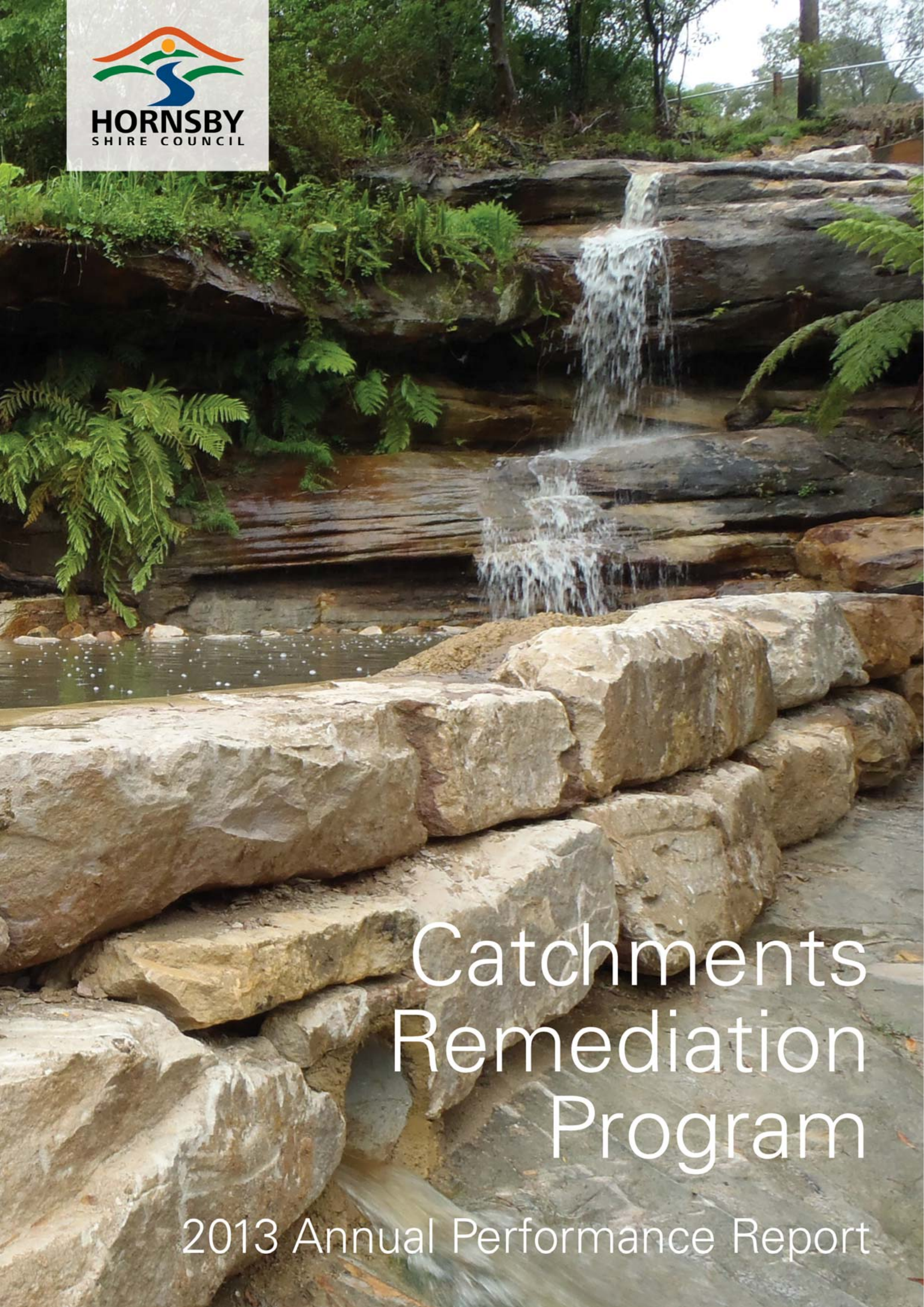


HORNSBY SHIRE COUNCIL

Catchments Remediation Program

2013 Annual Performance Report

HORNSBY SHIRE COUNCIL

Catchments Remediation Rate Program

2012 - 2013 Annual Report

Plate 1 – Apanie Place, Westleigh – Bioretention System

Acknowledgements

The 2012 - 2013 Catchments Remediation Rate Annual Report was produced by David Beharrell and Elizabeth Bulley under the direction of Diane Campbell - Manager, Natural Resources Branch, Hornsby Shire Council. Comments, assistance with programs and report contributions were provided by staff from Council's Natural Resources Branch.

For further information contact:

DAVID BEHARRELL

Natural Resources Operations Manager

Natural Resources Branch

Environment and Human Services Division

Tel: 02 9847 6860

Fax: 02 9847 6598

Email: dbeharrell@hornsby.nsw.gov.au

Web: www.crr.hornsby.nsw.gov.au

Table of Contents

TABLE OF CONTENTS **3**

LIST OF TABLES **4**

LIST OF FIGURES **4**

EXECUTIVE SUMMARY **5**

1. INTRODUCTION AND BACKGROUND **6**

1.1 Report Objective 6
1.2 Background of the Catchments Remediation Program 6
1.2.1. Catchments Remediation Program 6
1.2.2. Catchments Remediation Rate (CRR) and Panel 7
1.2.3. Synergy with Council's Strategic Direction 8
1.2.4. Statutory Considerations 9
1.2.5. Asset Auditing and Lifecycle Management 9

2. CATCHMENTS REMEDIATION RATE CAPITAL WORKS PROGRAM **11**

2.1 Delivery of Capital Work 11
2.1.1. Project Management and Construction 11
2.1.2. Work Health and Safety (WHS) and Risk Management 12
2.2 Types of Stormwater Quality Improvement Assets 13
2.2.1. Objective of Stormwater Treatment 13
2.2.2. Bioretention Systems 14
2.2.3. Gross Pollutant Devices and Sediment Basins 16
2.2.4. Constructed Wetlands 18
2.2.5. Stream Remediation 18
2.2.6. Projects Delivered in 2012 - 2013 19

3. CATCHMENTS REMEDIATION RATES ASSET MAINTENANCE **21**

3.1 CRR Asset Maintenance 21
3.1.1. Cleaning and Maintenance of CRR Assets 21
3.1.2. Bush Regeneration and Wetland Maintenance 23
3.1.3. Total Maintenance Costs 24

4. CATCHMENTS REMEDIATION RATES ASSETS PERFORMANCE **25**

4.1 Rainfall Measurement 25
4.2 Pollutant Removal Trends 25
4.3 Wetland Performance 28
4.3.1. Pollutant Removal Trends and Costs 28
4.4 Assessment of Nutrient Removal by the CRR program 28

5. LANDFILL AND LEACHATE REMEDIATION **31**

6. CATCHMENTS REMEDIATION RATE ENVIRONMENTAL EDUCATION **32**

7. STREET SWEEPING **34**

8. CONCLUSIONS **35**

9. REFERENCES **36**

APPENDIX A - SQUID SITE LOCATIONS **37**

APPENDIX B - RAINFALL DATA FOR HORNSBY LGA **41**

List of Tables

TABLE 1-1 - LINK TO COUNCIL'S COMMUNITY PLAN 8
TABLE 2-1 - POLLUTANT RANGES FOR STORMWATER TREATMENT MEASURES (ENGINEERS AUSTRALIA, 2006) 13
TABLE 2-2 - CAPITAL WORKS PROJECTS 2012 – 2013 20
TABLE 3-1 - MAINTENANCE OPERATIONS FOR STORMWATER TREATMENT MEASURES 22
TABLE 3-2 - SQID COMPARATIVE COSTS FROM JULY 2012 - JUNE 2013 23
TABLE 4-1 - CONSTRUCTED WETLAND ANNUAL COSTS AND MONITORING RECORDS TO END OF JUNE 2013 29
TABLE 4-2 - CAPTURE OF NUTRIENT EXPORTS (CANUTE) IN HORNSBY LGA FROM JULY 2012 TO JUNE 2013 30

List of Figures

FIGURE 2-1 - COMPARATIVE CONSTRUCTION OF BIORETENTION SYSTEMS (KNIGHTS *ET AL*, 2010) 12
FIGURE 4-1 - THE RELATIONSHIP BETWEEN AVERAGE MONTHLY VOLUME OF GROSS POLLUTANTS AND AVERAGE MONTHLY RAINFALL 25
FIGURE 4-2 - VOLUMES OF POLLUTANTS REMOVED FROM SQIDS (2012 - 2013) 26
FIGURE 4-3 - POLLUTANT VOLUME (M3) REMOVED FROM SQIDS AGAINST AVERAGE ANNUAL RAINFALL JULY 2008 – JUNE 2013 27
FIGURE 4-4 - PREDICTION OF ANNUAL GROSS POLLUTANT RATES USING LANDUSE AREA 27
FIGURE 7-1 - POLLUTION YIELD (M^3) EXTRACTED BY SQIDS AND STREET SWEEPING AGAINST AVERAGE ANNUAL RAINFALL JULY 2008 – JUNE 2013 34

Executive Summary

This report aims to provide both quantitative and qualitative commentary on a number of programs run as part of the Catchments Remediation Program and funded by the Catchment Remediation Rate. These programs include the capital works program, asset maintenance and monitoring, asset renewal, landfill and leachate remediation, street sweeping and catchment education.

The primary focus of the report is to provide quantitative data and analysis of the relative performance of different water quality treatment measures, including gross pollutant devices (GPD's), sediment basins, wetlands and bioretention systems that have been constructed to improve stormwater quality in Hornsby Shire. The results of the report will be used by stormwater and catchment managers to provide a better insight into determining the type of structures that are suitable for specific sites. Furthermore, the data provides valuable information about the costs (both capital and maintenance), benefits and device optimisation which can aid in the formulation of strategies to improve catchment and landuse practices by both structural and non-structural means.

Gross pollutant devices, sediment basins, wetlands and bioretention systems all come under the general description of Stormwater Quality Improvement Devices (SQUIDs). The principal objective of installing SQUIDs is to improve water quality by removing pollutants and in some instances retaining stormwater flows. In the 2012 - 2013 financial year, $925,000 was spent on capital works with 5 catchments remediation projects being initiated and completed. These works involved the construction and/or installation of:

- Three end-of-pipe bioretention systems: Hornsby Heights, West Pennant Hills and Westleigh;
- One creek stabilisation project: Hornsby;
- One stormwater reuse system and bioretention basin: Thornleigh; and
- 10,547 native plants at new and existing sites to replace weeds and help facilitate the process of water quality treatment

While these structural interventions treat and remove pollutants directly, the Catchments Remediation Program also promotes and funds non-structural initiatives in the pursuit of improving water quality in the Shire's creeks, waterways and receiving waters. These include: monitoring, maintenance, street sweeping, riparian bush regeneration, environmental education, business auditing, compliance programs, pollution clean-ups and estuary management initiatives.

The collection of performance data over the 2012 - 2013 financial year has allowed Council to quantify the volume of gross pollutant (sediment, litter and organic matter) removal from Council's 429 water quality improvement assets. The data show that 1,130 cubic metres of sediment, litter and organic matter collectively was captured and prevented from entering the Shire's waterways during this period. In addition, modelling indicates that over 1,090kg of phosphorous and 3,400kg of nitrogen was removed by CRR funded initiatives which is of particular significance because of their known detrimental impact on aquatic ecosystems, such as creeks and estuaries.

The total cost to Council to maintain its water quality improvement devices and adjacent landscaped areas was approximately $381,000 in the 2012 - 2013 financial year. This included $204,000 for the cleaning of SQUIDS and disposal of waste to landfill and $177,000 for landscaping maintenance and bush regeneration at the sites. Other associated costs included the monitoring and maintenance of leachate treatment facilities, tree work and staff wages.

The report also provides information on the design principles behind innovative stormwater treatment measures known as bioretention systems. A project of particular interest in the 2012 - 2013 period was a bioretention basin that cleans stormwater to be stored for a stormwater reuse system constructed on the corner of Dawson and Ferguson Avenues, Thornleigh. This uses storage boxes to store stormwater for reuse on the Thornleigh Oval after being purified with UV treatment.

Overall, the findings of this report give stormwater managers a better insight into the cost-effectiveness and performance of water quality improvement structures and the management of life-cycle costs for individual stormwater treatment measures. The performance of these devices allows Council to both refine and modify the design of future water quality control measures and judge their appropriateness for proposed remediation sites based on catchment size and land use impact.

1. Introduction and Background

Hornsby is located 25 kilometres north-west of the Sydney CBD and is the Council base for a Shire covering approximately 50,990 hectares and serving the needs of an estimated 157,000 residents (Australian Bureau of Statistics, 2011). The Shire extends from Epping in the south to Brooklyn and Wisemans Ferry in the north fronting a large expanse of the Lower Hawkesbury River. A majority of the northern and central Shire consists of National Park and Nature Reserve. This unique natural character combined with the many creeks and estuaries has led to Council being termed the 'Bushland Shire'.

In an attempt to conserve the ecological value of the Shire's many natural waterways and to improve the quality of urban stormwater, Hornsby Shire Council has taken an integrated approach to stormwater quality management by developing a range of capital and non-capital (preventative) measures. This initiative includes all major catchments under the Stormwater Management Plan framework, together with more closely modelled sub-catchment plans. Council's progressive strategy has recognised the need to tackle these challenges using a broad approach to understanding and managing the total water cycle. This has led to the development of a Sustainable Total Water Cycle Management Strategy (2005).

This report focuses on the performance of different stormwater treatment measures, including gross pollutant traps, constructed wetlands, sediment basins, stream remediation, and bioretention systems that have been constructed under Council's Catchments Remediation Rate (CRR) Capital Works Program. The report also outlines Council's work on leachate treatment and stormwater harvesting schemes.

1.1 Report Objective

To provide quantitative data and an analysis of the relative performance of different stormwater and leachate quality improvement devices that have been implemented under the Catchments Remediation Rate Program. Specific reference will be made to those devices constructed and / or installed in the 2012 - 2013 financial year.

1.2 Background of the Catchments Remediation Program

1.2.1. Catchments Remediation Program

In response to general water quality degradation, including red algal blooms and fish kills in the Berowra Creek estuary in September 1993, Hornsby Council placed a moratorium on all development assessments within the catchments of the West Hornsby STP. To resolve this, the Minister for Planning established a Technical Working Party (TWP), comprising representatives of Council, the Water Board (Sydney Water) and the Department of Urban Affairs and Planning (DUAP) which are now known as The NSW Department of Planning. Representatives from the Environment Protection Authority (EPA) and the Hawkesbury-Nepean Catchment Management Trust joined the TWP in early 1994. The TWP confirmed that the two Sewage Treatment Plants (STP's) contributed to the poor water quality of the creek. Moreover, it highlighted the significant role of polluted urban stormwater, particularly runoff from developing and newly developed residential areas.

On 27 April 1994, the participating organisations of the TWP signed a Statement of Joint Intent (SoJI - also known as the Community Contract for Berowra Creek) agreeing to work together to achieve the ecologically sustainable development (ESD) of the Berowra Creek catchment and the recovery of the environmental health of the creek. The Community Contract, included agreements to upgrade the STP's and it bound the parties to the preparation and implementation of a Water Quality Management Strategy. It also required Council to prepare and implement a strategy to reduce stormwater nutrient ingress to Berowra Creek and to utilise water sensitive design in its consideration of future developments.

However, the level of pollutants and the urgent need for action was not confined to Berowra Creek. Water quality in the other major catchments within the Shire had also deteriorated as a result of urbanisation. Remedial works to reduce pollution and improve water quality were required throughout the entire Shire including relevant areas draining the Cowan Creek, Lane Cove River and the Hawkesbury River catchments.

In 1995, the Water Catchments Team initiated the first phase of the ongoing strategic planning for catchment management within the Shire. The result was the production of a Catchments Remediation Program Five-Year Plan which detailed the proposed expenditure of the Catchments Remediation Rate towards meeting the objectives of the Statement of Joint Intent and in turn improving water quality in the Shire's waterways. The Plan included financial forecasts of rate income over a five year period together with capital investment and non-capital expenditure including asset management.

It was hoped that Hornsby Shire Council's Catchments Remediation Program would give stormwater managers a better insight into the cost-efficiency and performance of individual devices, but more importantly, monitoring of devices would reflect the individual characteristics of sub-catchments and the associated point sources of pollution, which can be targeted through pollutant minimisation strategies. It was also seen that community and industry awareness projects are important to complement the Catchments Remediation Program, whilst Local Government can also review work practices and strategies in relation to sediment and erosion controls on building sites (and their enforcement), street sweeping, street tree planting, rubbish collections and kerbside recycling collections.

Additional objectives of the Catchments Remediation Program, which still apply today, aim to address:

- Innovative Products and Services – generate and use ideas to add value to the community as stakeholders, provide productivity improvements, continue leadership and management capabilities in local government
- Health and Safety – provide a safe and healthy aquatic environment for the community, council staff and contractors
- Performance – to better understand community needs and expectations and deliver reliable devices which maximise the cost / benefit of installed capital projects
- Reporting – detail expenditure through regular reporting to the community; and
- Service – protect and service assets and continually improve operations.

1.2.2. Catchments Remediation Rate (CRR) and Panel

Council's catchments remediation work up to 1997 was only partly funded by the CRR, with the majority of funding being at the expense of other traditional Council services e.g. Parks. However, the cost of Council's 'Statement of Joint Intent (SoJI) for Berowra Creek' obligations and remediation works in the other catchments was highlighted to be much more than was covered by the rate. The proposal to increase the CRR from 2% to a 5% levy on ordinary rates in 1997 was presented with the idea to accelerate remediation capital works and return resources to traditional services that had suffered funding cuts. The increased funding was intended for planning, design, construction, maintenance and management of remediation devices. The proposal to increase the CRR to 5% was adopted by Council on the 13th April 1997 and still applies today.

Approximately 50% of the CRR is directed to non-capital costs including project management and a series of studies, associated with meeting the SoJI objectives. These studies are designed to identify more precisely the cause and effect mechanisms of pollution generation in the Shire, develop effective longer term remedies for the problems, and establish appropriate technological and monitoring techniques to determine and report progress. The remaining 50% of CRR funding is allocated to on-ground capital remediation works and subsequent routine maintenance of all constructed devices. Current remedial environmental protection works include the design and construction of wetlands, SQUIDs, leachate control from old landfill sites, sediment basins and creek stabilisation / rehabilitation.

The Catchments Remediation Rate Expenditure Review Panel (the Panel) was established in July 1997 following community consultation on increasing the CRR from 2% to 5%. The Panel meets twice annually to review expenditure following the second and fourth quarters of each financial year and currently comprises six community members, relevant council staff and two nominated Councillors. The purpose of the Panel is to ensure accountability and transparency of expenditure of CRR funds.

The terms of reference for the Panel were to:

- note the criteria which enables costs to be eligible for CRR funding;

- assess the validity of funding decisions made by Council staff against the criteria;
- note information relevant to CRR funding, available from Council's accounts;
- determine, in consultation with Council and staff, if the CRR funds have been appropriately assigned; and
- report to Council on the Panel's determination.

1.2.3. Synergy with Council's Strategic Direction

<u>Council's Community Plan 2010- 2020</u>

The Hornsby Shire Community Plan has been prepared by Hornsby Shire Council in partnership with local residents, our business community, other levels of government, educational institutions, non-government community and cultural organisations and neighbouring councils.

The Hornsby Shire Community Plan sets the strategic direction for where the people of Hornsby Shire want to be in 2020. It's a long term plan to deliver the best possible services to the people of the Hornsby Shire.

The Community Plan is aligned to the Hornsby Shire 2020 Framework for a Sustainable Future which states that a sustainable future requires a successful combination of:

- Protection and enhancement of our natural environment
- A resilient local economy and sustainable resource use
- Enhanced social and community wellbeing
- Effective community infrastructure and services
- Leadership that is accountable and effective

These strategic themes are supported by key goals that will guide the Shire for the next 10 years. The Catchments Remediation Program has a key role to play in delivering Goal 1.2: Maintain healthy waterways and catchments, which emphasises protecting the landscapes and health of our waterways and catchments, including the Hawkesbury River, Berowra Creek and associated tributaries and applying a total water cycle management approach to maintain water quality in our creeks, wetlands and rivers. The strategy pursuant to this goal and related actions are indentified below.

Table 1-1 - Link to Council's Community Plan

Goal	Strategy	Actions for Council
Maintain healthy waterways and catchments	**Strategy 1.2.1:** Protect and improve the catchments in the Shire by providing support and direction to the water catchments program	Construct water quality remediation devices as per the Catchments Remediation Rate (CRR) 10 year capital works program Undertake the Estuary Management Program
	Strategy 1.2.2: Identify and implement innovative water conservation and sustainable water cycle management practices	Implement the Total Water Cycle Management Strategy Implement water conservation and reuse projects
	Strategy 1.2.3: Work with the community to care for, protect, enjoy and enhance the health of waterways in the Shire	Provide education to the community on the importance of waterways and estuaries
	Strategy 1.2.4: Provide a water quality monitoring service using methods that are reliable, professional and contemporary	Monitor and report environmental conditions, including water quality, at creeks and estuaries

Total Sustainable Water Cycle Management Strategy

Council has shown leadership in successful water quality management since the break out of algal blooms in Berowra Creek in the early 1990s with the implementation of the Berowra Creek Water Quality Management Strategy. However, the Water Catchments Team recognised the need to expand traditional thinking of water quantity and quality, to include an understanding of the total water cycle which culminated in the adoption of the Sustainable Water Cycle Management Strategy 2005.

Council's recognition of the need to tackle these challenges using a strategic approach places it at the forefront of sustainable water cycle management and provides the inspiration for this project. The continuation of the Catchments Remediation Program is critical to the successful implementation of this strategic approach to total water cycle management.

Stormwater Drainage Asset Management Plan 2005-2025

The Stormwater Drainage Asset Management Plan (SDAMP) 2006 formalises the process for the financial and physical requirements for a 20 year long-term performance of Council's stormwater and water quality infrastructure assets. The Plan demonstrates responsible stewardship as well as defines and articulates how the stormwater and water quality infrastructure assets are and will be managed to achieve Council's objectives. The Plan also identifies the future service delivery funding requirements for the adopted levels of service, future demand for infrastructure, current asset performance, asset failure, risk, required works and funding constraints.

1.2.4. Statutory Considerations

It should be noted that the Hornsby Shire Local Environment Plan (LEP), 1994, permits Council to undertake the construction or maintenance of stormwater drainage and water quality treatment devices, bush regeneration and landscaping without obtaining development consent. The proposals for construction are assessed under Part V of the Environmental Planning and Assessment Act, 1979, which requires Council to prepare a Review of Environmental Factors (REF). This identifies and evaluates the impacts of an activity to determine whether the impacts are likely to significantly affect the environment. The REF must also consider impacts of the activity on critical habitat or threatened species, populations or ecological communities or their habitat, under section 5A of the EP&A Act.

The Threatened Species Conservation Act (TSC Act) 1995 specifies a set of seven factors which must be considered by decision makers in assessing the effect of a proposed activity on threatened species, populations or ecological communities, or their habitats. These factors are collectively referred to as the seven part test of significance.

The outcome of any threatened species assessment should be that activities are undertaken in an environmentally sensitive manner, and that appropriate measures are undertaken to minimise adverse effects on threatened species, populations or ecological communities, or their habitats.

1.2.5. Asset Auditing and Lifecycle Management

Lifecycle Management

Lifecycle management enables Council to plan interventions, whether its maintenance or renewal, at the optimum stage of an asset's deterioration to enable cost effective extensions of its useful life. There are a number of activities considered in lifecycle management:

- **Operations:** those activities that have no effect on asset condition but are necessary to keep the asset appropriately utilised.
- **Maintenance:** the day to day work required to keep assets operating at agreed service levels. This falls into two broad categories: planned (proactive) maintenance which are maintenance activities planned to prevent asset deterioration; and unplanned (reactive) maintenance which are maintenance activities to correct asset malfunctions and failures on an as required basis (e.g. emergency repairs). Maintenance work is required to maintain the asset's ability to provide the agreed service level but does not extend the life of the asset. Operations and Maintenance expenditure are considered an "Expense" for Council's financial accounting purposes. A key element of asset management planning is determining the most cost-effective mix of planned maintenance in order to reduce unplanned maintenance to a minimum.

- **Renewal work:** the substantial replacement of the asset, or a significant asset component, to its original size and capacity. This work generally aims to return the asset to a condition or state similar to the original asset.
- **Replacements (or reconstruction):** are those projects that are created for the extension or upgrading of assets required to cater for growth or to maintain or improve on the levels of service.

The Stormwater Drainage Asset Management Plan (SDAMP) 2006 was prepared to provide a financial forecast for water quality assets in the Shire over a 20 year period. Cumulative operating expenditure identified in the Plan includes the cumulative operation / maintenance expenditure and asset renewals and upgrades associated with assets reaching their optimum life or age. To ensure responsible financial management the assumptions made in the modelling were very conservative. Hence, both renewal and projected maintenance cost were set at a high level to allow for unforeseen circumstances or unpredictable rises in costs.

The key feature of these financial projections is that it is envisaged that operational and renewal costs will take an increasingly larger proportion of CRR funds in future years as the number of assets increases. The life cycle analysis modelling of the catchments remediation program, as with Council's Asset Management Plans, will be reviewed at regular intervals to allow for the input of monitoring and knowledge gained over time.

Asset Auditing

Over the previous 24 months Council's CRR Assets Officer has concentrated on assets auditing. By the end of the 2012-2013 period all of the 400 + assets had been audited. The audits were undertaken using a risk assessment approach which included assessing:

- Public Safety, resulting in:

  - An action register

  - Signage requirements

- Performance – both functionality and structural integrity
- Contractor and Staff OH&S requirements

This proactive auditing regime will be ongoing as it provides a much more realistic assessment of asset condition and hence the requirement for renewal and repair than lifecycle modelling. The information gained from this auditing process along with careful tracking of the costs associated with maintenance, renewal and repair have shown that at present there is little need for a CRR sinking fund for asset renewal/repair.

2. Catchments Remediation Rate Capital Works Program

2.1 Delivery of Capital Work

The selection and implementation of structural stormwater quality improvement devices involves numerous steps. These include: site identification and prioritisation; determination of treatment objectives; development of treatment train; concept design; comparison of potential treatments (modelling); detailed design; review of environmental factors; notification and authority to commence construction.

2.1.1. Project Management and Construction

Due to the varying degrees of expertise in different fields the Divisions of Environment and Human Services and Infrastructure and Recreation have forged a partnership approach to deliver CRR capital works projects. The Infrastructure and Recreation Division's Design and Construction Branch now incorporate the design, construction and project management responsibilities associated with CRR capital works routinely into their annual civil works improvement program.

There are a number of benefits to both Divisions and to the Council as a whole as a result of this partnership. Some of these are:

- Projects are developed ensuring compatibility with local engineering and environmental standards, and making sure that all issues are addressed;
- Experience and knowledge from involvement in these projects is utilised in all Council works so that Council sets the standard for developers / builders to follow;
- Opportunities for the Infrastructure and Recreation Division staff to be involved in environmentally "cutting edge" technologies;
- Involvement of staff in the Infrastructure and Recreation Division in an area of environmental management, with a flow-on effect resulting in better understanding of sustainability issues;
- Opportunities for Environment and Human Services Division staff to become more aware of engineering issues in the development of projects;
- Expansion of the core business of the Infrastructure and Recreation Division; and
- Flexibility during the construction phase not necessarily afforded in contractual arrangements.

The combination of the push towards competitive tendering and the need to seek specialised engineering and contractor services results in the contracting out or tendering of some of the design and construction activities. At present a small proportion of the works is contracted out (usually low-risk remediation projects such as stream remediation works and small scale gross pollutant devices) together with specialised design and consulting services.

To date the Environment and Human Services Division has been satisfied with the quality of work achieved and the cost-benefit involved. To reaffirm this, Council has benchmarked the cost of constructing bioretention systems against other Sydney Councils. As **Figure 2.1** illustrates the in-house arrangement represents good value for money.

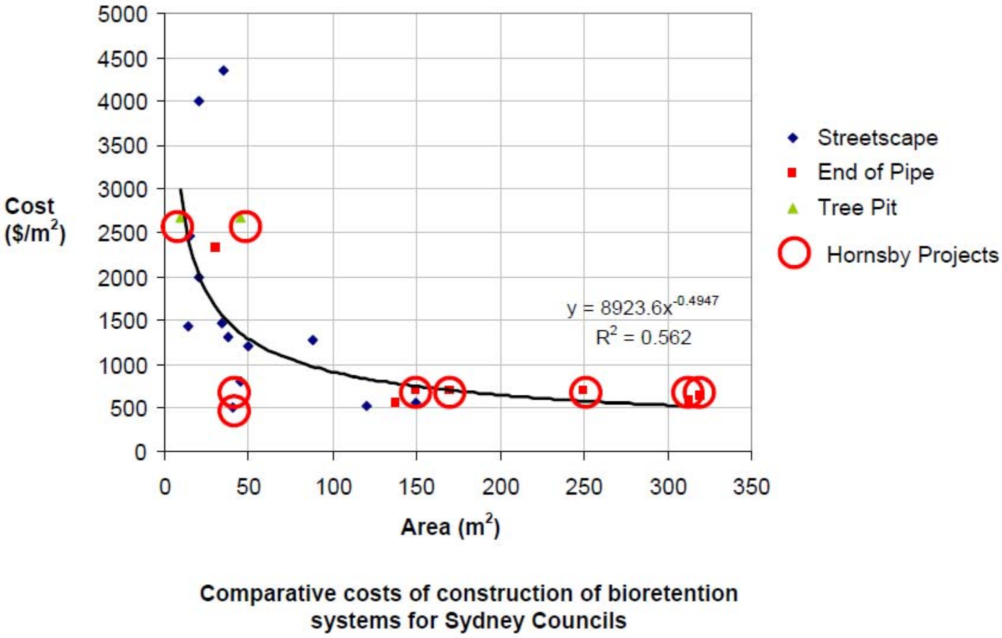


Figure 2-1 - Comparative construction of bioretention systems (Knights *et al*, 2010)

2.1.2. Work Health and Safety (WHS) and Risk Management

All contractors are required by Council to have a WHS Policy in accordance with the Work Health and Safety Act 2011 and The Work Health and Safety Regulation 2011 which aim to secure and promote the health, safety and welfare of people at work. Employers and supervisors of staff and contractors have a duty of care under the Act to protect employees and demonstrate due diligence in their WHS Management Systems. Council and contractor policies must address:

- certificates of currency for public liability, third party motor vehicle insurance and workers compensation;
- safe work practices and procedures (hazard identification and risk analysis per site / device);
- induction and safety training (Green or White card);
- corrective actions and documentation;
- incident / accident recording and investigation; and
- personal protective equipment (PPE).

By ensuring these requirements are met by both Council staff and contractors the risks identified during the cleaning and maintenance process can be analysed, evaluated and risk treatment plans implemented in accordance with AS / NZS 4360 Risk Management.

2.2 Types of Stormwater Quality Improvement Assets

2.2.1. Objective of Stormwater Treatment

Historically, the principal objective of stormwater treatment measures was to improve the quality of stormwater by removing pollutants, including litter, sediment, nutrients, metals and associated bacterial contamination. Stormwater treatment can be grouped into three categories: primary, secondary and tertiary (Refer to **Table 2.1** and **Section 2.2.2**).

Recent research suggests that to further protect stream ecosystems stormwater management systems should be designed to retain water from small-to-moderate rain events. By doing this the disturbance or damage caused by frequent events can be reduced (Walsh et al 2004).

With this in mind Council's Catchments Remediation Program has been implementing and providing funding to projects which retain and use stormwater, e.g., bioretention systems (through plant evapotranspiration) and stormwater harvesting schemes (through sports field irrigation).

Table 2-1 - Pollutant ranges for stormwater treatment measures (Engineers Australia, 2006).

Particle Size Grading	Treatment Measures	Treatment Process
Gross Solids > 5000 µm	Gross Pollutant Traps	Screening
Coarse- to Medium-Sized Particulates 5000 µm – 125 µm	Sedimentation Basins (Wet & Dry)	Sedimentation
Fine Particulates 125 µm – 10 µm	Grass Swales & Filter Strips; Surface Flow Wetlands	Enhanced Sedimentation
Very Fine/ Colloidal Particulates 10 µm – 0.45 µm	Infiltration Systems; Sub - Surface Flow Wetlands	Adhesion and Filtration
Dissolved Particles < 0.45 µm		Biological Uptake

Typical Stormwater Pollutants and Contaminants

- **Gross pollutants** are typically those materials greater than 0.05mm, both degradable and non-degradable, which detrimentally impact physically, visually and bio-chemically on aquatic ecosystems.
- The deposition of **suspended solids** can block pipes, change flow conditions, decrease light penetration and disrupt the habitat of aquatic invertebrates and fish (e.g. by infilling pool habitat). Equally important is that they are associated with other contaminants such as heavy metals, hydrocarbons and phosphorus (Engineers Australia, 2006).
- Increased **nutrients** (phosphorous and nitrogen) levels may cause excessive and unbalanced growth of plants and algae leading to oxygen depletion. Sources of nutrients include atmospheric deposition, tree leaves, domestic and agricultural fertilisers, industrial waste, sewer overflows, animal droppings, detergents and lubricants (Engineers Australia, 2006).
- A wide variety of **heavy metals** are present in stormwater and toxic effects can occur once concentrations exceed certain levels.

2.2.2. Bioretention Systems

Bioretention systems or basins can be simply thought of as “vegetated sand filters”. Stormwater run-off is delivered, either directly or via a low flow diversion, to the bioretention basin where it is spread over the vegetated area and slowly percolates through a filter media. Pollutant removal is achieved through the interface of the vegetation and filter media as a result of enhanced sedimentation in the vegetation zone, mechanical filtration, sorption and other chemical processes in the filter media and plant and biofilm uptake of pollutants (Hatt, et al 2006). An underdrain collects the treated water and delivers it to existing stormwater infrastructure or waterways.

Bioretention systems can be constructed at different locations within the catchment; they can be at-source within the streetscape (e.g. within traffic calming devices or tree pits) or at the “end-of-pipe” where stormwater infrastructure (pipes) run into bushland or waterways.

End-of-Pipe Bioretention Systems

These systems encapsulate the “treatment train” approach by providing primary, secondary and tertiary treatment through the one bioretention system.

To provide optimal treatment both the vegetation type and filter media have been specified to comply with recent research findings. While the concept is simple, extensive research has refined the specifications to optimise performance of these systems.

Primary Treatment: Stormwater flows into sediment forebays which captures larger sediments. It then flows into a distribution swale where the stormwater is evenly spread across the basin surface to allow litter, leaves and finer sediment to be trapped on the surface of the filter media. Through the CRR maintenance program these larger litter items and accumulated sediment are removed on an as needs basis.

Secondary Treatment: After the stormwater has entered the bioretention basin it percolates down into the filter media where finer sediment and pollutants are retained by attaching to soil particles or becoming trapped within pore spaces.

Tertiary Treatment: Tertiary treatment also occurs as biofilms on the highly fibrous root system of the plants take up nutrients and metals. In addition, this system has been installed with the option to create a permanent saturated zone which assists in the depletion of available nitrogen through the process of denitrification.

In January 2013, Council completed a bioretention basin with an additional stormwater harvesting component. Stormwater pollutants are removed through filtration and biological uptake. The filter media and plants work together to adsorb heavy metals, nutrients and hydrocarbons. The treated stormwater is collected in storage cells (similar in appearance to 'milk crates') and pumped to nearby Thornleigh Oval for irrigation purposes. The site was selected due to localised impacts from stormwater draining from the surrounding residential area. Sedimentation and nutrient rich runoff had created ideal conditions for exotic weeds that extended down the drainage line into national park bushland. Construction involved major earthworks, including rock walls and earth batters. The basin was then made watertight by the installation of a plastic liner before the water storage cells, filter media and plants were installed.

Plates 2-6: Dawson Avenue, Thornleigh - Bioretention Basin and Stormwater Harvesting System Constructed in January 2013.

2.2.3. Gross Pollutant Devices and Sediment Basins

Gross Pollutant Devices (GPD's) and sediment basins can operate in isolation to protect immediate downstream receiving waters or as part of a more comprehensive treatment system. When acting in isolation they are used primarily to protect downstream waters from litter or to address specific issues such as excessive leaf drop. When maintained at a prescribed level they can be useful in retaining a significant proportion of all pollutant types.

In an integrated treatment system (or treatment train), they are the most upstream measure and are important in protecting the integrity of downstream treatments (such as wetlands and bioretention systems) by removing the coarse fraction of contaminants (e.g. litter, coarse sediment etc) (Engineers Australia, 2006, p8-2).

For the purposes of this report, GPD's take many forms including trash racks, litter baskets, channel nets, pit inserts and underground sumps. Some GPD's are fabricated to fit specific locations, whereas others are bought off the shelf (proprietary devices). At present over 429 stormwater treatment measures have been installed and / or constructed throughout the Shire.

Hornsby Shire Council maintains 68 sediment basins throughout the Shire. As with GPD's, proper maintenance is essential to ensure optimal performance, therefore, Council scheduled the cleaning of a number of established basins in the 2012 - 2013 period. It is important that sediment basins are cleaned at least biennially (or at 30% capacity) so as to prevent colonisation of weeds and the release of potentially bio-available contaminants caused by disturbance events (e.g. scour and re-suspension).

In May 2013, Council instigated a cleanout of a large detention basin located in Ashleigh Madison Way, Mount Colah. This drains from a large, steep catchment with the basin accumulating large levels of sediment and organic matter from the surrounding streets and carparks. This cleanout resulted in a high level of sediment and organic matter being removed from site to restore capacity to the basin for future rainfall events.

Plates 7-10: Ashleigh Madison Way, Mount Colah - Sediment basin cleanout showing before, during and after cleanout.

2.2.4. Constructed Wetlands

Natural wetlands are transitional environments between terrestrial and aquatic habitats. They are characteristically shallow environments that are cyclically, intermittently or permanently inundated by fresh, brackish or saline water. Wetlands provide habitat for biota such as emergent macrophytes, macroinvertebrates, fish, amphibians, reptiles and birds which are dependant on the inundation of the wetland.

In managing urban stormwater pollution of natural waterways, constructed wetlands are often built to mimic nature and to achieve improvements in stormwater quality through natural physical and chemical processes. Furthermore, they provide additional benefits through the provision of habitat for aquatic and terrestrial fauna, maximising biodiversity and enhancing aesthetics.

As shown in Plates 7-10, Ashleigh Madison Way, Mount Colah had high levels of sediment removed to ensure future capacity. Additionally, a constructed wetland had sediment removed at John Savage Crescent, Cherrybrook. Efforts were made to retain some native aquatic vegetation on its edges and to time the cleanout to reduce impacts on duck breeding in the waterbody.

2.2.5. Stream Remediation

Many creeks become physically degraded when the natural hydrology of the catchment is altered. This most often results in creek bank scour and erosion which is accelerated through processes such as the clearing of riparian vegetation and increased stormwater runoff from impervious surfaces. This degradation can have a detrimental impact on water quality often resulting in an increase in sediment transport and associated sediment bound contaminates.

Aquatic flora and fauna are impacted through a loss of habitat, increased competition with weeds, poor light penetration into the water column due to increased turbidity levels and smothering of benthic organisms with increased sedimentation.

In the remediation of a degraded section of stream the following techniques are used:

- **Creek bank stabilisation -** Typically using locally sourced sandstone boulders that prevent the creek bank from eroding any further and provide habitat for fauna and flora on the rock surface and in cracks between rocks. A variety of softer creek bank armouring strategies may also be incorporated, including the pinning or staking of jute mesh/matting, woven blankets, fallen logs and chain-wire mesh. These approaches are often combined with the planting of native plant cells or tubestock.
- **Use of meanders -** To aid in the reduction of flow velocities during storms.
- **Riffle zones and natural rock fall structures -** Are used to provide in-stream habitat, stabilise the creek bed, aerate the water and allow maximum UV light treatment from sunlight to destroy faecal bacteria.
- **Pool zones -** Are incorporated to create habitat for fauna and macrophytes and to dissipate flow velocities which allows sediments to drop out for later removal.
- **Revegetation of riparian zone -** This zone is planted with indigenous native tubestock to improve habitat, enhance faunal corridors and vegetation links, provide a food source for both terrestrial and aquatic organisms and to stabilise the banks.
- **Stabilising stormwater outlets -** Rock armouring around stormwater outlets reduces erosion and scour caused by high flows.

In addition, the majority of stormwater treatment measures discussed in this report also incorporate some stream remediation to stabilise banks around the devices and improve habitat immediately up and downstream. Although the environmental benefit of stream remediation works is difficult to quantify, the works provide a significant benefit in terms of a reduction in erosion and associated sediment loads moving to the lower reaches of creeklines and receiving waters, improved native riparian and aquatic habitat and enhanced visual aesthetics.

In late 2012, Council carried out bank stabilisation works on Hornsby Creek in Edgeworth David Park, Hornsby. This reach of creek was showing signs of erosion and bank collapse in several sections. This creekline area was seen as particularly important to remediate due to its current habitat value. Rock armouring stabilised the bank and additional drainage was added to redirect flows and reduce erosion. Replanting of the riparian area was also completed.

Plates 11-12: Edgeworth David Park, Hornsby – Stream Remediation Works.

2.2.6. Projects Delivered in 2012 - 2013

In the 2012 - 2013 financial year, $925,000 was spent on capital works with 5 catchments remediation projects being initiated and completed. These works involved the construction of:

- Three end-of-pipe bioretention systems: Hornsby Heights, West Pennant Hills and Westleigh
- One creek stabilisation project: Hornsby; and
- One stormwater reuse system and bioretention basin: Thornleigh.

In addition:

- 10,547 native plants were planted at new and existing sites to replace weeds and help facilitate the process of water quality treatment
- One project from the previous year was completed
- Five projects on the 2012 - 2013 works schedule had survey and design work done

Some sites combined a number of measures to provide optimal treatment of stormwater, referred to as a treatment train, whereas others focused on a specific type of treatment. Catchment characteristics, site conditions and constraints are the core factors in determining what type of measure is constructed. However, where possible, Council aims to provide primary, secondary and tertiary treatment to optimise benefits to the downstream environment.

Following this is **Table 2.2** which lists the locations and treatment measures for projects completed in 2012 - 2013. A full list of all devices managed by Hornsby Shire Council is detailed in Appendix A with projects from the 2012 – 2013 period defined in bold.

Table 2-2 - Capital Works Projects 2012 – 2013

(1-main treatment 2- supplementary treatment, EP- End-of-pipe bioretention)

Project Location	Bioretention	Stormwater Treatment / Reuse	Creek / Channel Remediation
Northcote Road, HORNSBY			1
Apanie Place, WESTLEIGH	1(EP)		
Dawson Avenue, THORNLEIGH	1(EP)	2	
Bellamy Street, WEST PENNANT HILLS	1(EP)		2
Spedding Road, HORNSBY HEIGHTS	1(EP)		2

Plates 13-18: Bioretention Basins Constructed in 2012-2013
Bellamy Street, West Pennant Hills
Apanie Place, Westleigh
Spedding Avenue, Hornsby Heights (all during and post construction)

3. Catchments Remediation Rates Asset Maintenance

3.1 CRR Asset Maintenance

3.1.1. Cleaning and Maintenance of CRR Assets

Included within the CRR capital works budget is provision for monitoring and maintenance of all structures on a regular, recorded basis. Due to the current strain on Council's resources, the increasing number of structures being built and the resulting demand for timely and efficient maintenance, Council has continued to utilise contractors (on a 3 year contract) to undertake maintenance works under Council supervision.

Maintenance typically involves regular cleaning of SQUIDs and periodic maintenance of sediment traps and wetlands in terms of sediment removal and bank repair. Fundamental design principles allow ease of draining / flow bypass and access for maintenance of all water quality control devices which results in efficient and cost-effective maintenance techniques in the long term. The cleaning / maintenance contract was re-let for another three-year period in the 2009 - 2010 financial year. A further 3 year contract period has been re-let for cleaning / maintenance starting in the 2013-2014 period.

The existing contracts stipulate the contractor's responsibilities. These are outlined as follows:

- To maintain existing water quality remediation structures to ensure optimal functioning and a weed-free surrounding landscape of many devices;
- To ensure quality control / assurance throughout the maintenance process incorporating:
- Minimal pollution of the site during cleaning and transport of materials; and
- Efficient, accurately documented records of contents removed and / or actions taken.
- Contractors are required to provide both a status and cleanout report sheet for each structure after maintenance. Council requires this to evaluate SQID performance and device accountability;
- Contractors are required to dispose of waste material to a nominated landfill or a privately operated screening operation that offers a competitive rate per tonne. The only exception being the liquid / solid mix waste removed by vacuum from wet sump devices. This waste shall be disposed of to an approved location at Council's expense; and
- That the contractor has a proven record of Work Health and Safety (WHS) commitment, training and record keeping.

The frequency of maintenance varies between treatment measures and a majority of SQIDs need regular inspections and maintenance after each significant rainfall event. In 2012 - 2013 Hornsby Shire recorded approximately 29 large events (>10mm of rainfall in the previous 24hrs) and 2 very large events (>50mm in the previous 24hrs) which has resulted in higher yields than in previous years (refer to Appendix B for statistical data).

Larger wet vault SQIDs are inspected and maintained on a quarterly basis, whilst constructed wetlands and leachate treatment systems are maintained on a more regular schedule. Sediment basins are inspected regularly and maintained as required biennially. These basins need periodic maintenance in terms of sediment removal, bank repair or minor structural repairs. The scope of these works is based on additional quotations for specific works and upon joint inspection by Council's Assets Officer and the Contractor (Refer to **Table 3.1**).

Table 3-1 - Maintenance Operations for Stormwater Treatment Measures

Stormwater Treatment Measure	Inspection Frequency	Maintenance Frequency	Waste Destination	Reporting
GPD (end–of-pipe)	Storm event (>10mm in 48hrs)	Selective based on inspection (within 5 working days)	Council nominated site.	Within 2 weeks from completion
GPD (wet vault)	No inspection. Quarterly empty as scheduled	Quarterly empty as scheduled	Council nominated site. Liquid fraction decanted to passive open space or to an approved facility	Within 2 weeks from completion
GPD (pit insert)	Quarterly or after a Storm Event (>10mm in 48hrs)	Selective based on inspection (within 5 working days)	Council nominated site	Within 2 weeks from completion
Constructed wetlands, Leachate treatment, Bioretention	Monthly	Scheduled monthly or as required	Weed material composted onsite or disposed of to an approved facility. Sediment disposed of to a Council nominated site	Monthly
Sediment basins, Creek remediation	Biannually or after a storm event (depending on magnitude)	Selective based on inspection (within 10 working days)	Weed material composted onsite or disposed of to an approved facility. Sediment disposed of to a Council nominated site	Within 2 weeks from completion

Table 3.2 presents the efficiencies in terms of cubic metre of waste collected against the cost of maintenance in the July 2012 – June 2013 financial year for each type of device. The total clean cost for each device and average clean cost of devices emptied during this period are also presented. The table shows that reasonable efficiencies can be achieved with minimal fiscal input for devices such as Pit Inserts, Ski-Jumps and Trash Racks. Higher costs are associated with Net-Tech devices due to the fact that these devices can often release with minimal waste capture. Higher empty rates are also associated with vaults due to being reasonably labour intensive and requiring specific trucks and equipment.

Table 3-2 - SQID comparative costs from July 2012 - June 2013

Device	Total Clean Cost / Total m^3	Total Clean Cost for 2012-2013	Average Clean Cost of Devices Emptied
Net-Tech (Proprietary Net), (n=43)	$115.75/$m^3$	$4,278	$99.49
Proprietary Underground Vaults[1] (n=90)	$131.47/$m^3$	$24,705	$274.00
Litter Basket (n=11)	$93.66/$m^3$	$960	$87.00
Channel Nets (Proprietary Net), (n=45)	$83.80/$m^3$	$6,947	$154.00
Trash Rack (n=22)[2]	$58.01/$m^3$	$12,185	$270.00
Ski-Jump (Proprietary Device), (n=6)	$43.27/$m^3$	$1,060	$177.00
Pit inserts (n=329)	$49.35/$m^3$	$6,830	$21.00

[1]**Note:** Proprietary Underground Vaults include Rocla, CDS and Humeceptor Vaults.
[2]**Note:** m^3 collected included large sediment deposits upstream.
n: number of device empties

3.1.2. Bush Regeneration and Wetland Maintenance

Due to the increasing number of devices being built and the resulting demand for timely and efficient maintenance, Council has continued to engage bush regeneration contractors on a 2 year basis with an optional additional 1 year. The contracts are annually renewed based on a performance evaluation of the previous year's work and compliance with the conditions of the contract. The key objectives of the contract are:

- to maintain planted native vegetation around water quality structures and nominated wetlands, using methods that have minimal environmental impact on aquatic organisms and water quality;
- treatment and eradication of any riparian and aquatic weeds giving priority to the treatment of categorised noxious weeds, applying herbicide according to manufacturers specifications and in a responsible and recorded manner (in terms of both environmental and personal safety); and
- to provide a maintenance report for each site after treatment, including a more detailed maintenance report for the wetland sites which is required to assess the extent of plant growth and site recovery from weed infestation.

In 2012 - 2013, contractors were responsible for landscape maintenance of seventy eight sites at a cost of $106,000 (approximately 2585 hours) which covered bush regeneration activities on approximately 69,000m^2 of land managed under this contract. This involved weeding and spot spraying of the immediate area surrounding each water quality control asset including landscaped areas that have been mulched and planted with local native species. Some replacement planting and staking of existing tubestock is also required. Newly constructed devices will also require planting of terrestrial tubestock and in some cases, aquatic (macrophyte) plantings, with the majority of plant stock being supplied by Council's nursery. Maintenance reports and invoices are submitted to Council on a fortnightly basis. Targeted terrestrial weed species include - Privet, Camphor Laurel, Lantana, Blackberry, Turkey Rhubarb, Castor Oil plant, Balloon Vine, Madeira Vine, Honeysuckle, Morning Glory, Asparagus Fern, Mist Flower, Crofton Weed, Ochna, Ginger, Wandering Jew and other herbaceous weeds and grasses such as Kikuyu and Paspalum.

Wetland maintenance involves the weeding / spraying of riparian areas and removal of weeds and nuisance plants within the shallow wetland ponds. In 2012 - 2013, contractors were responsible for maintaining 16 wetland sites carrying out 1,816 maintenance hours at a cost of $71,000 (this includes four wetlands not built using funding from the CRR budget) and covered works on approximately 46,000 m2 of land and wetland under this contract. Of this, 56% was dedicated to Councils four largest wetlands (Wallumeda, Laurence Street, Hastings Road and Clarinda Street). Time is also allocated to the removal of stormwater litter / rubbish strewn throughout the pond and edge areas. Replacement planting with macrophytes is also carried out, including occasional wetland establishment at new sites. A wetland maintenance sheet is required to be completed when conducting works within wetlands, as Council requires this information for wetland condition monitoring.

Target aquatic weed species include Typha (Bullrush), Barnyard Grass, Milfoil, Watercress, *Cyperus eragrostis* and other undesirable or noxious water plants (e.g. *Ludwidgia peruviana*, Alligator Weed and Salvinia). If a W1 Noxious Weed category plant is found onsite, the Contractor is to immediately notify Council as required under the Noxious Weeds Act 1993.

3.1.3. Total Maintenance Costs

The total cost to Council to maintain its water quality improvement devices including cleaning, landscaping and wetland maintenance was approximately $381,000 in the 2012 - 2013 financial year. This included $204,000 for the cleaning of SQUIDS and disposal of waste to landfill and $177,000 for wetland maintenance and bush regeneration at the sites. Other associated costs included the monitoring and maintenance of leachate treatment facilities, tree work and staff wages.

4. Catchments Remediation Rates Assets Performance

4.1 Rainfall Measurement

Daily rainfall data is obtained from the Bureau of Meteorology at seven sites across the Shire. This data is used to examine the relationship between total yields of gross pollutants and rainfall. In 2012 - 2013 the Hornsby Council area recorded less rainfall than the 2011 - 2012 annual totals (Refer to Appendix B for statistical data).

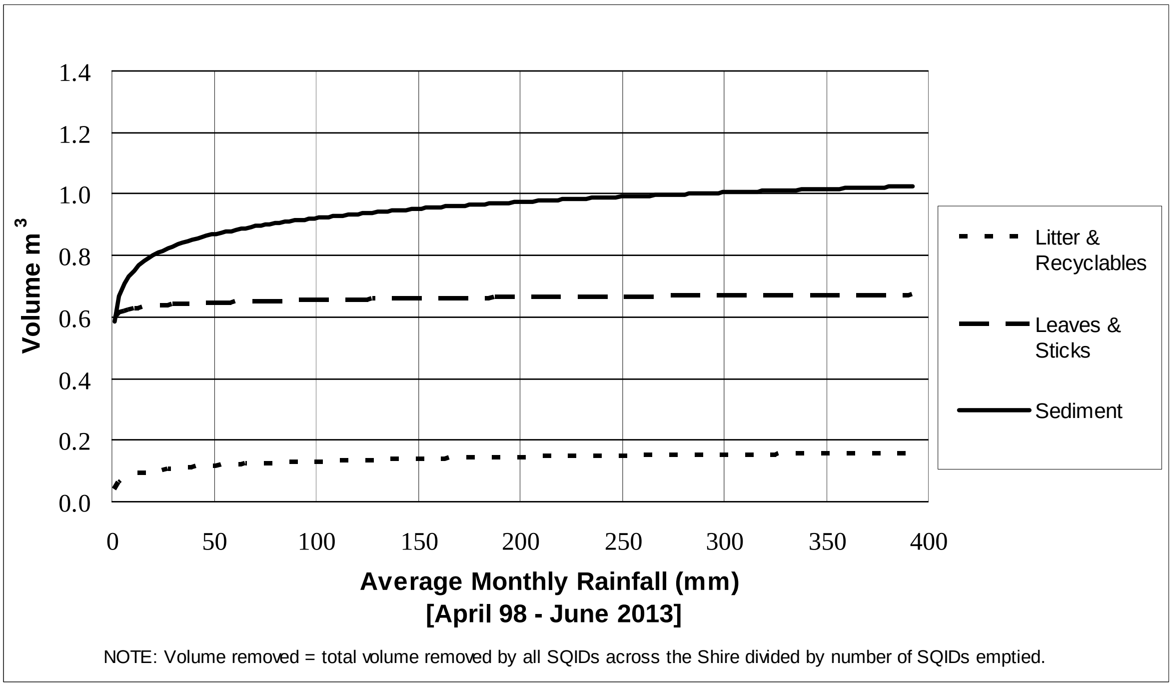
4.2 Pollutant Removal Trends

The collection of performance data over the 2012 - 2013 financial year has allowed Council to examine the indicative maintenance costs and gross pollutant removal trends for the 429 water quality improvement devices in the LGA. The results indicate that in 2012 - 2013, SQIDs have served to remove approximately 1,130 cubic metres of sediment, litter and organic matter from the Shire's waterways. These volumes were higher than the previous year which can be best explained by two anomalies:

- The elevated levels of rainfall experienced during the 2011-2012 period compared to the 2012-2013 financial year which can translate to a higher mobilisation of organic matter downstream before cleaning can be completed. This is further supported by frequent rain events often disrupting GPT maintenance schedules; and
- The high yield of sediment and organic matter resulting from the cleaning out of a number of large sediment basins in the 2012-2013 period.

The following series of figures examine the performance of SQIDs in 2012 - 2013 and against previous years.

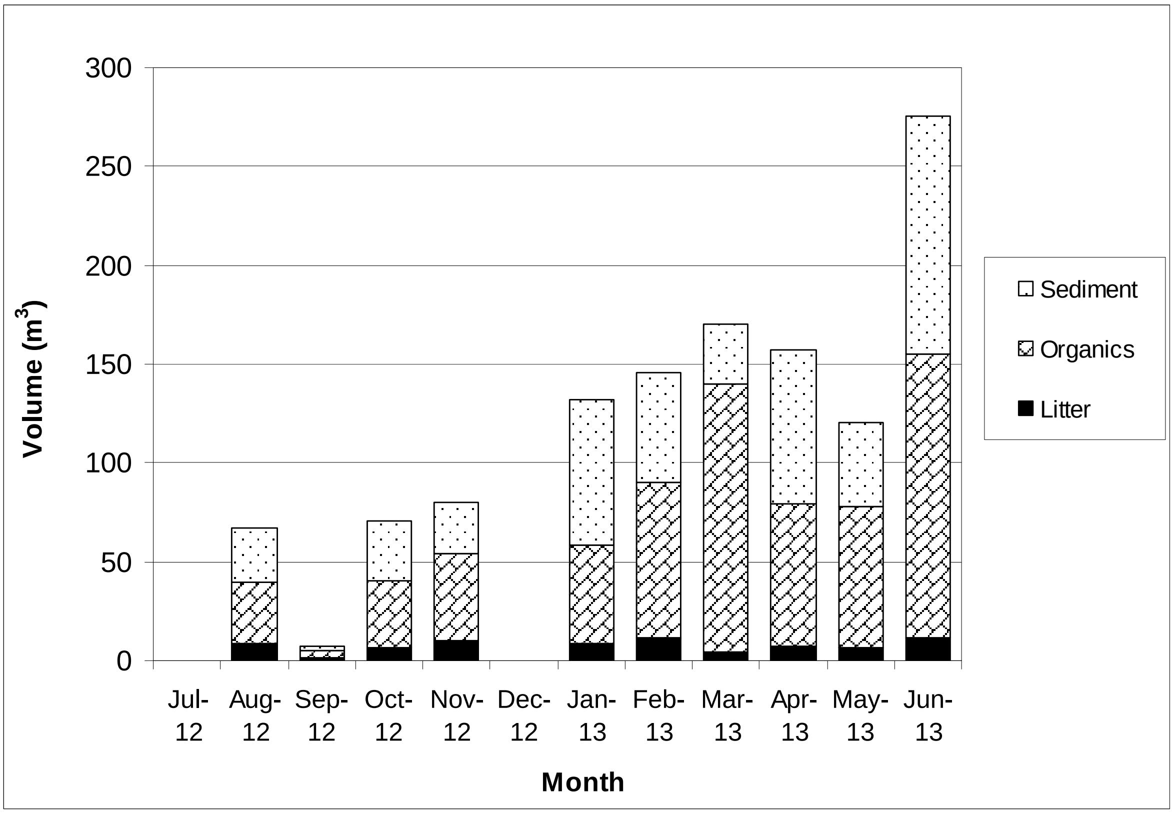
Figure 4-1 - The relationship between average monthly volume of gross pollutants and average monthly rainfall



When pollutant volume is analysed against average annual rainfall all three categories of gross pollutants are mobilised and captured after only 10 mm of rainfall as evidenced in **Figure 4.1** by the steep rise in the curve. This phenomenon is referred to as the “first flush” effect, after which the volume captured continues to rise at a much slower rate in relation to rainfall volumes.

It can be seen that the load of litter recovered from all devices over the period is fairly consistent for all size rainfall events (indicated by the relatively flat dotted line). This is most likely due to the fact that litter is readily mobile and floatable in the formal drainage system (curb, gutter and pipes) and most of it will be flushed and collected in downstream SQIDs, even in small rain events. However, the fact that the curve for sediment is steadily climbing, proportional to rainfall, illustrates that after the initial flush the transport of sediment is directly proportional to stormwater volumes and associated energy.

Figure 4-2 - Volumes of pollutants removed from SQIDs (2012 - 2013)



The actual volume of pollutants removed from month to month shown in **Figure 4.2** varied greatly in the 2012-2013 period. A clear correlation between monthly removal rates and rainfall cannot be made due to: 1) variable lag times between rainfall events and cleaning events, and 2) the disproportionally high volumes removed from sediment basins and wetlands evidenced in the June 2013 period which are in addition to regular cleaning events.

However, a strong correlation is found between rainfall and pollutant yield from Council’s SQIDs when viewed annually, as shown in **Figure 4.3**. With increased rainfall there is increased stormwater run-off into Council’s drainage system that results in pollutants being mobilised, transported and some being trapped by SQIDs. With higher rainfall it becomes difficult to carry out cleaning so devices may have bypassed resulting in the loss of some pollutant load. With the lower rainfall experienced in the 2012-2013 period there has been greater capture of pollutants due to more frequent empties. This may however be slightly skewed in the 2012 - 2013 period due to several large sediment basin and lake empties resulting in elevated capture of gross pollutants, sediment and organics.

Figure 4-3 - Pollutant volume (m3) removed from SQIDs against average annual rainfall July 2008 – June 2013

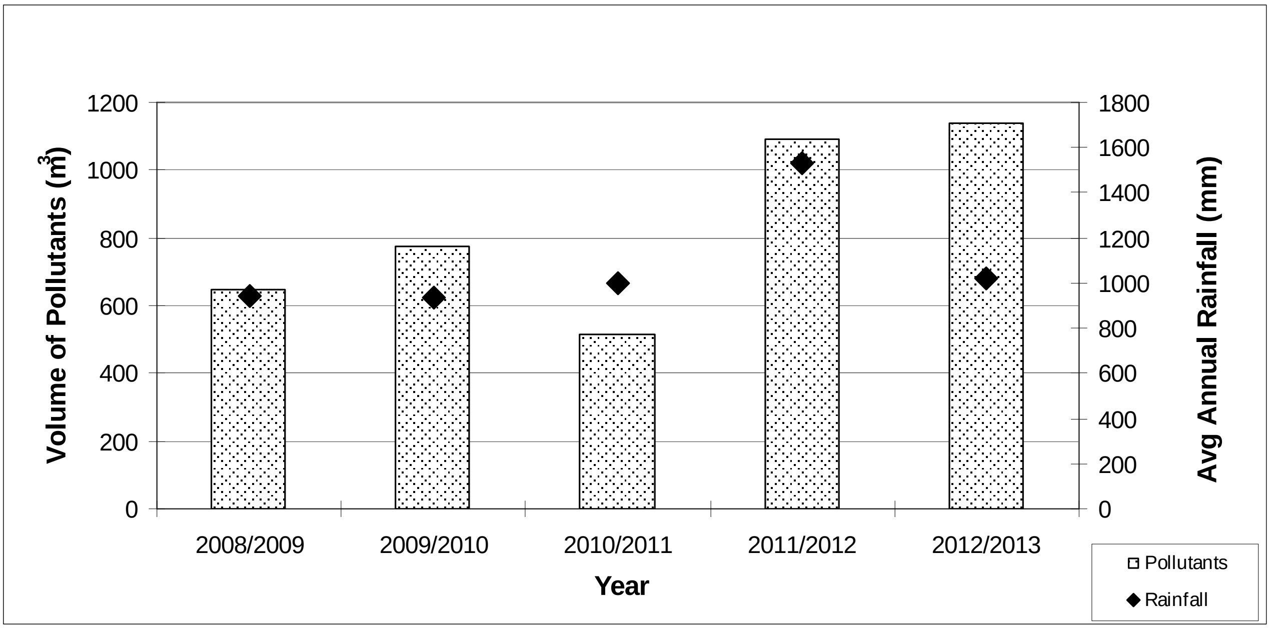
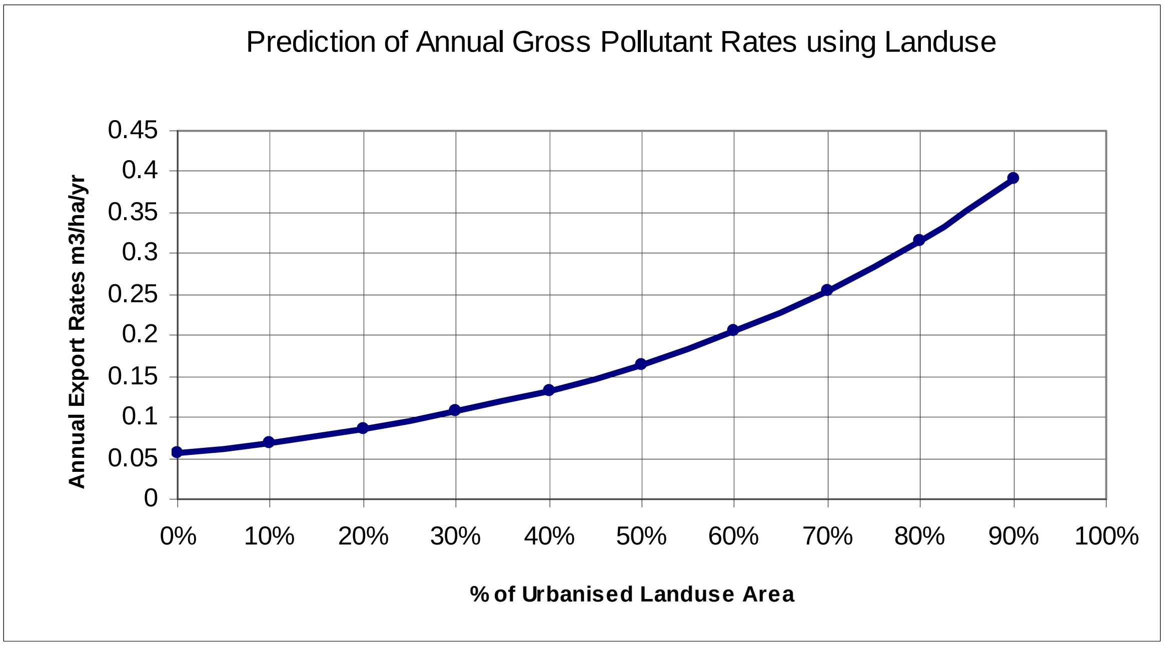


Figure 4-4 - Prediction of annual gross pollutant rates using landuse area



Hornsby Shire Council is now at a stage where the data gathered from the various SQIDs can be used to predict the annual gross pollutant (export) rates on the basis of landuse. **Figure 4.4** shows how the annual export rate of pollutants exponentially increases with the amount of catchment that is urbanised (excludes bushland / open space). This information can be used when planning for future devices, in terms of expected export rates and known device capabilities. Stormwater managers can then compare actual pollutant export rates with the predicted values in order to gauge the efficiencies of devices through time.

The high frequency of Hornsby Council's inspection and cleaning of the devices combined with the unique trap designs for ease of maintenance, ensures that the pollutant trapping efficiency is optimum for each storm event and that materials do not decompose or stagnate causing additional problems with the release of pollutants into downstream receiving waters.

4.3 Wetland Performance

4.3.1. Pollutant Removal Trends and Costs

The size of catchments draining to these constructed wetlands ranges from 15-400 hectares. The average pond surface area to catchment area ratio calculates at 0.23% which is below the minimum design size recommended by DLWC (1998) of 2% of the catchment area. It should be noted that this recommendation does not account for the variability associated with different catchment land uses, pollutant loads, peak flows, topography and soils. It is best used to determine preliminary wetland feasibility. Because the nature of Hornsby Shire is so topographically constrained (ridge top development that does not afford large areas for wetland construction) and contains significant remnant bushland, the wetland feasibility threshold is much lower than average.

Water quality monitoring of five separate systems managed by council over the past 10 years has shown that levels of total nitrogen, phosphorus, suspended solids and faecal coliforms are significantly reduced under base flow and small storm flow events. Monitoring results are based on both grab and load-based samples (and multi-probe analytes) obtained by Council over multiple rainfall events and inter-events.

4.4 Assessment of Nutrient Removal by the CRR program

The principal objective of the CRR program is to improve water quality by removing pollutants. From the beginning of the program there has always been a particular focus on the removal and/or capture of nutrients because of their known impact on aquatic ecosystems, such as creeks and estuaries.

Quantitative data recorded to date on the performance of SQIDs has primarily looked at the mass and/or volume of gross pollutants removed through maintenance. While this provides a good data source the Natural Resources Operations Team has been looking at ways that give a better indication of the amount of nutrients removed from our waterways by the CRR program.

To do so, Council has used the modelling software MUSIC (Model for Urban Stormwater Improvement Conceptualisation) and modelled all urban sub-catchments within the LGA. However, Council has found the continuous updating of these models cumbersome and that they don't truly represent all nutrient capture from GPT's and do not include the benefits of other non-structural initiatives such as street sweeping.

Consequently, Council commissioned the formulation of a tool to provide a simplified and rapid assessment of the mass of nutrients captured by the CRR Program, which explicitly included estimates of the pollutant loads captured by GPT's and street sweeping. The findings have been encouraging with the tool indicating that over 1,090kg of phosphorus and 3,400kg of nitrogen was captured and removed from our waterways in the 2012-2013 period. Furthermore, it shows that in areas where concerted catchment remediation initiatives, e.g. on-ground works and frequent street sweeping have been rolled-out the overall pollution reduction that has been achieved is relatively good (Refer to **Table 4.2**).

This will prove to be an effective tool for Council in reporting on water quality improvements over time as well as aiding in future decisions on the most appropriate devices for specific areas and situations. This will enable Council to make cost savings by choosing the best management options and will provide greater clarity as to the areas contributing the most nutrient input to the waterways.

Table 4-1 - Constructed Wetland annual costs and monitoring records to end of June 2013

Wetland (Year Built)	Capital Cost $	Pond Surface Area (m^2)	Pond Surface Area to Catchment Area (%)	Cost per m^2 of pond ($\$/m^2$)*	Average Annual Maint. Cost[2] ($/yr)	Monitoring Data (year/s)
Asquith						
Baldwin Avenue (2005)	38,000	123	0.46	325	1,925	Nil
Beecroft						
Lamorna Ave (2005)	134,000[4]	400	0.44	349	5,506	Nil
Midson Rd (2003)	252,000	1,220	0.03	209	2,402[3]	Nil
Plympton Rd (2000)	305,000	350	0.06	877	2,086[3]	Nov 99-Jun 2002
Brooklyn						
Brooklyn Rd (1997)	46,000	205	0.26	231	1,338[3]	Nil
Castle Hill						
Hastings Park (2002)	445,000	1,500	0.60	301	6,158	Jul 2001-Aug 2003
Cherrybrook						
Cherrybrook Lakes (1988)	70,000	4,615	0.58	16	1,608	2007-current
Dural						
Millstream Grove (1995)	60,000	1,014	1.06	61	2,307	Nil
Galston						
Sallaway Rd (2000)	36,000	190	0.01	193	702	Nil
Hornsby						
Clovelly Rd (1999)	117,000	210	0.02	563	1,232	Nil
Clarinda St (2001)	241,000	1,550	0.82	159	5,557[3]	Jul 2002-current
Pennant Hills						
Laurence St (1996)	135,000	225	0.06	621	4,624	Jun 1995-Jun 2002
Thornleigh						
Dartford Rd (2006)	80,000	250	2.27	326	1,538	Nil
West Pennant Hills						
Boundary Rd (1996)	288,000	1,875	0.14	159	9,857[3]	Aug 1998-Jun 2002
John Savage Cres (2004)	203,000	1,050	0.09	195	1,923[3]	Nil
Mean	**163,333**	**985**	**0.46**	**306**	**3,251**	NA

1 Includes monthly grab sampling (wet / dry) and probe (total of 13 parameters). Analysis by NATA lab
2 Includes weeding/spraying, sediment / rubbish/debris removal, planting / mulching and replacement and reporting (excludes volunteer Bushcare labour)
3 Volunteer Bushcare present onsite
4 Capital costs incorporates up to 100m of stream remediation
*Cost/m^2 of pond is calculated using capital cost and average annual cost / year

Table 4-2 - Capture of Nutrient Exports (CANUTE) in Hornsby LGA from July 2012 to June 2013

	Total Phosphorus				Total Nitrogen			
Sub-catchments	Source	To Receiving Waters	Reductions		Source	To Receiving Waters	Reductions	
	(kg)	(kg)	(kg)	(%)	(kg)	(kg)	(kg)	(%)
Berowra Creek	6,462	5,798	663	18%	72,317	70,170	2,147	7.6%
Hornsby Creek / Cowan Creek	745	597	147.9	24%	7,816	7,162	654	13%
Hawkesbury River (local total)	1,733	1,731	2.0	3.8%	14,316	14,316	0.7	0.2%
Lane Cove River	1,771	1,494	277	16%	12,902	12,304	598	5%

5. Landfill and Leachate Remediation

The Catchments Remediation Program has also been responsible for funding the treatment of polluted leachate from two of the Shire's largest former municipal tip sites at Arcadia Park, Arcadia and Foxglove Oval, Mt Colah. Instead of using the traditional technologies available for the treatment of leachate, Council has looked to more sustainable and innovative methods that can achieve pollution reductions and serve as a model for leachate treatment at a local government, state and national level.

This work is significant by way of the methodology which mimics natural processes of nitrification and denitrification. Council staff have worked together in a trans-disciplinary manner, together with specialised scientific consultants to design, construct and monitor both treatment systems. Council is committed to the long-term maintenance, monitoring and management of the two facilities in order to justify and apply the technological benefits to other landfills within the Shire. Monitoring to date has revealed a dramatic reduction in ammonia which has maximised the opportunities for reuse on adjoining open space and landscapes.

Monitoring results illustrating the high level of treatment achieved by the system can be viewed in the "Water Quality Monitoring Program 2012 – 2013 Annual Report".

6. Catchments Remediation Rate Environmental Education

Environmental education is delivered by Council's Catchment Remediation Education Officer to rate payers, residents, local business & industry, community groups, council staff, teachers and students within the Shire.

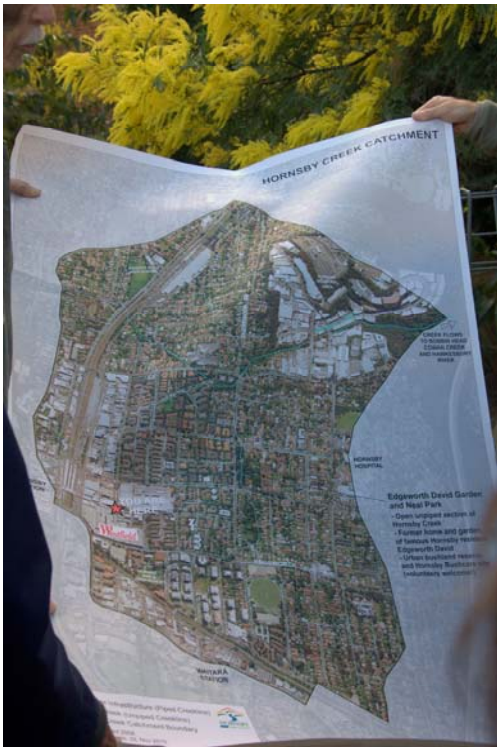
The definition of "environmental education" generally refers to organised efforts to teach about how natural environments function and, particularly, how human beings can manage their behaviour and ecosystems in order to live sustainably.

In the context of the Catchments Remediation Program, council's environmental education activities generally focus on promoting community awareness of:

- CRR-funded capital works program
- Stormwater quality improvement devices
- Hornsby's water quality monitoring program
- Hornsby's catchments, creeks and estuarine areas
- Total water cycle management
- Stormwater pollution
- Stormwater harvesting
- Water conservation
- Catchment care personal actions

Activities undertaken by the Catchment Remediation Education Officer have included:

- CRR Promotion at Community Events
- Hosting stalls and displays at various community events, such as
    - Bushland Festival
    - Berowra Woodchop Festival
    - Brooklyn Spring Fair
    - Hornsby's Christmas Spectacular
    - Hornsby TAFE Environmental Expo
    - Council's Native Plant Giveaways
- Media campaigns
- Promotional Material
    - developing print material and website content
    - preparing case studies of CRR devices
    - interpretive signage
- Catchment tours
- Guided tours promoting the CRR program and capital works installed
- Workshops
- Rainwater tank and grey water awareness workshops
- Schools program
- Hornsby Environment Network for Schools (HENS)
- School presentations
- Resource materials for school assignments
- Streamwatch water quality monitoring support
- Lane Cove River Catchment Day
- Grant funded projects
- Water for Life Council Partnership Kit (stormwater awareness)
- Catchment Connections (stormwater and catchment awareness)
- Tankscape – Rainwater Tanks in Schools Program
- Hornsby Creek Catchment Urban Sustainability Program



Environmental education is a learning process that increases people's knowledge and awareness about the environment and associated challenges, develops the necessary skills and expertise to address the challenges, and fosters attitudes, motivations, and commitments to make informed decisions and take responsible action (UNESCO, Tbilisi Declaration, 1978).

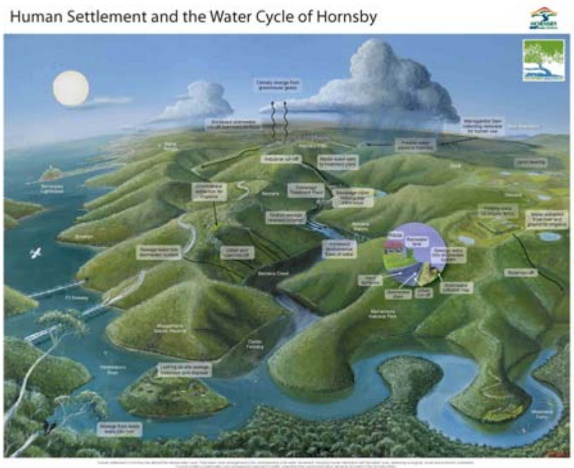


Plate 19-21 Educational Initiatives

(top to bottom)

Catchment Tour of CRR Bioretention Basin

Display material for Catchment Tour

Catchment Learning Resources

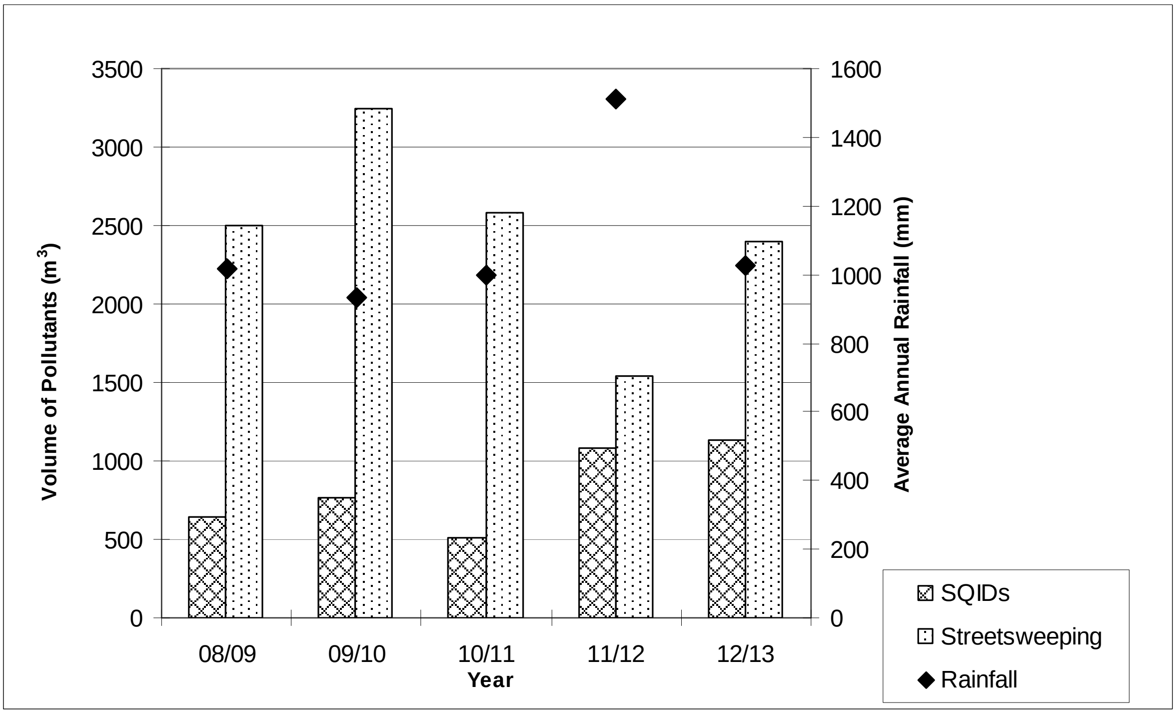
7. Street Sweeping

Since 1997, the Catchments Remediation Rate (CRR) has funded a proportion of Council's Street Sweeping Program at a total cost of $233,000 per year. Street sweeping is an effective method by which gross pollutants (sediment, leaves and litter) can be collected at source by targeting problem leaf drop areas and high pollutant load land use areas, e.g. commercial and industrial.

In 2012 - 2013, 2,400 cubic metres of material was collected from scheduled cleaning of roadside curb and guttering. This is a marked increase on the 1,536 cubic metres collected in the 2011-2012 financial year potentially due to the lower level of rainfall during 2012-2013 resulting in a reduction in delivery of this matter into nearby stormwater drains and on to streams and creeks.

Figure 7.1 compares volumes extracted by SQIDs against street sweeping. Interestingly, when comparing street sweeping in 2011-2012 to that for 2012-2013, the higher rainfall experienced in 2011-2012 appears to have resulted in lower street sweeping collection. This can be attributed to greater movement of litter from gutters into gross pollutant devices before street sweepers can collect this waste. Additionally, higher rainfall has potentially resulted in less bark and leaf drop from street trees and therefore less for street sweepers to collect.

Figure 7-1 - Pollution yield (m^3) extracted by SQIDs and street sweeping against average annual rainfall July 2008 – June 2013



8. Conclusions

This report has aimed to provide quantitative data and analysis of the relative performance of different water quality treatment measures, including GPD's, sediment basins, wetlands and bioretention systems that have been constructed to improve stormwater quality in Hornsby Shire. The results of the report can be used by stormwater and catchment managers to provide a better insight into determining the type of structure and suitability for specific sites. Furthermore, the data provides valuable information about the costs (both capital and maintenance), benefits and device optimisation which can aid in the formulation of strategies to improve catchment / landuse practices by both structural and non-structural means.

Overall, the findings of this report should give stormwater managers a better insight into the cost-effectiveness and performance of water quality improvement structures and the management of life-cycle costs for individual stormwater quality assets. The performance of these devices has allowed Council to both refine and modify future designs, and judge their appropriateness to proposed remediation sites based on catchment size and land use impacts.

9. References

Australian Bureau of Statistics (2011). Population Estimates by Local Government Area, 2001 to 2010. Report 3218.0.

Brisbane City Council (2006). Water Sensitive Urban Design – Technical Design Guidelines for South East Queensland. Version 1 released June 2006.

Collins, A. (2005). Stormwater Reuse Issues and Experiences – Hornsby Shire Council. Stormwater Industry Association 2005 Regional Conference, Port Macquarie, NSW, 20-22 April (12pp).

Cooperative Research Centre for Catchment Hydrology (2003). Model for Urban Stormwater Improvement Conceptualisation (MUSIC). Version 2 released December 2003.

Walsh et al (2004) Urban Stormwater and Ecology of Streams Cooperative Research Centre Freshwater Ecology and Catchment Hydrology

DLWC (1998). The Constructed Wetlands Manual – Volumes 1&2.

EPA (1999). Environmental Guidelines: Assessment, Classification and Management of Liquid and Non-Liquid Wastes.

Engineers Australia (2006) Australian Runoff Quality Engineers Media

Hatt, B et al (2006) Filter media for stormwater treatment and recycling: the influence of hydraulic properties of flow on pollutant removal Water, Science and Technology IWA Publishing

Hornsby Shire Council (1997). Catchments Remediation Program Five Year Plan (Revised Edition). Report prepared by The Water Catchments Team.

Hornsby Shire Council (2012). Catchments Remediation Rate Capital Works Program 2011 – 2012 Annual Report. Prepared by The Water Catchments Team, October 2012.

Hornsby Shire Council (2012). Water Quality Monitoring Program 2011 – 2012 Annual Report. Prepared by The Water Catchments Branch, October 2012.

Hornsby Shire Council (2006). Draft Stormwater Drainage Asset Management Plan. Prepared by the Water Catchments and Assets Branches, May 2006.

Rocla CDS® Technologies Pty Ltd, Gross Pollutant Traps Product Brochure, November 2007.

University of Technology, Sydney (2004). Environmental Assessment of HydroCon Stormwater Infiltration Systems at Hornsby. Faculty of Engineering.

Victoria Stormwater Committee (1999). Urban Stormwater: Best practise environmental management. CSIRO

WBM Oceanics (2005). Maintenance Guidelines for Stormwater Treatment Measures. Final Report January 2005. Prepared for Hornsby Shire Council under NSW Stormwater Trust funding.

Knights, D, Beharrell, D Jonasson, J (2010) What does it cost to build a water quality treatment system? Findings from Council retrofits in Sydney. Stormwater Industry Association 2010 National Conference, Sydney, NSW July 2010

Appendix A - SQUID Site Locations

Stormwater Quality Improvement Devices Non - Proprietary (35)

Trash Racks (24)

Beecroft
Norwood Avenue

Berowra
Berkeley Close
The Gully Road

Berowra Heights
Warrina Street

Castle Hill
Belltree Place

Cheltenham
Castle Howard Road

Cherrybrook
Woodgrove Road
Odney Close
Flametree Crescent (2)

Epping
Beecroft Road

Glenorie
Tekapo Road

Hornsby
Northcote Road
Water Street
Clarinda Street
Malsbury Road
Old Berowra Road

Mt Kuring-gai
Hamley Road

Normanhurst
Denman Parade

Pennant Hills
Bellamy Street

Thornleigh
The Comenarra Parkway
Larool Crescent

West Pennant Hills
New Farm Road
Wilga Street

Litter Baskets (11)

Asquith
Mittabah Road

Beecroft
Sutherland Road

Berowra
Bambil Road x 3

Berowra Heights
Berowra Waters Road

Cherrybrook
Shepherds & Macquarie Drives

Hornsby
Clovelly Road
Sherbrook Road

Thornleigh
The Comenarra Parkway
Janet Avenue

Stormwater Quality Improvement Devices (SQIDs) - Proprietary (275)

Net Techs / Pratten Nets / Channel Nets (74)

Asquith
Baldwin Avenue
Stratford Place

Berowra
Boundary Street x 3
Ti Tree Crescent

Berowra Heights
Currawong Road x 2
Joalah Crescent

Castle Hill
Childrey Place

Cheltenham
Castle Howard Road x 2
Kirkham Road x 2

Cherrybrook
Gavin Street
Glenoak Way
Kenburn Avenue
New Line Road x 5
Pecan Close

Cowan
Alberta Avenue

Dural
James Henty Drive
New Line Road x 3

Epping
Brucedale Road x 2
Ridge Street
Stanley Street

Hornsby
Burdett Street x 8
Clarinda Road
Pacific Highway
Rosemead Road x 2
Sherbrook Road
Binya Close

Hornsby Heights
Galston Road x 5
Raphael Drive

Mount Colah
Jessica Place
Murralong Road x 2
Parklands Road

Mount Kuringai
Gundah Road x 2
Pacific Highway x 5

Normanhurst
Hinemoa Avenue

Pennant Hills
Brittania Street x 2
Morrison Place x 2

Thornleigh
Blantyre Place x 2

Westleigh
Duneba Drive x 3
Russell Crescent

Underground Vaults (25)

Asquith
Dudley Street
Gardenia Street

Beecroft
Jacinta Avenue

Berowra
The Gully Road

Berowra Heights
Woodcourt Road

Berowra Waters
Dusthole Bay

Brooklyn
Dangar Road
George Street

Castle Hill
Foley Place

Cheltenham
Castle Howard Road

Cherrybrook
Greenway Park
Millbrook Place
Monterey Place
Rosemary Place

Dural
Lockyer Close

Eastwood
Blaxland Road (Somerville Park)

Epping
Somerset Street

Hornsby
Hunter Street

Hornsby Heights
Pike Road

North Epping
Boundary Road

Thornleigh
Dartford Road x 2
Sefton Road

Waitara
Unwin Road

West Pennant Hills
Cardinal Avenue

Ski-Jump Litter Traps (4)

Carlingford
Anthony Street

Hornsby Heights
Off Heights Place

Pennant Hills
George Street

Wisemans Ferry
Old Northern Road

Pit Inserts (172)

Beecroft / Carlingford / Epping
Various Locations (35)

Asquith
Mills Park Tennis Carpark
Wattle Street (3)

Berowra
Berowra Waters Road & Pacific Hwy (4)

Berowra Waters
Dusthole Bay

Brooklyn
Brooklyn Road (5)

Eastwood
Blaxland Road (Somerville Park) (2)

Glenorie
Cairnes Road

Hornsby
Hornsby Industrial area (20)
Dural Street (3)
CBD Various Locations (70)

Mount Colah
Pacific Highway
Sue Place (2)

Normanhurst
Denman Road (2)

Pennant Hills
Commercial area (4)

Thornleigh
Industrial / Commercial Zone (11)

Waitara
Thomas and Orara Streets (6)

Westleigh
Eucalyptus Drive

Bioretention Systems, Streetscape Raingardens, Tree Pit Bioretention and Stormwater Reuse Bioretention (60)

Bioretention Systems/Basins (21)

Berowra
Boundary Street

Berowra Heights
Currawong Road

Cheltenham
Castle Howard Road
Lyne Road

Cherrybrook
Lawson Place

Glenorie
Tecoma Drive

Hornsby
Stewart Avenue

Hornsby Heights
Margaret Avenue
Oorin Road
Peter Close
Spedding Road

Mount Colah
Parish Place

Mount Kuringai
Gundah Road

North Epping
Belinda Crescent
Malton Road
Braidwood Avenue
Eastcoate Avenue

Pennant Hills
Albion Street
Blackbutt Avenue

West Pennant Hills
Bellamy Street

Westleigh
Apanie Avenue

Streetscape Raingardens (21)

Berowra Heights
Turner Road (6)
Brooklyn
George Street (4)

Epping
Ray Road (4)
Cowan
View Street

Waitara
Alexandria Parade (4)
Galston
Fagan Park (2)

Tree Pit Bioretention (17)

Epping
Oxford Street (13)

Hornsby
Coronation Avenue (4)

Stormwater Reuse Bioretention (1)

Thornleigh
Dawson Avenue

Sediment Basins (68)

Asquith (1)
Beecroft (2)
Berowra (6)
Berowra Heights (1)
Cheltenham (5)
Cherrybrook (14)
Cowan (1)
Dural (2)
Epping (7)
Epping North (1)
Glenorie (1)
Hornsby (3)
Hornsby Heights (2)
Mount Colah (5)
Mount Kuringai (2)
Normanhurst (2)
Pennant Hills (3)
Thornleigh (4)
West Hornsby (1)
Westleigh (5)

Constructed Wetlands (13)

Beecroft
Lamorna Avenue
Midson Road
Plympton Road

Brooklyn
Brooklyn Road

Castle Hill
Hastings Park

Epping
Ridge Street

Galston
Sallaway Road

Hornsby
Clarinda Street
Clovelly Road

Pennant Hills
Laurence Street

Thornleigh
Dartford Road

West Pennant Hills
John Savage Crescent
Boundary Road

Developer Constructed Wetlands (10)

Berowra
Summer Hill Way

Castle Hill
Foley Place

Cherrybrook
Shepherds Drive (The Lakes)**

Dural
Millstream Grove

Hornsby Heights
Sydney Road**
The Outlook**

Mount Colah
Kalang Road**

Thornleigh
Huntingdale Way
Wild Ash Avenue

Westleigh
The Sanctuary

** Council managed

Stream Remediation Projects (47)

Berowra Creek Catchment	Hawkesbury River Catchment
Berowra - Boundary Street - Gwandalan Crescent Berowra Heights - Wymah Road Castle Hill - Hastings Park Cherrybrook - Woodgrove Road Glenorie - Tecoma Drive Hornsby - Clarinda Street - Reddy Park - Stewart Avenue Hornsby Heights - Heights Place Mount Colah - Murralong Road - Parrish Place - Parklands Road Pennant Hills - Albion Street - Laurence Street West Pennant Hills - John Savage Crescent - Wearne Avenue - Wilga Street Westleigh - Duneba Drive - Eloura Road Cherrybrook - Lakes of Cherrybrook	Brooklyn - Brooklyn Road
Cowan Catchment	**Lane Cove River Catchment**
Hornsby - **Sherbrook Road (Northcote end)**	Beecroft - Fearnley Park - Lamorna Avenue - Midson Road - Norwood Avenue - Plympton Road - Ray Park Carlingford - Anthony Street Cheltenham - Castle Howard Road - Kirkham Street - Lyne Road Cherrybrook - Flametree Crescent Epping - Brucedale Avenue - Kent Street - Ridge Street (east) - Ridge Street (west) - Pembroke Road - Stanley Street - Essex Street Normanhurst - Hinemoa Avenue - Nicholas Crescent North Epping - Belinda Crescent Pennant Hills - Orchard Street Thornleigh - The Comenarra Parkway - Thornleigh Street

Appendix B - Rainfall Data for Hornsby LGA

Location and Sources of Rainfall Data (BOM 2013)

Monthly / Annual Rainfall For Hornsby Shire (mm)								
Location and BOM Station No.s	Parramatta North 66124	Hornsby Pool 67065	Maroota 67014	Glenorie 67010	Pennant Hills 66047	Wisemans Ferry 61119	Wahroonga 66211	Monthly Average
Jul	30	42	17	20	33	15	32	**27**
Aug	10	5	8	4	7	7	6	**7**
Sep	27	33	64	47	29	29	36	**38**
Oct	31	36	26	28	32	19	39	**30**
Nov	42	54	57	35	48	64	57	**51**
Dec	39	50	79	45	55	77	57	**57**
Jan	115	166	164	147	166	175	193	**161**
Feb	148	193	237	160	195	225	220	**197**
Mar	11	91	131	98	103	151	100	**98**
Apr	69	124	87	113	131	85	156	**109**
May	44	84	60	82	80	60	105	**73**
Jun	185	206	131	117	218	97	241	**171**
TOTAL	**750**	**1081**	**1059**	**897**	**1097**	**1004**	**1241**	**N/A**

Note: Shaded monthly totals have not been quality assured.

Average rainfall and average number of days exceeding 10mm and 50mm of rain for 7 sites across the Shire 2012 - 2013. (Note: Figures in brackets are for 2011 - 2012)

Month	Average Monthly Rainfall 2012 - 2013 (mm)	Average No. of Days >10mm rain	Average No. of Days >50mm rain
Jul	27 (145)	1 (4)	0 (1)
Aug	7 (75)	0 (1)	0 (0)
Sep	38 (100)	1 (3)	0 (1)
Oct	30 (56)	1 (2)	0 (0)
Nov	51 (144)	2 (5)	0 (0)
Dec	57 (134)	1 (4)	0 (1)
Jan	161 (191)	3 (5)	1 (1)
Feb	197 (181)	4 (6)	1(0)
Mar	98 (185)	3 (7)	0 (1)
Apr	109 (161)	4 (3)	0 (2)
May	73 (19)	2 (1)	0 (0)
Jun	171 (137)	7 (3)	0 (1)
Total	**NA**	**29 (41)**	**2 (7)**

All Sites - Average Annual Rainfall vs 2012 - 2013 Annual Rainfall*

Sites	Maximums, Minimums and Average Annual Rainfall	2012 - 2013 Annual Total
Parramatta North - 66124	Since 1966 (Excluding 2 years of data) Maximum: 1713mm (1990) Minimum: 513mm (1979) Average: 969mm	750mm
Hornsby Pool – 67065	Since 2009 Maximum: 1349mm (2011) Minimum: 962mm (2009) Average: 1161mm	1081mm
Maroota – 67014	Since 1926 (Excluding 30 years of data) Maximum: 1773mm (1950) Minimum: 354mm (1953) Average: 912mm	1059mm
Glenorie – 67010	Since 1961 (Excluding 3 years of data) Maximum: 1681mm (1950) Minimum: 386mm (1944) Average: 987mm	897mm
Pennant Hills – 66047	Since 1901 (Excluding 62 years of data) Maximum: 2035mm (1950) Minimum: 573mm (1941) Average: 1057mm	1097mm
Wisemans Ferry – 61119	Since 1906 (Excluding 51 years of data) Maximum: 1498mm (1988) Minimum: 437mm (1906) Average: 855mm	1004mm
Wahroonga – 66211	Since 2011 (Excluding 0 years of data) Maximum: 1643mm (2011) Minimum: 1350mm (2012) Average: 1496mm	1241mm

*Note - Some data has been excluded as not quality assured by the BOM.
- Data totals up to 2012 from Jan-Dec, 2012-2013 annual totals from Jul 2012-Jun 2013.