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PITTWATER COUNCIL

Scotland Island

Stormwater Management Strategy

301015-01852

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PITTWATER COUNCIL
SCOTLAND ISLAND
STORMWATER MANAGEMENT STRATEGY

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PROJECT 301015-01852 - SCOTLAND ISLAND

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
A	Draft 1 SMS	MJS	MJS	MST	26-Mar-07	N/A	
B	Draft 2 (*Public Exhibition*)	MJS	MJS	MST	1-May-07	N/A	N/A
C	Draft 3 (2nd *Public Exhibition*)	MJS	MJS	MST	6-Aug-08	N/A	N/A
D	Final	MJS	MJS	MST	25-Sep-09		N/A

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EXECUTIVE SUMMARY

WorleyParsons have been engaged by Pittwater Council to develop a strategic plan for management of stormwater on Scotland Island (*ie a Stormwater Management Strategy*).

Because of their inter-relationship this Stormwater Management Strategy has been developed in parallel with a Road Reserve Strategy for the Island (*refer to separate WP report titled ".Scotland Island Road Reserve Strategy"- 24 September 2009*).

Both documents have now been finalised and incorporate several years of investigations, consultation and review. An umbrella document has also been developed, which presents a summary of both reports (*refer to separate WP report titled "Scotland Island Road and Stormwater Management Strategy Overview" – 28 September 2009*).

Both strategy reports have made a number of conclusions regarding the treatment of the Islands roads and stormwater management system and put forward a range of short, medium and long term recommendations.

Because the reports are high level strategy documents it is anticipated that a number of more detailed site/issue specific investigations will need to be undertaken before implementation of some recommendations. However, it is also anticipated that many recommendations can be implemented directly.

1. INTRODUCTION

WorleyParsons (*WP*) (*now incorporating Patterson Britton & Partners (PBP)*) have been engaged by Pittwater Council (*Council)* to develop a strategic plan for management of stormwater on Scotland Island (*the Island*).

To date a number of catchment related studies have been completed for the Island, however there does not appear to be a strategic plan in place to pull together the recommendations from each of these studies. In addition, a Road Reserve Strategy is currently being developed for the Island and development of suitable drainage systems has been critical to this plan.

Historically, drainage does not appear to have been addressed adequately at the planning phase of the Islands development (*ie back when development was first introduced on the Island*). Rather it appears that drainage has been implemented on a needs basis only as the consequences of poor drainage systems were experienced (*ie flooding, erosion or contaminated waterways*).

This study involved review of all previous studies as well as undertaking our own strategic investigations to develop a plan for managing both the conveyance and quality of stormwater on Scotland Island. The final recommendations are cognisant that there appears to be a proactive community, genuinely interested in implementing appropriate drainage solutions for the Island.

1.1 Study Objectives

This study is strategic in nature and as such provides a vision for sustainable long term drainage solutions on the Island. However, implementation of this ultimate strategy is likely to take a considerable amount of time and as such interim solutions may be necessary.

Based on the above and the direction provided by Council, the study objectives have been defined as follows:

1. Provide a strategic plan for management of stormwater runoff quantity, quality and conveyance so as to minimise the impact of erosion, flooding and contamination;
2. Provide guidance on practical interim solutions;
3. Provide drainage solutions that recognise the unique characteristics of the Island, including a preference for softer engineered solutions where appropriate; and
4. Provide drainage solutions that have low ongoing maintenance requirements.

2. BACKGROUND

Scotland Island is located at the southern end of Pittwater, Broken Bay. Neighbouring mainland suburbs include Church Point to the south, Taylors Point to the east and Elvina Bay to the west. Ku-ring-gai Chase National Park is located immediately to the west of the Island from which McCarrs Creek emanates and forms the main creek system delivering freshwater flows to the Southern end of Pittwater.

The Island is approximately 53ha in area and is surrounded by a coastline perimeter of approximately 3km. The nearest mainland access point is Church Point, from which ferries regularly depart for the Island. Five wharves are available on the Island for public access: Tennis,

Cargo, Bell, Carols and Eastern Wharfs. Refer to **Diagram 1** below for an illustration of the Island.

Diagram 1 – Scotland Island

2.1 Other Studies

As mentioned in the introduction of this report, a number of catchment related studies have been completed for Scotland Island in the past.

With the assistance of Pittwater Council and representatives of the Scotland Island Residents Association *(SIRA*) a list of relevant background studies was compiled as follows:

- " *Bushfire Management Plan – Scotland Island*" Brian Parry and Associates;
- "*Draft Scotland Island Road Reserve Masterplan*" G Witheridge, August 2004;
- "*South Precinct Catchment Study, Scotland Island*" WS Rooney & Associates Pty Ltd, April 2004;
- "*Scotland Island Residents Association Roads, Paths and Drainage Taskforce – Survey Report*" SIRA, July 2000;
- "*Pittwater Stormwater Management Plan*" Patterson Britton & Partners, May 1999;
- "*Catherine Park Catchment Study, Scotland Island*" WS Rooney & Associates Pty Ltd, September, 1998;
- "*Report on Investigation into Dieback of Native Trees on Scotland Island*" Woodlots and Wetlands, 1997;
- "*Scotland Island Matters*" J Cullen, 1997;
- "*Scotland Island Wastewater Impact Study (Stage 1)*" Martens & Associates, July 1997;
- "*Water and Sewerage Options Study: Scotland Island, Sydney NSW (Stage 2)*" Martens & Associates, 1997;
- "*Scotland Island Proposed Walking Track Management Plan*" Department of Conservation and Land Management NSW, 1993; and
- "*Scotland Island – Considerations for the Development of a Stormwater and Pollution Runoff Plan*" A Cullen, 1992.

All of the above studies were reviewed in detail. A summary of the relevant information gained from these documents is provided below.

- Historical stormwater management and erosion related issues;
- Historical road stabilisation initiatives;
- General historic information;
- The residents opinions/vision;
- The Islands physical properties;
- The Islands existing drainage systems;
- Road improvement/upgrade recommendations;
- Drainage improvement/upgrade recommendations;
- Pathway/walking track improvement/upgrade recommendations;

- Road reserve improvement/upgrade recommendations;
- Road reserve maintenance requirements/recommendations;
- Existing water supply and wastewater treatment systems;
- Wastewater impacts(*public health and environmental*);
- Wastewater and water supply improvement/upgrade recommendations;
- Hydrological information;
- Hydraulic information;
- Geomorphologic information;
- Water quality monitoring results;
- Stormwater pollutant load predictions;
- The lack of existing formalised overland flowpaths/easements, trunk drainage routes on the Island;
- Bushfire management requirements; and
- Dieback of native trees potentially due to current onsite wastewater treatment/disposal systems.

2.2 Site Inspection

Detailed site reconnaissance was carried out on two separate occasions (*10th August 2006 and 15th/16th January 2007*) to assist in identification of problem areas, modelling assumptions and possible treatment measure locations.

Photographs from the above inspections are contained at the rear of this report. In summary the following observations were made:

- A substantial proportion of the Island roads are currently unsealed;
- Some of the steeper roads are showing signs of excessive erosion (*ie Hilda Ave, Cecil St, Kevin Ave, Thompson St*);
- Some of the flatter roads appear to be relatively stable in an unsealed state;
- Some of the older sealed sections of road incorporating a dish drain appear to be in relatively good condition (*ie near intersection of Thompson St and Harold Ave*);
- The Cargo Wharf concrete road appears to be stable and well suited to this situation;
- The sediment basins constructed at some stormwater outlets appear to be working well;
- The cross banks constructed along some of the unsealed sections of road appear to be working well, although there are some exceptions;
- There are many rainwater tanks located on each developed lot on the Island. Many of the older tanks have rusted and been left onsite;
- The Poly Ethylene (*PE*) emergency water supply line runs along most roads on the Island at or above ground level;

- There is a distinct lack of formalised trunk drainage routes as well as minor piped drainage systems;
- Sewerage odour was evident in many parts of the Island;
- Many existing drainage structures were blocked with sediment;
- Many of the existing drainage grates appear to have been damaged by vehicular loads;
- Some (*not all*) of the road/drainage repair works appear to have been completed without proper design;
- The Island has a relaxed rural atmosphere. There appears to be a desire to implement soft engineering solutions in keeping with this atmosphere but also a realisation that hard engineering solutions must be implemented in more critical areas (*ie on steep erodable slopes etc*);
- Many private driveways/pathways appear to be protruding into the roads, blocking dish drains and initiating erosion;
- Many unsealed roads exhibit inadequate cross fall;
- Some houses/structures appear to have been constructed over major overland flow paths;
- Filling has occurred within some natural creeklines and overland flow paths;
- Many road culvert pipes appear to be PVC or recycled plastic;
- There is little opportunity within the road reserves and existing open space reserves for implementation of large public based water quality control measures (*ie wetlands, water quality control ponds, bio-retention systems, etc*);
- There also appears to be little opportunity due to the steep topography, rock outcrops and low infiltration capable soils to implement onsite water sensitive urban design (*WSUD*) measures (*ie other than rainwater tanks linked to reuse*);
- Litter was observed at the outlet of the Cargo Wharf drainage line;
- Many road culverts lack formalised headwalls;
- Some small regular shaped rock lined channels have been constructed through private property to convey lows flows; and
- The PE emergency water supply line has been laid through some drainage structures (*pipes, culverts and pits*) potentially reducing capacity and promoting blockage.

2.3 Land Use

The Island has a predominant residential land use incorporating some small to medium pockets of open space (*refer to **Figure 1***). Overall, there are approximately 370 residential allotments and five main parks/reserves; Catherine Park, Pat Hilda Reserve, Elizabeth Park, Harold Reserve, and Leahvera Reserve.

It is estimated that around 344 houses have been constructed on the Island, with the potential for another 32 to be constructed in the future. The 2001 Census indicated an island population of 730. At present it is predicted that the population may be closer to around 1000 people.

The existing open space generally consist of vegetated reserves although active open space is provided in Catherine Park.

The Island has a relaxed rural type atmosphere.

2.4 Slopes and Topography

Martens and Associates provide a detailed description of the Islands slopes and topography in their 1997 "*Scotland Island Wastewater Impact Study*" report. An excerpt from this description is provided below.

"*Topography on the island is largely the result of underlying geology. ………In general, local relief is approximately 30-90m and slopes are frequently moderate to steep (>20%). The island rises to a central ridge and saddle unit composed of Hawkesbury sandstone at an elevation of 80-90m AHD. The western ridge top represents the highest point on the island reaching approximately 92 mAHD ……*

A digital terrain model of the island (DEM) was constructed ……… to determine the nature and coverage of each slope class and provide a shaded relief map of the island …

More than 80% of the island contains slopes greater than 10% and almost a third of the Island contains slopes greater than 20%."

Table 1 below provides a summary of the PBP measured slope categories.

Table 1 – Scotland Island Slope Categories

Category	Slope (%)	Aerial coverage (ha)	Aerial coverage (%)
Low	<5	4.2	**7.9**
Moderate	5-10	4.6	**8.7**
Steep	10-20	28.9	**54.6**
Very steep	>20	15.2	**28.7**
TOTAL	**-**	**52.9**	**100.0**

2.5 Geology and Soils

WS Rooney and Associates provide a detailed description of the Islands geology and soils in their 2004 "*South Precinct Catchment Study, Scotland Island*" report. An excerpt from this description is provided below.

"*The Island is capped by Middle Triassic sandstones of the Hawkesbury Group. These are medium to coarse grained sandstones forming steep, rugged slopes and ridges with rocky outcrops. The natural vegetation consists mostly of uncleared open woodland with pockets of tall open forest and closed forest. The soils are shallow and discontinuous, and are associated with rock outcrops. The dominant soil materials are coarse sands, sandy clay loams, and light clays with the overall fertility being generally low (Chapman & Murphy, 1989, SCS, 1993).*

The Hawkesbury sandstones are underlain by the older Triassic, and more litholgically diverse series of the Narrabeen Group, comprising interbedded sandstones, shales and claystones. It is this series of rocks that form the slopes of Scotland Island, and upon which most of the building and tracks are constructed. It forms soils that may be shallow or deep on sandstones, and moderately deep on shales. The natural vegetation consists of tall eucalypt open forest and closed forest. The dominant soil types are stony sandy loams, sandy clay loams, sandy clays, and clays with the overall fertility ranging from low to moderate (Chapman & Murphy, 1989, SCS, 1993).

The Soil Conservation Service of NSW produced soil landscape maps and descriptions for the Sydney Region, which integrated both soil and topographic information into on unit to provide constraints to urban and rural development (Chapman and Murphy 1989). That report also provided general urban and rural capability ranking for each soil landscape unit. …..

Two landscape units are found on Scotland Island: the Watagan and Hawkesbury soil landscapes. The Watagan soil landscape is related to the soils produced from the Narrabeen Group lithology; and thee Hawkesbury soil landscape is related to the soils produced from the younger Hawkesbury Group lithology. The capability ranking for both of these soil landscapes provides a clear explanation for the erosion that is evident on the Island today with continued urban development:

	URBAN LAND CAPABILITY	RURAL LAND CAPABILITY
WATAGAN	*not capable of urban development*	*Not capable of regular cultivation or grazing*
HAWKESBURY	*not capable of urban development*	*Not capable of regular cultivation or grazing*

It is unfortunate the such maps and capability rankings were not available to earlier owners and planners of the Island who subdivided it into around 355 private building blocks and designed access tracks around the Island and across the slope, because it would have been quite evident that such intense urban development was very ill advised.

The Watagan soil material has generally low to moderate erodability on gentle terrain, but the steep slopes of the Island produce and erosion hazard for non-centred flows which is extreme.

The Hawkesbury soil erosion hazard for non concentrated flows is generally very high and ranges from moderate to extreme. The calculate soil loss for the first twelve months of urban development ranges up to 109t/ha for topsoil and 394t/ha for subsoil. The soil erosion for concentrated flow is extreme.

The calculated soil loss from the Watagan and Hawkesbury soil landscapes during the first twelve months of urban development, noted about by Chapman and Murphy (1989), are presumed to decrease significantly once developed sites are vegetated, and of course only refer to actual areas of disturbance, not the whole catchment" WS Rooney (2004).

In addition, geotechnical field work undertaken by Martens & Associates for their July 1997 report provides an important insight into the Islands typical soil profile and hydraulic properties as follows:

"*Surveying revealed that much of the Island soil cover is only moderate with total depth (A and B horizons) averaging slightly below 1.00m. The GIS interpolation analyses reveals that only approximately 7% of the Island contains soils which exceed a total depth of 1.25m.*

Native A horizons are characteristically thin with approximately 0.45m average thickness. They frequently exist in a somewhat degraded (compacted) state and have been eroded to some extent, further reducing their thickness. This is particularly so in areas close to urban establishment. Spatial variations in A horizon thickness related to both the morphologic land unit (and therefore catenary or slope position) and the underlying rock type. In general, soil thickness, notably that of the A horizon increases from ridge units through to swales. The average depth of A horizons in swales (0.60m) is approximately twice that of the ridges (0.35m). Results indicate that A horizons are slightly thinner on the Hawkesbury group than on the Narrabeen rocks. No differences in B horizon thickness were found to occur between these two groups" (Excerpt from Section 6.1.1 Martens and Associates, July 1997).

"*Initially, field determination of saturated hydraulic conductivity for both A and B horizons was attempted. However, B horizons proved to be too impermeable to make field measurement possible. At one site, a zero reading was taken after and hour of measurement. Hydraulic conductivities for subsoil horizons were therefore estimated according to their textual characteristics (AS1547. 1994).*

Results of A horizon field measurements using the constant head well permeameter varied significantly between 363 mm/day. Approximately 80% of the Island had surface hydraulic conductivities which were moderate (20-60mm/hour. Hazelton and Murphy, 1992). Some 12% maintained lower hydraulic conductivities, while approximately 6% was highly permeable (>60mm/hour).

Given that B horizons predominately vary in texture from light clays to sand clay loams permeability's are probably in the range of <30mm/day (AS1547, 1994). …….. Wastewater disposal within the B horizon would be almost totally bound by the surrounding soil and ponded within the trench.

Some variation between the morphologic units was observed. Ridges and slope were approximately similar with saturated hydraulic conductivities of approximately 1000mm/day. Swales (except for site 11 which was on alluvial material) maintained hydraulic conductivities approximately half (400-500 mm/day) that of ridges and slopes. It also appeared that the Hawkesbury group was somewhat more permeable than the Narrabeen group, although the statistical validity of this has not been confirmed.

Variation in A horizon saturated hydraulic conductivity did not significantly correlate with other soil parameters (eg ESP." (Excerpt from Section 6.1.4 Martens and Associates, July 1997)

From the above it can be concluded that generally the soils on the Island are shallow, low in fertility, have poor deep infiltration capacity and are highly erodable.

2.6 Existing Drainage Structures

Figure 3 illustrates the existing drainage structures present on the Island. Generally the drainage is in keeping with the rural feel of the Island, limited to culverts where creeks or overland flow paths cross the roads, minor piped drainage lines at limited locations and road side swales.

There appears to be a distinct lack of formalised overland flow paths connecting the top of the Island to Pittwater.

Some of the existing roads/tracks are sealed, however a large proportion remain unsealed and hence are not capable of conveying major flows.

Cross banks or waterbars have been constructed across many of the roads to divert road runoff away from the road surface and into table drains or mitre drains.

Many of the Islands culvert outlets and/or mitre drains lack appropriate levels of stabilisation. However, a limited number of sediment basins have been constructed downstream of some outlets which appear to be working well (*ie as is the case on the stormwater outlet downstream of the intersection of Catherine Park Rd and Pitt St – refer to **Plate 3***and ***Plate*** 4)

2.7 Surface Water Quality

Martens & Associates provide a description of existing surface water quality on the Island as part of their 1997 "*Scotland Island Wastewater Impact Study*" report.

For the above study, three surface water quality sampling sites were established to determine water quality during both dry and wet weather. The results of the surface water quality sampling are summarised in Sections 6.3 and 7.4 of the Martens and Associates report and are also reproduced in part in

Table 10 of this report.

The results show that runoff from the events sampled was of extremely poor quality, with excessive nutrient (*ie TP and TN*), suspended solid (*SS*) and faecal coliform (*FC*) concentrations. The poor readings are suspected to be as a result of wastewater discharging from onsite treatment systems and unstabilised road surfaces.

Note that as the above sampling was undertaken at a limited number of locations and over a relatively short timeframe it provides a snapshot of water quality only.

2.8 Unique Scotland Island Features

The draft Scotland Island Road Reserve Masterplan (*Witheridge, August 2004*) identifies some important features that need to be considered in development of any strategic plan for the Island as summarised below:

- An endangered Spotted Gum Forest Plant Community;
- The surrounding marine ecosystem/environment;
- A low vehicular usage, pedestrian environment;
- A rural atmosphere;
- An air of informality;
- An acknowledgement of the communities commitment to self regulation and shared decision making;
- The existence of highly erosive and moderately dispersive soils;
- An island topography consisting of mostly steep slopes;
- The need to provide a road and track system that provides safe, all weather pedestrian access without causing unacceptable harm to surrounding terrestrial and marine environments;
- Fire control and nutrient limitations associated with the Spotted Gum Plant Communities;
- The requirements of the Rural Fire Service (*RFS*); and
- The costs and limitations associated with importing materials onto the Island.

3. HYDROLOGY

3.1 Catchment Layout

Scotland Island can be divided into eight main catchments, as shown in **Figure 1**. All catchments currently contain residential development. Areas of natural catchment and/or parkland exist primarily at the summit of the island and in discrete pockets adjacent the water line in catchments A, B D and G.

All catchments discharge directly to Pittwater.

3.2 XP-RAFTS

XP-RAFTS were used to model the hydrology of the Scotland Island catchments. For the purposes of this study only the 5-year Average Recurrence Interval (*ARI*) and 100-year ARI design storm events were considered.

The XP-RAFTS model is used to simulate the rainfall/runoff process and estimate hydrographs at defined points for a specified set of catchment conditions and rainfall events.

The catchment is typically divided into a number of sub-catchments based on watershed boundaries. Data required for each sub catchment includes catchment area, slope, percentage of impervious surfaces, rainfall loss rates and a surface roughness factor. The hydrographs generated for each sub-catchment outlet are then routed or lagged through the channel network to the catchment outlet. The XP-RAFTS model has been used extensively by authorities throughout Australia on both rural and urban catchments.

The XP-RAFTS model is capable of separately routing the impervious and pervious sections of each sub-catchment, which is appropriate when modelling runoff from urban areas. The model is also capable of routing flows through a storage (*e.g. retarding basins, dams*) to assess the flood mitigation benefits downstream of the storage.

3.3 Model Parameters

Details of all adopted RAFTS parameters are included in **Appendix A** and summarised below.

Intensity-frequency-duration (*IFD*) data (*refer*

Table 2) was derived for the catchment from the 1987 edition of Australian Rainfall and Runoff (*ARR87*). Note that ARR87 is currently the "best practice" source for long term Australian hydrological data but has not been updated to incorporate possible climate change implications.

Rainfall loss parameters (*refer* ***Table 3***) were selected based on guidance provided in ARR87 and considered estimation based on visual inspection of the site. Loss values adopted account for the identified poor infiltration capacity of the Islands soils (*refer* ***to Section 2.5***).

Due to the catchments effectively discharging simultaneously to Pittwater, lagging of flow from each catchment was not employed.

Table 2 – Scotland Island IFD Data

Duration	2-yr Intensity (mm/h)	50-yr Intensity (mm/h)
1 hour	40.0	**81.5**
12 hours	9.0	**17.5**
72 hours	**2.7**	**5.7**

Note: G=0, F2=4.295 and F50=15.85 (*ARR87 V2*)

Table 3 – Rainfall Loss Parameters

Storm Event	Impervious Areas		Pervious Areas	
	Initial Loss (mm)	Continuing Loss (mm/h)	Initial Loss (mm)	Continuing Loss (mm/h)
5-yr and 100-yr ARI	**5**	**0**	**15**	**1.5**

The Manning's "n" coefficients or PERN values adopted for the various catchment surfaces in both the "natural and the "existing" scenarios were as follows:

- Impervious areas: n = 0.02
- Pervious areas: n = 0.04

These values were adopted based on visual inspection of the sub-catchments across the Island.

3.4 Catchment Characteristics – Natural Conditions

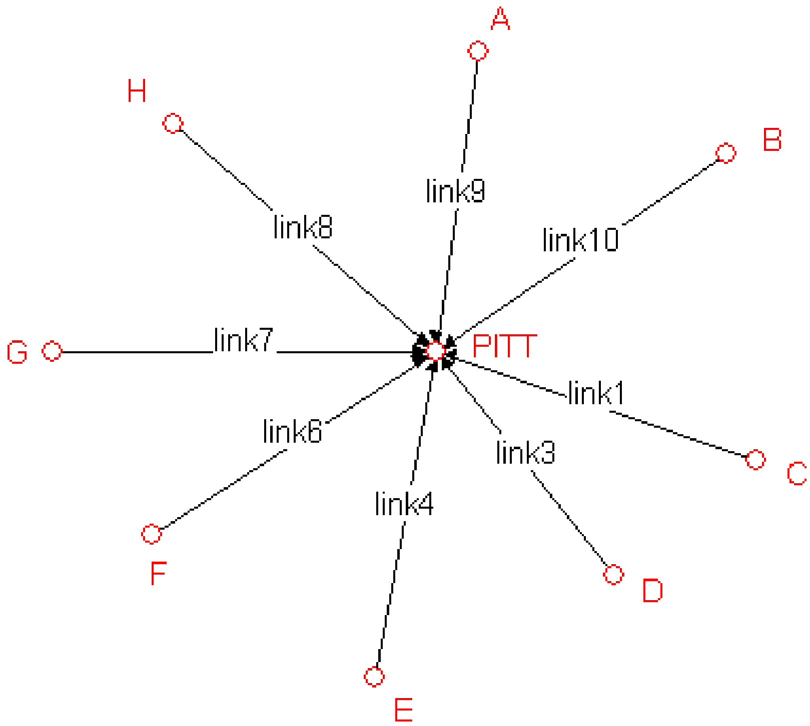
Catchments on Scotland Island were first analysed for peak flows during the 5yr and 100yr ARI events in its "natural" (*i.e. pre-developed*) state.

Diagram 2 shows the schematic developed in XP-RAFTS for the assessment of the Island in its natural state. The schematic is intended to demonstrate the model network structure only. For an illustration of the catchments and their relative location refer to **Figure 1**. **Table 4** shows the individual catchment characteristics used in the natural state analysis. A printout of inputs to XP-RAFTS for each catchment under natural conditions is included in **Appendix A**.

Areas of catchments and vectored average slopes of catchments were measured directly from MapInfo data provided by Pittwater Council.

Through visual inspection of the remaining natural areas on Scotland Island it was estimated that each catchment on the Island would be approximately 25% impervious due to presence of shallow soils and exposed rocky outcrops.

Diagram 2 – Natural Conditions XP-RAFTS Network



Note (*refer to Figure 1 also for an illustration of the catchment locations*)

Table 4 – Catchment Characteristics (Natural Conditions)

Catchment Name	Imperv. Area (ha)	Pervious Area (ha)	Imperv. Frac. (%)	Vectored Av. Slope (%)
A	2.5	7.4	25	**23.1**
B	1.7	5.1	25	**22.8**
C	1.7	5.1	25	**25.7**
D	1.0	3.1	25	**22.3**
E	1.8	5.3	25	**28.5**
F	1.4	4.2	25	**28.5**
G	1.4	4.3	25	**30.0**
H	1.7	5.2	25	**30.0**
TOTALS	**13.2**	**39.7**	**25**	**-**

3.5 Catchment Characteristics – Existing Conditions

Table 5 shows the catchments characteristics as modelled in the existing scenario. **Diagram 3** shows the adopted layout used in the XP-RAFTS modelling software. A printout of inputs to XP-RAFTS for each catchment under existing conditions is included in **Appendix A**.

Each catchment shown under existing conditions (*refer* ***Figure 1***) was further divided into sub-catchments representing:

- remaining natural areas or parkland present at the top of each catchment;
- developed areas within each catchment; and
- areas of parkland located at or near the bottom of each catchment (*as appropriate*).

Natural/parkland sub-catchments located at the top of each catchment discharge to the developed sub-catchments. Developed sub-catchments and natural/parkland sub-catchments located near the base of each catchment discharge directly to Pittwater (*refer* **Diagram 3**).

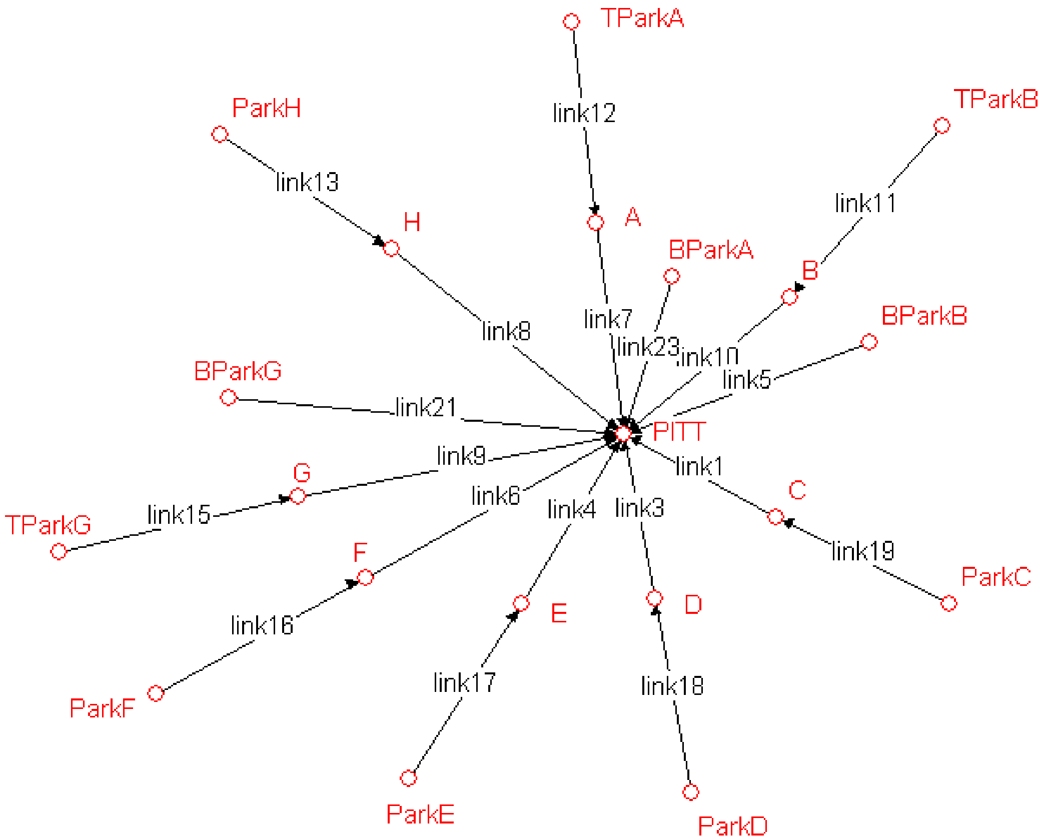
Note that it is considered that the Island under existing conditions is close to the limit of its ultimate development capability and hence no future ultimate development scenarios were considered necessary to model.

Table 5 – Catchment Characteristics (Existing Conditions)

Catchment Name	Imperv. Area (ha)	Pervious Area (ha)	Imperv. Frac. (%)	Vectored Av Slope (%)
A	2.52	2.06	55	**23.1**
TParkA	0.80	2.40	25	**31.0**
BParkA	0.51	1.53	25	**8.3**
B	3.40	2.78	55	**22.8**
TParkB	0.06	0.18	25	**22.2**
BParkB	0.11	0.33	25	**22.8**
C	3.69	3.02	55	**25.7**
ParkC	0.02	0.06	25	**20.5**
D	2.07	1.70	55	**22.3**
ParkD	0.08	0.23	25	**26.8**
E	2.90	2.37	55	**28.5**
ParkE	0.43	1.30	25	**21.0**
F	2.68	2.19	55	**28.5**
ParkF	0.18	0.55	25	**30.0**
G	2.70	2.21	55	**30.0**
TParkG	0.05	0.15	25	**16.4**
BParkG	0.15	0.45	25	**30.6**

Catchment Name	Imperv. Area (ha)	Pervious Area (ha)	Imperv. Frac. (%)	Vectored Av Slope (%)
H	3.63	2.97	55	**30.0**
ParkH	0.07	0.21	25	**14.1**
Total	**26.05**	**26.69**	**49.4**	**-**

Diagram 3 – Existing Conditions XP-RAFTS Network



Note (*refer to Figure 1 also for an illustration of the catchment locations*)

3.6 Stormwater Detention

Stormwater detention is a form of stormwater quantity control and is commonly adopted by Councils to minimise the flood impacts of urbanisation. As levels of impervious areas increase due to urbanisation (*ie by adding roofs, paved areas, roads etc*) flow rates also increase, sometimes well beyond natural conditions and the capacity of older constructed drainage systems.

Stormwater detention temporarily stores stormwater to reduce downstream flow rates to either natural conditions or the capacity of constructed drainage systems. Retention storages are similar but hold all or part of the runoff so it can infiltrate into the surrounding soils.

Detention can be provided in a number of ways. Below is a summary of some of the more common forms of stormwater detention:

- On-Site Detention or OSD which is provided on individual lots (*ie concrete tanks beneath driveways or incorporated as part of rainwater tank*s);
- Regional detention basins (ie *in parks or large open spaces*); and
- Extended detention systems (ie *detention provided above wetlands, water quality control ponds etc*).

Councils Pittwater 21 DCP outlines the detention requirements for new development within the LGA. The Pittwater 21 DCP detention controls apply to "*All land in the Pittwater LGA which is not flood prone or not capable of appropriately discharging its stormwater directly into a receiving water - not including the Pittwater waterway or Warriewood land release area*". This means that the policy currently applies to all lots on Scotland Island that do not directly adjoin Pittwater.

The objective of the control is to ensure that development does not increase stormwater discharge downstream of the land over and above that of the existing stormwater discharge conditions.

The requirements for size (*ie volume*) and allowable discharge rates for on-site detention systems is included in Section B5.3 of the current Pittwater 21 DCP and Section B5.8 of the Draft but soon to be updated Pittwater 21 DCP. The rate of storage volume equates to approximately 100m^3/ha for the current policy and 300m^3/ha for the soon to be updated policy (*assuming in both cases that the extent of development on an individual lot is limited to a state of 50% impervious*). For comparison, detention rates which currently apply in Warriewood Valley range from 368m^3/ha up to 519m^3/ha depending on the Sector. Rates of between 200m^3/ha to 350m^3/ha are more common for other Sydney Councils.

It is considered that application of the LGA wide detention rates (*ie those specified in the Pittwater 21 DCP*) are not directly applicable to Scotland Island as many of its characteristics vary significantly to the typical urban suburbs of Pittwater. Some of these differing characteristics include:

- The Islands steeper than average catchments;
- The Islands soils which have a low permeability;
- The high levels of equivalent impervious areas under the Islands natural state due to its geology (*ie rock outcrops and shallow soils*) and soil type (*ie shallow and impervious B Horizon*);
- The lack of existing formalised drainage systems;
- The lack of existing formalised detention systems on the Island;
- The abundance of existing rainwater tanks which in part act as detention systems;
- The limits on the extents of development possible due to the Islands steep topography and other factors; and

- The Islands sensitivity to flow regime changes (*ie in terms of increased erosion and water quality*).

For the above reasons it was considered that a preliminary Island specific detention analysis be undertaken, the results of which are contained in the following sections. Note that should the concept of an Island specific detention policy be adopted (*ie similar to that of Warriewood Valley*) then a more detailed analysis should be undertaken in the future.

For simplicity, it has been assumed in this preliminary analysis stage that all post development flows up to and including the peak 100yr ARI flows will be brought back to the 5yr ARI natural condition flows by OSD tanks. This approach may be refined for the detailed analysis stage but it is considered more than appropriate at this preliminary stage considering that it is both conservative and similar anyway to the simplified OSD tank system that are likely to be implemented in the difficult environment of Scotland Island (*ie no complicated multiple stage outlets are likely to be constructed*).

The impact of the above should be to overstate the required detention storage rate, however working against this increase will be the modelling assumption that the gap between the natural baseline conditions and ultimate development conditions will be less than that say for Councils mainland suburbs (*ie the nature state has a higher than normal impervious fraction and the ultimate development state is lower than typical*).

3.7 RAFTS Results

The peak flows from each catchment under natural catchments during the 5-year ARI event were compared with peak flows from the existing catchments (*ie under the current state of urbanisation*) during the 100-year ARI event. These results were used to determine the volume of detention required to reduce peak discharges from each catchment during all events up to and including the 100-year ARI event back to the appropriate 5-year ARI event flows under natural conditions (*refer **Section 3.7.1***).

Resultant output from XP-RAFTS for all analyses presented in this Section has been included in **Appendix A**.

Additionally, the Rational Method (*ARR87, Vol.1, Section 5.3*) was used to derive an estimate of alternative peak flows for comparison with the XP-RAFTS generated flows for Catchment A under 100% pervious conditions. The Rational Method yielded a peak 5-year ARI flow of 1.89 m^3/sec, using the Bransby-Williams formula to estimate the time of concentration for the catchment. This is approximately 36% less than the peak flow for the same catchment determined by XP-RAFTS (*2.96 m^3/sec*). However, the result derived using XP-RAFTS is considered acceptable when compared that determined using the Rational Method due to the ability of the computer model to account for the estimated minimal initial and continuing losses across the catchment and more the sophisticated flow routing method employed. Hence, the peak flow obtained using XP-RAFTS in the following analyses are deemed to be reliable.

3.7.1 Natural Conditions

Table 6 presents the peak flows as modelled using XP-RAFTS from each catchment occurring during the 5yr and 100yr ARI events under natural conditions. The peak flows for each catchment in the 5y and 100yr ARI events under natural conditions occurred during the 90-minute storm event (*ie termed the critical storm event)*.

Table 6 – Peak Flows, 5yr and 100yr ARI Events (*Natural Conditions*)

Catchment Name	5-year ARI Peak Flow	100-year ARI Peak Flow
	(m^3/s)	**(m^3/s)**
A	3.34	**5.70**
B	2.40	**4.05**
C	2.44	**4.08**
D	1.49	**2.51**
E	2.56	**4.25**
F	2.07	**3.46**
G	2.12	**3.54**
H	2.56	**4.24**
TOTAL (PITT)	***18.98***	***31.83***

3.7.2 Existing Conditions

Scotland Island under existing conditions (*ie in an urbanised state*) was analysed in XP-RAFTS for peak flows from each catchment during both the 5yr ARI and 100yr ARI storm events.

Results for the hydrological analysis of Scotland Island under existing conditions are presented in **Table 7**. Total Flows at the Pittwater node increased compared with natural conditions by 9% and 7% for the 5yr ARI and 100yr ARI storms respectively due to the increase in impervious fraction from 25% up to 55%. The critical storm duration for all existing condition models remained generally at 90 minutes.

3.7.3 Existing Case with Detention

Scotland Island under existing conditions with the addition of lot based stormwater detention was analysed in XP-RAFTS for peak flows from each catchment during the 100-year ARI storm event.

Large (*i.e. infinite*) areas of detention were added to each developed sub-catchment within the existing conditions model to assess the overall volume of detention required to ensure that all events up to and including the 100-year ARI event are discharged at no greater than the natural conditions 5-year ARI event peak flow.

Results for the 100-year ARI hydrological analysis of Scotland Island under existing conditions with detention measures are presented in **Table 7**. The total volume of detention required for each catchment and per each developed hectare within each catchment is also presented in **Table 7**.

It should be noted that detention was not applied to natural or parkland sub-catchments within the existing model that discharge directly to Pittwater (*i.e. natural/parkland sub-catchments located towards the base of each catchment*). This is reflected in the marginally higher overall peak discharge during the 100-year ARI event under existing conditions after detention has been applied (*20.48 m^3/sec*) when compared with the peak 5-year ARI event discharge under natural conditions (*18.98 m^3/sec*).

Table 7 – Peak Flows, 5yr and 100yr ARI Event (*Existing Conditions*)

Catchment Name	5-year ARI Peak Flow (*Pre. Det.*)	100-year ARI Peak Flow (*Pre. Det.*)	Peak Flow With Detention in Developed Catchments	Volume of Detention Required	Volume of Detention Required per Developed Hectare
	(*m^3/s*)	(*m^3/s*)	(*m^3/s*)	(*m^3*)	(*m^3/ha*)
A	3.07	5.06	3.34	518	**113**
TParkA	1.24	2.06	2.06*	0	**0**
BParkA	0.63	1.16	1.16*	0	**0**
B	2.56	4.19	2.40	657	**106**
TParkB	0.10	0.16	0.16*	0	**0**
BParkB	0.18	0.18	0.18*	0	**0**
C	2.71	4.45	2.44	754	**112**
ParkC	0.03	0.05	0.05*	0	**0**
D	1.65	2.69	1.49	481	**128**
ParkD	0.13	0.21	0.21*	0	**0**
E	2.8	4.57	2.56	745	**142**
ParkE	0.67	1.10	1.10*	0	**0**
F	2.27	3.71	2.07	618	**127**
ParkF	0.30	0.50	0.50*	0	**0**
G	2.07	3.37	2.12	428	**87**
TParkG	0.08	0.13	0.13*	0	**0**
BParkG	0.25	0.41	0.41*	0	**0**
H	2.77	4.55	2.56	723	**109**
ParkH	0.11	0.18	0.18*	0	**0**
TOTAL (*PITT*)	**20.73**	**34.08**	**20.48**	**4,923**	**115 (*Average*)**

Note: * denotes no detention applied to these open space/reserve catchments

The resultant detention rates vary from 87m^3/ha up to 142m^3/ha with an average of 115m^3/ha. The above rates incorporate road areas, which are unlikely to be part of any Island detention systems. Hence, the OSD rates should be increased by a factor of 30% to allow for this shortfall. Based on this, an average rate of around 150m^3/ha would seem reasonable for implementation of OSD systems on Scotland Island, striking a balance between the difficult terrain upon which to construct detention systems, the natural impervious state and the sensitive nature of Islands catchments to increased flows.

4. WATER QUALITY

4.1 MUSIC

"*MUSIC simulates the performance of a group of stormwater management measures, configured in series or in parallel to form a treatment train*." In this case, MUSIC has been run on a continuous basis (*6 minute intervals from January 1976 to December 1982 – 7 years*), allowing rigorous analysis of the merit of proposed strategies over the long-term.

"*The adoption of a continuous simulation approach is recommended in water quality modelling. This stems from the fact that impacts of poor stormwater quality on aquatic ecosystem health are associated with cumulative pollutant loads and frequency of aquatic ecosystem "exposure" to poor water quality. Pollutant loads delivered to receiving waters from many of the small storm events (e.g. of magnitude less than the 3 month ARI peak discharge) can make up in excess of 90% of the annual loads discharged from the catchment.*

The evaluation of the adequacy's of the stormwater management systems is based on a risk-based approach associated with examination of the long-term mean annual pollutant load delivered to the receiving waters.

MUSIC is designed to simulate stormwater systems in urban catchments and have the capability to operate at a range of temporal and spatial scales, suitable for catchment areas from 0.01 km^2 to 100 km^2. Modelling time step can range from 6 minutes to 24 hours to match the range of spatial scale.

The model's algorithms are based on the known performance characteristics of common stormwater quality improvement measures. These data, derived from research undertaken by CRCCH and other organisations, represent the most reliable information currently available in our industry" MUSIC Manual, CRC for Catchment Hydrology (*Version 1*) May 2002.

4.2 Development Scenarios

The entire area of Scotland Island was modelled in MUSIC under five different development scenarios as follows:

Scenario 1 - Pre-development or "natural" conditions (*i.e. prior to European settlement*);

Scenario 2 - Existing conditions with no treatment measures, but including:

a. Currently installed rainwater tanks; and

b. Event Mean Concentrations (*EMC's*) for Total Suspended Solids (*TSS*), Total Phosphorus (*TP*) and Total Nitrogen (*TN*) representative of the currently individually used septic systems (*based on actual monitored data for Scotland Island, refer **Section 4.3.2***);

Scenario 3 - Existing conditions as per Scenario 2 (*above*) but including additional WSUD treatment measures (*gross pollutant traps and bio-retentions systems*);

Scenario 4 - Existing conditions with no treatment measures, but including:

a. Currently installed rainwater tanks; and

b. EMC's for TSS, TP and TN representative of urban environments with traditional sewer collection, treatment and disposal systems (*i.e. connected to regional sewerage treatment systems, refer **Section 4.3.2***); and

Scenario 5 - Existing conditions as per Scenario 4 (*above*) but including the additional WSUD treatment measures modelled in Scenario 3.

4.3 MUSIC Input Data

4.3.1 Rainfall and Evapotranspiration

Rainfall data used in the MUSIC modelling (*all scenarios*) was sourced from the Bureau of Meteorology (*BoM*).

Daily rainfall gauges located in the vicinity of the site along with their long term annual averages are listed below:

- Palm Beach (*BoM Station: 66128*) 1,160 mm
- Newport (*BoM Station: 66045*) 1,211 mm
- Mona Vale (*BoM Station: 66141*) 1,089 mm
- Avalon Beach (*BoM Station: 66079*) 1,152 mm

The closest BoM controlled Pluviograph record for the site is generated by the Duffy's Forest (*Namba Road*) station (*BoM Station No. 066142*). This rain gauge is located approximately 10 km south-west of Scotland Island and is still operating. It has rainfall records in six-minute increments dating back to 1987.

Based on the quality of the data and the stations proximity to the site, six minute rainfall data was adopted from the Duffy's Forest station for a range of rainfall years representing a mix of average, wet and dry years for the region (*January 1993 to December 2003 - 10 years*). This range of rainfall generated an annual average of 1031mm, which is considered approximate to the long term average for the region.

The adopted average monthly areal potential evapotranspiration data adopted for the site was that supplied with the MUSIC software for the Sydney region. A summary of the adopted monthly values (*average areal potential*) is listed in **Table 8**.

Table 8 – Average Potential Areal Evapotranspiration Rates Adopted in MUSIC

Month	Jan	Feb	Mar	Apr	Ma	Jun	Jul.	Au	Sep	Oct	Nov	Dec
PET (*mm/month*)	180	135	128	85	58	43	43	58	88	127	152	163

4.3.2 Event Mean Concentration (EMC) Data

The pollutants modelled in MUSIC are those typical of urbanised catchments and include gross pollutants, sediments, nitrogen and phosphorous (*i.e. diffuse source pollutants*). MUSIC does not model faecal coliform pollution which is typically a point source pollutant (*i.e. such as overflow from the sewage system*).

The five different scenarios were chosen to allow comparison of pre-developed conditions with that following urbanisation and the impact of existing on-site sewerage treatment systems and water reuse measures versus those that may be proposed in the future.

Event Mean Concentration (*EMC*) refers to the average pollutant loading estimated in stormwater runoff from a given catchment based on land use. Values of EMC's for Total Suspended Solids (*TSS*), Total Phosphorus (*TP*) and Total Nitrogen (*TN*) used in this analysis (*and presented in*) are sourced from the findings of a comprehensive review of stormwater quality in urban catchments (*Fletcher et. al., 2003*).

In addition to the data supplied from the above-mentioned resource, relevant EMC data was also sourced from the "Scotland Island Wastewater Impact Study" undertaken by Martens and Associates Pty Ltd in 1997. In this study, surface water quality was monitored within three catchments across the Island during five rainfall events. The results of this study, including averages, are provided in

Table 10.

The overall Scotland Island average EMC's for TSS, TP and TN for this study were applied in Scenarios 2 and 3 for all "*Road*" and "*General Urban*" nodes within the MUSIC models.

While the monitored value of TSS is extremely high when compared with the published in Table 2.43 of Fletcher et. al 2003, it is comparative with the high sediment loads from similar catchments containing unsealed roads with dispersive soils and/or steep slopes published elsewhere in Section 2 of Fletcher et. al. 2003 and also within Sheridan and Noske, 2005.

The default MUSIC baseflow concentrations for TN, TP and TSS have been adopted for all models.

Table 9 – Adopted EMC Data (Wet Weather Concentrations)

Catchment Type	**Scenario**	**EMC (*mg/L*) (*Typical Value*)**		
		TSS	**TP**	**TN**
Roof	2, 3, 4 and 5	20	0.13	2
General Urban (*inc. Road*)	4 and 5	140	0.25	2
Natural	ALL	40	0.08	0.9
Measured Values	2 and 3	4,350	0.28	3.93

Table 10 – Scotland Island Surface Water Quality (from Martens & Assoc., 1997)

Catherine Park Catchment	**TSS**	**TP**	**TN**
Storm 1	6,605	0.541	3.835
Storm 2	16,040	0.124	6.230
Storm 3	12,708	0.200	4.900
Storm 4	1,236	0.250	5.920
Storm 5	7,020	0.159	5.540
Catchment Average:	***8,722***	***0.255***	***5.285***
Richard Road Catchment	**TSS**	**TP**	**TN**
Storm 1	1,765	1.120	5.500
Storm 2	1,765	0.118	3.645
Storm 3	5,464	0.194	4.435
Storm 4	88	0.198	4.660
Storm 5	613	0.150	3.130
Catchment Average:	***1,939***	***0.356***	***4.274***
Harold Reserve Catchment	**TSS**	**TP**	**TN**
Storm 1	1,197	0.462	2.055
Storm 2	2,985	0.083	1.950
Storm 3	4,200	0.116	2.045
Storm 4	2,330	0.366	3.670
Storm 5	1,278	0.085	1.425
Catchment Average:	***2,398***	***0.222***	***2.229***
Estimated Scotland Island Average:	***4,353***	***0.278***	***3.929***

4.3.3 Water Usage

As there is currently no formal connection to town water supply within the Island, all allotments were modelled containing a rainwater storage tank with an average storage volume of 10 kL (*note that this represents the component of total rainwater tank storage on each lot that is currently filled with roofwater only*). Daily demand for water from these rainwater tanks was adopted from data resulting from the SIRA Water Use Survey (*1993*), subsequently published in Martens & Associates Pty Ltd (*1997*). This survey determined the average daily demand from stored rainwater at 298 litres per household.

Subsequent to the above survey SIRA have also made the following important observations about rainwater tanks on SI (2009):

- "*The average daily demand for water is probably significantly higher now* (2009) *than in the 1993 survey. There were more weekend properties and less families then*";
- "*The storage capacity of tanks on lots is not the limiting factor. In heavy rain, gutter size and pump capacity (from collecting tank to storing tank) typically limit how much can be collected. These would need to be standardised and upgraded in all households*";
- "*Even though almost all properties have tanks, not all collect rainwater. Some houses are rented and the collection systems are not maintained, some are weekenders, some roofs and gutters are too dirty. Therefore some properties buy "emergency water" when needed and do not collect. This missing volume needs to be compensated for in the other proposed collection systems*".

Any future detailed investigations into rainwater tanks should consider the above comments. Note however that even considering the above, the assumptions used in this strategic document are conservative and hence likely to underestimate the current impact of rainwater usage.

4.3.4 Soil Properties

Table 10 includes a summary of the adopted soil properties used for input into the runoff module of MUSIC. The parameter values adopted were developed through calibration of the model to provide volumetric runoff coefficients similar to what is estimated to be expected under both a 0% impervious condition and 65% impervious condition. The values shown in **Table 11** resulted in a volumetric runoff coefficient of 0.28 for the 0% impervious case and 0.68 for the 65% impervious case. It should be noted that the model is "*significantly more sensitive to the accurate definition of the fraction impervious and the selection of simulation time step*" MUSIC Manual (*CRCCH, 2002*).

Table 11 – Adopted MUSIC Soil Properties

Parameter	All Scenarios
Impervious area rainfall threshold (mm/d)	1.0
Perv area soil storage capacity (mm)	90
Initial storage (% cap)	30
Field capacity (mm)	70
Infiltration capacity Co-efficient "a"	180
Infiltration capacity Co-efficient "b"	1
Groundwater initial depth (mm)	10
Groundwater daily recharge rate (%)	25
Groundwater daily baseflow rate (%)	5
Daily deep seepage rate (%)	0

4.4 Catchment & Sub-Catchment Areas

For consistency, the same catchment delineation was used as in the hydrological modelling (*refer to **Figure 1***).

The pre-development conditions were modelled with a 25% impervious fraction for all catchments due to the overall steepness of the site and the presence of exposed bedrock throughout remaining natural areas within the island. All remaining existing natural or "*green*" areas within the island were subsequently modelled with 25% imperviousness in Scenarios 2 to 5.

MapInfo data supplied by Council was used to assist in the delineation and measurement of catchments for the natural conditions modelled in Scenario 1 (*refer* **Table 12**).

Catchments were further broken into the areas listed in

Table 13 for the modelling of Scenarios 2 and 4. Certain assumptions were required to be made regarding the existing development layout. Each lot identified from Council's MapInfo data was assumed to contain a roof averaging 150m^2. These roofs were assumed to discharge to a rainwater storage tank averaging 10 kL per lot (*refer **Section 4.3.3***). Areas of Road were measured as per Council's supplied MapInfo data.

These catchment were further delineated to assess the effectiveness of the modelled WSUD treatment measures in Scenarios 3 and 5. Due to the large number of catchments, this data has been provided in **Appendix B**.

Table 12 – Catchment Characteristics (Ha) – Scenario 1

Catchment Name	Area (Ha)	% Imp.
A	9.823	25%
B	6.852	25%
C	6.783	25%
D	4.073	25%
E	6.994	25%
F	5.601	25%
G	5.700	25%
H	6.877	25%

Table 13 – Catchment Characteristics (Ha) – Scenarios 2 and 4

Catchment Name	Roads	Green	Roof	General Urban (GU)	Totals
A	1.484	5.246	0.420	2.673	***9.823***
B	1.408	0.666	0.855	3.923	***6.852***
C	1.232	0.074	0.825	4.652	***6.783***
D	0.691	0.309	0.375	2.698	***4.073***
E	0.884	1.732	0.780	3.598	***6.994***
F	0.865	0.733	0.735	3.268	***5.601***
G	1.120	0.801	0.675	3.103	***5.700***
H	1.001	0.274	0.855	4.747	***6.877***

Each sub-catchment in

Table 13, above, was attributed the following impervious fraction:

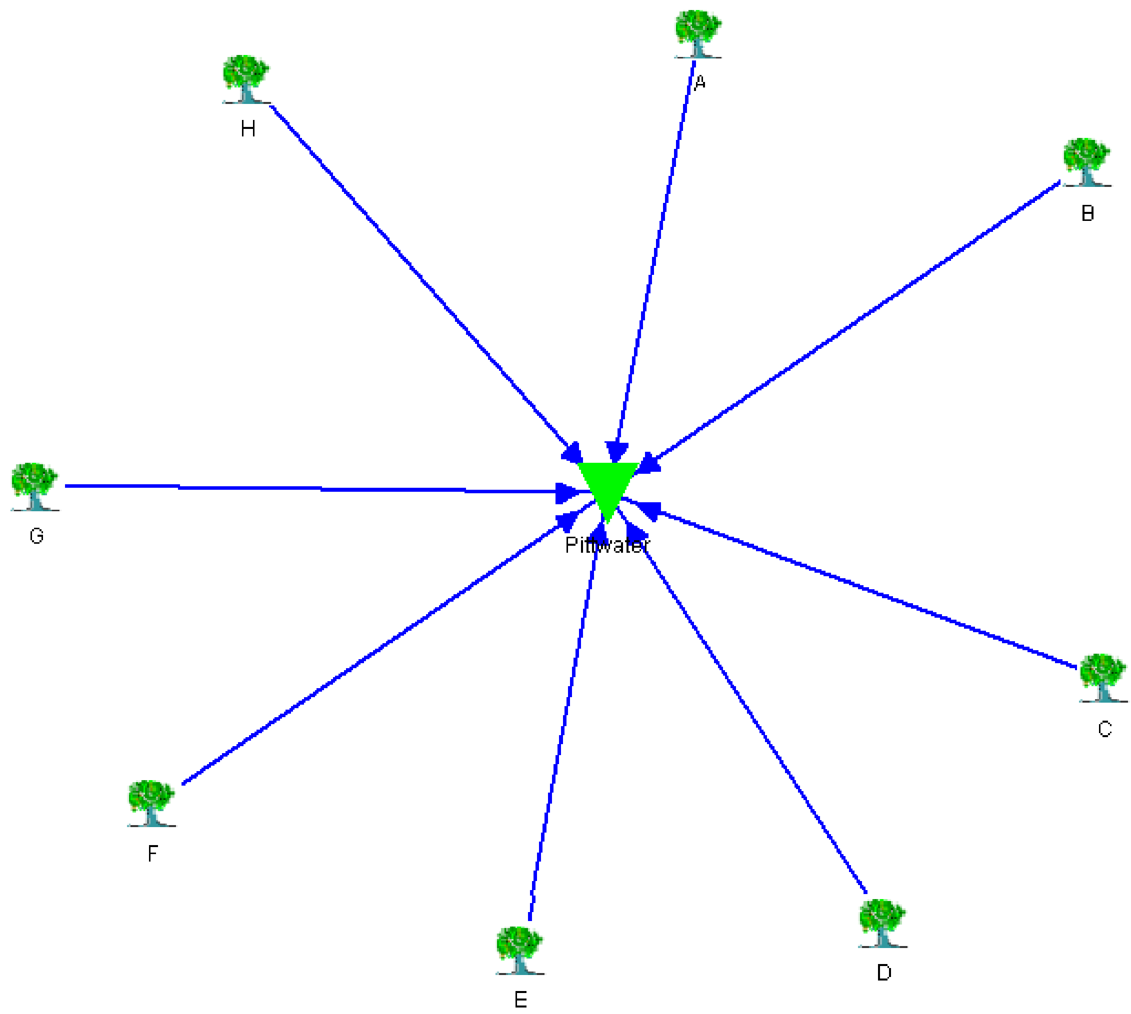
- Roads 100% Impervious
- Green 25% Impervious
- Roof 100% Impervious
- General Urban 33% Impervious

This results in developed areas (*Roads, Roofs and General Urban*) having an overall imperviousness of 55% (*as per the XP-RAFTS hydrological modelling, refer* ***Section X***) and overall site imperviousness of 50%.

4.5 MUSIC Network Layout

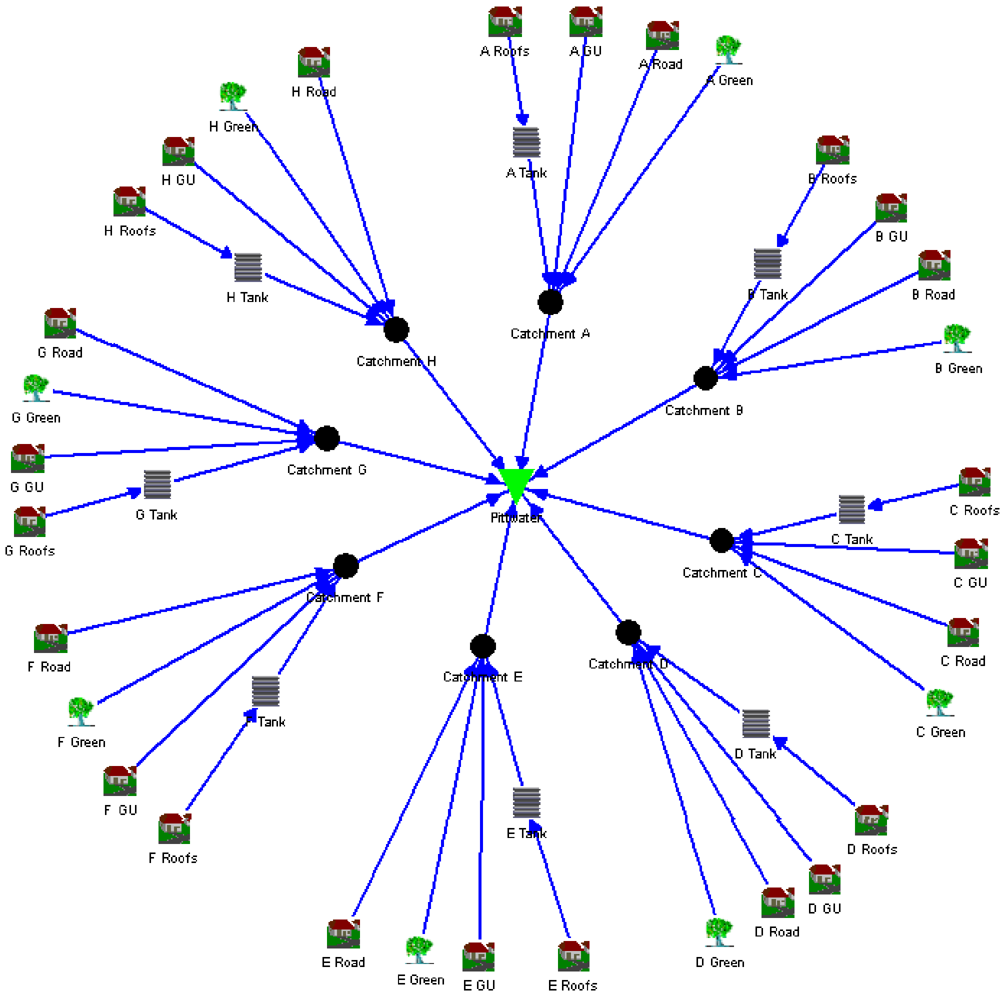
MUSIC model networks were constructed based on the catchment discretisation described in **Section 3**. **Diagrams 4-6** show the resultant networks for each of the five scenarios modelled. It should be noted that the MUSIC model layout was the same for Scenarios 2 and 4 and similarly for Scenarios 3 and 5. Only the EMC data for the "Road" and "General Urban (*GU*)" nodes differ between the Scenarios.

Diagram 4 – MUSIC Scenario 1 – Natural



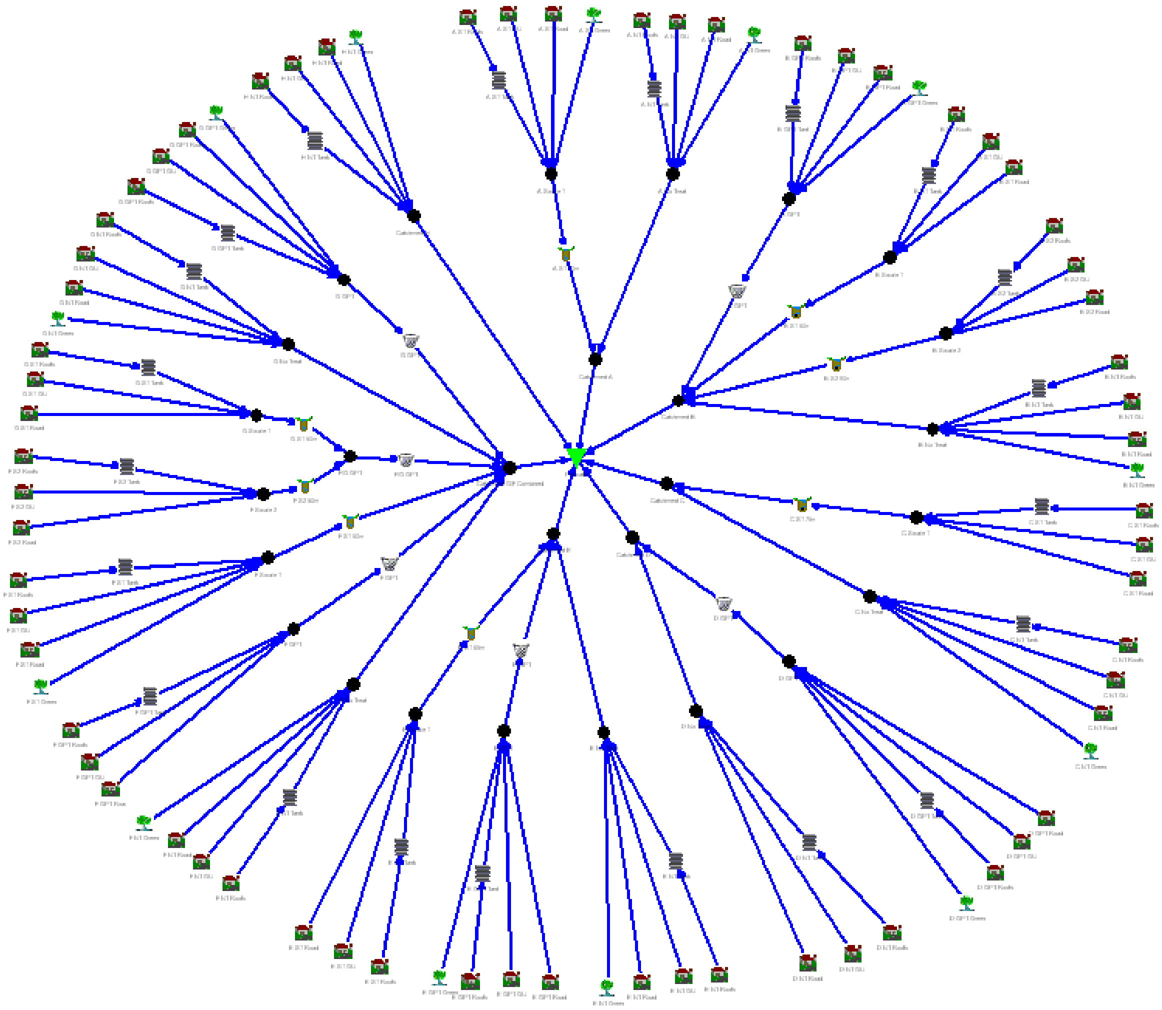
Note (*refer to Figure 1 also for an illustration of the catchment locations*)

Diagram 5 – MUSIC Scenarios 2 and 4 – Existing (Septic Systems and Unsealed Roads), No Additional WSUD Treatment Measures



Note (*refer to Figure 1 also for an illustration of the catchment locations*)

Diagram 6 – Scenarios 3 and 5 – Existing (Regional Sewer Connection and Sealed Roads) with Additional WSUD Treatment Measures



Note (*refer to Figure 1 also for an illustration of the catchment locations*)

4.6 Pollutant Reduction Assumptions

4.6.1 Existing Measures

There are many existing rainwater tanks on the Island which collect roofwater for reuse. These are considered indirect lot based water quality treatment measures because the use of rainwater tanks reduces the export of pollutants from a site through an overall reduction in discharge from a catchment via collection, storage and reuse of rainwater. The average size of tanks and adopted daily demand per lot is presented in **Section 4.3.3**.

4.6.2 Proposed Water Sensitive Urban Design (WSUD) Measures

WSUD water quality control measures considered appropriate for the Island were determined through site inspection and include:

- Gross pollutant traps (*GPT's*);
- Sediment traps; and
- Bio-retention systems.

A distinct lack of available large flat open space effectively rules out the use of measures such as constructed wetlands or water quality control ponds on Scotland Island. Equally lot based systems such as raingardens and infiltration systems would be difficult to implement due to the steep topography and low permeability of the Islands soils.

For information a brief description of the role of GPT's, sediment traps and bio-retention systems is included below.

4.6.2.1 GPT's

Gross Pollutant Traps or GPT's are classified as primary treatment devices (*as opposed to secondary and tertiary treatment devices*) and are commonly used as a first line of defence to remove the more visible pollutants carried by stormwater runoff such as litter/debris and coarse sediments.

GPT's can either be purpose designed and built to suit a particular location or more commonly these days they are proprietary or off the shelf units which come in a range of sizes to suit the identified application. The key treatment mechanism of most GPT's is physical screening and settling.

GPT's can be constructed/installed in a range of configurations such as below ground or above ground and offline or online. They can either treat close to the source at grate/pit entries or at the "*end of the line*" near stormwater outlets.

Each GPT type has their own unique selling point (*ie such as specific pollutants targeted, extra storage capacity, minor differences in treatment efficiencies, non blocking screens, added hydrocarbon treatment, wet or dry sumps, low head loss, low excavation depth, differing maintenance commitments etc*) which may or may not make one proprietary GPT better suited to a particular location than another. However, essentially they all perform the same role of providing a primary treatment function in removal of litter and coarse sediment.

The two important design distinctions are that offline GPT's and sizing of the GPT to treat at least the peak 3 month ARI storm (*ie to treat approximately 90% of the annual runoff volume experienced*) tend to result in better treatment efficiencies over the life of any GPT.

For more details on GPT's refer to Chapter 8 of ARQ (*Engineers Australia*).

4.6.2.2 Sediment Traps

Sediment traps can take the form of purpose built settling basins, inlet ponds or GPT's (*refer to **Section 4.6.2.1***). The key treatment mechanism of most sediment traps is physical settling, although fine screening and/or secondary flow motion is also often employed.

Purpose built settling basins can either be temporary, constructed as part of the construction phase of a subdivision development or permanent. Permanent basins may be dedicated to sediment removal only or combined with other treatment processes. Permanent sediment basins are often located offline to avoid disturbance/re-suspension of captured material.

"*Basin type traps can be concrete basins…or more natural ponds constructed within site soils. They retain sediments by simply enlarging a channel so that velocities are reduced and sediments settle to the bottom*" ARQ Engineers Australia p8-11.

The larger concrete lined style sediment traps (*ie popular in Canberra*) are often combined with a trash rack to collect litter in addition to sediment. Proprietary below ground GPT's also perform this dual function, with a substantial proportion of the total load captured consisting of sediment.

Inlet ponds are often incorporated within larger constructed wetlands or water quality control ponds (*WQCP's*) to act as a collection point for the majority of coarse sediment and to protect the more sensitive areas of the wetland from being smothered.

For more details on sediment traps refer to Chapter 8 of ARQ (*Engineers Australia*).

4.6.2.3 Bioretention Systems, Buffer Strips and Vegetated Swales

Bio-retention systems (*ie swales or basins*) promote a combination of surface flow conveyance and stormwater filtration through a filter media to treat stormwater runoff. They are typically vegetated and are also sometimes referred to as biofiltration systems, biofilters and raingardens. "*Bio-retention systems can provide efficient treatment of stormwater through fine filtration, extended detention and some biological uptake. They also provide flow retardation and have good potential for nitrogen removal via uptake and denitrification. Bio-retention systems may be designed to promote infiltration or to be lined to retain all water for discharge via the outlet pipe. Such a decision will depend on factors such as salinity, potential interaction with shallow groundwater and proximity and sensitivity to water of nearby infrastructure*" (ARQ Page 10-6).

Bio-retention systems are often constructed at an allotment scale as a source control but are also suited to linear catchments (*eg roadsides*) where they are also double as conveyance systems, or as large end of line basins.

A buffer or filter strip is a grassed or vegetated area of land over which uniformly distributed flows (*sheet flows*) can run. They function by promoting sedimentation and filtration of pollutants. It is important to ensure that the flow over the strip is uniform across the full width of the strip. This ensures that the strip operates at its highest efficiency and erosion is less likely to occur.

The extent of pollutant removal from buffer/filter strips is dependent on many variables. Hairsine (*1996*) reports that under low flows (*a few cm/sec*), up to 98% of sediment can be removed. In urban runoff much of the phosphorus load is attached to particulate matter, filtering out sediment will therefore greatly reduce phosphorus loads as well. For example, Muscutt et al (*1993*) and Norris (*1993*) cite evidence that riparian zones which can act like buffer strips greatly reduce nutrient loads in streams (*greater than 80%).*

Filter strips may also be beneficial in removal of bacteria. The processes involved in this form of treatment include filtration, desiccation, adsorption, UV radiation and predation (*Metcalf & Eddy (1991) and McNeill (1992)*).

Vegetated or grass swales are channels that convey stormwater runoff, usually from roads. They can be used as an alternative to kerb and guttering, where water runs off the road, or any other impervious surface, into the swale. The swale slows the flow of water, causing sedimentation. The swale can then lead into a further stormwater pollution control device or into the drainage system. Swales can be built with check dams in place, which act as a further barrier to sediment flow. It is important that flow velocities are kept low, to prevent erosion of the swale. Grassed swales may also act in a similar way to filter strips in removal of pollutants such as nutrients and bacteria. For long term effectiveness these vegetated swales will need regular maintenance, e.g. weeding, clearing of blockages, trimming etc. However careful design can minimise the extent of maintenance required.

For more details on bio-retention systems, buffer strips and vegetated swales refer to Chapter 10 of ARQ (*Engineers Australia*).

Diagram 7 – Example of Bioretention Swale Design (WorleyParsons)

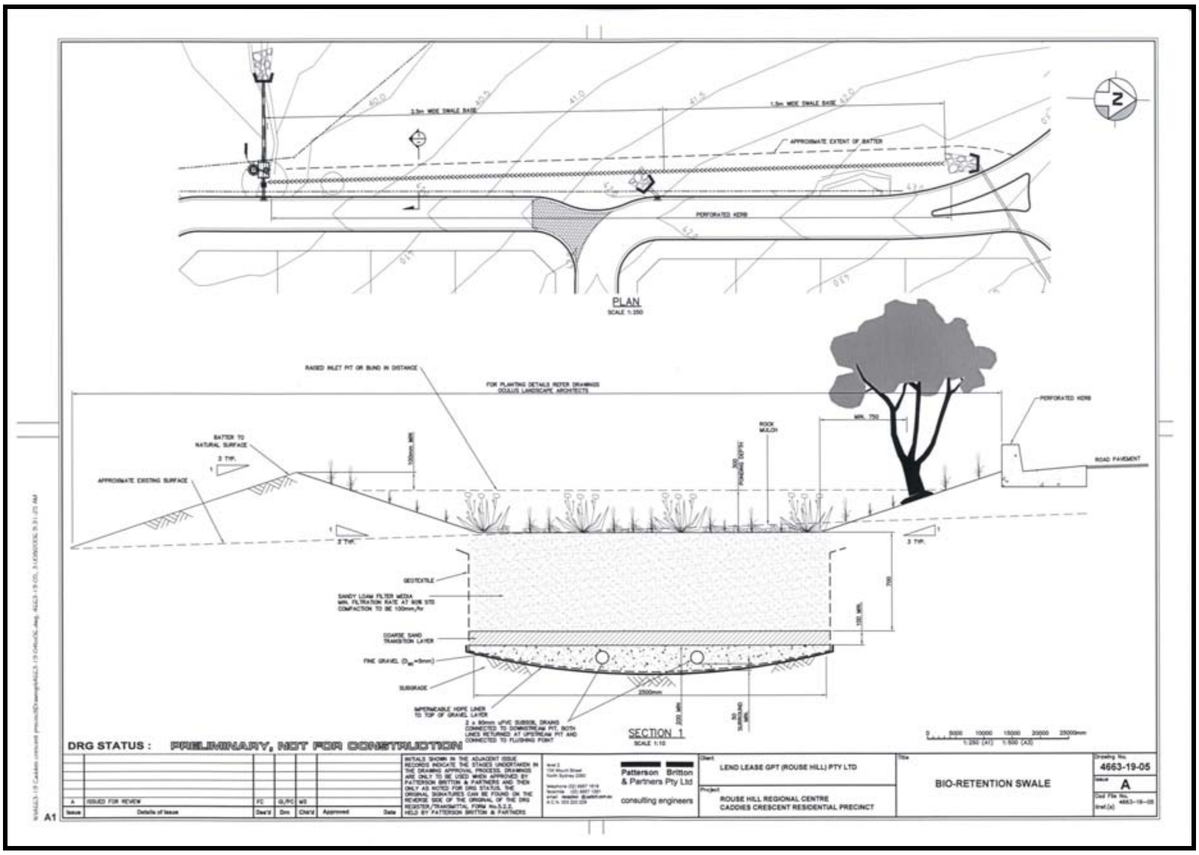


Diagram 8 – Example of Bioretention Swale (WorleyParsons Design, Warriewood)

Diagram 9 – Example of Bioretention Swale (WorleyParsons Design, Warriewood)

4.9.2.4 WSUD Measure Assumptions

The GPT pollutant removal efficiencies adopted in the Scenarios 3 and 5 MUSIC models were as follows:

- 95% litter (*gross pollutants*);
- 80% TSS;
- 30% TP; and
- 6% TN.

These adopted values were based on adoption of offline systems and the following papers:

- "*Removal of Suspended Solids and Associated Pollutants by a CDS Gross Pollutant Trap*" Walker et al, CRC for Catchment Hydrology, 1999;
- "A comparison of the Efficiency of Various Stormwater Remediation Devices in Removing Contaminants from Stormwater – 2. Continuous deflective Separation Unit – Weddle Ave, Chiswick" UNSW Environment Geology Group, May 2000; &
- "*A Decision Support System for Determining Effective Trapping Strategies for Gross Pollutants*" Allison et al, CRC for Catchment Hydrology, 1998.

The adopted TSS efficiency of 80% includes a proportion of fine sediment, however it is expected that the GPT's will primarily target coarse and medium sediment only. As it stands MUSIC does not currently break TSS down into the varying sediment gradings and hence the effectiveness of removal of these varying types of sediment cannot be modelled in MUSIC.

Based on best practice, an efficiency of greater than 85% capture of sediment 0.2mm and greater would be expected for modern proprietary GPT's. In addition, as modern GPT's are generally located offline, an estimate of the average peak three month ARI flows to each GPT was made and applied in each required model as a high flow bypass (*note that the three month flow equates to approximately 90% of the annual runoff volume*).

The proposed GPT locations are illustrated in **Figure 7**. Depending on detailed design and maintenance requirements, these measures may take many forms including below ground proprietary systems, net type systems or simple sediment/trash traps.

The location of swales/bio-retention systems was based on site inspection and the existing MapInfo data supplied by Council. At this conceptual stage, the following attributes were applied to each swale/bio-retention system:

- 1 m filter width;
- 0.7 m filter depth;
- Median filter particle diameter of 2 mm; and
- 0.3 m extended detention depth.

The approximate location of swales/bio-retention systems are shown in **Figure 7**. The length of each system modelled within MUSIC is presented in **Table 14**.

Table 14 – Swale/Bio-Retention System Areas (Scenarios 3 and 5)

Catchment	Swale 1 (m^2)	Swale 2 (m^2)
A	360	-
B	240	360
C	300	-
E	260	-
F	200	200
G	200	-

4.6.3 Proposed Civil Infrastructure Measures

The connection of the Island to the regional sewerage network will markedly impact pollutant export from the Island through minimising re-mobilisation of sediments and pollutants that occurs through overflows and leaks from on-site septic systems.

In a similar fashion, sealing of roads will minimise the re-mobilisation of sediment due to traffic and encourage the re-vegetation and stabilisation of road verges.

4.7 MUSIC Modelling Results

4.7.1 Overall Results

All MUSIC output and results for each Scenario is contained in **Appendix B** and discussed below.

Table 15 presents a summary of pollutants exported from Scotland Island, as modelled in MUSIC, under all Scenarios. A graphical representation of this data is presented in **Graphs 1 to 4**.

Table 15 – Pollutant Export from Scotland Island – All Scenarios

Scenario	Gross Pollutants (*kg/year*)	TSS (*kg/year*)	TP (*kg/year*)	TN (*kg/year*)
Scenario 1 - Natural	5,980	9,990	20.0	225
Scenario 2 - Existing (*No Measures*)	6,980	902,000	64.1	885
Scenario 3 - Existing with WSUD Measures	4,770	741,000	56.0	798
Scenario 4 - Existing with Civil Infrastructure Upgrades (*ie connection to mains sewer and sealing all roads*)	6,980	30,800	57.9	486
Scenario 5 – As per Scenario 4 but with WSUD measures as well	4,770	25,400	50.9	444

4.7.2 Scenario Comparison

The data presented in **Table 15** shows the following percentage increases in pollutant export between the natural case (*Scenario 1*) and the current existing case (*Scenario 2*):

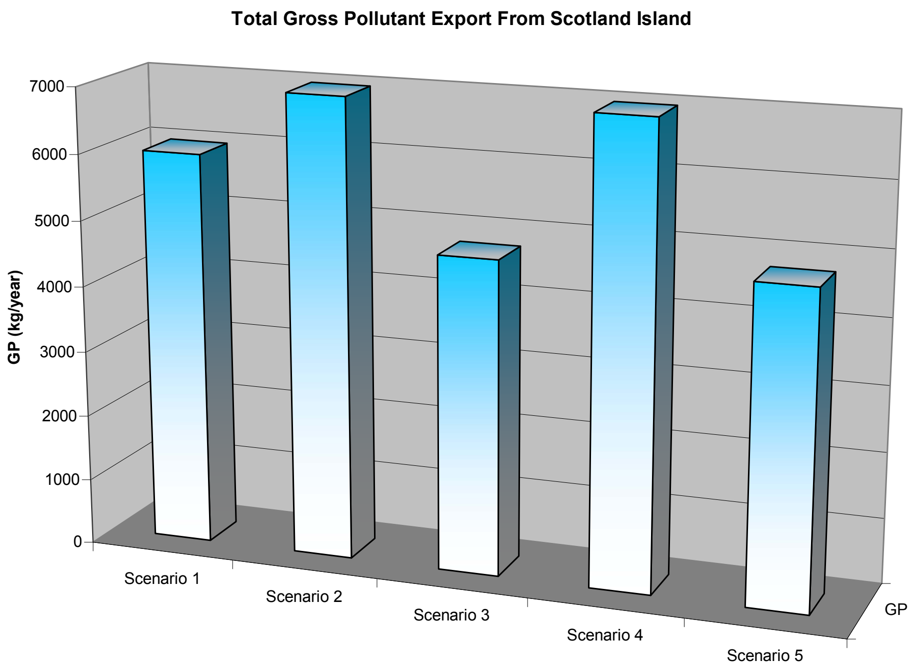
Scenario 1 (Natural) Vs. Scenario 2 (Existing with no Measures)

- Gross Pollutants 17% increase
- Total Suspended Solids 8929% increase
- Total Phosphorus 221% increase
- Total Nitrogen 293% increase

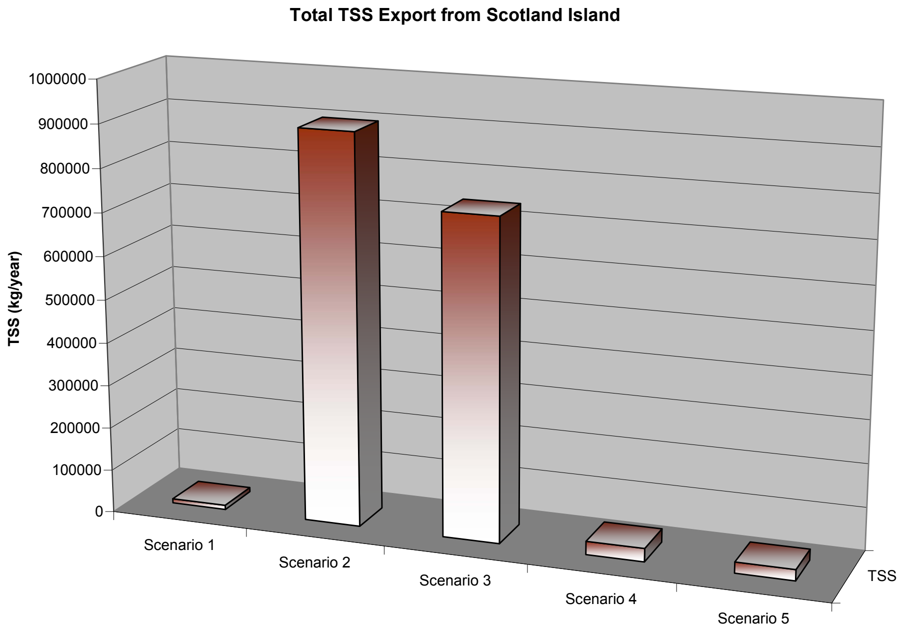
This is due to the introduction of development, the use of on-site septic sewerage treatment systems and the exposure of soils and subsequent due to vegetation removal during development and the use of unsealed roads for vehicular travel.

The incorporation of the proposed WSUD treatment measures only (*i.e. no civil infrastructure improvements, such as connection to regional sewerage treatment systems or the sealing of roads*) results in the following pollutant export reductions from Scotland Island when compared with the existing case (*Scenario 2 compared with Scenario 3*):

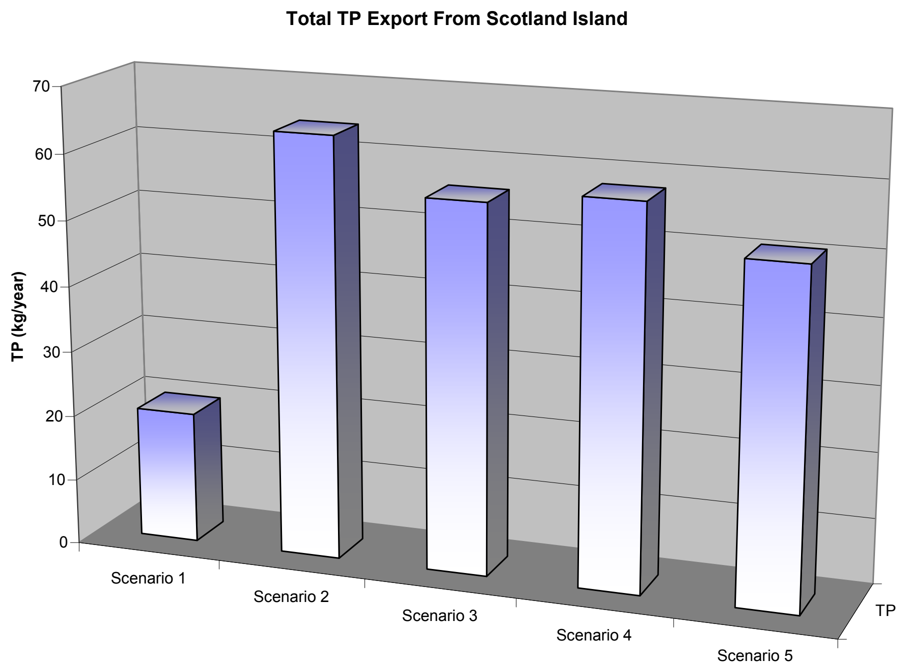
Graph 1 – Gross Pollutant Export from Scotland Island (All Scenarios)



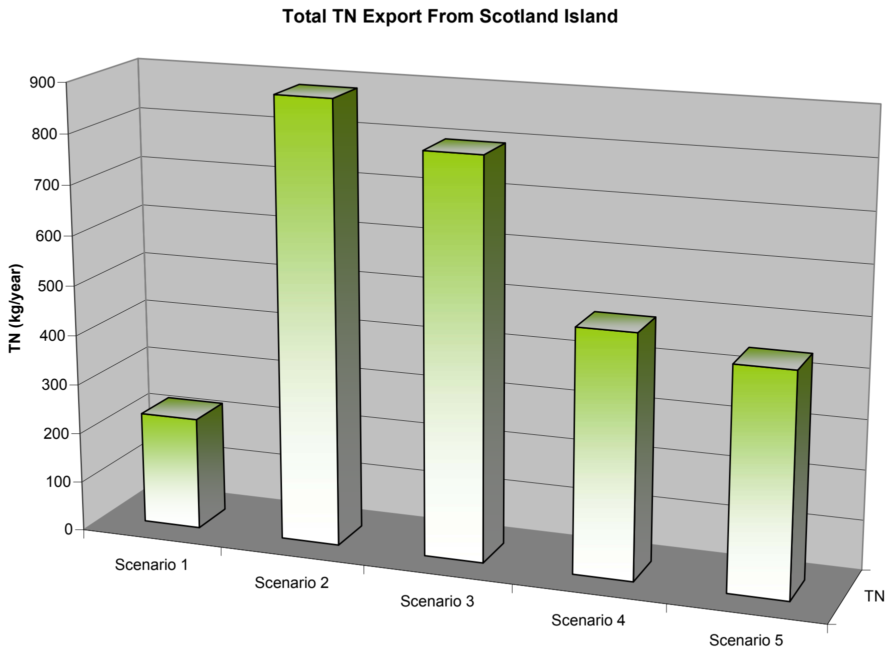
Graph 2 – TSS Export from Scotland Island (All Scenarios)



Graph 3 – TP Export from Scotland Island (All Scenarios)



Graph 4 – TN Export from Scotland Island (All Scenarios)



Scenario 2(Existing with no Measures) Vs. Scenario 3(Existing with WSUD Measures)

- Gross Pollutants 32% reduction
- Total Suspended Solids 18% reduction
- Total Phosphorus 13% reduction
- Total Nitrogen 10% reduction

Due to the limited locations available to place standard urban WSUD treatments, only a minimal improvement in water quality can be achieved.

However, a marked improvement in both TSS and TN reduction can be achieved through the sealing of roadways and connection of the Island to the regional sewerage treatment network, as indicated below:

Scenario 2(Existing with no Measures) Vs. Scenario 4(Existing with Civil Infrastructure Upgrades)

- Gross Pollutants 0% -
- Total Suspended Solids 97% reduction
- Total Phosphorus 10% reduction
- Total Nitrogen 45% reduction

It should be noted that no improvement in the export of gross pollutants is achieved through the implementation of civil measures as these strategies only target the movement of sediment, through the sealing of roads, and the effective transport and treatment off-site of sewerage.

In addition to the above, when WSUD measures are incorporated with the implementation of the civil infrastructure upgrades described above (*i.e. Scenario 4*), the following pollutant reductions can be achieved when compared with the existing case (*Scenario 2*):

Scenario 2(Existing with no Measures) Vs. Scenario 5 (Existing with Civil Infrastructure Upgrades and WSUD Measures)

- Gross Pollutants 32% reduction
- Total Suspended Solids 97% reduction
- Total Phosphorus 21% reduction
- Total Nitrogen 50% reduction

The above represents only a marginal further reduction in TSS and TN export from Scotland Island, when compared with the reduction achieved in Scenario 4, however a significant reduction in overall gross pollutant export can be attained.

Overall, it is evident that introduction of the civil infrastructure improvements (*ie sealing of road network and removal of onsite sewerage treatment systems*) has the greatest impact on water quality improvements.

4.7.3 Results Comparison

Table 16 illustrates a comparison between the PBP predicted pollutant load exports from Scotland Island with those estimated from previous studies. Overall it is considered that the PBP analysis was more thorough than any previous studies, however the results compare fairly well which is not surprising seeing that the PBP assumed EMC's were based in part on the monitoring work undertaken by Martens (1997). The primary difference in approaches and hence results appears to be the hydrological assumptions.

Table 16 – Annual Pollutant Load Comparison (Existing Conditions)

Pollutant	**PBP MUSIC Results (*Annual Load for Island*) t/year**	**Martens (*1997*) Results (*Annual Load for Island*) t/year**
TSS	902	**778**
TP	64.1	**47.5**
TN	**885**	**704**

5. MAJOR/MINOR DRAINAGE SYSTEMS

It appears that a major/minor system philosophy was not embraced in the early planning stages of the Islands development (*ie at subdivision stage*). This is evidenced by the distinct lack of formal overland flow routes (*also referred to as trunk drainage routes*) from the top of the Island down to Pittwater, construction within/over natural creeks and the lack of private drainage easements.

The principles of the major/minor philosophy are described in Australian Rainfall and Runoff (*ARR*). Put simply, it involves separating major flows which occur infrequently (*ie such as 100yr ARI flows*) from those that occur more frequently (*ie such as 5yr ARI flows*). An example of this in an urban setting is provision of the road reserve to carry 100yr ARI flows overland, whilst catering for 5yr to 20yr ARI flows within the drainage pipes beneath the road.

Figure 1 illustrates the eight broad topographical catchments of Scotland Island. Construction of roads and drainage lines has meant in some instances that these topographical catchment boundaries have been altered. A review of existing drainage systems has shown that not all have been planned to coincide with the major topographical watercourses or overland flow paths of each of the major catchments (*ie some drainage lines exist near the boundaries of catchments rather than in the valleys*).

Modern stormwater management planning at subdivision stage is likely to have led to more streets or reserves being located at the major topographical watercourse locations as shown in **Figure 2**. Instead private property has been positioned within these locations and in some instances drainage lines and channels diverted away from their natural alignment. Catchment B is probably the only exception to the above with Pathilda Reserve forming the major overland flow route. Catchments A and D provide for overland flows to travel from the lower ring roads to Pittwater, however they lack any formal drainage pathway between the upper and lower roads. The remaining catchments provide no public connections.

Strategically two options exist to enable rectification of the above problem. The first and preferred option involves purchase of private property and reinstatement of the required major trunk drainage routes, bringing ownership back into the public domain . The second option would be to ensure that sufficient easements and development controls exists to allow these major trunk drainage routes to exist within private property.

As it currently stands, it is unlikely that the first option would be viable for Scotland Island (*ie based on expense and the extent of existing development*).

5.1 Benefits of a Major/Minor System Philosophy

Adopting a major/minor drainage system on Scotland Island will bring the existing systems up to a best practice standard and provide the following benefits:

- Improving public safety;
- Protecting the roadways and other public infrastructure from flood related damage;
- Protecting private dwellings from flood impacts;

- Minimising nuisance flooding; and
- Reducing erosion and improving water quality.

Adopting a major/minor system philosophy on Scotland Island does not mean adopting the standard urban drainage solutions adopted elsewhere in Sydney. A site specific solution needs to be developed for the Island that accounts for its unique characteristics.

5.2 Existing Drainage Easements

A search of existing property titles by Council has shown a distinct lack of drainage easements at the identified major topographical watercourse locations. This does not provide adequate protection for these critical flowpaths. Firstly existing and future property owners may not be aware of their role and secondly future development may impact their function.

We understand that legally Council are entitled to enforce controls on existing and future development upon those lots that contain watercourses, however argument over exact watercourse locations can weaken Councils ability to achieve a desirable outcome.

It is recommended that gradual introduction of drainage easements over those lots containing major watercourses (*ie as listed in **Table 18***) be enforced in any future development applications (*DA's*). The easement terms should clearly state their role as overland flowpaths in benefit of the public and stipulate the need for no future filling or development which could alter their function/capacity.

5.3 Overland Flow Hydraulics

Based on the Islands steep topography (*ie more than 80% of the island contains slopes greater than 10% and almost a third of the Island contains slopes greater than 20% - refer to **Table 1***) its catchments have a very short time of concentration and flows generally travel at high velocity to the catchment outlet. This translates to high erosion potential but also a much reduced commitment to floodway or overland flow path widths compared say with floodplains.

Preliminary hydraulic calculations have been undertaken to assess the width of major overland flow paths required to contain the peak 100yr ARI flows generated by the Islands catchments under existing conditions. This inturn allows the width of drainage easements as discussed in **Section 5.1** to be determined. **Figure 5** illustrates the results of the above analysis, which generally shows that most overland flow paths can be contained within an easement width of less than 3m.

The overland flow hydraulic assumptions used in the above calculations are as follows:

- Use of Mannings equation;
- RAFTS derived hydrology (*critical peak flows only*);
- Peak 100yr ARI flow channel capacity;
- Mannings "n" of rock lined channels incorporating some vegetation = 0.055;
- Slope as measured (*varies between 20 to 40%);*
- Simple triangular shaped channel with 1(v):2(h) side slopes; and
- No freeboard allowance.

The consequence of a reduced overland flowpath width is a much greater flow velocity and the need for some form of armouring to protect against erosion. The Islands unique characteristics of extremely steep topography and dispersive soils mean that even under natural conditions some form of armour would be required to protect against erosion (*ie natural stabilisation measures such as vegetation alone is unlikely to afford adequate protection*). Under existing conditions (*ie an urbanised Island*) armouring is even more critical as flows are increased as a result of development.

It is proposed a series of rock lined channels/creeklines be formed at the location of all major topographical overland flow paths (*refer to **Figure 4***). **Diagram 10** illustrates the general form of these proposed channels but obviously at a much steeper grade. The rocks/boulders would be sized in accordance with the velocities of each respective channel. The channel would be underlain by geotextile and vegetation would be established both between the rocks and at the edges of the channels. Rock pools and riffles could be established at regular intervals to provide habitat opportunities in keeping with a natural rock channel system. To maintain effectiveness the channels will require regular maintenance, however careful design can minimise the extent required.

Diagram 10 – Example of Rock Lined Channel

Construction of the proposed major system rock lined channels could be undertaken in a piecemeal fashion by DA's as those lots listed in **Table 18** redevelop in the future or by Council in a staged manner (*ie in order of priority*).

5.4 Culvert Hydraulics

Preliminary sizing of all major culverts was undertaken to provide an indication of the pipes sizes required to ensure 100yr ARI flow capacity without overtopping the roadway. The resultant major culvert sizes are illustrated in **Figure 4** and range from 525mm diameter up to 900mm diameter.

These culvert sizes are indicative only based on a nominal culvert slope of 5.0%. Detailed design should be undertaken for each culvert as site conditions may vary from those assumed. Equally site conditions may determine that equivalent capacity box culverts or multiple circular pipes are more appropriate.

Along with the overland flow channels described in **Section 5.2**, the culverts form a critical component of the Islands major stormwater drainage system.

5.5 Minor Piped Drainage System

To protect the roadways and prevent nuisance flooding it is recommended that a minor drainage system of overland flow channels and pipes be adopted on Scotland Island as illustrated in **Figure 6**.

Minor piped drainage lines would only be implemented in the immediate vicinity of the major culverts described in **Section 5.4**. The remaining sections of roadway would contain a series of concrete or rock lined channels at the inside edge of the pavement. Road runoff would fall to these dish drains, running longitudinally until entering the minor piped drainage lines via grates and eventually discharging into the major system culverts.

All minor system components (*ie dish drains, grates and pipes*) will be designed to cater for the peak 5yr ARI flows. Flows in excess of this will be contained within the roadway itself until they reach the major system culverts and overland flow paths.

5.6 Lot Based Drainage

Lot based drainage systems should generally be constructed in accordance with the requirements of Pittwater 21 DCP. However, there are some special considerations which are unique to the Island. The emphasis of lot based drainage systems should be on water conservation, water reuse, avoiding infiltration systems and avoiding concentration of flows. Below is a summary of the envisaged typical lot based drainage systems for Scotland Island properties:

- Minimising the extent of impervious surfaces (*ie not greater than 50% of the total lot area*);
- Stabilising all pervious areas with vegetation;
- Avoiding long runs of unstabilised and/or exposed pathways/driveways (*ie interrupt with berms or steps*);
- Connection of all roof runoff to a rainwater reuse system (*ie rainwater tank connected to non potable household uses*);
- Connection of overflow from the above system and any other impervious surfaces within the lot to a small OSD system;
- Direct connection of the outflows from the OSD system to the minor street drainage system (*ie to the dish drains and or pipes*), to a major overland flowpath or to Pittwater;
- If the above is not possible dispersal of the above flows over a wide area (*ie via a level spreader*); and
- Construction of dwellings clear of major overland flow paths.

Figure 9 illustrates an example of the above lot based features.

6. FLOODING

Flooding on Scotland Island is possible from two main sources as follows:

- Flooding from Pittwater itself (*termed estuarine flooding by Council*); and
- Flooding from localised creeks and overland flowpaths.

Pittwater Council currently provides policy documentation that deals with both of the above forms of flooding as follows:

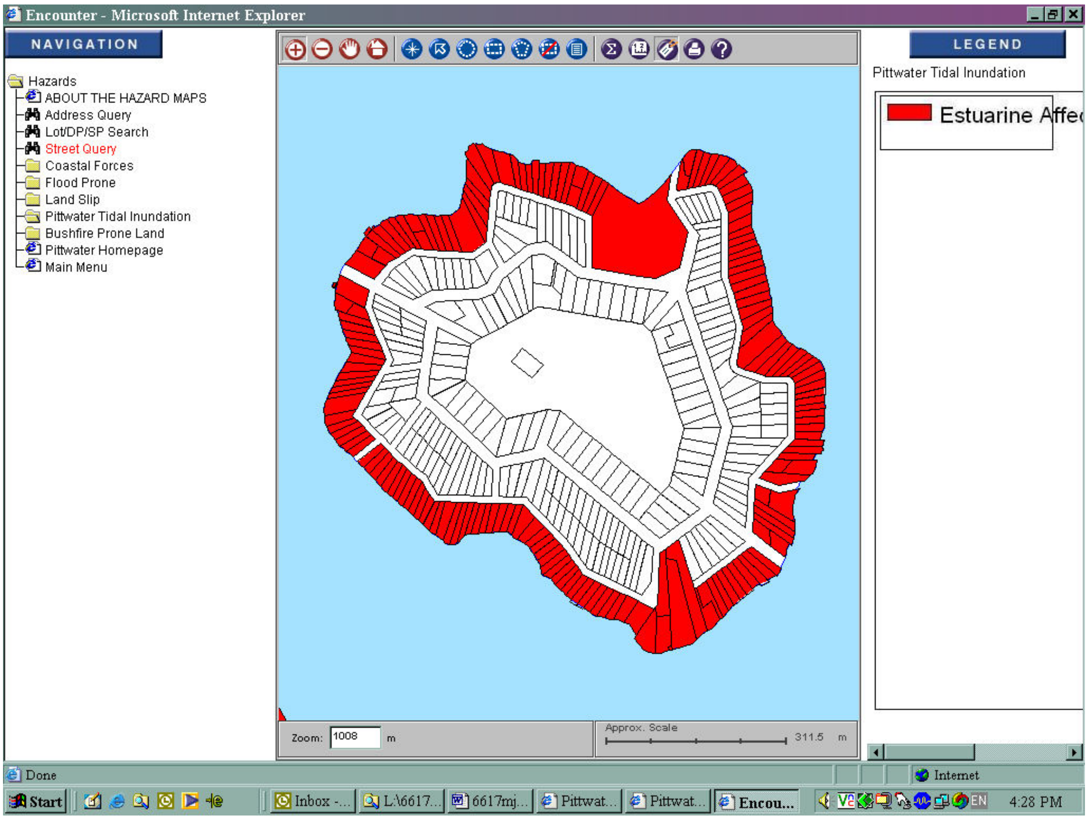
- "*Estuarine Risk Management Policy for Development in Pittwater*" September, 2004; and

"*Flood Risk Management Policy for Pittwater*" December, 2002.

6.1 Estuarine Flood Risk

At present, all properties on Scotland Island that directly front Pittwater are listed by Council as being potentially affected by estuarine wave action and tidal inundation (*refer to* **Diagram 11**).

Diagram 11 – Estuarine Flood Risk Plan for Scotland Island



Any development on these highlighted properties is required to comply with the requirements of Councils Estuarine Risk Management Policy, September 2004.

The study upon which this policy has been based is titled "*Estuarine Planning Level Mapping Pittwater Estuary*" Lawson & Treloar, September 2004. This report establishes the Estuarine Planning Level (EPL) for properties around Pittwater, which consists of the combination of 100yr ARI storm tide levels in Pittwater, an allowance for 200mm sea level rise due to climatic conditions (*ie Greenhouse effect*), wind setup, wave runup and a freeboard allowance of 0mm to 300mm depending on adopted edge treatment and the height of wave runup.

A summary of the EPL's for various locations on Scotland Island is provided in **Table 17**.

Table 17 – Estuary Planning Levels for Scotland Island

Location	Estuary Planning Level (*EPL*) (*mAHD*)				
	ET 1	ET 2	ET 3	ET 4	ET 5
34 - Pitt Point (*ie north side of Island*)	2.7	2.5	2.3	3.1	**3.1**
35 - East Scotland Island	2.8	2.6	2.4	3.1	**3.2**
36 - Harold Reserve (*ie south side of Island*)	3.0	2.6	2.4	3.6	**3.8**
37 - NW Scotland Island	**2.8**	**2.6**	**2.4**	**3.3**	**3.4**

Notes : A. - ET = Edge Treatment at site. ET1 = sandy beach, ET2 = vertical wall with crest at RL 1.5mAHD, ET3 = vertical wall with crest at RL 2.0mAHD, ET4 = sloping rock wall and ET5 = natural rocky shoreline.

B – A reduction in EPL also applies based on distance development is from foreshore. Refer to Appendix B of "*Estuarine Planning Level Mapping Pittwater Estuary*" Lawson & Treloar, September 2004 for details.

6.2 Overland Flow Flood Risk

Currently there are no properties on Scotland Island that are listed by Council as being within a primary flood prone area (*refer to* **Diagram 12**). This means that none of the properties are currently classified as Flood Category 1 or 2 in accordance with Councils Flood Risk Management Policy (*December 2002*). However, properties located outside of primary flood prone areas but within major drainage systems, local overland flowpaths or drainage easements, (*ie as is the case at various locations on Scotland Island*) can still be classified as Flood Category 3.

Flood Category 3 properties are subject to development controls as stipulated in the Pittwater 21 DCP. In summary, the following restrictions apply to single dwelling residential development proposed on Flood Category 3 properties:

- Habitable floor levels must be a minimum of 500mm above the 100yr ARI flood level (*termed the Flood Planning level – FPL*);
- Any structures below the FPL must be constructed from flood compatible materials;
- All development must be designed and constructed so that it will have a low risk of instability due to flood hazard;
- All development must be designed and constructed so that it will not impact on surrounding properties or flooding processes for any event up to and including the PMF;

- All foundation structures, where the floor level is 500mm above the existing ground level, are to incorporate a suspended floor on open pier/pile footings to allow for the flow of surface water and flood storage;
- All electrical equipment, wiring, fuel lines or any other service pipes and connections shall be waterproofed to the Probable Maximum Flood (*PMF*) level or FPL, whichever is the highest;
- Building heights must not exceed 8m above the FPL
- A Section 88B notation is placed on the title of the land;
- Filling of land within the floodway is only permitted if there is not net decrease in floodplain storage capacity and there is no demonstrated impact to surrounding properties;
- Basement carparking must have all access and potential water entry points above the PMF or FPL whichever is the highest; and
- Subdivision of Flood Category 3 properties is not permitted where additional flood affected residential allotments will be created below the FPL.

Properties on Scotland Island that potentially fall under the Flood Category 3 definition are included in **Table 18** and illustrated in **Figure 8**.

Diagram 12 – Existing Council Flood Category Notations on Scotland Island

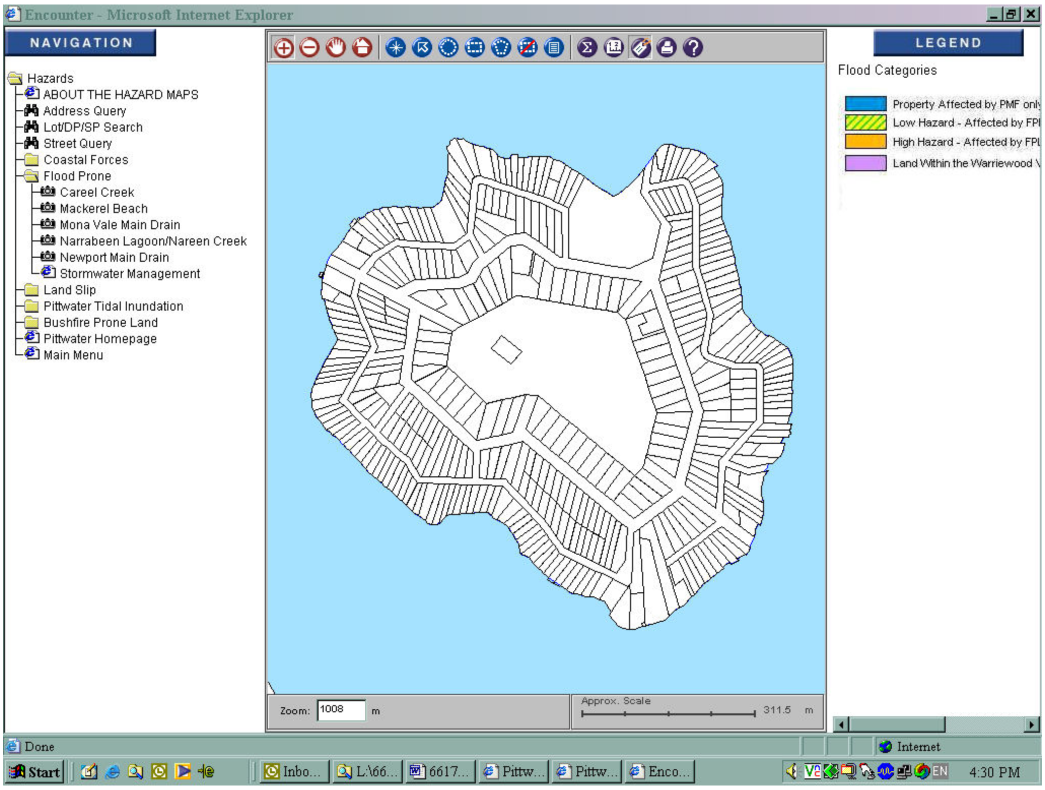


Table 18 – Potential Flood Category 3 Affected Properties on Scotland Island

No.	Street Address	Lot No.	DP	Catchment
1	72 Thompson St	301	12749	F
2	70 Thompson St	302	12749	F
3	123 Thompson St	177	12749	F
4	121 Thompson St	178	12749	F
5	119 Thompson St	179	12749	F
6	117 Thompson St	180	12749	F
7	115 Thompson St	181	12749	F
8	113 Thompson St	182	12749	F
9	58 Thompson St	308	12749	E
10	95 Thompson St	191	12749	E
11	93 Thompson St	205	12749	E
12	91 Thompson St	206	12749	E
13	89 Thompson St	207	12749	E
14	56 Richard Road	173	12749	F
15	36 Richard Road	190	12749	E
16	32 Richard Road	192	12749	E
17	30 Richard Road	193	12749	E
18	61 Richard Road	20	12749	F
19	59 Richard Road	21	12749	F
20	57 Richard Road	22	12749	F
21	55 Richard Road	23	12749	F
22	53 Richard Road	24	12749	F
23	51 Richard Road	25	12749	F
24	39 Richard Road	31	12749	E
25	37 Richard Road	32	12749	E
26	35 Richard Road	33	12749	E
27	117 Richard Road	157	12749	G
28	115 Richard Road	158	12749	G
29	113 Richard Road	159	12749	G
30	137 Thompson St	291	12749	G
31	135 Thompson St	292	12749	G
32	133 Thompson St	293	12749	G

No.	Street Address	Lot No.	DP	Catchment
33	25 Robertson Rd	139	12749	**H**
34	25 Robertson Rd	1	852841	**H**
35	18 Robertson Rd	276	12749	**H**
36	20 Robertson Rd	275	12749	**H**
37	22 Robertson Rd	2	560241	**H**
38	41 Robertson Rd	301	514985	**H**
39	39 Robertson Rd	11	880339	**H**
40	25 Robertson Rd	2	542864	**H**
41	94 Thompson St	352	12749	**H**
42	120 Thompson St	339	12749	**A**
43	122 Thompson St	338	12749	**A**
44	11 Florence Tce	108	12749	**B**
45	13 Florence Tce	107	12749	**B**
46	29 Florence Tce	100	706791	**B**
47	67 Florence Tce	4	816673	**B/C**
48	69 Florence Tce	3	816673	**B/C**
49	71 Florence Tce	2	816673	**B/C**
50	99 Florence Tce	69	813222	**C**
51	101 Florence Tce	67	738039	**C**
52	103 Florence Tce	68	738039	**C**
53	121Florence Tce			**C**
54	123 Florence Tce			**C**
55	66 Florence Tce	229	12749	**C**
56	35 Thompson St	230	12749	**C**
57	32 Thompson St	321	12749	**D**
58	34 Thompson St	320	12749	**D**
59	36 Thompson St	319	12749	**D**
60	38 Thompson St	318	12749	**D**
61	57 Thompson St	2	771611	**D**
62	86 Florence Tce	1	771611	**D**
63	5 Harold Ave	151	1028258	**D**
64	1 Harold Ave	153	1028258	**D**

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Scotland Island is unique and as such necessitates its own stormwater management procedures.

Historically, it appears that best practice drainage systems were not adopted in the planning stages of the Islands development. This has resulted in impacts such as excessive erosion, flooding and poor stormwater quality.

An assessment of the Islands hydrology revealed that the Islands development is not sustainable without some form of stormwater quantity control (*ie On Site Detention*).

An assessment of the Islands stormwater quality revealed that existing litter, sediment and nutrient loads are high. However, it was determined that minimal opportunity was available to implement traditional lot or public based treatment systems (*ie due to the topography and soil conditions*). Instead, implementation of traditional civil infrastructure improvements such as sealing roads and eliminating onsite effluent disposal systems provided the greatest improvement to stormwater quality.

An assessment of stormwater conveyance revealed that adoption of a major/minor drainage system philosophy incorporating major overland flow channels and culverts in combination with minor dish drain/pipes systems within the roadways would minimise many of the Islands current stormwater related impacts.

Finally, it is concluded that implementation of any future stormwater management measures should be cognisant of the unique characteristics of the Island, including a preference for softer engineered solutions where appropriate.

7.2 Recommendations

Our recommendations focus on the long term but also provide some guidance on solutions in the short to medium term.

7.2.1 Long Term

A summary of the recommended long term stormwater management improvements for the Island are as follows:

1. Stabilise and seal all public road/shareway surfaces (*ie bitumen, concrete or other*);
2. Close off any unused/surplus sections of public road reserve and reinstate with native vegetation;
3. Stabilise all walking tracks in accordance with the techniques described in the "*Scotland Island Proposed Walking Track Management Plan*" DCLM, 1993;
4. Disconnect all lot based onsite effluent disposal systems and replace with a conventional reticulated mains sewer (*ie with off-Island treatment*);

5. Define and construct 100yr ARI capacity major trunk drainage routes for all major catchments. These are envisaged to consist of naturalistic rock lined creeks/overland flow channels (*refer to **Figure 4***) in combination with culverts at all road crossings (*refer to **Figure 4***);
6. Create drainage easements across all lots that will be affected by the above trunk drainage routes and in other locations as required (*refer to **Table 18** and **Figure 5***);
7. Install 5yr ARI capacity minor piped drainage lines within the public roads/shareways feeding into all trunk drainage culverts (*refer to **Figure 6***);
8. Provide a typical 1 way cross fall road/shareway incorporating stabilised dish drain (*rock, bitumen or concrete*) on the cut side of all roads (*refer to **Figure 6***);
9. Maintain use of rainwater tanks for emergency firefighting purposes and reuse of water in toilet flushing, irrigation, laundry washing machine use and hot water systems (*minimum 10KL*);
10. All future stormwater management measures should be designed by a qualified engineer backed up by construction supervision by a qualified engineer;
11. Implement and maintain public stormwater treatment measures as illustrated in **Figure 7;**
12. Provide special attention to any future development applications on the lots illustrated in **Figure 8 and Table 18**; and
13. Implement typical lot based drainage systems as illustrated in **Figure 9**.

7.2.2 Short to Medium Term

A summary of the recommended short to medium term stormwater management improvements for the Island are as follows:

1. Implement the specific short to medium term stormwater related recommendations from the W Rooney and G Witheridge studies as shown at **Appendix C**;
2. Ensure that a "*Flood Study and Flood Risk Report*" is submitted for all new development within those properties listed in **Table 18**. The required reports are to comply with Sections 7.3 and 7.4 of DCP 30 (*December 2002*) and must undertaken by an appropriately qualified professional as stipulated under Section 7.5 of DCP30 (*December 2002*);
3. Ensure that the appropriate easements and major trunk drainage systems are implemented for all new development within those properties listed in **Table 18;**
4. Develop and implement a unique set of development controls for onsite effluent treatment and disposal on Scotland Island;
5. Develop and implement a unique set of development controls for erosion and sediment control on Scotland Island;
6. Implement a unique On-Site Detention (*OSD*) policy for all future lot based development on the Island. Utilise a Site Storage Requirement (SSR) rate of 150m^3/ha and a 5yr ARI Permitted Site Discharge (PSD). Undertake a detailed OSD study to verify the above rates; and
7. Seal some of the steeper sections of road on the Island (*ie Hilda Ave, upper sections of Kevin Ave etc*).

7.3 Preliminary Costings

Preliminary estimates of the capital cost of each long term measure have been made as part of the study. Short to medium term costs have not been determined as part of this study as the focus is on strategic long term measures.

Note that these cost estimates are preliminary only and are based on WP's experience and judgement as a firm of practising professional engineers familiar with the construction industry. However, they can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. The estimates may exclude items which should be considered in an overall cost plan. Examples of such items are design fees, project management fees, authority approval fees, contractors risk and project contingencies (*e.g. to account for construction and site conditions, weather conditions, ground conditions and unknown services*). Any cost estimate by WP is not to be relied upon in any way. If a reliable cost estimate is required, then an appropriately qualified Quantity Surveyor should be engaged.

The predicted capital costs of each proposed measure are summarised in **Table 19**. Note these estimates do not include any ongoing maintenance or decommissioning costs.

Table 19 – Long Term Measure Cost Estimates

Measure No.	Measure Description	Capital Cost Estimate ($AUS 2007)
1	Stabilise/seal all public roads/shareways.	$1,553,000
2	Close off any unused/surplus sections of public road reserve and reinstate with native vegetation.	$86,000
3	Stabilise all walking tracks in accordance with the techniques described in the "Scotland Island Proposed Walking Track Management Plan" DCLM, 1993	$60,000
4	Disconnect all lot based onsite effluent disposal systems and replace with a conventional reticulated mains sewer (*ie with off-Island treatment*).	High
5	Define and construct 100yr ARI capacity major trunk drainage routes for all major catchments. These are envisaged to consist of naturalistic rock lined creeks/overland flow channels (*refer to **Figure 4***) in combination with culverts at all road crossings (*refer to **Figure 4***)	$950,000
6	Create drainage easements across all lots that will be affected by the above trunk drainage routes and in other locations as required (*refer to **Table 18** and **Figure 5***).	By dedication + Legal conveyancing costs
7	Install 5yr ARI capacity minor piped drainage lines/pits within the public roads/shareways feeding into all trunk drainage culverts (*refer to **Figure 6***).	$350,000

Measure No.	Measure Description	Capital Cost Estimate ($AUS 2007)
8	Provide a typical 1 way cross fall road/shareway incorporating stabilised dish drain (*rock, bitumen or concrete*) on the cut side of all roads (*refer to* ***Figure 6***). Note road seal and stabilisation costs included in Measure 1 cost.	$400,000
9	Maintain use of rainwater tanks for emergency firefighting purposes and reuse of water in toilet flushing, irrigation, laundry washing machine use and hot water systems (*minimum 10KL*).	$185,000
10	All future stormwater management measures should be designed by a qualified engineer backed up by construction supervision by a qualified engineer.	-
11	Implement public stormwater treatment measures as illustrated in **Figure 7**.	$1,060,000
12	Provide special attention to any future development applications on the lots illustrated in **Figure 8** and **Table 18**	-
13	Implement typical lot based drainage systems as illustrated in **Figure 9**.	$1,850,000

Figures

Photographs

Plate 1 – Damaged Pit Grate on Pitt Street

Plate 2 – View East on Florence Street (note crushed concrete dish drain)

Plate 3 – Existing Sediment Basin at Stormwater Outlet into Catherine Park

Plate 4 – Existing Sediment Basin at Stormwater Outlet into Catherine Park

Plate 5 – Earth Water Bar (aka Cross Bank) on Kevin Avenue

Plate 6 – Steep Section of Kevin Ave (on bend looking Downhill)

Plate 7 – Rock Water Bars on Overland Flow Channel (Kevin Ave)

Plate 8 – Track erosion (Hilda Ave)

Plate 9 – Unprotected soil stockpile on Richard Road works site

Plate 10 - Construction of new culvert under Richard Road at landslip site

Plate 11 - View from new culvert downstream (*Richard Road*)

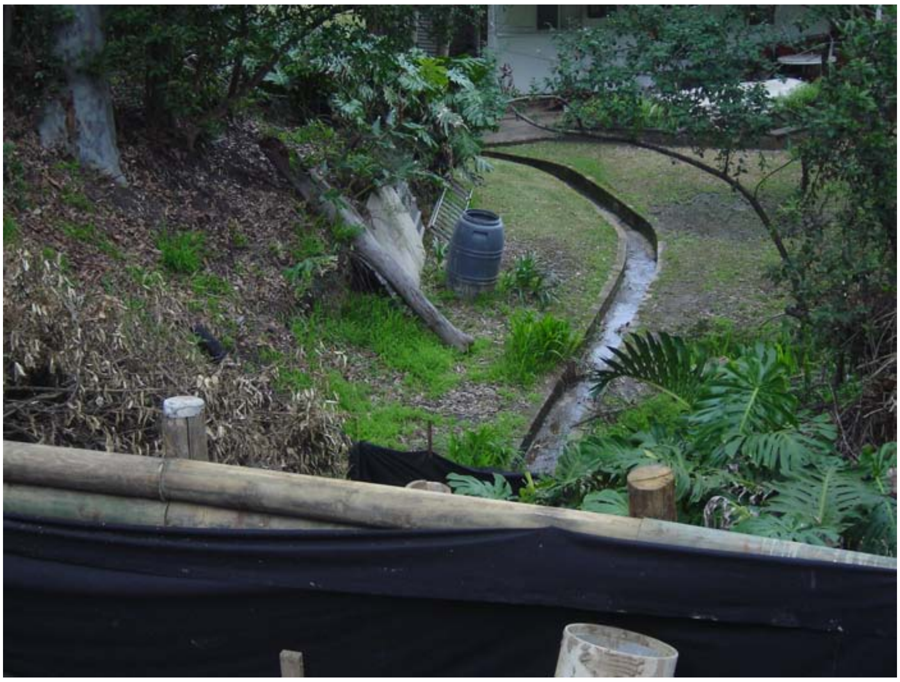


Plate 12 - Deposition of eroded track material

Plate 13 - Pathilda Reserve Culvert, Florence Terrace

Plate 14 - Typical rainwater tank installation

Plate 15 - Eastern Wharf stairway

Plate 16 - Obstruction within ex. O/L flow path to south of Eastern Wharf Stairs

Plate 17 - Drainage pit at intersection of Elise and Florence (*blocked wth sediment*)

Plate 18 - View of track/stairs on Elise St

Plate 19 - Damaged pit grate at bottom of Harold St

Plate 20 - Damaged pit grate at bottom of Harold St

Plate 21 - Completed culvert at Richard Rd landslip site

Plate 22 - Blocked pit at int. of Richard Rd and Cecil St

Plate 23- Blocked drain at int. of Richard Rd and Cecil Street

Plate 24 - Natural creek channel at No. 155 Richard Rd (*looking u/s*)

Plate 25 - Natural creek channel at No. 61 Richard Road (*looking d/s*)

Plate 26 - Hilda Ave (*looking uphill*)

Plate 27 - Richard Rd at int Hilda Ave

Plate 28 - Stormwater outlet at end of Vivian St

Plate 29 - Drainage pit in Richard Rd west of Vivian St

Plate 30 - Drainage pit in Richard Rd west of Vivian St

Plate 31 - Sealed section of Richard Rd, south of Cargo Wharf

Plate 32 - Location of natural valley on Richard Road (*No.s 111-115*)

Plate 33 - Intersection of Fitzpatrick Ave and Robertson Rd (*ie at Cargo Wharf*)

Plate 34 - Pit on Cargo Wharf Rd

Plate 35 - Concrete dish drain and pit on Cargo Wharf Rd

Plate 36 - Concrete dish drain and pit on Cargo Wharf Rd

Plate 37 - Concrete dish drain and pit on Cargo Wharf Rd

Plate 38 – Stormwater outlet at Cargo Wharf

Plate 39 – Litter at stormwater outlet, Cargo Wharf

Plate 40 - Drainage pit on Robertson Rd

Plate 41 - Drainage pit on Robertson Rd

Plate 42 - Regular stone lined channel at No. 25 Robertson Rd

Plate 43 - Sealed section of Robertson Rd

Plate 44 - Robertson Rd Corner at No. 41

Plate 45 - Overland channel through No.s 39/41 Robertson Rd

Plate 46 - Eroded section of Robertson Rd

Plate 47 - Small culvert at Robertson Rd, west of Catherine Park

Plate 48 - Resin sealed section of Rd behind Catherine Park

Plate 49 - Culvert upstream of Catherine Park (*highside of Rd*)

Plate 50 – O/L channel upstream of Culvert in Plate 49

Plate 51 - Outlet of culvert shown in Plate 49

Plate 52 - Grassed swale (*O/L flow path*) through Catherine Park

Plate 53 - Culvert in Catherine Park

Plate 54 - Culvert in Catherine Park

Plate 55 – Lack of formal headwall on culvert

Plate 56 - Drainage pit on Pitt St

Plate 57 – Drainage Pit near Fire Station

Plate 58 – Drainage channel Kevin Ave/Pitt St

Plate 59 - Water bar on Kevin Ave

Plate 60 - Outlet of Waterbar from Plate 59

Plate 61 - Stormwater Culvert on Kevin Ave

Plate 62 - Kevin Ave

Plate 63 - Kevin Ave

Plate 64 - Kevin Ave

Plate 65 - Kevin Ave

Plate 66 - Kevin Ave

Plate 67 - Damaged pipe, Kevin Ave

Plate 68 - Sealed section of Kevin Ave near Elizabeth Park

Plate 69 - Thompson St near Elise

Plate 70 - Thompson St just past int. with Harold (*note concrete water bars*)

Plate 71 - Rubbish/materials stockpiled near culvert on Thompson St (*No. 52*)

Plate 72 - Cecil St

Plate 73 – Concrete dish crossing on Thompson St (*between Cecil and Hilda*)

Plate 74 - Hilda Ave

Plate 75 - RFS Tank at top of Fitzpatrick Ave

Plate 76 - Thompson Rd

Appendix A - RAFTS

Appendix B - MUSIC

Appendix C - Short to Medium Term Recommendations

Priority Rank	Action Item	Estimated cost			Required Action
Outstanding Stormwater Management Related Short to Medium Term Recommendations from Appendix G of Witheridge Draft Report dated August 2004 "*Scotland Island Road Reserve Masterplan*" **(*refer to Plan SIR025 for Action Item Location*)**					
	78	L			Repair bitumen potholes at intersection of Harold and Thompson
	44	L			Repair potholes in bitumen on Robertson Rd adjacent to Aoma Street
	77	L			Repair potholes in bitumen at intersection of Thompson Street and Elsie Street
	28		M		Stabilise Hilda Avenue such that it is safe for walking. Possibly a timber stairway on eastern side of the street.
	29		M		Adopt short-term solution to the stabilisation of the trafficable area of Hilda Avenue.
	17		M		Temporarily stabilise Cecil Street if it has not been closed to traffic.
	30			H	Reform drainage on Hilda Avenue.
	18		M		Closure of Cecil Street to all but emergency vehicles.
	89		M		Re-profile Thompson St & Hilda Ave intersection and direct flow down Thompson St instead of Hilda Ave.
	8		M		Modify the private driveway entries or Richard Road east of the eastern creek crossing to allow flow down a newly reshaped and stabilised table drain. Then re-profile the road as necessary to regularly direct stormwater runoff into the table drain possibly with the use of cross banks.
	48		M		Construct additional cross banks on the steep section (*R5*) of Robertson Road between the Catherine Park and Thompson Street.
	52		M		Construct cross banks on the steep section (*T10*) of Thompson Street west of Robertson Road.
	71		M		Re-Profile Florence Terrace north of Lowanna Street to allow drainage infall to a table drain and to prevent stormwater runoff flowing off the road into the down-slope private property.
	93		M		~~Install cross banks on Elizabeth Park track through western cutting~~.

Priority Rank	Action Item	Estimated cost			Required Action
	97		M		~~Install a cross bank at top of eastern cutting on the Elizabeth Park track and allow drainage to the south.~~
	95		M		Install two banks on the Elizabeth Park track east of summit between the two cuttings.
	111		M		Install two cross banks on southern arm of the Elizabeth Park track.
	85			H	Re-profile the Thompson Street- Cecil Street intersection to control the direction of stormwater runoff.
	19			H	Construct suitable storm water drainage down Cecil Street.
	10	L			Stabilise the drains that enter the eastern creek crossing on Richard Road.
	5	L			Replace the stormwater inlet grate on the intersection of Harold Avenue and Richard Road.
	56	L			Re-profile and resurface/stabilise the walker track through Catherine Park. Possible trial of a 'structural soil' footpath.
	1	L			Rehabilitate the vehicular and walking tracks passing through Harold Reserve.
	66	L			Repair potholes on Florence Terrace north of Pathilda Reserve.
	72	L			Repair potholes on Florence Terrace north of Lowanna Street.
	99	L			~~De-silt cross bank at base of eastern cutting on the Elizabeth Park Track.~~
	86	L			Repair potholes in Thompson Street west of Cecil Street.
	92	L			Fix the log sediment trap on the western cutting of the Elizabeth Park track.
	38		M		~~Replace the stormwater inlet grates on Cargo Hill.~~
	26		M		Replace the stormwater grates on the Richard Road- Hilda Avenue intersection.
	45		M		Replace the stormwater inlet grates on Robertson Road east of Yamba.
	3		M		Stabilise the gully erosion downstream of the stormwater outlet on the intersection of Harold Avenue and Richard Rd.
	76			H	Re-profile Elsie Street between Florence Terrace and Thompson

Priority Rank	Action Item	Estimated cost			Required Action
					Street to allow emergency fire truck access.
	46		M		Re-profile Robertson Road east of Yamba to form infall drainage and form a table drain. One or more cross banks may be required to direct water off the road.
	75		M		Re-profile the intersection of Florence Terrace and Elsie Street to prevent stormwater runoff bypassing the stormwater inlet.
	104		M		Add a cross bank to the south loop of the Elizabeth Park track.
	67		M		Stabilise gully erosion forming in Pathilda Reserve up-slope of Florence Terrace.
	4		M		Stabilise gully erosion upstream of Harold Reserve extending up to Thompson Street.
	115		M		Install additional cross banks on upper Kevin Street.
	69		M		Form a table drain on Florence Terrace immediately south of Pathilda Reserve.
	74		M		Re-profile Florence Terrace between Lowanna Street and Elsie Street to form infall drainage and form a table drain.
	50		M		Re-profile the intersection of Thompson Street and Robertson Road to sheet stormwater off Robertson Road and through the upper section of Catherine Park; stabilise and formalise stormwater drainage running down Thompson St leading into the Thompson/Robertson intersection.
	36		M		Install a litter/pollution trap on the stormwater outlet on Cargo Hill.
	43		M		~~Construct formal culvert crossing into private properties along Robertson Road between Cargo Hill and Yamba to allow flow down the table drain. The table drain may need to be reinstated in some locations.~~. Note this measure may need to be revisited as SIRA reports not effective.
	15			H	Re-profile Richard Road west of the eastern creek crossing to allow flow to enter the existing concrete table drain. Or otherwise, remove the concrete drain and form a new rock-lined table drain.
	65		M		Formulate a table drain along Florence Terrace north of Pathilda Reserve
	82		M		Construct and stabilise a table drain along Thompson Street between Harold Avenue and Cecil Street. Where necessary, install cross banks to direct stormwater into the table drain.

Priority Rank	Action Item	Estimated cost			Required Action
	83		M		Construct culvert under Thompson Road at creek crossing between Harold Avenue and Cecil Street.
	109	L			Establish slit storage areas in Elizabeth park or any other suitable location. Use these areas to store silt collected from table drain maintenance operations. Treat with gypsum and mix with organise to form a source of topsoil for the rehabilitation of road banks and table drains.
	112	L			Revegetate sections of southern arm of the Elizabeth Park track to minimise the amount of exposed soil.
	118	L			Stabilise (*rock line*) the table drain in Thompson Street south of Kevin Avenue.
	9	L			Revegetate the road batter east of the eastern creek crossing on Richard Road.
	56	L			Cleanout the sediment trap in Catherine Park down-slope of Kevin Street.
	91	L			Direct flow off Thompson Street down the unnamed (*40ft wide*) road reserve.
	100	L			Form a silt trap at base of eastern cutting on the Elizabeth Park track.
	101	L			Cut drains through earth windrow on north side of the Elizabeth Park track east of eastern cutting.
	105	L			Clean out silt trap on the Elizabeth Park track.
	107	L			Clean the culvert on the Elizabeth Park loop.
	31		M		Re-profile the bend on Richard Road north-west of Hilda Avenue to prevent excess runoff down through private property.
	32		M		Fix the drainage on Richard Road opposite unnamed (*40ft wide*) road.
	64		M		Fix drainage on Florence Terrace east of Pitt View Street. Possible remove the concrete table drain and replace with a rock-lined drain set lower into the road.
	108		M		Install additional cross bank to the eastern side of the loop on the Elizabeth Park track.
	58			H	Replace the stormwater pits in Catherine Park with traps that have sediment trapping ability

Note: The above short to medium term stormwater management recommendations also incorporate the recommendations from the Rooney 1998 and 2004 Catherine Park and South Precinct Catchment Studies. The priority ranking listed is that adopted by G Witheridge.