Addressing wastewater overflows in catchment management planning

A. McAuley[1] and D Knights[1]

[1] Equatica

Catchment management plans are typically prepared with an over-arching goal to improve the health of receiving waterways. This may involve addressing flows, pollutant loads, water quality and physical condition. It is well known that urban stormwater has significant negative impacts on receiving waterways, including increased runoff, peak flows and pollutant loads. Therefore it is logical that urban catchment management plans should have a strong stormwater management focus. Increasingly, local authorities are taking an holistic approach to urban catchment management, considering all facets of the water cycle including mains water, wastewater and stormwater.

This paper explores the relative pollutant load contribution from stormwater and wastewater overflows in urban catchments of Sydney. The paper looks at five different catchments, where catchment management plans have recently been or are currently being prepared. Modelling and quantitative analysis for each catchment has allowed a comparison between pollutant loads (including suspended solids, nutrients and pathogens) from stormwater with those from wastewater overflows. The analysis allowed catchment managers to understand whether more effort should be directed towards reducing wastewater overflows, or whether to maintain the focus on stormwater flows and pollutant loads.

In addition to the findings from these catchments, this paper also presents a method for catchment managers to undertake similar analysis elsewhere.

1 Introduction

As a key land manager in urban areas, local government has an important role to play in catchment management. Catchment management in urban areas has traditionally focused on stormwater – for example in the 1990s, the NSW EPA required all local governments in NSW to prepare stormwater management plans, which were focused on a single facet of the urban water cycle. Today, many local governments have broadened their focus from stormwater management to water cycle management, including drinking water and wastewater streams. This approach encourages local government catchment managers to engage with water cycle management issues beyond their traditional area of focus, including water supply and wastewater management issues.

The key driver for catchment management remains environmental protection, with the overarching goal to improve waterway health. Therefore catchment managers seek to understand the key issues affecting waterway health, and to identify the most appropriate actions to improve waterway health.

Over the last three years, Equatica has worked on many local government projects with a catchment management focus, including several catchment management plans. One of the common objectives for many of these projects has been to define the relative importance of wastewater overflows and stormwater runoff in the catchment. In some cases, wastewater overflows were thought to be a significant problem in the catchment; however it was not known how these overflows compared with stormwater in terms of pollutant loads.

2 Objectives

This paper brings together a selected set of results from five different catchment management projects across Sydney, where we have studied the relative importance of stormwater and wastewater overflows. The objectives of each project differed, however this paper draws on the parallels between each project to elucidate some common lessons with relevance to all urban catchment managers.

The objectives of this paper are to:

- Compare pollutant loads from stormwater runoff and wastewater overflows in five typical urban catchments in Sydney
- Present a method for this process, which can be applied to other urban catchments
- Discuss the implications for urban catchment managers

3 Background

The five catchments which formed part of this study are shown in Figure 1, with key catchment characteristics summarised in Table 1. All of the catchments are predominantly residential. The nature of the development is briefly described as follows:

- **Tennyson Street**: Urban development occurred around the 1890s to 1920s. Significant sections of the catchment have been redeveloped, and the catchment now contains a mix of flats, detached and semi-detached dwellings.
- **Manly Lagoon**: This catchment is largely residential but also includes some commercial & industrial development as well as approximately 24% bushland. Urban development occurred from the 1900s to 1950s.
- **Yeramba Lagoon**: Urban development occurred around the 1950s. Small areas have been redeveloped, including townhouses, but most of the catchment remains detached dwellings. The catchment includes 46% bushland.
- **Gordon Creek**: Urban development occurred from the 1890s to 1950s. Some redevelopment has occurred but the catchment remains largely detached residential. The catchment includes approximately 27% bushland.
- **Lovers Jump Creek**: Urban development occurred from the 1890s to 1950s. Some redevelopment has occurred but the catchment remains largely detached residential. The catchment includes approximately 21% bushland.

The Tennyson Street catchment drains into an estuarine reach of the Cooks River. Both the Manly Lagoon and Yeramba Lagoon catchments, as their names suggest, drain into permanent water bodies. Manly Lagoon is a natural estuarine system, while Yeramba Lagoon is a freshwater system created by a man-made weir. It is located adjacent to the Georges River. Gordon Creek and Lovers Jump Creek are small freshwater streams which drain into Middle Harbour Creek estuary and Cowan Creek estuary respectively. While the catchment management issues differ in each case, water quality is an important issue in each receiving water.

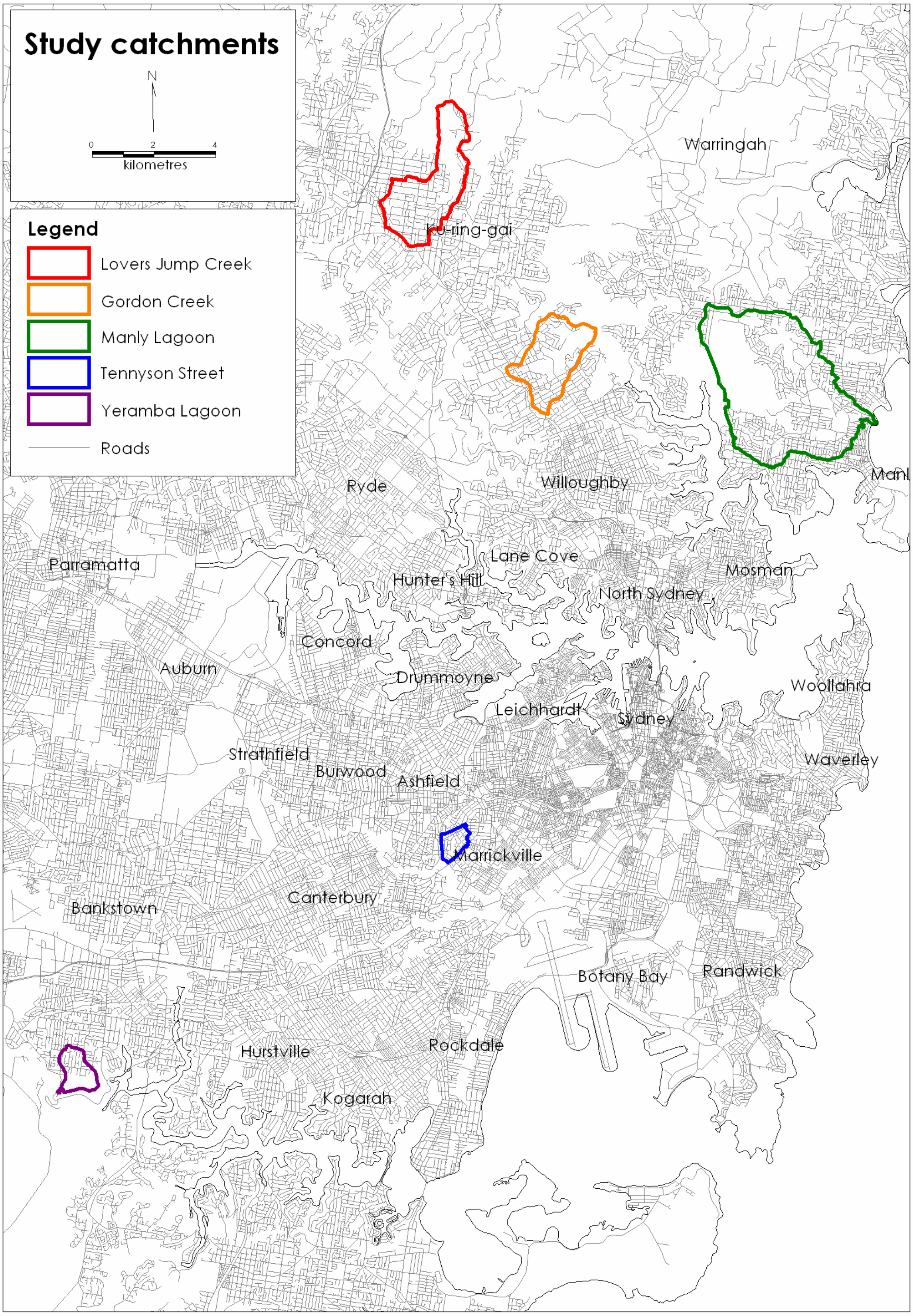

Figure 1: Study catchments

Table 1: Summary of catchment characteristics

Catchment name	Suburbs	Whole Catchment		Urban Area	
		Area (ha)	Impervious fraction	Area (ha)	Impervious fraction
Tennyson Street	Dulwich Hill	71	72%	71	72%
Manly Lagoon	Allambie Manly Vale North Balgowlah	1808	55%	1375	72%
Yeramba Lagoon	Picnic Point	128	32%	69	59%
Gordon Creek	Lindfield Roseville	453	40%	330	55%
Lovers Jump Creek	Turramurra Wahroonga	623	35%	493	44%

The studies in which we investigated each catchment were:

- "Tennyson Street Subcatchment Management Plan" (prepared by Equatica for Marrickville Council, June 2009)
- "Manly Lagoon Catchment – Annual Sediment and Pollutant Loading" (prepared by Equatica for Warringah Council, January 2011)
- "Yeramba Lagoon Concept Design for Weir Modification" (prepared by Equatica for Bankstown Council, March 2011)
- Gordon Creek and Lovers Jump Creek sustainable water management feasibility study and concept designs (project currently underway for Ku-ring-gai Council)

4 Method

Within each catchment, we made an estimate of the mean annual loads of pollutants derived from stormwater and wastewater overflows. This included suspended solids, nitrogen and phosphorus. In the Manly Lagoon catchment, we also estimated faecal coliform loads. The method was essentially the same in each catchment and is summarised in this section.

Stormwater pollutant loads

Stormwater pollutants are transported in the urban environment via a process of build-up and wash-off (Engineers Australia 2006). Build-up is the process by which pollutants accumulate on impervious surfaces via dry deposition between rainfall events. Wash-off is the process by which accumulated pollutants are removed from impervious surfaces during rainfall. Pollutants are entrained in surface runoff and conveyed to receiving waters in the stormwater system.

Pollutant concentrations in stormwater vary significantly between and also within individual storm events, and a large data set is required to obtain an accurate picture of stormwater quality. However (like many environmental variables), stormwater pollutant concentrations consistently fall within a log-normal distribution, and it is possible to describe this by way of a mean and standard deviation.

A comprehensive review of stormwater quality in urban catchments was undertaken by Duncan (1999). Duncan reviewed over 500 literature studies on stormwater runoff quality from both Australia and overseas to determine typical pollutant concentrations for various land uses. Duncan's data set is summarised in *Australian Runoff Quality* (Engineers Australia 2006) as well as in Fletcher et al (2004). Both of these sources were used to define stormflow pollutant concentrations for the study catchments. Typical event mean concentrations for key parameters are shown in Table 2.

Table 2: Typical stormwater quality (Fletcher et al 2004)

Constituent	Event mean concentrations		
	Residential Catchments	**Commercial/ Industrial Catchments**	**Natural/ Forested catchments**
Total suspended solids (mg/L)	140	140	40
Total phosphorus (mg/L)	0.25	0.25	0.08
Total nitrogen (mg/L)	2.0	2.0	0.9
Faecal coliforms (cfu/100 mL)	20,000	4,000	600

Stormwater pollutant loads depend on both the concentration in runoff and the quantity of runoff. In all of the catchments in this study, the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was used to estimate runoff volumes. MUSIC incorporates a continuous simulation rainfall-runoff model as well as pollutant parameters. Based on a given mean and standard deviation for pollutant concentrations in stormflow and baseflow, MUSIC generates pollutant concentrations stochastically within a log-normal distribution. The model is set up to simulate suspended solids, phosphorus and nitrogen, but can also be used to simulate other pollutants.

MUSIC was set up using at least 25 years of daily rainfall data for each catchment. The most suitable rainfall station was selected based on proximity to each catchment and the length and quality of the data set. Impervious areas were broken down into roads, roofs and other surfaces and modelled separately, with different pollutant parameters according to the type of surface. Where possible, local data was used to set rainfall-runoff (soil) parameters in MUSIC, however these parameters are only important for pervious area runoff, and in urban areas impervious runoff always dominates stormwater flows and pollutant loads.

Wastewater overflow pollutant loads

Wastewater overflows can occur in dry weather or wet weather. Dry weather overflows occur when there is a problem such as a blockage in the wastewater system, or mechanical failure at a pumping station. Dry weather overflows are generally less frequent and less voluminous than wet weather overflows and rarely reach waterways. Any dry weather overflows which reach a waterway are reported to the NSW Office of Environment and Heritage (OEH). Wet weather overflows occur when stormwater flows enter the wastewater system and cause flows in the sewer to exceed the system capacity. Stormwater enters the wastewater system when surface openings are flooded, through direct stormwater to wastewater system connections and infiltration from saturated soils.

Wastewater systems can have a large number of points where stormwater can enter and it is very difficult to find these to address the problem at its source. They occur equally throughout public and privately owned sections of the wastewater system.

To reduce the wet weather overflow to inhabited areas, relief points are included on the sewer. The points, called emergency relief structures, direct the excess flows to stormwater drains and waterways. The inclusion of relief structures is not always sufficient and discharges can also occur in an uncontrolled manner from surface openings including property gullies and maintenance chambers.

Sydney Water has a large wastewater overflow abatement program that is prioritised by impact on properties, swimming sites and the ecosystem, in that order. The frequency and volume of wastewater overflows in an area are key indicators to characterise the overflow performance. Sewer models are a planning tool used by Sydney Water to estimate the level of these indicators and investigate the benefits of overflow abatement options.

Sydney Water has developed hydraulic models of the sewer system as part of their Sewer Catchment Area Management Plans (SCAMPs). The SCAMP models include the higher flow sewers that account for about 15% of the sewers by length and all the sewers downstream of an emergency relief structure. The land area included in each model is about 100 to 500 hectares. The models can be run for a period of rainfall and the discharge from the emergency relief structures is predicted. The period from 1985 to 1994, a period of fairly typical rainfall, is used as the "yard stick" for long term average performance.

Sydney Water provided overflow frequency and volume predictions for the 1985 to 1994 period for each of the study catchments discussed in this paper. This is a calibrated and validated dataset used by Sydney Water for modelling. We have then estimated pollutant loads by applying typical wet weather overflow pollutant concentrations as shown in Table 3.

Table 3: Typical Sydney Wastewater Quality (Sydney Water, 1997)

Constituent	Dry weather wastewater flows	Wet weather overflow
Suspended Solids (mg/L)	300	90
Biological Oxygen Demand (mg/L)	275	80
Nitrogen (mg/L)	55	20
Phosphorus (mg/L)	12	4
Faecal coliforms (cfu/100 mL)	$1x10^7$	$1x10^6$

5 Results

A summary of results for total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN) and faecal coliforms is presented in Table 4 to Table 7. Each table compares the contribution to pollutant loads from stormwater and wastewater overflows within each catchment.

The results show that within the study catchments:

- 0.1 to 0.6% of TSS loads are derived from wastewater overflows
- 2-11% of TP loads are derived from wastewater overflows

- 1-8% of TN loads are derived from wastewater overflows
- 17-49% of faecal coliform loads are derived from wastewater overflows

Table 4: Total Suspended Solids (TSS) loads

Catchment	Stormwater contribution (tonnes/year)	Wastewater overflow contribution (tonnes/year)	Proportion from wastewater overflows
Tennyson Street	113	0.4	0.4%
Manly Lagoon	3,500	2.3	0.1%
Yeramba Lagoon	101	0.23	0.2%
Gordon Creek	620	3.7	0.6%
Lovers Jump Creek	904	2.0	0.2%

Table 5: Total Phosphorus (TP) loads

Catchment	Stormwater contribution (kg/year)	Wastewater overflow contribution (kg/year)	Proportion from wastewater overflows
Tennyson Street	300	18	6%
Manly Lagoon	5,690	102	2%
Yeramba Lagoon	185	10	5%
Gordon Creek	1260	163	11%
Lovers Jump Creek	1710	87	5%

Table 6: Total Nitrogen (TN) loads

Catchment	Stormwater contribution (kg/year)	Wastewater overflow contribution (kg/year)	Proportion from wastewater overflows
Tennyson Street	1,890	89	4%
Manly Lagoon	41,930	511	1%
Yeramba Lagoon	1,580	50	3%
Gordon Creek	9,280	817	8%
Lovers Jump Creek	14,240	435	3%

Table 7: Faecal Coliforms loads

Catchment	Stormwater Contribution (CFU/year)	Wastewater Overflow Contribution (CFU/year)	Proportion from wastewater overflows
Tennyson Street	1.2×10^{14}	4.5×10^{13}	27%
Manly Lagoon	2.7×10^{14}	2.6×10^{14}	49%
Yeramba Lagoon	1.2×10^{14}	2.5×10^{13}	17%
Gordon Creek	6.5×10^{14}	4.1×10^{14}	39%

Lovers Jump Creek	9.7×10^{14}	2.2×10^{14}	18%

These results indicate that wastewater overflows are a very minor contributor to suspended solids loads. Wastewater overflows make a more significant contribution to nutrient (TP and TN) loads, although nutrient loads from wastewater overflows are still 1-2 orders of magnitude lower than those from stormwater. The catchment with the highest proportion of nutrient loads from wastewater overflows is Gordon Creek. However even within this catchment, TP and TN loads from wastewater overflows are still an order of magnitude lower than those from stormwater.

Faecal coliforms are present in the faeces of all warm blooded animals and are measured as an indicator for the potential presence of human pathogens. In comparison with nutrients and other pollutants, they are relatively short-lived in natural waterways, but are significant in terms of potential impacts on human health. The results indicate that both stormwater and wastewater overflows are significant contributors to faecal coliform loads. However these results should be treated with caution, as the modelling has not taken into account the source of faecal coliforms in stormwater. Stormwater pollutant concentrations are based on monitoring results collated by Duncan (1999). Faecal coliforms in stormwater monitoring data could have arisen from surface runoff (from roads, roofs and other surfaces) as well as wastewater overflows. This is discussed further below.

6 Discussion

This study has found that for total suspended solids, total phosphorus and total nitrogen stormwater loads are significantly higher than wastewater overflow pollutant loads in a range of catchments across Sydney. While there is some uncertainty around the estimation of both stormwater and wastewater overflow pollutant loads, the estimated loads differ by orders of magnitude, eclipsing the uncertainty around each estimate.

This finding was surprising to some of the catchment managers involved in each study. For example, in the Yeramba Lagoon catchment, previous reports (A J Morison and Associates 2000 and Ecological Australia 2003) had consistently highlighted wastewater overflows as a significant issue in the catchment and referred to anecdotal evidence of their regular occurrence. The local council had no reason to believe that there was anything questionable about this assertion. This highlights the need for the best available data to inform catchment management decisions.

There is evidence in the literature that stormwater can contribute faecal coliform loads in the absence of any wastewater overflows. A Californian study (Griffith et al 2010) found that natural (undeveloped) catchments could contribute sufficient quantities of faecal indicator bacteria (including total coliforms, E coli and enterococci) during wet weather to exceed the State of California water quality thresholds at beaches downstream. In the urban context, potential sources of faecal coliforms are even more significant. A study of the water quality in rainwater tanks (Coombes et al 2006) found that while faecal coliforms were absent from rainwater itself, they were present within rainwater tanks, suggesting a source on the roof. It is important to understand that the presence of faecal coliforms in water does not necessarily indicate that there is contamination from *human* faecal matter. Faecal coliforms can be from other animals, including birds, possums and domestic animals common in the urban environment. However surface runoff sources would have lower levels of *human* pathogens compared to wastewater overflows and so the risk to human health for equivalent faecal coliform levels is likely to be less.

The 2009-2010 State of the Beaches Report (DECCW 2010) includes the level of enterococci measured at a total of 127 swimming locations in the Sydney, Hunter and Illawarra regions (NSW OEH 2011). Enterococci, like faecal coliforms, are used as an indicator for the potential presence of human pathogens and are present in the faecal matter of all warm blooded animals. They are considered superior as an indicator particularly in saline waters because of their better survival. Included in the State of the Beaches report are the results of a Sanitary Inspection Survey that allocates the risk of pollution to key sources including dry and wet weather wastewater overflows and stormwater. For many beaches the largest contributor to the risk is stormwater discharge.

7 Conclusions

This paper has brought together the results of five catchment management projects across Sydney, which compared pollutant loads arising from stormwater to those arising from wastewater overflows. Total suspended solids, total phosphorus, total nitrogen and faecal coliform loads were examined. The results show that wastewater overflows contribute negligible loads of total suspended and small loads of total phosphorus and total nitrogen in typical Sydney catchments. Wastewater overflows are more significant in terms of faecal coliforms, but even in this case stormwater can contribute to faecal coliform loads in the absence of wastewater overflows.

The results of this study suggest that while wastewater overflow abatement is an important issue in the urban environment, this particularly applies where there is a target to meet water quality guidelines for swimming. Stormwater management is crucial to addressing broader waterway health objectives, as stormwater contributes the vast majority of total suspended solids and significant majority of nutrient loads to Sydney's urban waterways.

This paper has presented a method for estimating stormwater and wastewater overflow pollutant loads in other catchments, so that catchment managers can examine the best available data for their own local areas.

8 Acknowledgements

The authors wish to thank Sydney Water for providing wastewater overflow data and commenting on a draft of this paper. In particular, we would like to thank Rodney Kerr, Natalie Marshall and Stephen Blockwell.

9 References

A J Morison and Associates (2000) "Yeramba Stormwater Project" prepared for Bankstown City Council and the National Parks and Wildlife Service.

Coombes, P, Dunstan, H, Spinks, A, Evans, C and Harrison, T (2006) "Key Messages from a Decade of Water Quality Research into Roof Collected Rainwater Supplies" 1st National HYDROPOLIS Conference, Perth, Western Australia.

Duncan, H (1999) “Urban Stormwater Quality: A Statistical Overview” Cooperative Research Centre for Catchment Hydrology Report 99/3.

Ecological Australia (2003) “Yeramba Lagoon Management Options” prepared for the NSW National Parks and Wildlife Service and Bankstown City Council.

Engineers Australia (2006) *Australian Rainfall and Runoff*.

Equatica (2009) “Tennyson Street Subcatchment Management Plan” prepared for Marrickville Council.

Equatica (2011a) “Manly Lagoon Catchment – Annual Sediment and Pollutant Loading” prepared for Warringah Council.

Equatica (2011b) “Yeramba Lagoon Concept Design for Weir Modification” prepared for Bankstown Council.

Fletcher, T, Duncan, H, Poelsma, P and Lloyd, S (2004) “Stormwater flow and quality, and the effectiveness of non-proprietary stormwater treatment measures — a review and gap analysis” Cooperative Research Centre for Catchment Hydrology Technical Report 04/8.

Griffith, JF, Schiff, KC, Lyon, GS and Fuhrman, JA (2010) “Microbiological water quality at non-human influenced reference beaches in southern California during wet weather” *Marine Pollution Bulletin* 2010 Apr;60(4):500-8.

NSW OEH (2011): http://www.environment.nsw.gov.au/beachapp/default.aspx

NSW DECCW (2010) Beachwatch annual report: State of the Beaches 2009-10

Sydney Water (1997), “Sewer Overflow Licensing Project - Environment Impact Assessment”, Sydney.