BMT WBM Pty Ltd
126 Belford Street
BROADMEADOW NSW 2292
Australia
PO Box 266
Broadmeadow NSW 2292

Tel: +61 2 4940 8882
Fax: +61 2 4940 8887

ABN 54 010 830 421 003

www.wbmpl.com.au

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9 July 2008

BBK Development Corporation Pty Ltd
PO Box 79
Coffs Harbour NSW 2450

Attention: Barry Mann

Dear Barry

RE: 45 HEARNES LAKE ROAD, WOOLGOOLGA – REVISED STORMWATER MANAGEMENT STRATEGY

This report summarises hydrologic and stormwater quality investigations undertaken for a proposed residential subdivision within Lot 21 DP 714858 located at 45 Hearnes Lake Road, Woolgoolga. The report presents a stormwater management strategy that responds to the hydrologic and stormwater quality investigations. A review and interpretation of the 50m buffer to the SEPP26 Littoral Rainforest boundary for water quality protection as required by the Hearnes Lake / Sandy Beach DCP is also provided within this report.

This strategy was revised from a previous strategy dated 23 May, 2006 to include consideration of an amended development layout shown on de Groot and Benson drawing "Overall Concept Plan" dated 13 September 2007.

1 Executive summary

The stormwater quality management strategy proposed is in accordance with the requirements of the *Hearnes Lake / Sandy Beach DCP – Appendix A* that specify the types and size of measures required in the Northern Precinct to achieve the water quality targets. The strategy incorporates treatment measures in series to capture, convey and/or filter stormwater prior to discharge into the receiving waters. The stormwater quality management measures include filter strips, vegetated swales, a bioretention swale, a combined bioretention/detention basin, raingardens and rainwater tanks to manage common stormwater pollutants (TSS, TN and TP).

The proposed stormwater quality management strategy was also configured and sized conceptually using MUSIC software and compared against the "modified source and conveyance control treatment strategy" to determine if the strategy would also achieve these targets. The modelling results indicate that the development would achieve the TSS, TP and TN reduction targets in the modified source and conveyance control treatment strategy. The runoff reduction target of 33% would not be achieved as limited options are available within the site for stormwater harvesting and irrigation re-use (which is the main feature of that strategy).

Although the strategy would not achieve the "modified source and conveyance control treatment strategy" runoff reduction target, it is considered that in addition to achieving the specific requirements outlined in the DCP, the strategy exceeds current best practice.

A part of BMT in Energy and Environment

The proposed stormwater quantity management elements including roof gutters, property roof drainage lines, interallotment drainage lines, kerb and gutter, vegetated swales, roads and pipes would be appropriate for conveyance of peak developed flows for the 10 and 100 year ARI design events. A detention basin is proposed within the south-western corner of the site to achieve the DCP objective that requires the development to have no adverse change to the flood behaviour for adjacent properties or elsewhere in the catchment. For the purposes of this assessment, the 10 and 100 year design events were adopted for evaluating the performance of the detention basin against the DCP objectives. It is considered that the proposed detention basin would achieve the DCP objectives.

The Hearnes Lake / Sandy Beach DCP indicates that a 50m buffer should be provided between a proposed development and a SEPP 26 Littoral Rainforest boundary for the protection of water quality. The development layout shown in Figure 2-3 provides a narrower buffer that varies between 20-50m for five of the eastern lots. For this site, the SEPP 26 Littoral Rainforest is separated from the development by an ephemeral wetland that intermittently captures and stores runoff prior to infiltration/evaporation/transpiration. The ephemeral wetland would therefore intercept runoff from the development site preventing it from flowing into the SEPP 26 Littoral Rainforest. To minimise the potential for elevated loads of stormwater pollutants to be conveyed to the ephemeral wetland, a series of rainwater tanks, vegetated swales and raingardens are proposed along the rear of the eastern lots. It is considered that the proposed measures in this area would effectively perform the role of a water quality buffer for the ephemeral wetland by filtering the runoff and also increasing the length of the flowpath for runoff draining from the eastern lots to the wetland. For these reasons it is considered that provision of a formal 50m buffer would not provide any additional significant benefit for protecting water quality for the SEPP26 Littoral Rainforest.

2 Site Description

The site is bounded to the north and west by land zoned 2E (tourist residential), to the south by Hearnes Lake Road and to the east by crown land forming a SEPP26 Littoral Forest and coastal dune system. The existing site is primarily cleared of indigenous vegetation and is currently grassed with some scattered trees. Two residential dwellings and ancillary buildings are located within the cleared site area and an unsealed driveway provides access to the dwellings from Hearnes Lake Road. The eastern section of the site incorporates an ephemeral wetland located adjacent to a SEPP 26 Littoral Rainforest.

A locality map showing the development site is provided in **Figure 2-1**.

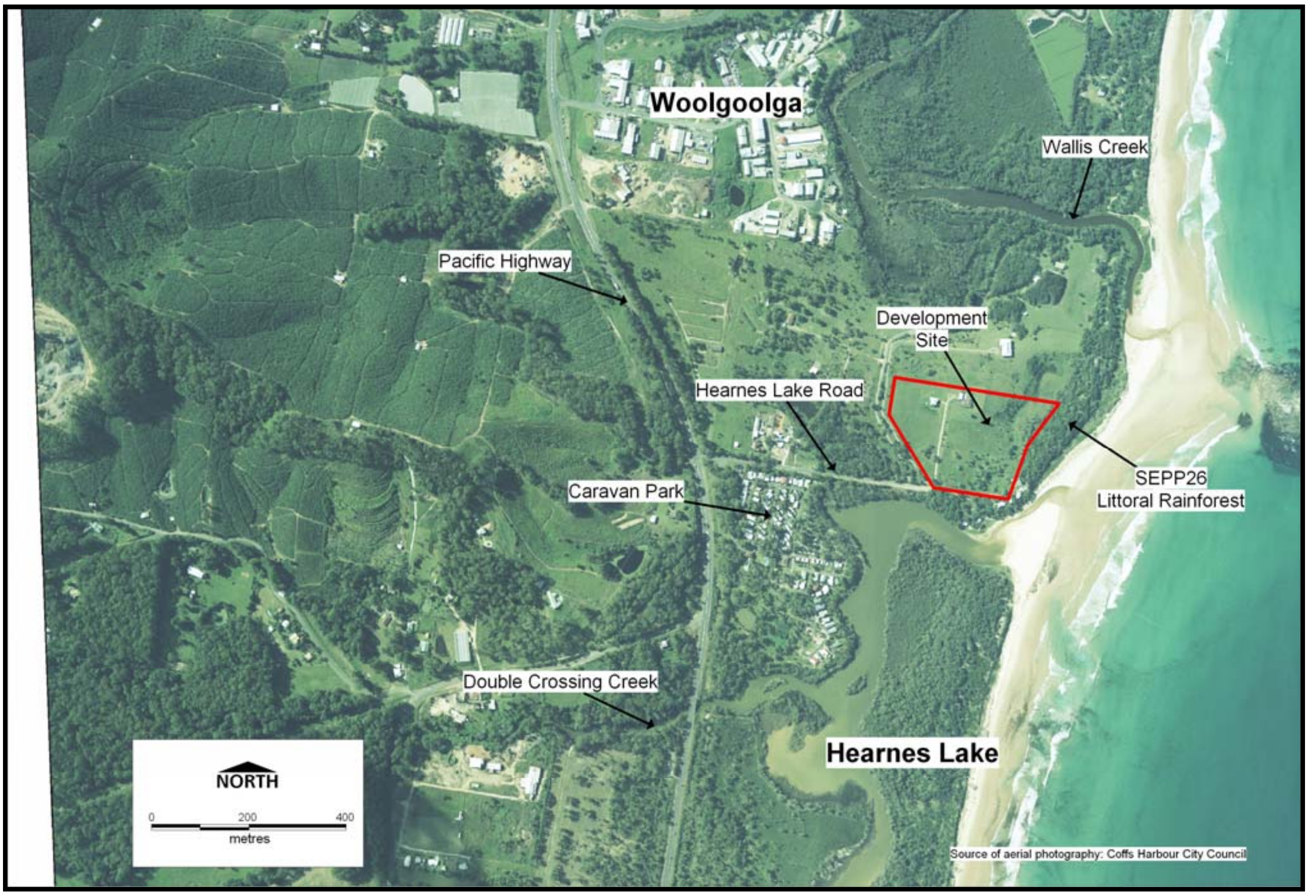

Figure 2-1 Locality map of study area

The natural drainage pathways within the site are influenced by a ridge through the site. On the western and southern sides of the ridge, runoff from approximately 60% of the site is directed south and into an existing table drain adjacent to Hearnes Lake Road. This table drain conveys runoff in a westerly direction to a box culvert that discharges into Hearnes Lake. On the eastern side of the ridge, runoff from approximately 30% of the site is directed to an ephemeral wetland located adjacent to the SEPP 26 Littoral Rainforest. The remaining northern section of the site (approximately 10% of the site area) drains overland in a northerly direction to adjacent properties. The existing site contours and drainage pathways across the site are shown in **Figure 2-2.**

The average gradient across the entire site is approximately 11%. Surface gradients to the east of the ridge, between the ridge and the ephemeral wetland are considerably higher (approximately 20-40%) than areas west of the ridge. Surface gradients on the western side of the ridge typically vary between 10% and 20%, reducing to less than 5% in the south-western corner of the site.

Geotechnical investigations undertaken by Holmes & Holmes (2003) describe the soils within the upper slopes of the proposed development site as typically comprising silty clays. Soils within the lower slopes typically comprise high plasticity clay soils overlain by a silty surface layer which becoming wet and soft following a prolonged wet period. Field testing of the soil saturated hydraulic conductivity was undertaken by de Groot & Benson Pty Ltd for five locations within the site on 25 June 2008. Testing was undertaken in accordance with the method outlined in the Argue, 2006. This testing identified that the saturated hydraulic conductivity across the site varied between 0.3mm/hr and 2.8mm/hr for four of the boreholes. The remaining borehole demonstrated a saturated hydraulic conductivity of 198mm/hr. A saturated hydraulic conductivity of 0.5mm/hr was adopted for modelling.

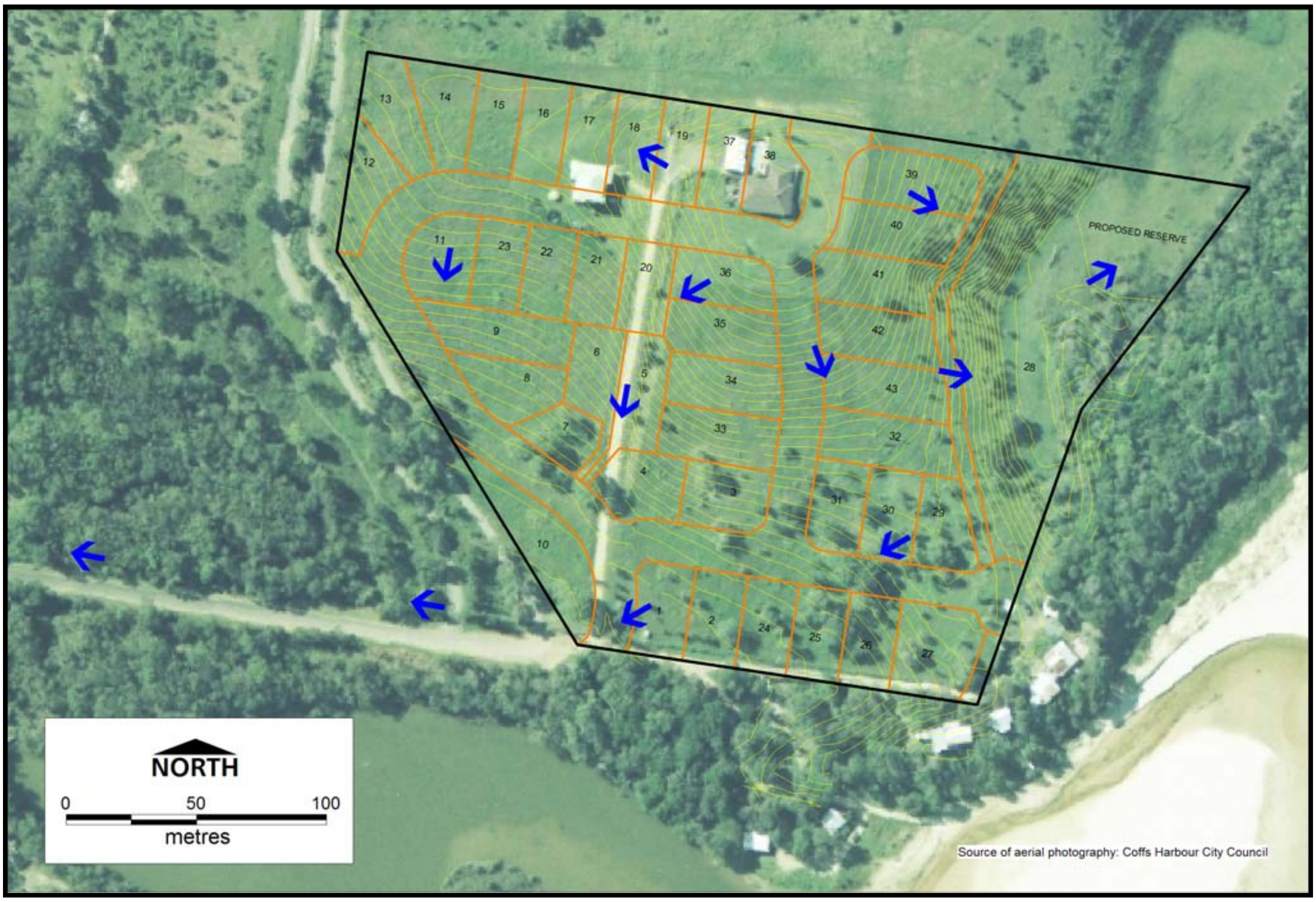

Figure 2-2 Existing site contours and drainage pathways (proposed layout shown for reference)

This report was prepared considering the proposed development layout shown in **Figure 2-3.** The development is planned to be staged and the stormwater management strategy has been developed considering this staging. The proposed layout incorporates low density residential lots, road reserves, pathways, a stormwater management lot and environmental protection area.

A total of 41 residential dwelling lots are proposed within the development. The proposed residential dwelling lots situated to the east of the ridge are typically larger than residential dwelling lots in the remainder of the site.

The road reserves within the development are proposed to be either 16m wide (8m wide sealed pavement and 4m wide footpaths) or 14m wide (6.5m wide sealed pavement and 3.75m wide footpaths). A minimum 6.3 metre wide easement is proposed at the rear of the proposed lots on the eastern side of the site. This easement would be utilised for a public pathway, stormwater management and maintenance access. A separate lot in the south-western corner of the site is proposed to be dedicated for the primary purpose of stormwater management.

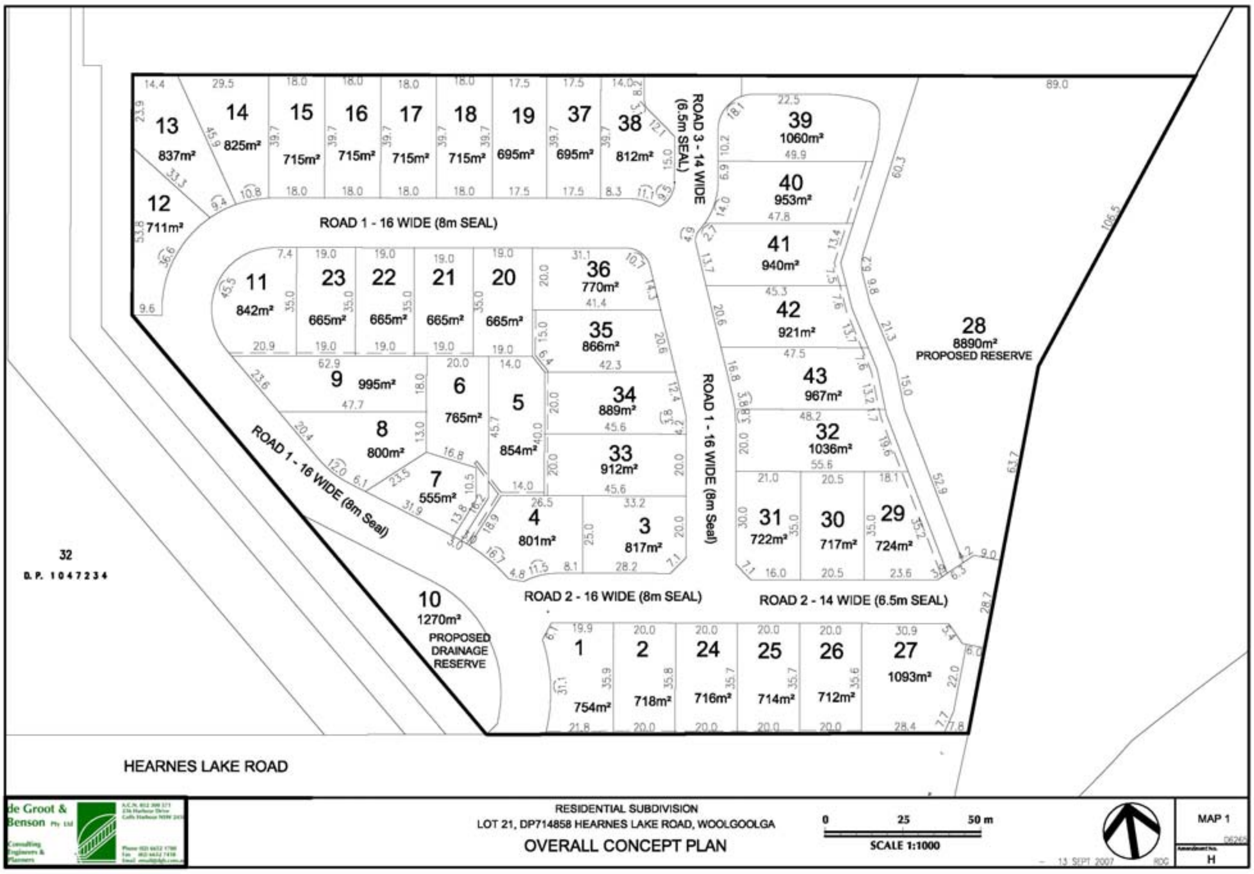

Figure 2-3 Proposed development layout (source: de Groot & Benson Pty Ltd)

3 Stormwater management objectives and targets

Targets relevant to stormwater management for this site were determined from a review of the *Hearnes Lake / Sandy Beach DCP* and associated *Appendix A – Water Quality Targets*. The DCP implies two options for confirming appropriate stormwater quality management requirements for a particular development. The first option prescribes specific types and sizes of stormwater treatment measures to be incorporated within a development to satisfy the DCP objectives and targets. The second option requires development proponents to demonstrate achievement of the targets outlined within the "modified source and conveyance control treatment strategy" outlined within the MUSIC modelling of Hearnes Lake Catchment report (WBM, 2005). The strategy is compared within this report against both these objectives, although the DCP only requires that one set of targets is achieved.

The first option essentially represents a default option for development proponents. The requirements for this site were calculated and these are summarised below. The requirements were estimated based on the ratio of the site area to the total area within the Northern Precinct (it is estimated that the site represents 13% of the Northern Precinct). The objectives and targets include-:

- Rainwater tanks shall be provided for all residential lots and have a minimum capacity of 5kL;
- Rainwater tanks shall only capture roof water and a minimum of 50% of the roof area shall drain to the tank;
- A 1m wide filter strip shall be provided behind kerb and gutter to filter runoff where gradients are unsuitable for swales;
- The minimum surface area of vegetated swales required for the Northern Precinct is 3500m^2 (equivalent to a 455m^2 contribution from this site);

- The minimum and maximum width of vegetated swales is 2m and 3m respectively;
- The minimum surface area of bioretention swales / basins required throughout the Northern Precinct is 2600m^2 (equivalent to a 340m^2 contribution from this site); and
- The minimum permanent pond volumes required per hectare of development area in the Northern Precinct is125m^3/ha (equivalent to a 700m^3 contribution from this site).

The second option requires that the development demonstrates achievement of the "modified source and conveyance control treatment strategy". This strategy outlines the following load-based performance targets-:

- 33% reduction in runoff volume
- 87% reduction in TSS
- 56% reduction in TN
- 74% reduction in TP
- 99% reduction in GP

The DCP also states that "no adverse change to the flood behaviour will be permitted, either on properties adjoining the site or elsewhere including upstream and downstream". To achieve this objective, a system of flow mitigation would be required to ensure that flow from the site to the existing table drain and culvert in Hearnes Lake Road does not exceed pre-development flooding conditions. Discussions with Coffs Harbour City Council have indicated that Council currently does not have a specific policy for the design events to be considered when assessing flow mitigation requirements for new development. For the purposes of this assessment, the 10 and 100 year design events were adopted for evaluating the performance of the detention facilities against the DCP objectives.

4 Stormwater Modelling

4.1 MUSIC Model Description

Stormwater quality modelling was undertaken utilising the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). MUSIC includes algorithms for evaluating continuous hydrology and concentrations/loads of common stormwater pollutants from urban catchments. The software also includes options to assess the potential for stormwater treatment measures to capture these pollutants.

MUSIC was designed to continuously simulate urban stormwater systems over a range of temporal and spatial scales utilising actual rainfall records. MUSIC is considered within the industry to be an appropriate conceptual design tool for the assessment and sizing of stormwater treatment measures. Additional calculations are required to size inlets and outlets to these measures.

MUSIC requires input of the following variables to develop a base stormwater quality model of the development-:

- Rainfall data (time steps varying from 6 minutes to 1 day);
- Areal potential evapotranspiration rates;
- Catchment parameters (area, % impervious and pervious areas);
- Impervious and pervious area parameters (rainfall threshold, infiltration rates, field capacity, soil storage depths and groundwater parameters); and
- Storm event and base flow stormwater pollutant concentrations.

Following development of the base developed scenario model incorporating the above parameters, appropriate stormwater management measures were input to the model to simulate the effectiveness of these measures in achieving the objectives for the site. A summary of the approach undertaken to determine the model inputs is summarised in the following sections.

4.2 Rainfall Data Input

Local pluviograph data was sourced from the Bureau of Meteorology (BoM) for the period 1960-2005 for BoM Rainfall Station 59040 (Coffs Harbour MO). The rainfall station is located approximately 20km south of the proposed development site and for the purposes of this study was adopted as reasonably representative of rainfall conditions at this location.

The long-term mean annual rainfall for Stn. 59040 is 1667mm. The rainfall data was reviewed to determine a suitable length of continuous rainfall data that reflected this long-term mean annual rainfall. The period selected was also reviewed to ensure it had a reasonable balance of wet and dry years and contained minimal periods of missing or accumulated data. The period 1999-2003 with a mean annual rainfall of 1680mm was considered to appropriately reflect these criteria. This 5 year period of the record was adopted for input to the MUSIC model. A 6 minute model time step was adopted for simulating the strategy within MUSIC.

4.3 Potential Evapotranspiration Data

The average monthly areal potential evapotranspiration (PET) rates for the study site were derived from evapotranspiration maps published by BoM. The PET values adopted within the model are summarised in **Table 4-1**.

Table 4-1 Adopted average monthly areal potential evapotranspiration rates

Month	Average monthly areal PET rates (mm/month)
January	195
February	160
March	150
April	95
May	65
June	55
July	55
August	70
September	105
October	145
November	170
December	190

4.4 Catchment Parameters

Using contour data provided by BBK, the site was divided into 5 sub-catchments each representing a part of the proposed development that drains to a discrete location. The average slope for each sub-catchment was estimated from a Digital Elevation Model (DEM) prepared from the provided contour data. The same sub-catchment distribution was used for both the XP-RAFTS and MUSIC models and the distribution is shown in **Figure 4-1**.

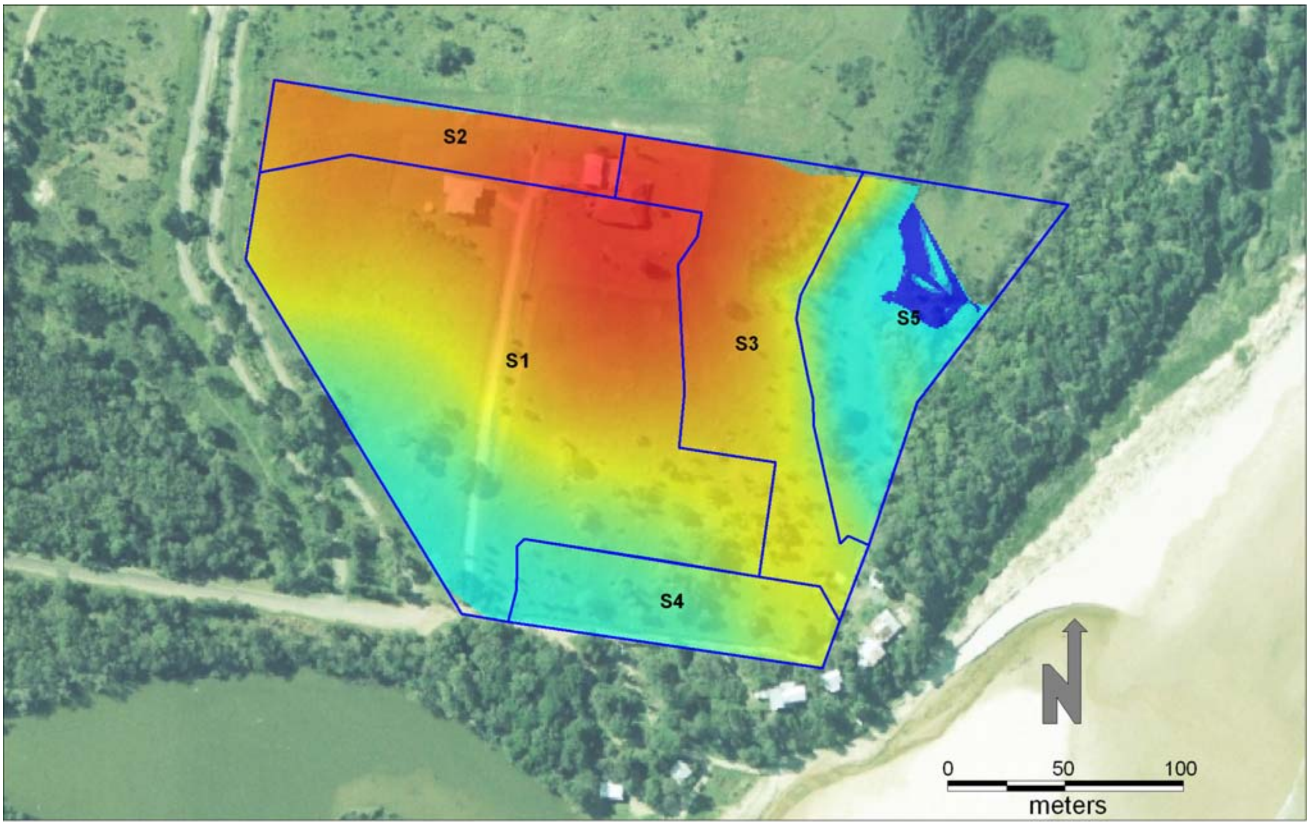

Figure 4-1 Developed scenario - Sub-catchments

The primary catchment parameter that impacts on surface runoff within an urban catchment is the effective impervious area (EIA). The EIA is typically less than the total impervious area (TIA) within an urban catchment and is broadly indicative of the proportion of impervious area that drains directly to a constructed drainage system prior to discharging from this system into a receiving watercourse. The EIA in a conventional urban catchment is typically 50 to 80% of the TIA. Catchments with a high proportion of residential development are typically within the lower range of EIA/TIA ratios.

Applying the principles of Water Sensitive Urban Design (WSUD) within a development assists with reducing the effective impervious area by disconnecting the drainage system, and will result in reduced runoff volumes when compared to conventional development. MUSIC requires the input of directly connected impervious areas to simulate hydrologic conditions for the catchment.

The total impervious area (TIA) for each developed sub-catchment within the site was estimated adopting the following assumptions-:

- Roof area = 50% of the lot area up to a maximum of 400m^2;
- Driveway area within each lot = 30m^2;
- Soft landscaping area = minimum of 185m^2 or 50% of the non roof, pool or driveway area;
- Hard landscaping area = remaining lot area (including swimming pools);
- Road reserve 1 = 8m wide sealed pavement, 2 x 4m footways (including 1.2m wide concrete footpath on one side) and a 3m wide driveway crossing for every 20m of road reserve;
- Road reserve 2 = 6.5m wide sealed pavement, 2 x 3.75m footways (including 1.2m wide concrete footpath on one side) and a 3m wide driveway crossing for every 20m of road reserve;
- Stormwater management lot (10% impervious); and
- Pathway / drainage easement (25% impervious).

Adopting these assumptions, the estimated total impervious area for the developable site area (total site area excluding the proposed 7(a) area) would be 68%. The estimated total impervious area for the individual sub-catchments following development is summarised in **Table 4-2** along with the % impervious and % directly connected impervious area (DCIA) assumptions.

Table 4-2 Developed sub-catchment characteristics

Sub-catchment	Land use	Surface type	Area (m^2)	% impervious	DCIA (%)
S1	lots	roof (S1)	8,325	100	100
	lots	roof (S2)	1,970	100	100
	lots	landscaped	7,485	50	15
	lots	driveway	840	100	30
	road	footway	4,835	15	5
	road	pavement	4,835	100	100
	drainage reserve	landscaped	1,270	10	5
S2	lots	landscaped	2,365	50	15
S3	lots	roof	3,165	100	100
	lots	landscaped	3,940	50	15
	lots	driveway	210	100	100
	road	footway	300	15	5
	road	pavement	300	100	100
	drainage/pathway	landscaped	1,240	25	25
S4	Lots	roof	2,205	100	100
	Lots	landscaped	2,420	50	15
	Lots	driveway	180	100	100
	Road	footway	400	15	5
	Road	pavement	400	100	100
Total developable area			46,685		
S5	Reserve	Wetland	8,890	0	0
Total site area			55,575		

The effective impervious area (EIA) for each developed sub-catchment within the site was estimated adopting the following assumptions-:

- Roof areas are 100% directly connected;
- Pool, driveway, soft and hard landscaping areas are 30% directly connected;
- Road pavement areas are 100% directly connected;
- Footpaths and driveway crossings are 30% directly connected;
- Stormwater management lot is 50% directly connected; and
- Pathway / drainage easement is 100% directly connected.

Adopting these assumptions, the estimated total directly connected impervious area for the proposed development scenario is 53%.

4.5 Impervious and Pervious Area Parameters

The impervious area rainfall threshold parameter (a measure of the typical daily rainfall loss within impervious areas) for roads and hard landscaping areas was adopted from the MUSIC modelling previously undertaken by WBM for the Hearnes Lake / Sandy Beach DCP. The rainfall threshold parameter for roofs was assumed to be 0.2mm, which is reflective of the combination of a small initial loss from zinc-alum roofs (or similar) and a first flush device for rainwater tanks.

Pervious area parameters relating to the infiltration rates, field capacity, soil storage depths and groundwater adopted the values derived from calibrated MUSIC modelling previously undertaken by BMT WBM for the Department of Environment and Climate Change (DECC).

4.6 Stormwater Management Measures

The stormwater management measures that are considered most appropriate for managing stormwater quality and quantity within this site include rainwater tanks, a filter strip, vegetated swales, raingardens, a bioretention swale and a bioretention basin. A description of the measures, reasons for proposing these measures and assumptions adopted in sizing the measures are provided below.

4.6.1 Rainwater Tanks

Rainwater tanks are proposed to capture roof runoff from all lots within the proposed development site. Rainwater tanks have multiple benefits including reducing stormwater runoff volumes and peak flow rates, capturing stormwater pollutants loads and reducing demand on the potable water supply. For this report the benefits relating to stormwater are considered.

The strategy incorporates rainwater tanks with a minimum 15kL capacity for all lots with an area less than 920m^2. Rainwater tanks with a minimum 40kL capacity would be provided in lots where the area exceeds 920m^2 (generally the eastern lots that drain to the ephemeral wetland). It was assumed that 10% of the total storage volume for each rainwater tank would be allocated for temporary storage to control the runoff discharge rate during events that exceed the capacity of the tanks.

It was assumed for modelling that the rainwater captured within the tanks, would be utilised for outdoor irrigation, toilet, laundry and hot water supply. The estimated water demands for each dwelling included a constant water demand of approximately 479L/day for indoor uses (toilet, laundry and hot water). The estimated water demand for outdoor water use (garden watering, topping up pools, carwashing) was assumed to vary seasonally with a demand of approximately 240L/day in the spring and summer months, and approximately 75L/day in the autumn and winter months. The total annual water demand for each tank was estimated to be 232kL.

Overflow from rainwater tanks in S1 and S4 would be directed to interallotment drainage or kerb outlets. Overflow from rainwater tanks in S2 will be directed to kerb outlets (it was assumed that all roofs in S2 could feasibly be drained to the road). Rainwater tank overflow from dwellings in S3 would drain to the rear of the lots and be conveyed to raingardens via vegetated swales.

4.6.2 Filter Strip

A native landscaped filter strip with a minimum width of 1m would be provided along the Hearnes Lake Road site frontage to filter overland flow from the driveways and paved landscaping areas.

4.6.3 Vegetated Swales

Vegetated swales are proposed to drain along the rear of lots adjacent to the ephemeral wetland in S3. The swales are proposed to have a minimum total length of 75m. Surface runoff from the lots grading to the rear boundary would be intercepted by the swale prior to draining into the ephemeral wetland. The surface runoff would be treated and conveyed along this swale to raingardens for further treatment prior to discharging into the adjacent ephemeral wetland.

To minimise the potential for erosion within the swales in S3, a series of cascading swales may be required along the flow path. The maximum gradient of the vegetated swale should be 4% to minimise the erosion potential. Each of the vegetated swales was modelled adopting the following design criteria-:

- The swales would be trapezoidal in shape with a base width of 1m, a top width of 3m, maximum side slopes of 1(v) in 4(h) and corresponding maximum 0.25m depth;
- The typical infiltration loss through the base of the swale would be 0.5mm/hr;
- Vegetation would be appropriate indigenous grass species to protect the ephemeral wetland from being colonised by inappropriate exotic species;
- Vegetation should be maintained at a minimum height of 150mm; and
- Maximum gradient allowable without reinforcement of the surface or provision of a series of cascading swales shall be 4%.

Figure 4-2 Vegetated swale (DEC, 2004a)

4.6.4 Raingardens

Raingardens have a similar configuration to bioretention basins, although the scale of the measure is typically significantly smaller. These types of measures are typically provided within streets to treat runoff from a small area of road pavement. For this development, raingardens are proposed at four locations along the rear of the lots adjacent to the ephemeral wetland. Two raingardens would be provided to treat runoff from the turning heads at the end of the 14m wide roads and two raingardens would be provided near existing minor overland flow paths at the rear of the eastern lots.

Each of the raingardens proposed were modelled adopting the following design criteria-:

- The raingardens at the end of the turning heads each have a top surface area of 30m^2 and a biofilter area of 9m^2;
- The raingardens at the rear of the eastern lots have a total surface area of 150m^2 and a biofilter area of 75m^2;
- The raingardens each have a minimum extended detention depth of 0.25m;
- The primary drainage path for filtered runoff would be to a constructed sub-soil drainage pipe at the base of the filter, rather than infiltration into the insitu clay soils;
- The filter material would primarily consist of sandy loam with a saturated hydraulic conductivity of 100mm/hr;
- The depth of the filter material would be 0.6m; and

- The typical infiltration loss through the base of the filter would be 0.5mm/hr.

4.6.5 Bioretention Swale

A bioretention swale is proposed along the western side boundary in S1 to capture and treat runoff from the adjacent road and lots areas. The swale would also partially convey overland flow during large storm events (in addition to the roadway). It was assumed that 30% of the area in S1 would be directed to the bioretention swale. The swale would be a minimum of 50m long and 3m wide. The extended detention would be 0.25m deep with a 0.6m deep biofilter.

The existing gradient along the proposed alignment of the bioretention swale is approximately 7%. The longitudinal gradient would be modified by the creation of check dams to reduce the hydraulic gradient to approximately 3%. Suitable erosion control measures would be incorporated into the design.

4.6.6 Bioretention Basin

A bioretention basin would be provided in the south-western corner of the site within a dedicated stormwater management lot. The bioretention basin would be formed in the base of the detention basin provided for flood management.

The geotechnical report prepared for the site and adjacent areas (Holmes & Holmes, 2003) indicates that the soils in the south-western corner of the site where the bioretention basin is proposed are clayey sands to a depth of 0.8m, overlying a 1.7m deep layer of firm-stiff high plasticity clay, overlying a weak fractured claystone. During the geotechnical investigations no groundwater was observed in the profile. It is considered that the soil profile observed would be suitable for the purposes of stormwater treatment at this location. The bioretention basin configuration is summarised in Table 5-2 and key modelling assumptions are summarised below-:

- The filter surface area would be 600m^2;
- The extended detention depth would be 0.4m (bioretention depth only, flood detention is additional);
- The depth of the filter material would be 0.6m;
- The primary drainage path for filtered runoff would be to a constructed sub-soil drainage pipe at the base of the filter, rather than infiltration into the insitu clay soils (due to the low infiltration capacity of the insitu soils);
- The filter material would be a sandy loam with a saturated hydraulic conductivity of 100mm/hr; and
- The average infiltration loss through the base of the filter would be 0.5mm/hr.

An example of a small bioretention basin with a central filter is shown in **Figure 4-3.**

Figure 4-3 Bioretention basin with central filter (ARQ Draft, 2004)

4.7 Stormwater pollutant concentrations

The MUSIC program currently incorporates four stormwater pollutants where a reasonable level of research has been undertaken to determine typical source concentrations from urban catchments. The stormwater pollutants modelled within MUSIC include total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS) and gross pollutants (GP). In addition to the source concentrations, research has also been undertaken for a number of common stormwater management measures to estimate the performance of these measures at improving stormwater quality.

The stormwater pollutant concentrations input to MUSIC model for roof, road and residential areas were adopted from the values recommended for NSW in Fletcher (2004). Private landscaping areas and driveways were simulated adopting the values presented for residential areas.

The model was simulated utilising the stochastic approach to estimate pollutant concentrations for each model time step.

4.8 MUSIC model results

A MUSIC model was prepared to evaluate the performance of the stormwater strategy at achieving the objectives. The model results are presented for the developed without WSUD and developed with WSUD scenarios in **Table 4-3**.

Table 4-3 MUSIC modelling results

Scenario	**Estimated stormwater loads**				
	Flow (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	GP (kg/yr)
Developed (no WSUD)	54.9	3860	11.9	108.0	990
Developed (with WSUD)	44.0	353	3.1	47.5	53
Estimated performance (% reduction)	**20**	**91**	**74**	**56**	**95**
Targets (% reduction)					
Modified source scenario targets	33	87	74	56	99
NSW best practice targets[1]	-	80	45	45	-

1. "Australian Runoff Quality guidelines" (Engineers Australia, 2003).

The MUSIC model results indicate that the proposed strategy would achieve the "modified source control" targets established for the Northern Precinct for TSS, TP and TN. The runoff reduction target of 33% was not achieved, although the estimated strategy performance would significantly exceed current best practice management objectives for NSW. Further discussion of this issue is provided in **Section 7.**

The conceptual locations and extents for each stormwater management measure are shown on the conceptual stormwater quality / quantity management strategy presented in **Figure 4-4.**

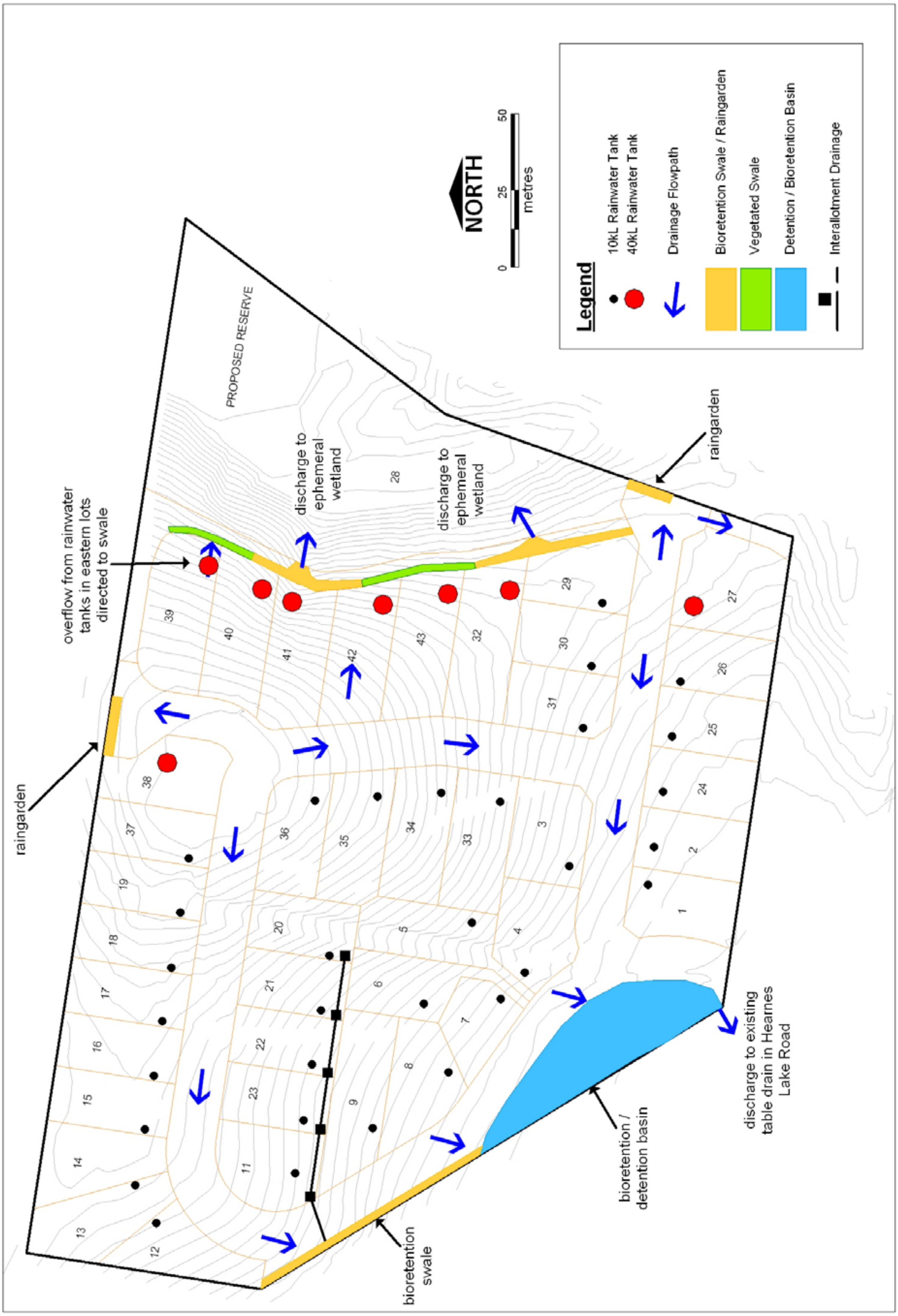

Figure 4-4 Stormwater quality / quantity management strategy

5 Event-based hydrologic modelling

5.1 Modelling approach

Event rainfall-runoff modelling was undertaken utilising XP-RAFTS software to determine critical storm durations and peak flows within the site for existing and developed site conditions. For the purposes of assessing the event hydrology and estimating detention requirements, minor and major design storm events with design Average Recurrence Intervals (ARI) of 10 years and 100 years respectively were adopted. Detention requirements were estimated to mitigate any increases in peak design flows resulting from development of the site.

The modelling approach applied the split sub-catchment routine within XP-RAFTS (impervious and pervious proportions modelled separately for each sub-catchment). Each sub-catchment for the existing conditions was conservatively assumed to be entirely pervious. The imperviousness of each sub-catchment for the developed condition was evaluated adopting the same assumptions outlined for the catchment parameters in **Section 4.4**.

The model requires the input of initial and continuing loss parameters to model rainfall loss within the catchment. The loss rates adopted for pervious surfaces for the existing and fully developed scenarios were 20mm and 2.5mm/hr respectively. An initial loss of 1.5mm and continuing loss of 0mm/hr were adopted for impervious surfaces for the developed scenario. These values are consistent with the recommended values presented in Australian Rainfall and Runoff (AR&R) 1998.

A range of storm durations were simulated utilising temporal patterns outlined in (ARR) Vol. 2, 1987 to determine the critical duration event. The design rainfall intensity for each storm was determined using the methods outlined in ARR 1998. Storm durations of 30, 60, 90, 120, 180, 270 and 360 minutes were simulated for the existing and developed site conditions.

Additional sub-catchment model parameters including slope and surface roughness were estimated from the site inspections, survey data and professional judgement.

5.2 Detention requirements

A detention basin would be provided in the south-western corner of the site to manage peak flows from the S1 and S4 sub-catchments during infrequent design events. Flows would enter the basin via the minor stormwater drainage system or as overland flow along roads.

Runoff from S3 would have no adverse impact on flood behaviour for upstream and downstream properties as this catchment drains directly to the ephemeral wetland. It is considered that management of more frequent environmental flows for this sub-catchment is more critical. Runoff from ground surfaces within S2 would bypass detention due to topographic constraints. To allow for this bypass area, additional storage would be provided within the detention basin to ensure that the flood mitigation objectives are achieved.

Roof runoff would be routed through the rainwater tanks for each lot. At this stage the potential benefit of rainwater tanks for detention purposes was conservatively not included within the analysis. The detention storage volumes were reduced in the model by 10% to allow for loss of storage due to vegetation in the basin.

The size of the detention basin necessary to mitigate increased peak design flow rates following development have been estimated in XP-RAFTS adopting the following key design assumptions-:

- Basins would be trapezoidal shaped with a maximum internal basin side slope of 1(v):4(h);
- A low stage outlet would be provided to control flows for the 10 year ARI design event;
- A high stage outlet would be provided to control flows up to the 100 year ARI design event;
- An emergency overflow weir spillway would be provided to control flow from the basins for design events in excess of the 100 year ARI design event or in the case of blockage of the low and/or high stage outlets; and
- The basin discharges would be inlet controlled.

The low level outlet from the basin would be sized to ensure that the post development peak design 10 year ARI flow does not exceed the corresponding pre-development flow. The high level weir outlet was sized to ensure that the combined discharge from the low level and high level outlets would not exceed the peak design 100 year ARI pre-development flow post development.

5.3 XP-RAFTS Model Results

The estimated peak site discharges for the existing development were assessed to be similar for the 90 and 120 minute design duration for both the 10 year and 100 year ARI design storms. The estimated peak site discharges for the developed with detention scenario were assessed within XP-RAFTS to be lower than the existing development scenario for the critical 90 and 120 minute duration events. A summary of the estimated 10 year and 100 year ARI peak flow rates for the site area draining to Hearnes Lake for the critical duration events are shown shaded in Table 5-1. Additional model runs were performed for other design storm durations and these results are provided in Table 5-1.

Table 5-1 Estimated peak flows for various storm durations (developed with detention)

Storm Duration	Estimated Peak Site Discharge to Hearnes Lake (m^3/s)			
	10yr ARI		100yr ARI	
	Existing	Developed (with Detention)	Existing	Developed (with Detention)
30	0.7	1.1	1.4	1.4
60	1.0	1.1	1.8	1.5
90	1.2	1.1	2.0	1.5
120	1.2	1.2	2.0	1.5
180	0.9	1.0	1.4	1.2
270	0.8	0.9	1.2	1.1
360	0.7	0.7	0.9	0.9

The results indicate that the provision of a dry detention basin with characteristics outlined in Table 5-2 would be sufficient to mitigate any increase in design storm discharges from the site for a range of design storm durations relevant to local flooding for sub-catchments draining to the culvert under Hearnes Lake Road.

Table 5-2 Preliminary Detention/Bioretention Basin Configuration

Relative level	Bioretention/Detention Basin Element	Cumulative Volume (m^3)	Surface Area (m^2)
-0.6m	Invert of 1.35 x 0.45m RCBC	-	-
-0.6m	Base of biofilter	-	-
0.0m	Top of biofilter	-	-
0.0m	Base of bioretention extended detention	0	600
0.4m	Top of bioretention extended detention	250	680
0.4m	Base of detention basin	250	900
0.4m	Inlet to detention basin low level outlet	250	900
1.2m	High level weir spillway level	1050	1300
1.4m	Detention basin crest level	1300	1370

6 Review of SEPP26 Littoral Rainforest Buffer

An area of SEPP 26 Littoral Rainforest is located adjacent to the eastern site boundary. The main objective of SEPP 26 as specified within the policy is to “provide a mechanism for the consideration of applications for development that is likely to damage or destroy littoral rainforest areas with a view to the preservation of those areas in their natural state”. The policy applies to land enclosed within defined SEPP 26 boundaries and land within 100 metres of this boundary (except residential zoned land and land to which SEPP 14 applies).

The Hearnes Lake / Sandy Beach DCP indicates that a 50m buffer should be provided between a proposed development and a SEPP 26 Littoral Rainforest boundary for the protection of water quality. The DCP requires the buffer to be rehabilitated and revegetated using indigenous native species and dedicated as environmental protection land. The locations of the SEPP 26 Littoral Rainforest boundary and 50m buffer are shown in **Figure 6-1.**

For this site, the SEPP 26 Littoral Rainforest would be separated from the development by an ephemeral wetland that intermittently captures and stores runoff prior to infiltration/evaporation (refer **Figure 6-2**). The ephemeral wetland would therefore intercept runoff from the development site, preventing it from flowing into the SEPP 26 Littoral Rainforest. Although surface runoff would not drain directly to the littoral rainforest, it is likely that untreated surface runoff from the development would convey elevated stormwater pollutant loads to the ephemeral wetland. To minimise the potential for elevated loads of stormwater pollutants to be conveyed to the ephemeral wetland, it is proposed that a series of stormwater interception/treatment measures be provided along the rear of lots adjacent to the ephemeral wetland. It is considered that the proposed measures in this area would exceed best practice management for stormwater quality and quantity and would form an effective water quality buffer for runoff discharging into the ephemeral wetland (refer to **Section 4.6** for a discussion of the proposed controls).

It is important to note that the provision of best practice management measures for stormwater does not guarantee protection of the ephemeral wetland from increased stormwater pollutant load inputs. Rather, the best practice measures represent the limitations of current research and technologies available to treat stormwater. Further, whilst protection of water quality is one of the objectives targeted through provision of the buffer, the buffer may also be required to address other environmental objectives that are beyond the scope of this report.

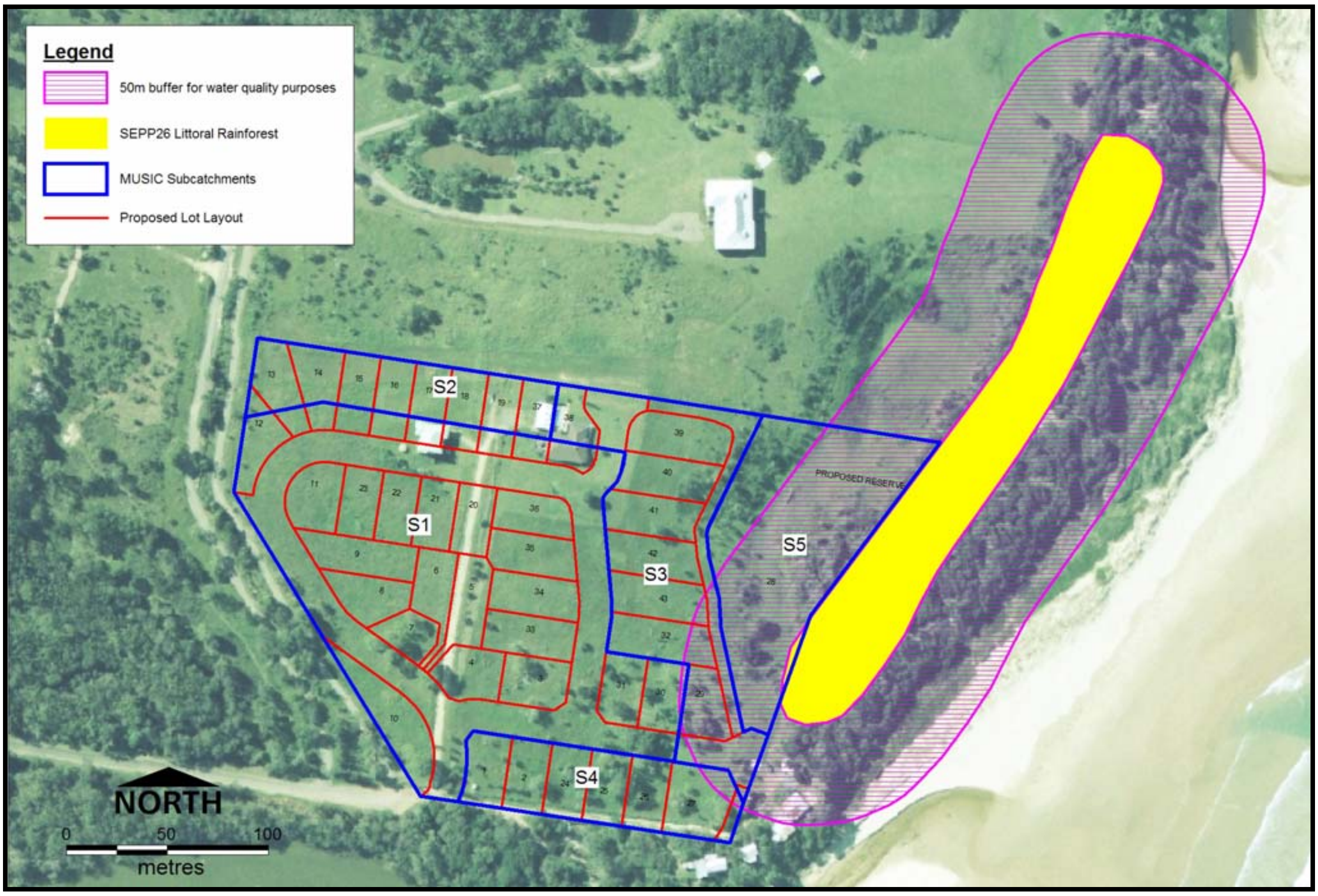

Figure 6-1 Location of SEPP26 Littoral Rainforest and proposed 50m DCP buffer

Figure 6-2 Existing ephemeral wetland

7 Summary and conclusions

The proposed stormwater management strategy for the site incorporates measures to manage stormwater quantity and quality. The stormwater quantity management elements would be appropriate for conveyance and mitigation of peak developed flows for the 10 and 100 year ARI design events relevant to flooding in the local catchment. The size and extent of stormwater quality management measures proposed is in accordance with the *Hearnes Lake / Sandy Beach DCP*.

Stormwater quality is proposed to be managed by incorporating treatment measures in series to capture, convey and/or filter stormwater prior to discharge into the receiving waters. The stormwater quality management strategy includes filter strips, vegetated swales, the combined bioretention/detention basin, raingardens and rainwater tanks to manage common stormwater pollutant loads (TSS, TN and TP). The proposed stormwater quality management strategy has been configured and sized (conceptually using MUSIC software) to target reduction of TSS, TN and TP loads in accordance with water quality objectives outlined in the Hearnes Lake / Sandy Beach DCP. The targets for stormwater quality management outlined in *Appendix A* of the DCP, and the intended management approach for this site are summarised below -:

1 *Rainwater tanks shall be provided for all residential lots and have a minimum capacity of 5kL.*

Each lot would be provided with a rainwater tank with a minimum capacity of 15kL. Lots draining to the ephemeral wetland would be provided with rainwater tanks with a minimum capacity of 40kL.

2 *Rainwater tanks shall only capture roof water and a minimum of 50% of the roof area shall drain to the tank.*

It is proposed that 100% of dwelling roof areas are directed to rainwater tanks.

3 *A 1m wide filter strip shall be provided behind kerb and gutter to filter runoff where gradients are unsuitable for swales*

A 1m wide vegetated filter strip would be provided behind the kerb and gutter along each road within the development where vegetated swales are unable to be provided.

4 *The minimum surface area of vegetated swales required for the Northern Precinct is 3500m^2*

The minimum surface area requirement is equivalent to a 455m^2 contribution for this site. The combined surface area of vegetated swales for this site is 225m^2. Although the area of vegetated swales is lower, additional compensatory bioretention swale area is provided within the strategy. An equivalent area of bioretention swale would be more effective at improving runoff quality.

5 *The minimum and maximum width of vegetated swales is 2m and 3m respectively.*

The proposed width of all vegetated swales within the development is 3m.

6 *The minimum surface area of bioretention swales / basins required throughout the Northern Precinct is 2600m^2*

The minimum surface area requirement is equivalent to a 340m^2 contribution for this site. The proposed total surface area of bioretention swales and basins within the development is 950m^2 which significantly exceeds the requirements for this development.

7 *The minimum permanent pond volumes required per hectare of development area in the Northern Precinct is 125m^3/ha.*

The minimum pond volume requirement for this site is equivalent to a 585m^3 contribution for this site (4.67ha x 125). The permanent pond volume requirement for this development would be provided by the permanent storage available within the rainwater tanks that exceeds the minimum requirement of 5kL. The total volume above 5kL provided in the tanks would be 760m^3 (i.e. 33 lots x 10kL + 8 lots x 35kL). Assuming that approximately 5% of this volume would be allocated as an air space in each tank, the volume would reduce to approximately 580m^3, which is approximately equivalent to the DCP requirement.

The strategy was also modelled within MUSIC and compared against the "modified source and conveyance control treatment strategy" to determine if the strategy would also achieve these targets. The MUSIC model results indicate that the proposed strategy would achieve the "modified source control" targets established for the Northern Precinct for TSS, TP and TN. The runoff reduction target of 33% would not be achieved (20% reduction achieved) as opportunities for large scale re-use (which is the main feature of the "modified source and conveyance control treatment strategy") are limited for this development. Capture and re-use of stormwater runoff from ponds is more feasible on a larger catchment scale where harvested water can be utilised for irrigating large open space areas, golf courses and other large pervious areas. If runoff from this site could feasibly be drained to an external central facility it is considered that the runoff reduction target outlined within the "modified source and conveyance control treatment strategy" could be achieved.

A constructed stormwater drainage system is proposed to convey minor flows up to the peak 10 year ARI flow for each sub-catchment. The runoff would be managed utilising conventional minor stormwater drainage elements including roof gutters, property roof drainage lines, interallotment drainage lines, kerb and gutter, and pipes. Swales in some locations would also perform a conveyance role during minor flow events. Major stormwater drainage elements including swales and roads would be provided to convey the peak 100 year ARI discharge for each sub-catchment to the outlet considering factors including pedestrian safety and vehicle stability. The major stormwater drainage system elements would be evaluated and sized during detailed design when the vertical alignment of the streets is confirmed.

A detention basin is proposed within the south-western corner of the site to achieve the DCP objective that requires the development to have no adverse change to the flood behaviour for adjacent properties or elsewhere in the catchment. For the purposes of this assessment, the 10 and 100 year design events were adopted for evaluating the performance of the detention facilities against the DCP objectives. It is estimated that a detention basin conforming to the key design criteria summarised in Section 5.3 would achieve the DCP objectives. Bioretention would be incorporated into the base of the detention basin for the treatment of stormwater quality. Additional detailed design would be required for this basin to confirm the size and location of inlets and outlet structures.

The Hearnes Lake / Sandy Beach DCP indicates that a 50m buffer should be provided between a proposed development and a SEPP 26 Littoral Rainforest boundary for the protection of water quality. The proposed development layout provides a narrower buffer that varies between 20-50m for five of the eastern lots. For this site, the SEPP 26 Littoral Rainforest would be separated from the development by an ephemeral wetland that intermittently captures and stores runoff prior to infiltration/evaporation. To minimise the potential for elevated loads of stormwater pollutants to be conveyed to the ephemeral wetland a series of stormwater interception/treatment measures are proposed along the rear of the eastern lots to ensure that runoff from the development is not directly connected to the ephemeral wetland. The rainwater tanks would be particularly effective at minimising the number of rainfall events that result in runoff discharging to the ephemeral wetland following development and combined with the bioretention swales, it is considered that the proposed measures in this area would effectively perform the role of a water quality buffer for the ephemeral wetland. For these reasons it is considered that provision of a formal 50m buffer would not be essential for protecting water quality within the SEPP26 Littoral Rainforest.

Yours Faithfully
BMT WBM Pty Ltd

Mark Wainwright
Associate

References

Argue, J. (2006) *Stormwater Management (Source Control) – Appendix A Measurement of Hydraulic Conductivity in Soils for Use in Water Sensitive Urban Design*, Engineering Education Australia.

Chiew, F.H.S. & McMahon, T.A (1997) *Modelling Daily Runoff and Pollutant Loads from Urban Catchments*, Water (AWWA Journal) 24:16-17

CRCCH (2004) *Stormwater flow and quality and the effectiveness of non-proprietary stormwater treatment measures,* Co-operative Research Centre for Catchment Hydrology.

Holmes & Holmes (2005) *Geotechnical Assessment for Proposed Residential Development at Hearnes Lake – Woolgoolga, Report 034 135B,* unpublished.

WBM (2005) *MUSIC modelling of Hearnes Lake Catchment, r*eport prepared for Coffs Harbour City Council*.*