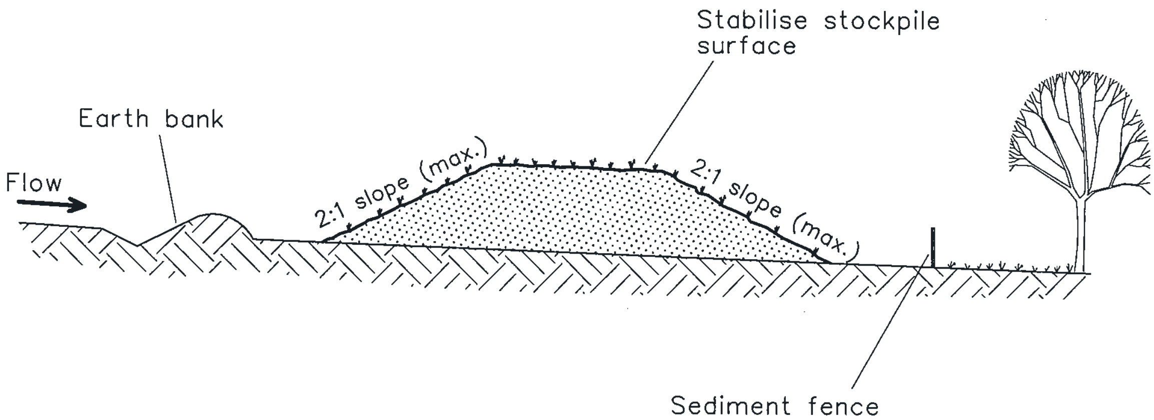
6.0 REFERENCES

Landcom (2004) *Managing Urban Stormwater; Soils and Construction – Volume 1*

Morse McVey (1994) *Land Capability Report for Nebraska Estate, The Wool Road, St Georges Basin*, Morse McVey and Associates.

APPENDIX A

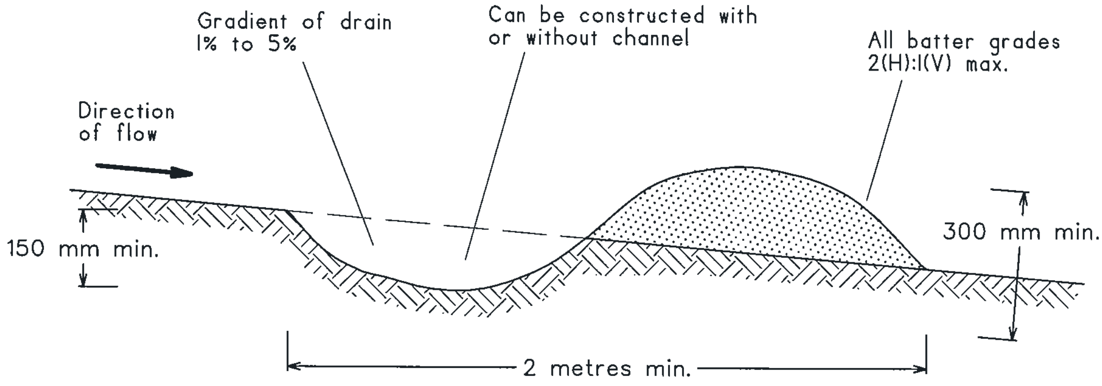
Standard Erosion Control Measures



Construction Notes

1. Place stockpiles more than 2 (preferably 5) metres from existing vegetation, concentrated water flow, roads and hazard areas.
2. Construct on the contour as low, flat, elongated mounds.
3. Where there is sufficient area, topsoil stockpiles shall be less than 2 metres in height.
4. Where they are to be in place for more than 10 days, stabilise following the approved ESCP or SWMP to reduce the C-factor to less than 0.10.
5. Construct earth banks (Standard Drawing 5-5) on the upslope side to divert water around stockpiles and sediment fences (Standard Drawing 6-8) 1 to 2 metres downslope.

STOCKPILES **SD 4-1**

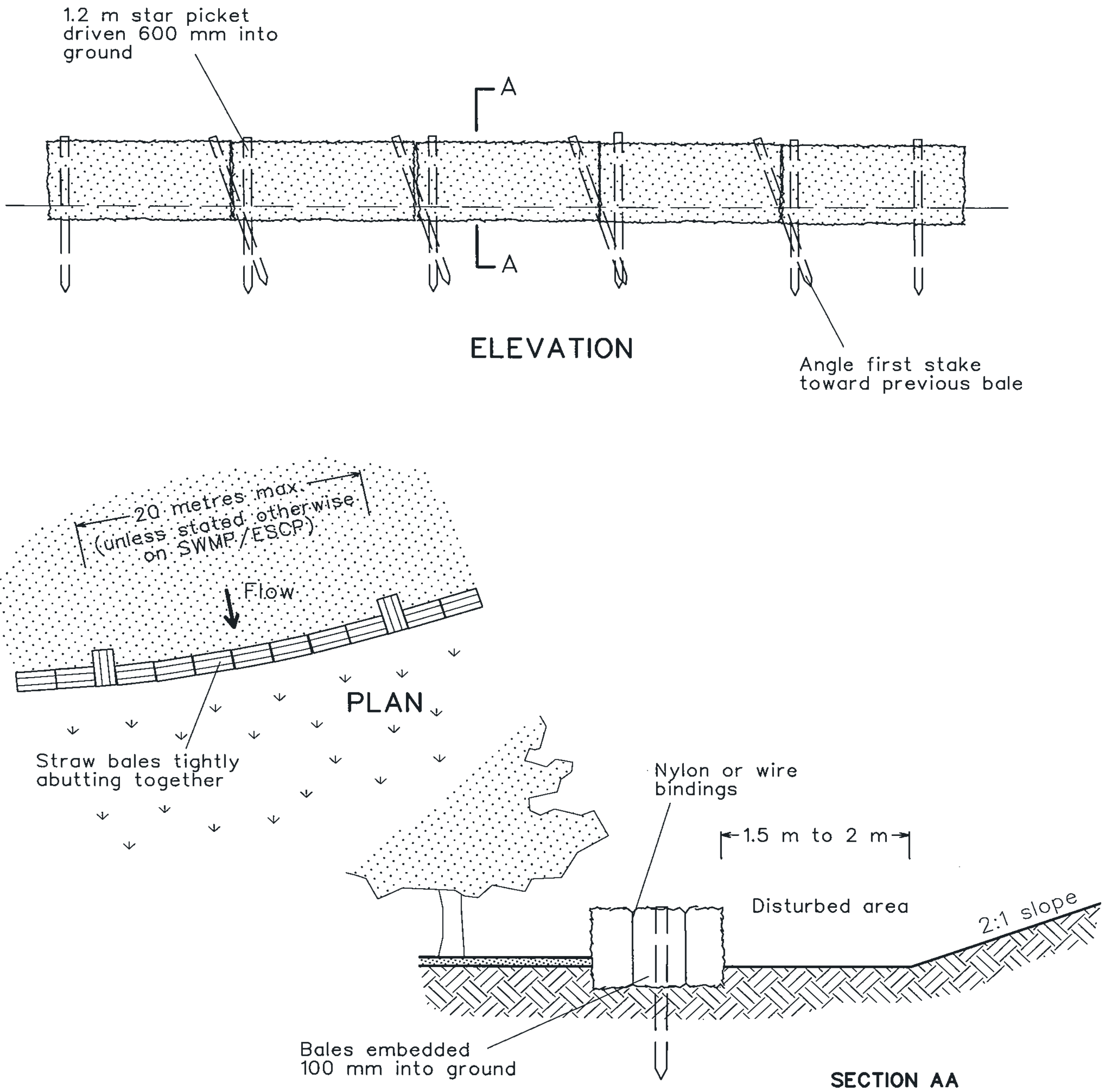


NOTE: Only to be used as temporary bank where maximum upslope length is 80 metres.

Construction Notes

1. Build with gradients between 1 percent and 5 percent.
2. Avoid removing trees and shrubs if possible - work around them.
3. Ensure the structures are free of projections or other irregularities that could impede water flow.
4. Build the drains with circular, parabolic or trapezoidal cross sections, not V shaped.
5. Ensure the banks are properly compacted to prevent failure.
6. Complete permanent or temporary stabilisation within 10 days of construction.

EARTH BANK (LOW FLOW) SD 5-5

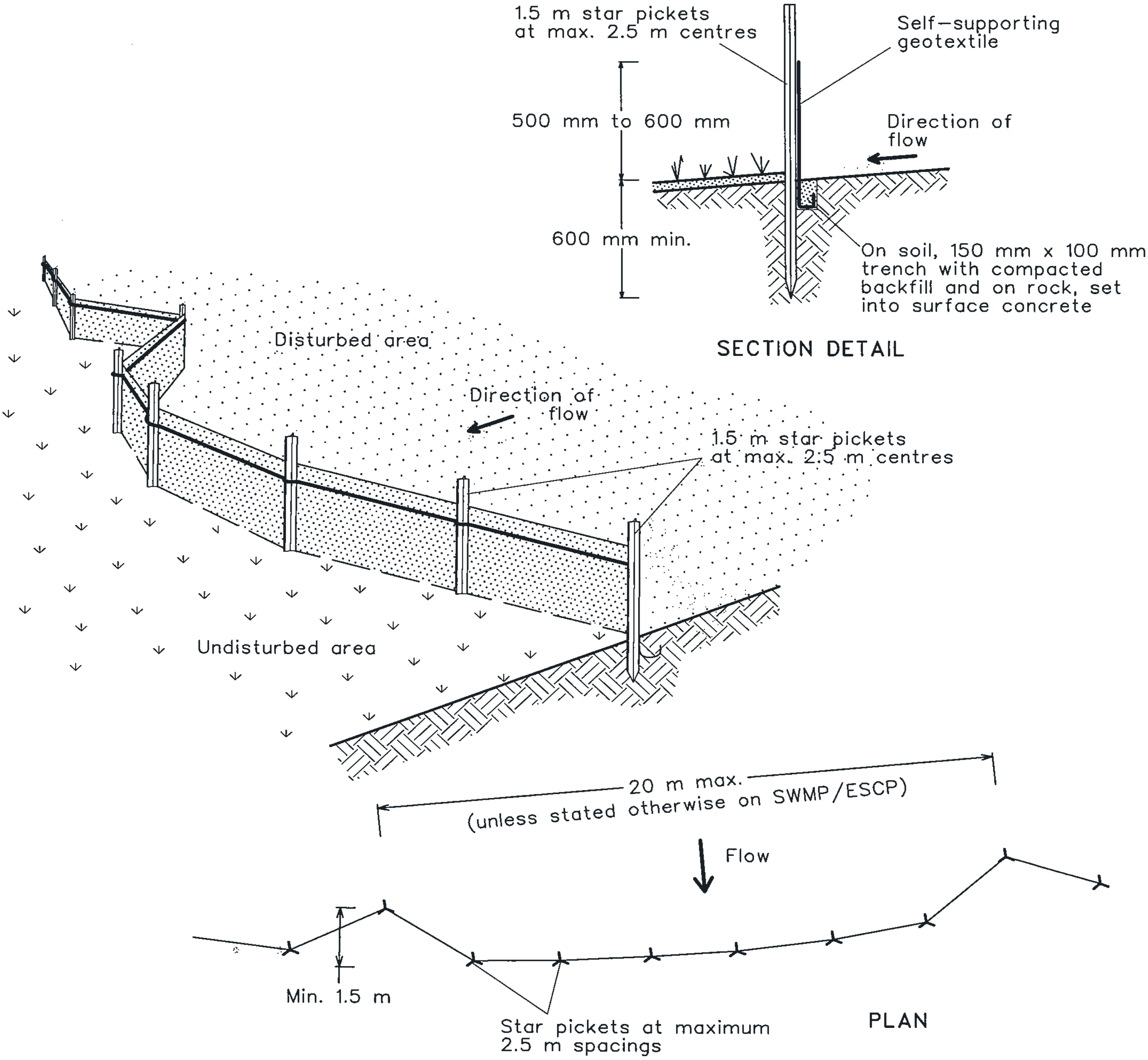


Construction Notes

1. Construct the straw bale filter as close as possible to being parallel to the contours of the site.
2. Place bales lengthwise in a row with ends tightly abutting. Use straw to fill any gaps between bales. Straws are to be placed parallel to ground.
3. Ensure that the maximum height of the filter is one bale.
4. Embed each bale in the ground 75 mm to 100 mm and anchor with two 1.2 metre star pickets or stakes. Angle the first star picket or stake in each bale towards the previously laid bale. Drive them 600 mm into the ground and, if possible, flush with the top of the bales. Where star pickets are used and they protrude above the bales, ensure they are fitted with safety caps.
5. Where a straw bale filter is constructed downslope from a disturbed batter, ensure the bales are placed 1 to 2 metres downslope from the toe.
6. Establish a maintenance program that ensures the integrity of the bales is retained - they could require replacement each two to four months.

STRAW BALE FILTER

SD 6-7



Construction Notes

1. Construct sediment fences as close as possible to being parallel to the contours of the site, but with small returns as shown in the drawing to limit the catchment area of any one section. The catchment area should be small enough to limit water flow if concentrated at one point to 50 litres per second in the design storm event, usually the 10-year event.

2. Cut a 150-mm deep trench along the upslope line of the fence for the bottom of the fabric to be entrenched.

3. Drive 1.5 metre long star pickets into ground at 2.5 metre intervals (max) at the downslope edge of the trench. Ensure any star pickets are fitted with safety caps.

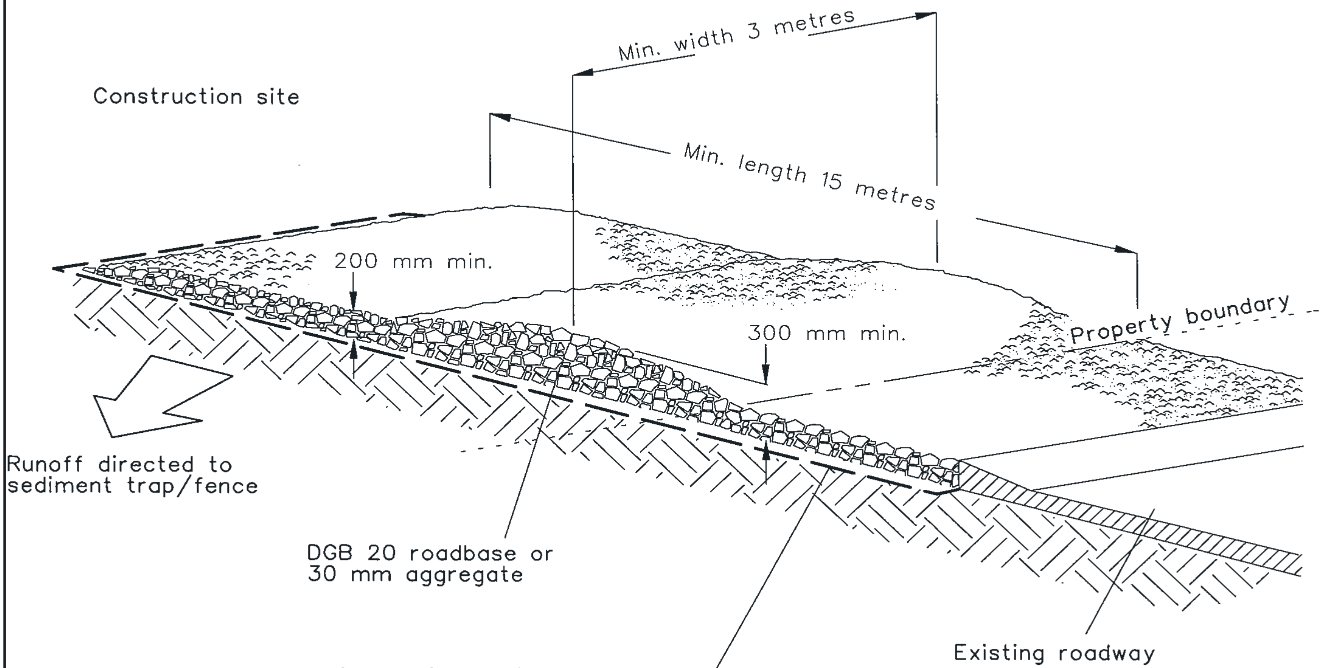
4. Fix self-supporting geotextile to the upslope side of the posts ensuring it goes to the base of the trench. Fix the geotextile with wire ties or as recommended by the manufacturer. Only use geotextile specifically produced for sediment fencing. The use of shade cloth for this purpose is not satisfactory.

5. Join sections of fabric at a support post with a 150-mm overlap.

6. Backfill the trench over the base of the fabric and compact it thoroughly over the geotextile.

SEDIMENT FENCE

SD 6-8



Construction Notes

1. Strip the topsoil, level the site and compact the subgrade.
2. Cover the area with needle-punched geotextile.
3. Construct a 200-mm thick pad over the geotextile using road base or 30-mm aggregate.
4. Ensure the structure is at least 15 metres long or to building alignment and at least 3 metres wide.
5. Where a sediment fence joins onto the stabilised access, construct a hump in the stabilised access to divert water to the sediment fence

STABILISED SITE ACCESS

SD 6-14