Sewage overflows management in the Sydney coastal region

Literature Review | December 2015

SYDNEY COASTAL COUNCILS

On the Cover

A picture of a pollution sign.
Image is the work of Rachael Smith.
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The primary aim of this project is to scope management options to reduce and mitigate the impacts of sewage overflows in the Sydney coastal region, based on a review of international best practice and historical trends in sewage management in Sydney. The topic was chosen as the 15 member councils of the Sydney Coastal Councils Group nominated sewage overflows as their common issue of greatest concern. This review was prepared as a supporting document to the Issues Paper on Sewage overflows management in the Sydney coastal region.

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1. BACKGROUND / CONTEXT

Water management in Sydney is best understood in the context of the natural water cycle, the history of water governance in Sydney, the urban water cycle and the interconnectedness of water systems. Section 1 will examine each of these elements.

1.1 Water Management in Sydney

1.1.1 The natural water cycle

Water constantly moves through a natural cycle of evaporation, condensation, precipitation and infiltration through which it is cleaned and recycled. This cycle is called the natural water cycle and is illustrated in Figure 1.

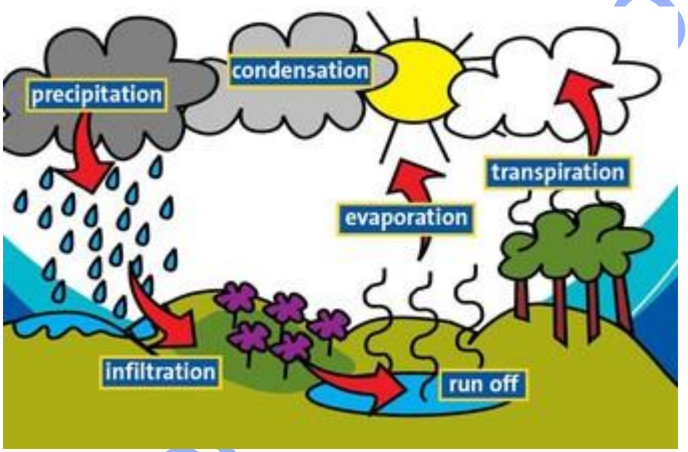


Figure 1: *The Natural Water Cycle (Sydney Water Corporation, 2015f)*

As cities develop, the water cycle becomes modified to create an urban water cycle. Today's urban water cycle is a function of the history of water management in Sydney. This history will now be explored.

1.1.2 History of water management in Sydney

The development of any complex system which has taken place over a long time period and has been contributed to by many different people is always a combination of what in hindsight turns out to be some poor decisions made for short term expediency and some better decisions made by long term planning. "What is possible for the future is very largely determined by what has gone before" **(Henry, 1939)**. This is certainly true of the water supply and sewerage systems of Sydney. The systems we have today are a legacy of their past history of management, and similarly what will be possible for the future will be a product of the decisions we make today.

History of Sydney's Water Supply Management

Sydney has unreliable rainfall, so supplying adequate water for the growing population has been a constant challenge since white settlement in 1788.

Water in fact determined the site of Sydney. Governor Phillip knew the new settlement would need to be located near a source of fresh water. So between 18th and 20th of January 1788 he set out to find such a site, and discovered a clear running stream in Sydney Cove. This stream became known as the 'Tank Stream' after three tanks that had been excavated near its channel. The settlement grew on either side of this stream. However within 28 years the population of Sydney had grown to 10,000 and the stream had become so polluted by waste from households and industry, that it resembled an open sewer. No longer suitable as a water source and to reduce the risk of disease, the stream was eventually covered in with a tunnel and became the main sewer line for Sydney. Between 1826 and 1830 the town relied on wells and rainwater, but a new water source was needed.

From 1830 to 1858 Sydney's second source of water supply was Busby's Bore, in the Lachlan Swamps (now Centennial Park). The population had reached about 20,000 and convict labour was used to build a tunnel from the Lachlan Swamps to Hyde Park, where water carts then delivered water to various parts of the city. This was Sydney's first water reticulation system.

By 1849 the city's population had grown to 40,000, then by 1852 to 50,000, due to the gold rush. An additional water supply source was again needed and in 1858 the Botany Swamps Water Supply Scheme was introduced. Pumping stations were built to pump water from the Botany Swamps to reservoirs at Crown Street, Paddington, Woollahra and Waverley Park. Dams were also constructed along the course of the Botany Swamps to provide water during drought and to meet the needs of the growing city.

In 1886 a reservoir built at Prospect took over the supply of water to Sydney, which had a population by this time of 296,000. To meet predicted water demand, the Upper Nepean Scheme was then introduced to tap the waters of the Nepean River and its tributaries. Four storage dams were constructed: the Cataract storage dam completed in 1911, the Cordeaux and Avon Dams completed in 1926 and the Nepean Dam completed in 1933. These four dams completely controlled the run off from three quarters of the Nepean catchment area, with the balance controlled by weirs. A 1924 Act gave the Metropolitan Water Sewerage and Drainage Board (Sydney Water's predecessor) control over the catchment area and the ability to prevent actions likely to contaminate the water.

By 1939 Sydney's population had grown to 1.5 million and to meet its needs and cope with drought, the Woronora Dam was completed in 1941. In 1948 construction of one of the world's largest reservoirs of water, the Warragamba Dam began. It was completed in 1960 (Aird, 1961) and today remains Sydney's largest water source.

In 1996 the privately built, owned and operated (BOO) Prospect Water Filtration Plant was completed (today 90 percent of Sydney's water is treated and filtered in privately owned filtration plants).

In 2001-2002 the Rouse Hill Recycled Water Scheme delivered recycled water to local residents using dual reticulation (separate pipes to drinking water pipes). This is the southern hemisphere's largest residential dual reticulation system.

Low rainfall between 1998 and 2007 caused Warragamba Dam to reach an all time low of 32.5 percent of capacity (Sydney Catchment Authority, 2007). Level three water restrictions were in place preventing the use of sprinklers, filling pools, or hosing paths, cars and buildings. In response to the water shortage and to future proof the city against drought and climate change, a desalination plant at Kurnell was commissioned and completed in 2010. It has the capacity to supply 15 percent of Sydney's water needs and to supply water to 1.5 million people. Construction of the plant was controversial as the options of recycling wastewater and stormwater were ruled out due to lack of community acceptance of recycled water . The plant has been on standby since 2012 as the drought eased. In 2012, the Sydney Desalination Plant was leased to private investors for 50 years, providing funds to the NSW Government.

In 2010 the St Marys Advanced Water Recycling Plant began to release high quality treated recycled water into the Nepean River for environmental flows, allowing additional drinking water to be held back in Warragamba Dam for Sydney.

Today Sydney has a population of 4.84 million and is forecast to reach 5 million in 2016 and 8 million by 2056 (Wade, 2015). Our future water needs will be met by a combination of dams, desalination, water efficiency and wastewater recycling.

History of Sydney's Sewage and Stormwater Management

By 1854 an urgent need for a sewerage system in Sydney had become evident, so five main sewage outfalls were constructed in the 1850's to discharge into Sydney Harbour, with minor sewers placed in almost every street. In 1875 the resulting pollution of Sydney Harbour, led the Sewerage and Health Board to recommend that sewage instead be discharged to Botany Bay and to the ocean at Bondi.

Sydney's first sewers were combined, carrying both sewage and stormwater. Later it was required that all new buildings and renovations have separate systems and funding was allocated to speed up the separation of existing sewers.

In 1880 Sydney's first water and sewerage authority, the Board of Water Supply and Sewerage was formed and in 1894 took over maintenance of major stormwater channels in Sydney. This body would later become Sydney Water Corporation. Between 1880 and 1894 stormwater channels were constructed to replace creeks running through the suburbs and flowing into the Harbour and Parramatta River.

Increasing sewage pollution of Sydney Harbour led to the construction of the Northern System Bondi ocean outfall and of the Western and Southern System at Botany Bay, between 1880 and 1989. The Bondi system intercepted old sewers that had flowed into the Harbour and instead carried the wastewater to the ocean. The Western and

Southern system carried sewage to a sewage farm at Botany. The Botany Sewage Farm was Sydney’s first sewage reuse scheme. Sewage was screened and given basic treatment then the sludge ploughed into filter beds. For a couple of years vegetable crops did well. However the volume of sewage at the farm grew in line with increasing population and by 1908 the cultivation areas had become almost continuously flooded with sewage. Complaints from local residents and council forced the farm’s abandonment in 1916.

The sewage previously taken to the sewage farm was then discharged into the ocean at Malabar via the newly completed Southern and Western Suburbs Ocean Outfall Sewer (S&WSOOS) No 1. To meet the needs of Northern Sydney, the Northern Suburbs Ocean Outfall Sewer (NSOOS) was constructed between 1916 and 1930. Then to reduce pollution, Sydney’s first sewage treatment plant (STP) at Bondi was constructed between 1936 and 1953. To amplify the sewer to the ocean, the S&WSOOS No 2 was completed in 1941.

In 1959 the Cronulla Sewerage System was commissioned and work commenced on Sydney’s largest STP at Malabar. Between 1972 and 1984 the North Head STP was constructed. Increasing levels of sewage pollution of Sydney’s beaches led to community demands for action to improve the quality of the beaches. The alternatives were: construction of deepwater ocean outfalls to disperse the primary treated sewage further out to sea, or construction of higher-level secondary or tertiary STPs to further treat the wastewater. The decision was made to construct deepwater ocean outfalls at Bondi, North Head and Malabar STPs, as it was less expensive and would involve less community disruption. These outfalls were built between 1984 and 1990.

In 1987 the Metropolitan Water, Sewerage and Drainage Board was reconstituted as the Sydney Water Board, then in 1994 the Board was corporatised and renamed Sydney Water Corporation.

Construction on the a 20 kilometre Northside Storage Tunnel began in 1996, to reduce wet weather sewage overflows into Sydney Harbour, by capturing and temporarily storing overflows until they can be treated and disposed.

In the late 1990s, Sydney Water began using biogas from wastewater treatment plants to produce renewable energy. Together with hydroelectric generators these biogas plants now supply about 20 percent of Sydney Water’s energy needs (excluding the desalination plant). The first hydroelectric plant in Australia to generate power from treated wastewater was built at the North Head plant in 2010. Together with cogeneration – where methane produced during wastewater treatment is turned into green energy – the plant now generates about 40% of its own power during normal operations. A recycled water facility also generates 95% of the water used on site.

In 2010 Sydney Water worked with the City of Sydney Council on Sydney's largest stormwater harvesting and water re-use facility at Sydney Park, St Peters. Stormwater is captured and naturally treated using wetlands to provide water for irrigating the park and for nearby industry.

1.1.3 The urban water cycle

As discussed, as Sydney's population increased, the natural water cycle could no longer provide a constant water supply and safe wastewater disposal for Sydney. Therefore the natural cycle was modified to create the urban water cycle shown diagrammatically in Figures 2 and 3.

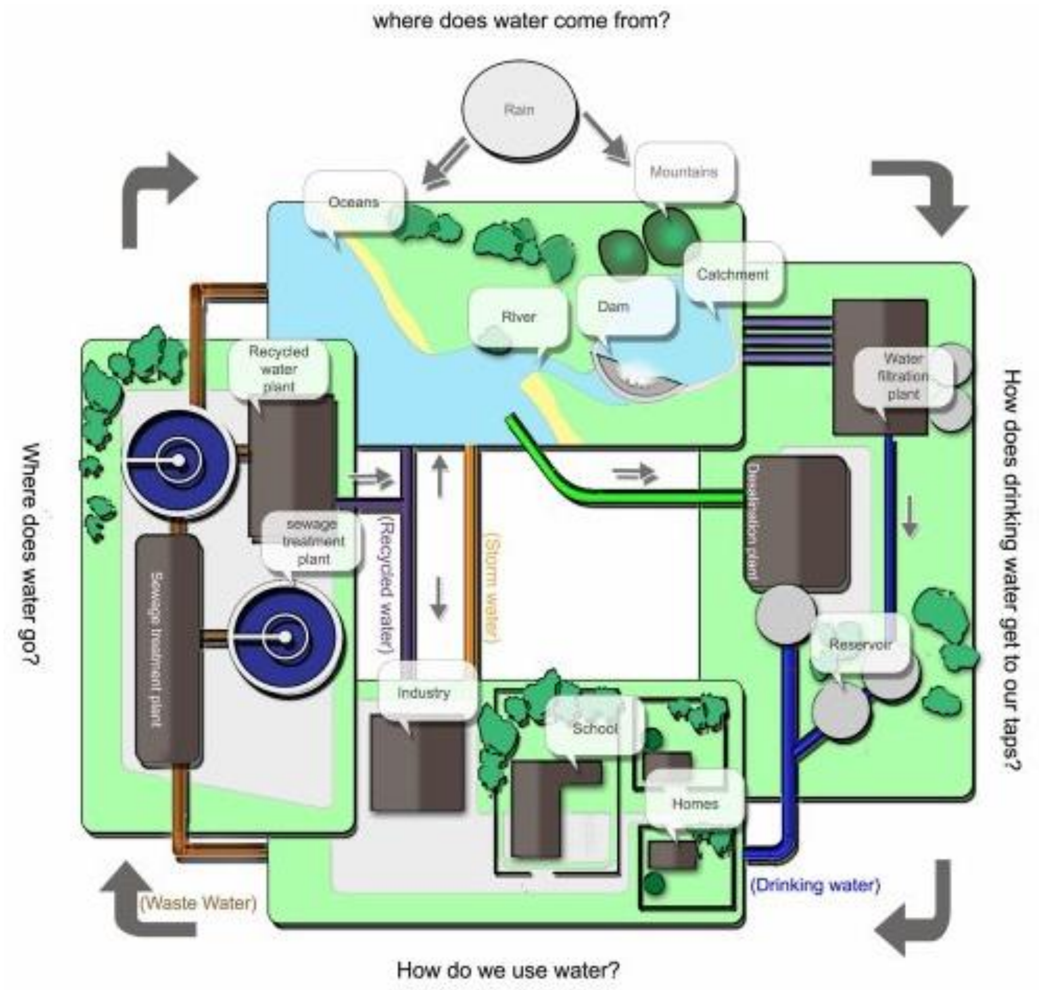


Figure 2: *The Urban Water Cycle (Sydney Water Corporation)*

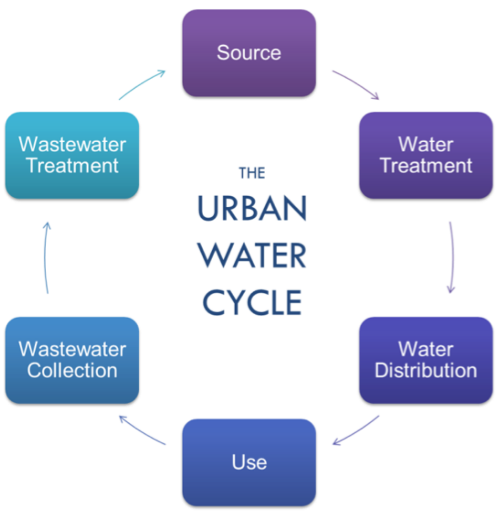


Figure 3: *Stages of the Urban Water Cycle (Sowby, 2014)*

Elements of the urban water cycle will now be discussed.

Source

Potential water sources in Sydney include surface water, ground water, recycling and desalination. In 2013-14, 93% of water was sourced from surface water and 7% from recycled water (IPART, 2015). The surface water is rainfall that falls on land in the Hawkesbury-Nepean catchment, flows into rivers and is collected in dams. The Warragamba Dam is the largest and supplies 80% of Sydney's water supply. WaterNSW, a state owned corporation, supplies this bulk water to retailer Sydney Water Corporation.

Desalination and ground water are reserve water sources for Sydney. The Sydney Desalination Plant at Kurnell is to be utilised when dam levels fall below 70% and until levels reach 80% (NSW Office of Water, 2010). The plant uses the process of reverse osmosis to desalinate seawater into drinking water.

Water treatment and distribution

From dams, water is transported to reservoirs, then to filtration plants where Sydney Water treats the water to drinking quality, then distributes it to end users. Sydney Water's water supply network comprises nine filtration plants, 251 reservoirs, 164 pumping stations and 24,346 kilometres of pipes, one of the longest reticulation systems in the world (Sydney Water Corporation, 2015a) (Sydney Water Corporation, 2014).

Use

Residential users are the largest water users in Sydney. In 2013-14 Sydney Water supplied 66% of water to residential users, 23% to commercial/ industrial/ municipal users and 11% to others (including agricultural users) (IPART, 2015).

Wastewater collection and treatment

Wastewater is the used water of a community or industry, containing dissolved and suspended matter (ARMCANZ and ANZECC, 2004a). Sydney Water is responsible for collecting Sydney's wastewater. The wastewater is transported in a sewerage network, separate to the stormwater network, to one of 30 wastewater treatment or recycling plants where it is treated. The treatment level produces different levels of water quality depending on whether primary, secondary or tertiary wastewater treatment is undertaken. The treated wastewater called effluent is then either reused or released into freshwater waterways or the ocean.

1.1.3.1 Potable water

Potable water is water suitable for drinking and Sydney Water treats all bulk water at filtration plants to drinking quality standards, including water used for toilets and industry. The quality of water supplied is governed by Australian Drinking Water Guidelines (NHMRC and NRMMC, 2011), which are in line with the World Health Organisation guidelines (WHO, 2011). The water filtration plants remove colour, particles and pathogens (disease causing organisms), including *Cryptosporidium* and

Giardia, which can cause intestinal illnesses. NSW Health monitors water quality results closely and notifies Sydneysiders immediately of any public health risks.

1.1.3.2 Sewage

Sewage is the used water from domestic, commercial and industrial sanitary appliances containing dissolved and suspended matter (ARMCANZ and ANZECC, 2000b), such as heavy metals, organochlorines (including pesticides and pharmaceuticals), viruses, and protozoa . Sewage may also contain approved trade wastes. A licence from the Environment Protection Authority (EPA) is required to discharge industrial waste into the sewer system in NSW. Industrial wastewater has often received pre-treatment at the factory before discharge, to reduce the pollutant load of the wastewater.

Primary (mechanical) treatment at a sewage treatment plant (STP) is the first and most basic standard of treatment. Simple processes are used, such as screening to trap rubbish and solid waste material, removing grit and sand from the bottom of tanks, and scraping off oil and grease from the top.

Secondary (biological) treatment is a higher level of treatment, which removes dissolved organic matter that has escaped primary treatment. Secondary treatment uses biological activity to break down organic matter and remove nutrients including nitrates and phosphates. The solids are separated from the liquids, creating a phosphorus rich by-product called sludge. The sludge is then treated to create biosolids, which can then be sold for reuse as fertiliser to improve soil quality in agriculture, forestry, landscaping and mine site rehabilitation.

Tertiary treatment is additional treatment of the clear wastewater produced from secondary treatment. It involves filtering and disinfecting the wastewater to remove additional Nitrogen and Phosphorus and remaining solids, as well as disinfection with chlorine to remove pathogens (disease-causing organisms such as bacteria, viruses and parasites). The chlorine is then removed before discharge into waterways, as chlorine is harmful to water quality and aquatic life. Tertiary treatment can remove over 99 percent of all impurities, however it does not remove all antibiotic residues. Tertiary treated wastewater can be a significant source of antibiotic resistant genes in receiving waterways (LaPara et al., 2011).

After treatment, effluent is reused, recycled or discharged to receiving waters in the environment.

1.1.3.3 Stormwater

Stormwater is the runoff from rainfall unable to be absorbed within a catchment. In nature, usually 90 percent of rainfall is absorbed and 10 percent is runs off, but in Sydney's urban and industrial areas this ratio is reversed. Hard surfaces such as roads, roofs and footpaths prevent rain soaking into the ground, so instead the stormwater system is used to direct the water through drains into a network of pipes. In Sydney this stormwater system is separate to the sewerage system, as illustrated in Figure 4. In contrast, many older cities in other parts of the world use classical combined sewerage and stormwater systems.

Sydney stormwater is not treated and flows directly from streets and gutters into rivers, the harbour and the ocean. In some cases it is filtered through traps to remove rubbish. Storm water in many part of Sydney flows into rivers, then out to sea. Stormwater in western Sydney flows back into the Hawkesbury and Nepean river systems (Cormack, 2015). The 447-kilometre stormwater network of pipes owned by Sydney Water comprises less than 5 percent of metropolitan stormwater infrastructure and is located mainly in south and southwestern Sydney. The balance of the system is the responsibility of local councils (Cormack, 2015).

Along the way to receiving waters, stormwater picks up pollutants including:

- Nutrients and microorganisms such as Phosphorus and Nitrogen from animal faeces, sewer overflows and garden fertilisers
- Oil residues such as diesel and petroleum from roads
- Rubbish
- Heavy metals such as copper and zinc from industrial areas, and lead from vehicle emissions on road surfaces and from older paints
- Viral pathogens from sewage overflows (Freewater, 2004)
- Pharmaceutical products, chemicals and antibiotics

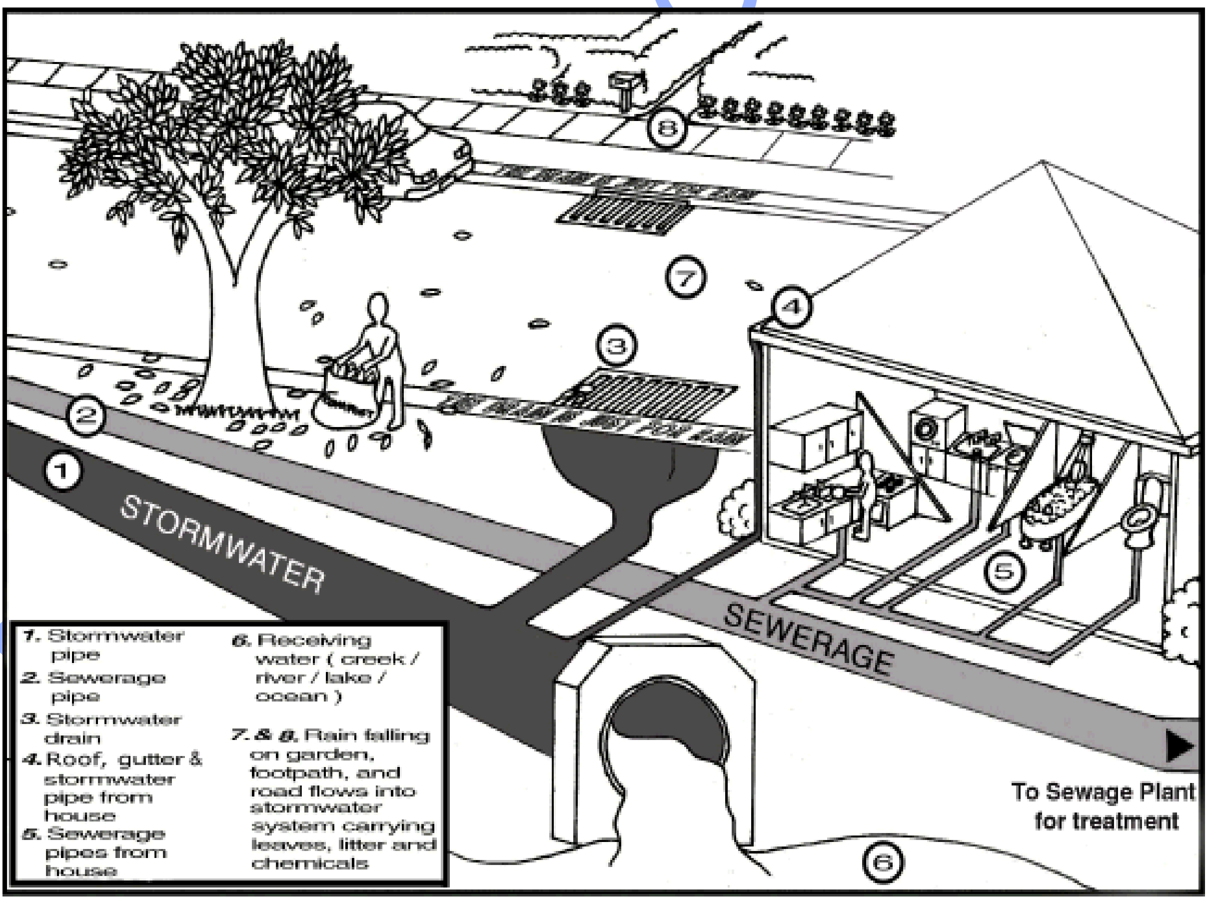


Figure 4: *Separated sewerage and stormwater systems (NSW Office of Environment & Heritage, 2011)*

the contamination in stormwater pollutes receiving waterways. It also indirectly impacts the receiving environment, as often a proportion of stormwater finds its way into sewers, where it creates wet weather overflows (Winder, 2003). Many of the chemicals in stormwater will either never break down or will take decades to do so (Freewater et al., 2014). It is estimated that each year stormwater contributes an average of 475 t of total Nitrogen, 63.5 t of total Phosphorus and 343,000 t of total suspended solids to Sydney Harbour. In a particularly wet year these levels can be three times as great (Birch et al., 2010). Stormwater pollution now constitutes the major threat to the ecological integrity of Sydney Harbour (Freewater et al., 2014).

One way to reduce these environmental impacts is stormwater harvesting, where stormwater is collected, cleaned and reused to water gardens, sports fields and golf courses. In addition, this reuse of stormwater saves drinking quality water from being unnecessarily used for these purposes.

Another alternative is 'water sensitive urban design' (WSUD), where buildings and landscapes are designed from the beginning to enhance opportunities for at-source water conservation. WSUD captures rainfall runoff, treats it using natural infiltration and uses it all at-source (ARMCANZ and ANZECC, 2000a). The stormwater that flows to receiving waterways has been cleaned and filtered by the plants and soil (Woodcock and Retamal, 2013). Research conducted for the Sydney Water Project in 1995 indicated that there is community support for WSUD with 93 percent of community workshop respondents supporting the capture, treatment and reuse of stormwater for non-drinking purposes, and 80 percent were willing to pay more for this (Dowsett et al., 1995).

1.1.4 Interconnectedness

Sydney's water infrastructure is highly interconnected, both physically and in terms of management responsibility. Management is shared between agencies or different tiers of government through shared financial responsibility, asset management, overlapping governance or planning accountability (ARUP, 2012). The interconnectivity of Sydney's water infrastructure systems means coordinated management will increasingly be required, as urban growth and ageing infrastructure place stress on the urban water system. Climate change and future population growth and density will further exacerbate these pressures (ARUP, 2012).

The stormwater system in some areas of Sydney is the responsibility of Sydney Water, yet in most is the responsibility of local councils. Assets owned and/or maintained by Sydney Water and/or local councils impact on interconnected assets owned and maintained by the other parties. This complex web of ownership and accountability means coordinated decision making regarding stormwater runoff on a catchment-wide basis is not occurring (Dowsett et al., 1995). Yet coordinated management is essential as research indicates stormwater pollution is a major threat to the ecological integrity of Sydney waterways, including Sydney Harbour. An appropriately empowered and resourced state agency accountable for coordination and overall performance of the stormwater system could ensure integrated coordinated decision making to meet uniform catchment-wide goals (Dowsett et al., 1995).

Sydney's stormwater and sewerage networks are also physically interconnected through cross leakage. Although the two networks are built as separate systems, stormwater can enter the sewerage system through cracks in sewer pipes and similarly sewage can leak out of sewerage pipes into the stormwater system. See Figure 5.

Infiltration is when rainwater or groundwater enters the sewer and exfiltration is when wastewater leaks out. Cross leakage between sewage and stormwater infrastructure can allow untreated raw sewage to reach receiving waters, where faecal contamination of waterways creates a risk to public and environmental health.

Inflow of stormwater into sewers can occur due to illegal stormwater connections to the sewer network.

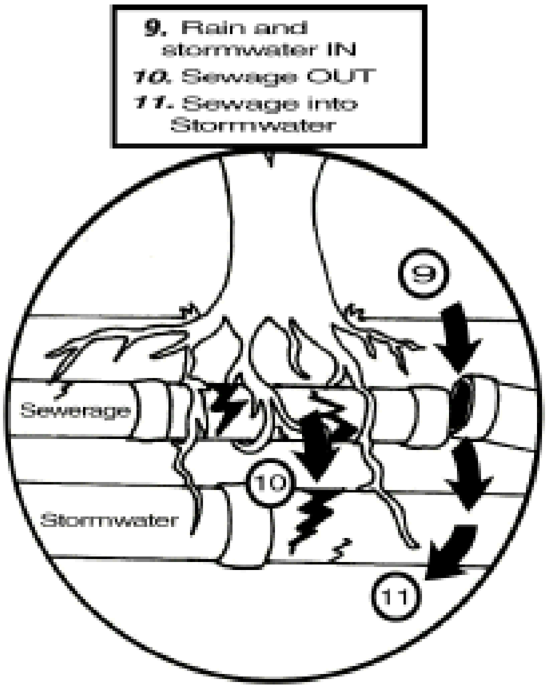


Figure 5: *Sewage and stormwater leaks (NSW Office of Environment & Heritage, 2011)*

2. SYDNEY'S URBAN SEWERAGE SYSTEM

Sydney's sewerage system comprises two parts, the Sydney Water owned part of the network and the part of the network owned by private property owners. Section 2 will examine both parts of the network, as well as the governance framework for Sydney's sewerage system.

2.1 Sydney Water sewerage system

Sydney Water operates 24 separate wastewater systems across Greater Sydney, the Blue Mountains and Illawarra area. Each system consists of a network of reticulation sewer pipes, large trunk sewers, pumping stations and at least one sewage treatment plant (STP) (Sydney Water Corporation, 1997a). The Malabar system has three STPs and the Wollongong system has two. The Sydney sewerage system delivers raw sewage from 1.6 million properties and consists of 650 pumping stations, 24,800 kilometres of sewer pipes, 16 wastewater treatment plants and 14 water-recycling plants (Sydney Water Corporation, 2015e). This is one of the world's largest sewerage systems (Harris, 2014). See Figure 7 for a map of Sydney's wastewater systems. Of the 30 treatment plants, 11 are coastal plants that discharge to the ocean and 19 are inland plants that discharge to rivers or creeks.

Sydney uses a gravity sewerage system, where sewerage pipes are laid with a gradual slope underneath footpaths, roads, private property and parks, allowing wastewater to flow using gravity downhill to the pipe network and then to pumping stations (called lift stations in the diagram below), and finally to a STP for discharge or recycling. This process is illustrated in Figure 6. Where topography does not allow gravity to move wastewater through the system, pumping stations are used to lift the wastewater from low-lying areas.

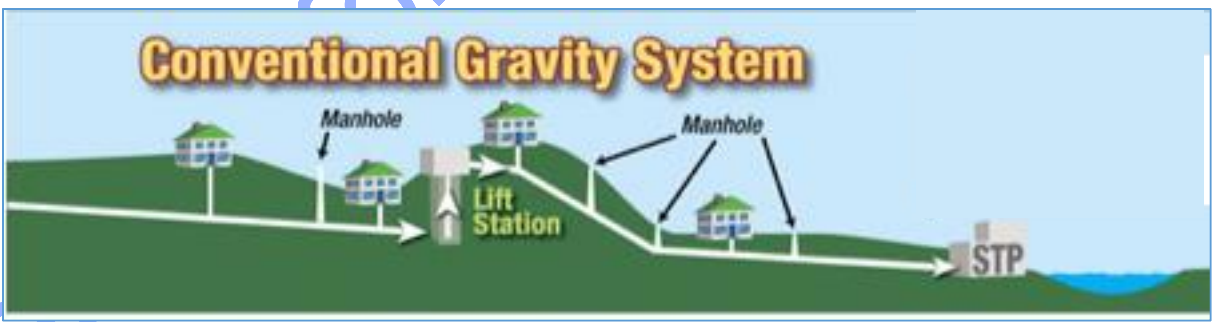
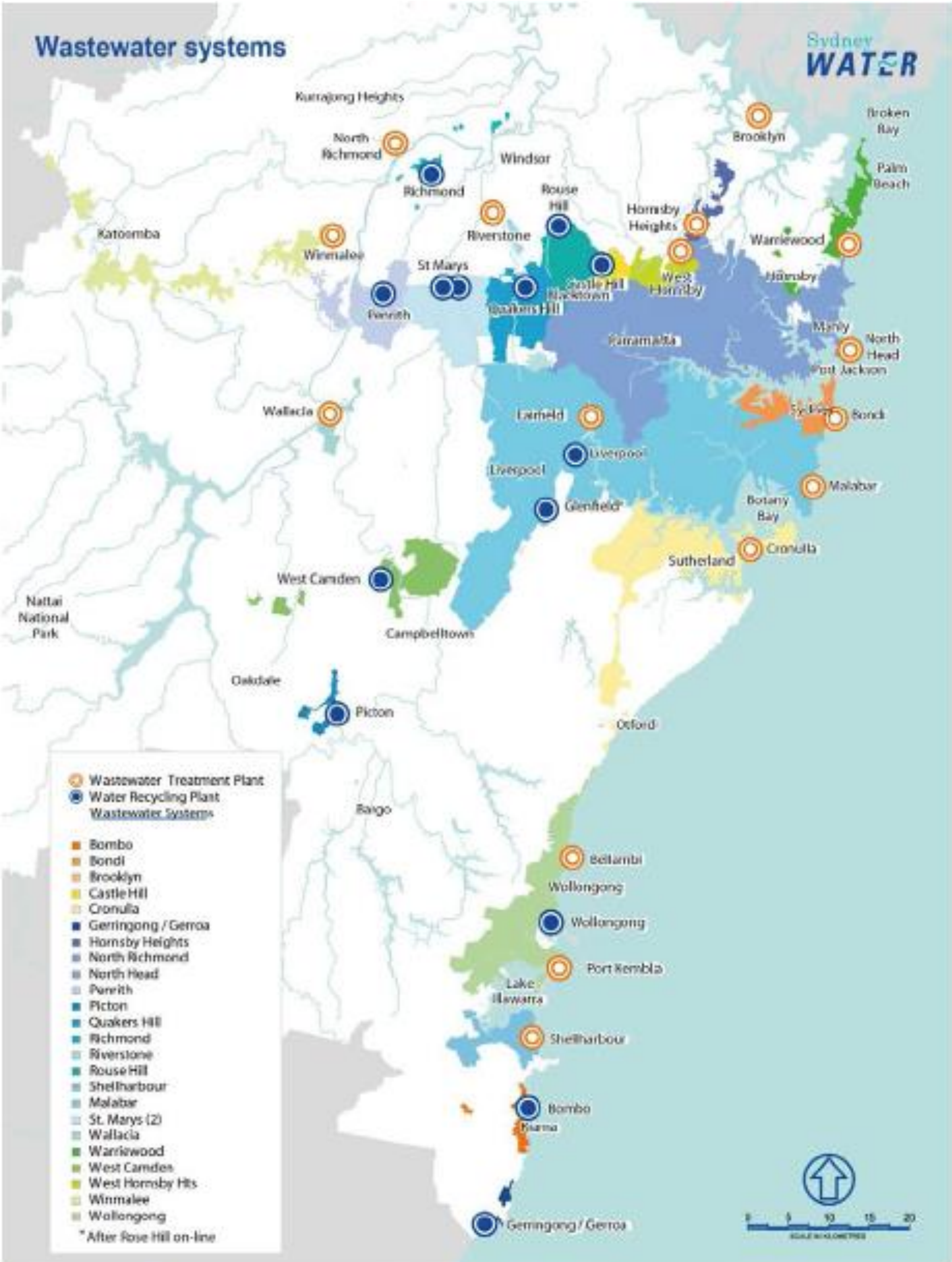


Figure 6: *Gravity Sewerage System (Orenco Systems Inc, 2015)*

The Sydney Water sewerage system treats sewage to different levels of water quality depending on the level of treatment at the STP. The treatment level depends on the STP location, when it was built and the discharge point. The three oldest and largest sewerage systems in Sydney are the coastal systems that deliver wastewater to Bondi, Malabar and North Head STPs. These systems together carry nearly 80 percent of Sydney's wastewater. They treat wastewater to primary level before discharge to the ocean via deep-water ocean outfalls located 2 to 4 kilometres offshore. The balance is carried by the newer, smaller sewerage systems in the Hawkesbury-Nepean River catchment, and the coastal catchments of Warriewood, Cronulla and the Illawarra. These STPs are all secondary or tertiary pants, except the Bellambi, Fairfield and Port Kembla sites, which are specialised storm STPs that come online only during heavy rainfall. They treat wastewater to primary level only. The inland STPs have higher-level treatment as they discharge to inland waterways that cannot disperse pollution as rapidly as the ocean.

Most of Sydney's sewage is treated to primary level, simply screening out rubbish, grit from the bottom and oils from the surface. Organic material, Phosphorus and Nitrogen, and pathogens remain. In 2013-14, 74 percent of Sydney's sewage was treated to primary level, 3 percent to secondary level and 23 percent to tertiary level (IPART, 2015). When the deep-water outfalls at Bondi, Malabar and North Head were constructed it was argued that "the solution to pollution is dilution", and that as the waste was being discharged far out to sea, secondary or tertiary treatment was not required. In addition less than 1 percent of Sydney's total sewage is discharged untreated into the ocean at Vaucluse, Diamond Bay and Diamond Bay South, from rock face outfalls. All other major STPs in Australia's capital cities other than Darwin treat sewage to at least secondary or tertiary level.

Sydney's wastewater treatment level is also below effluent standards in most of the developed world. For nearly 25 years the European Union has required at least secondary sewage treatment for all sewage, with higher tertiary treatment required for the 34 percent of sewage that discharges to sensitive areas *(Directive 91/271/EEC)*. Similarly the US *Clean Water Act* requires at least secondary treatment by STPs. There are similar standards required in New Zealand, Singapore and Japan. Canada is an interesting case. Like Australia, until recently Canada lacked a national minimum wastewater standard. However in January 2015 the *Wastewater Systems Effluent Regulations SOR/2012-139* were passed. These regulations mandate minimum secondary wastewater treatment by 2020, 2030 and 2040 for all STPs in the country, depending on the risk category of the wastewater system. Whilst Canadian Government recognises that the estimated costs of the required STP upgrades are significant, the overall quantified benefits are estimated to be three times greater. These benefits include healthier fish and aquatic ecosystems, increased commercial fisheries use and increased value placed on ecosystem and water quality by individuals and households for the benefit of both current and future generations (Government of Canada, 2010). Canada also justifies the new regulation as helping Canada to respond to the United Nations *Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities* (GPA), which both Canada and Australia adopted in 1995. The GPA targets sewage as one of the key sources of marine pollution and proposes action be taken at national and regional levels to reduce such pollution. As yet no national action to require sewage to be treated to a minimum secondary standard has been taken in Australia.



Note: Gerringong/Gerroa system is included for completeness. It is owned by Sydney Water but operated by Veolia Water

Figure 7: *Sydney's wastewater systems, showing location of plants (Sydney Water Corporation, 2012)*

As well as STPs, Sydney has 14 recycled water plants, which treat wastewater for reuse to secondary, partial tertiary, or full tertiary level. Effluent reuse conserves water and protects the environment by reducing wastewater discharges. The recycling plants produce water used for: environmental flows, industrial usage, irrigation, STP usage and non-drinking urban uses. Any treated water surplus to reuse requirements is discharged to local creeks and rivers, except the Glenfield and Liverpool plants, which discharge surplus treated water to the ocean through the Malabar deep-water ocean outfall. The Rouse Hill water treatment plant produces water for non-drinking urban uses, including residential laundry washing, toilet flushing and garden watering. As at 2011, 20,000 homes and businesses in the area had been fitted with dual reticulation systems, as illustrated in Figure 8, with capacity to expand to 36,000 homes as the area grows (Sydney Water Corporation, 2011). Dual reticulation is also used in Newington and commercial properties in Olympic Park. Similar schemes are being built at Ropes Crossing and Hoxton Park in Western Sydney.

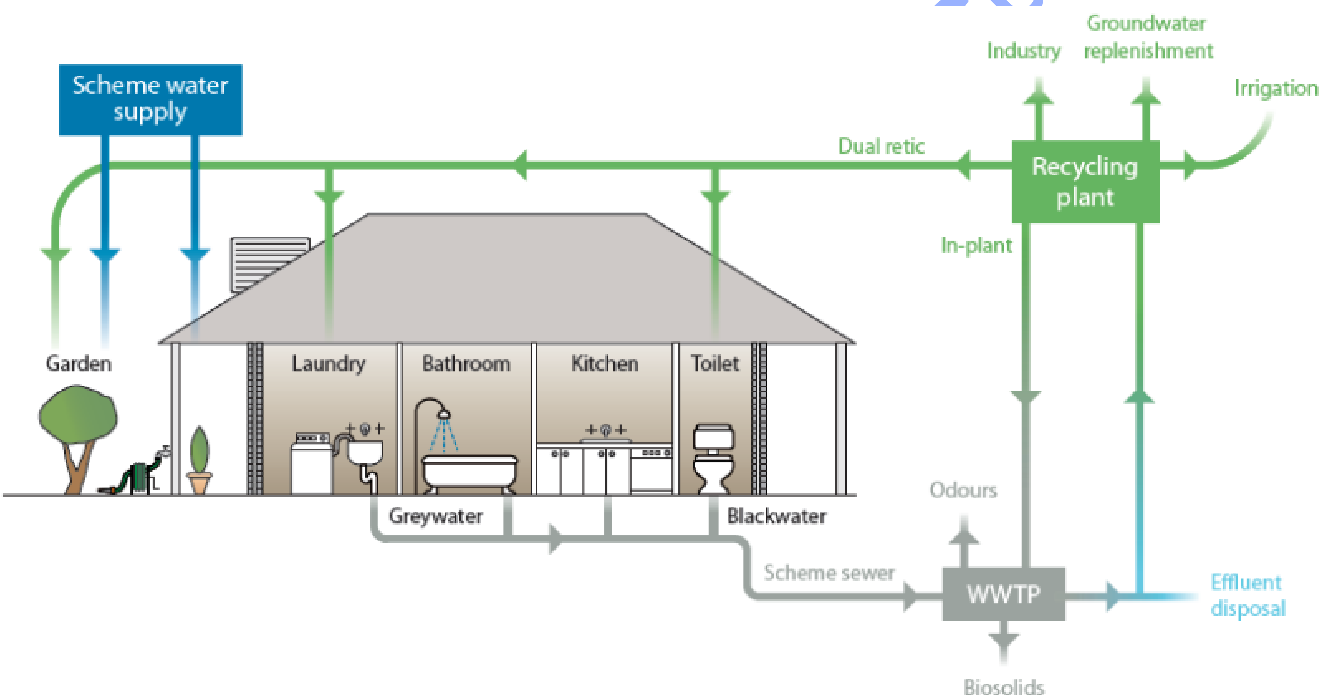


Figure 8: *Dual reticulation system using recycled water for residential gardens, toilets and laundry (Water Corporation, 2013)*

Sydney's largest recycling scheme is at St Marys in western Sydney. The St Marys Advanced Water Treatment Plant produces high quality tertiary treated wastewater. It uses ultrafiltration, reverse osmosis and de-carbonation to remove additional Phosphorus and Nitrogen and for disinfection. The purified water is discharged into the Hawkesbury-Nepean River for environmental flows, which enables more water to be held back in Warragamba Dam for urban drinking purposes. The largest uses of recycled water in Sydney are for environmental flows and for recycling on site. See Figure 9 for 2013-14 volumes of recycled water supplied to various end users.

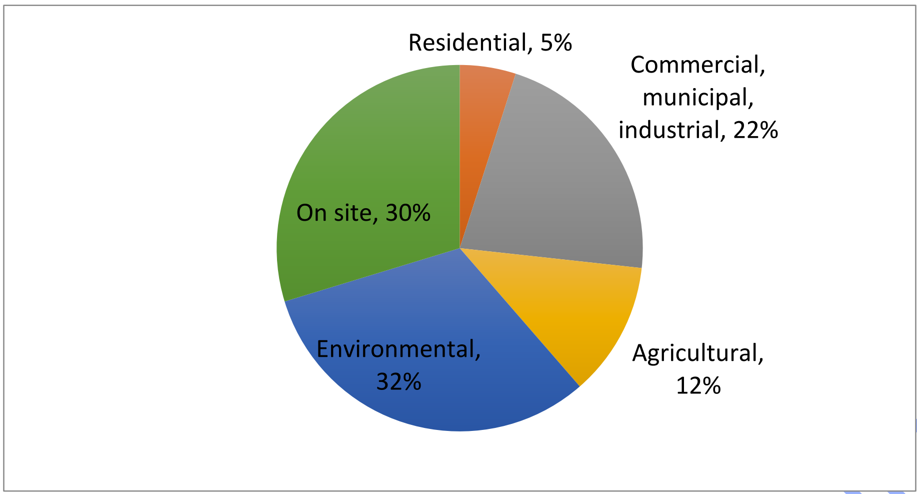


Figure 9: *Percentage of recycled water supplied by Sydney Water Corporation for various uses during 2013-14 (IPART, 2015)*

As Sydney's population grows and new suburbs are developed in western Sydney, Sydney Water will need to make decisions whether to simply send this wastewater to Malabar for primary treatment and ocean discharge, or whether to construct the infrastructure required for secondary or tertiary treatment and recycling. If a long-term view is taken, the initial higher up front costs of high level treatment and recycling, will be outweighed by the future savings of valuable drinking water, particularly as drinking water becomes scarcer due to climate change.

2.2 Private sewerage system

The private sewerage system is the part of the sewerage network that is owned by property owners, and is not the responsibility of Sydney Water. Private property owners are responsible for the operation and maintenance of their private wastewater pipes up to the point where it connects to the Sydney Water main and Sydney Water is responsible for the sewerage system from this point. The private sewer system in Sydney is roughly equal in length to the 24,000 kilometres Sydney Water sewerage network (Sydney Water Corporation, 2014).

2.3 Governance

2.3.1 Independent Pricing and Regulatory Tribunal

The prices charges to sewerage system users in determined by the Independent Pricing and Regulatory Tribunal of New South Wales (IPART). IPART is an independent body that oversees regulation in the water, gas, electricity and public transport industries in NSW. With regard to Sydney Water, IPART sets the maximum prices that can be charged to residential and non-residential customers for the provision of water, sewerage, stormwater, trade waste and some of its recycling services. These prices are reviewed every four years, with a review for the prices from 1 July 2016 to 30 June 2020 currently underway.

IPART is also responsible for annually monitoring and reporting on Sydney Water's compliance with the operating, reporting and auditing obligations set out in its Operating Licence. IPART reviews the Operating Licence every 5 years, to determine if it is meeting objectives and whether it can be amended to make it more efficient. The term of the current Operating Licence is 1 July 2015 to 30 June 2020.

IPART also determines the maximum funding available to Sydney Water for its capital expenditure programs, including wet and dry weather abatement. If the costs of these programs are greater than the IPART recent medium term pricing determination, then a separate submission must be made to IPART and these additional costs recovered from customers through charges. Or alternatively Sydney Water may renegotiate priorities with the regulator.

2.3.2 EPA

The NSW Environment Protection Authority (EPA) regulates Sydney Water's wastewater discharges to the environment. The EPA is the prime environmental regulator in NSW. It regulates wastewater discharges through Environment Protection Licences (EPLs) issued under section 43 of the *Protection of the Environment Operations Act 1997* (POEO Act). These licences require Sydney Water to monitor and report on discharges from each of their wastewater systems. EPLs for sewage treatment systems include overflows from STPs, pumping stations and reticulation systems. The EPA is required to undertake a five-year statutory review of each licence. The EPA may require specific pollution reduction programs on the EPLs for specific wastewater systems. Sydney Water would apply to IPART for funding for these programs, including for dry and wet weather abatement programs.

2.3.3 Sydney Water

Sydney Water is responsible for Sydney's wastewater system, as well as the supply of water to households, businesses and industry. Sydney Water is jointly responsible for the stormwater system with local councils, however councils control the majority of the stormwater network.

3. OVERFLOWS AND THEIR MANAGEMENT

Section 3 will examine the various types of sewerage overflow in Sydney, their location and impacts, as well as how the sewerage system will be impacted by climate change. Current management strategies will be outlined and community and media attitudes to sewage overflows examined.

3.1 What is a sewage overflow?

A sewage overflow is any discharge of sewage from the sewerage system in wet or dry weather. When pipes become blocked or the capacity of the system is exceeded, the sewage backs up and overflows from the pipe openings, resulting in a sewage overflow (ARMCANZ and ANZECC, 2004b). Sewage overflows can be a major source of pollution, particularly within estuarine and enclosed waterways, as these waterways are poorly flushed by tidal action. It can take days before bacterial contamination from sewage falls to acceptable levels.

3.1.1 Wet weather overflows

A wet weather overflow is a spillage of untreated sewage and stormwater from sewer pipes that occurs in wet weather when the hydraulic capacity of the sewer is exceeded. During heavy rain, stormwater enters the sewerage system through cracks and faults in the pipes (infiltration) and via illegal plumbing connections, gully pots and openings in manhole covers (inflow). Together these sources of stormwater that enter the sewerage system are called infiltration/inflow (I/I).

Sewerage systems around the world are designed with openings in the pipes called overflow points. These points stop wastewater from backing up into people's homes and properties when the sewer exceeds capacity, by directing the excess flow into waterways. There are an estimated 3,000 designed overflow points in Sydney Water's sewerage system (NSW Office of Environment & Heritage, 2011).

If the combined wastewater and stormwater flow exceeds the capacity of the sewers, it discharges to waterways from designed overflow points, manholes or wastewater treatment plants (Harris, 2014). The designed capacity of Sydney's sewers is 4 times dry weather flow, but during storms, flows within the system can increase to up to 10 times the dry weather flow (Sydney Water Corporation, 1997a).

Sydney has an average annual rainfall of 1200mm, which primarily falls between October and May in high intensity storms. Due to the frequency of these storms, wet weather overflows to receiving waterways are a significant issue for Sydney Water to manage (Harris, 2014).

A sewer's capacity is limited by pipe failure, or blockages, or growth in the service area that has taken up wet weather capacity with regular dry weather wastewater flow. Wet weather overflows typically consist of about 20 percent wastewater and 80 stormwater (Sydney Water Corporation, 2015b). Wet weather overflows can have adverse human health impacts due to human pathogens in sewage, which cause illness. For this reason it is recommended not to swim for three days after storms. They also have adverse environmental impacts, due to the presence of pathogens in wet weather overflows reaching waterways.

3.1.2 Dry weather overflows

Dry weather overflows are overflows from the sewer that occur during dry weather. The sewage in these overflows is undiluted, so poses a significant risk to public health (through the potential for transmitting pathogens) and to the environment (through high nutrient loads and toxins). As such, dry weather overflows should be eliminated or reduced where possible (Winder, 2003). They are mainly caused by:

- Blockages in wastewater pipes (called chokes), usually caused by tree roots in pipes, but also by build up of oil, grease and debris
- Leakage of sewage from wastewater pipe breakages
- Sewage pumping station factors, such as malfunctions from equipment or power failures, which cannot be fixed before the storage capacity of the plant is exceeded
- Sewers and pumping stations that are too small to cope with the volumes of sewage resulting from urban growth, such as new subdivisions or commercial areas connecting to existing sewer lines
- Large quantities of trade wastewater being discharged from multiple industries simultaneously (ARMCANZ and ANZECC, 2004b)

Tree roots are the main cause of dry weather overflows, creating about 80 percent of all dry weather overflows (approximately 14,000 overflows each year) in Sydney (Sydney Water Corporation, 2010a). Dry weather overflows are also more frequent in periods of low rainfall, as during drought tree roots search for a source of water within sewer pipes, eventually blocking and breaking them, resulting in overflows.

3.1.3 'Private' overflows

A private overflow is a dry or wet sewage overflow that occurs in the privately owned part of the sewerage system. Private property owners are responsible for maintenance and repair of the sewer from their property up to the connection point where the private sewer connects to the Sydney Water main. This point can be outside private property boundaries, but residents often mistakenly assume that their responsibility for sewerage pipe breaks and blockages finishes at their own property boundary. Often this is only discovered when a property owner personally experiences a private sewage overflow.

3.2 Quantifying the issue: sites, impacts and risks

3.2.1 Overflow locations

Of the 3,000 designed overflow points across the sewerage network (Sydney Water Corporation, 2015h), about 250 are dry weather overflow points, which are managed separately to wet weather overflows. For wet weather overflows, Sydney Water's sewerage system licences set long-term frequency targets for overflows from the trunk system. These overflows are called 'licenced overflows' and there are 1,039 across the system (Sydney Water Corporation, 2015h). The remaining overflows are unlicenced and are located in the local reticulation system. They are still considered in Sydney Water's planning and are represented in the system model as a node or cluster of overflow points. From the node the worst performing overflow point is used as an indicator of how that part of the system operates.

Figure 10 shows the location of licenced overflows in Sydney, colour coded for risk under a proposed new risk based approach for wet weather overflow management. This approach will be discussed in section 3.3.4 of this report.

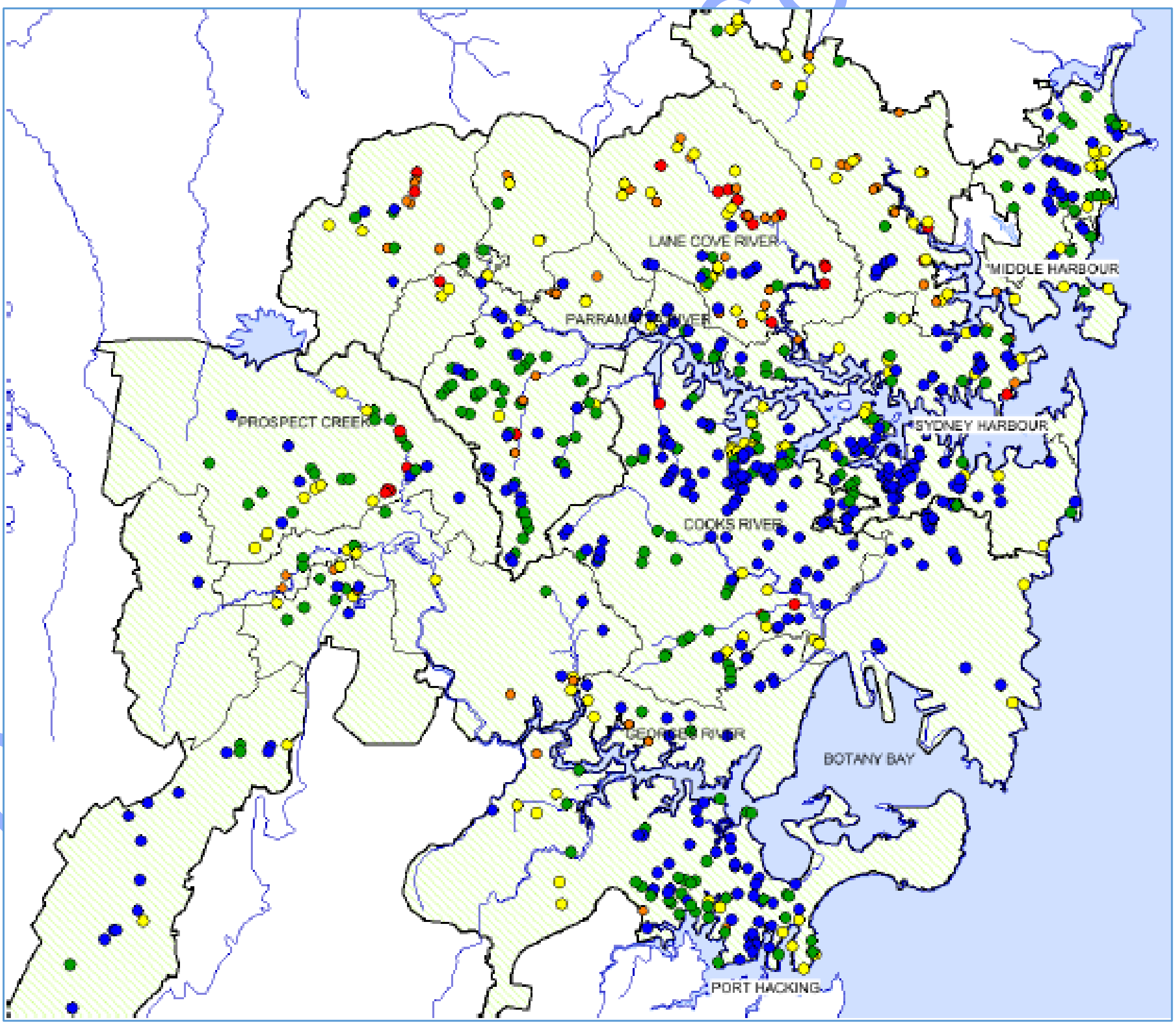


Figure 10: *Map of overflows in Sydney region, categorised for overall risk. Red is highest, then orange, yellow, green, with blue the lowest (Sydney Water Corporation, 2015g)*

Coastal wastewater systems overflow with more frequency and volume than inland catchments, as the coastal systems are older and the catchment areas are larger and more densely populated. Therefore they leak more frequently and create more wet weather overflows. The coastal systems of Malabar, Bondi and North Head carry around 80 percent of Sydney's wastewater, so the volume of overflows from these systems is much greater than newer, smaller sewerage systems in the Hawkesbury-Nepean River catchment and Warriewood, Cronulla and the Illawarra.

The greater volume and frequency of both wet and dry weather overflows in coastal systems than in inland systems, is demonstrated by comparing Figures 11 and 12. In Figure 11, for 2012-13 the coastal (ocean) plant catchments were responsible for a total wet weather overflow volume of 13,468 ML and overflow frequency of 93 times. Whereas in figure 12 the 2012-13 inland catchments had an overflow volume of 390 ML and overflow frequency of 25 times (Sydney Water Corporation, 2013).

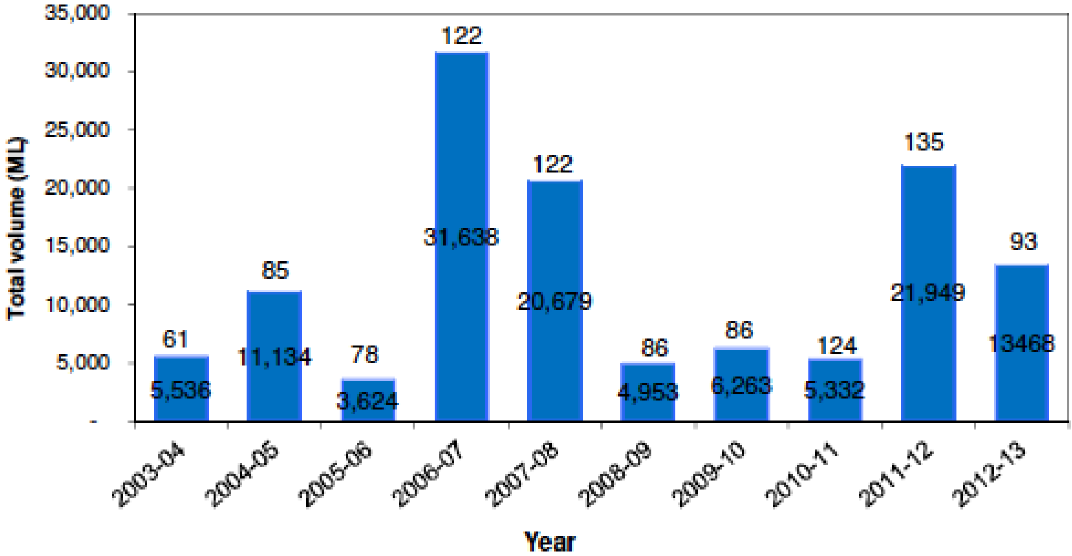


Figure 11: *Yearly trend in modeled wet weather overflow volumes and frequency by all ocean wastewater systems (Sydney Water Corporation, 2013)*

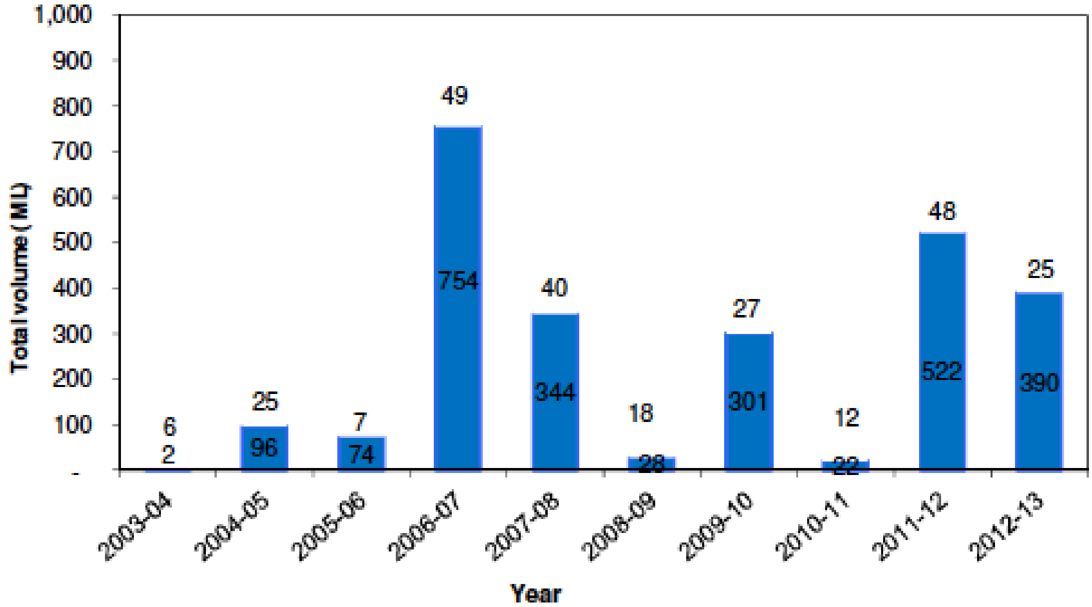


Figure 12: *Yearly trend in modeled wet weather overflow volumes and frequency by all inland wastewater systems (Sydney Water Corporation, 2013)*.

Similarly comparing Figures 13 and 14 shows the higher frequency and volumes of dry weather overflows in coastal systems compared to inland systems.

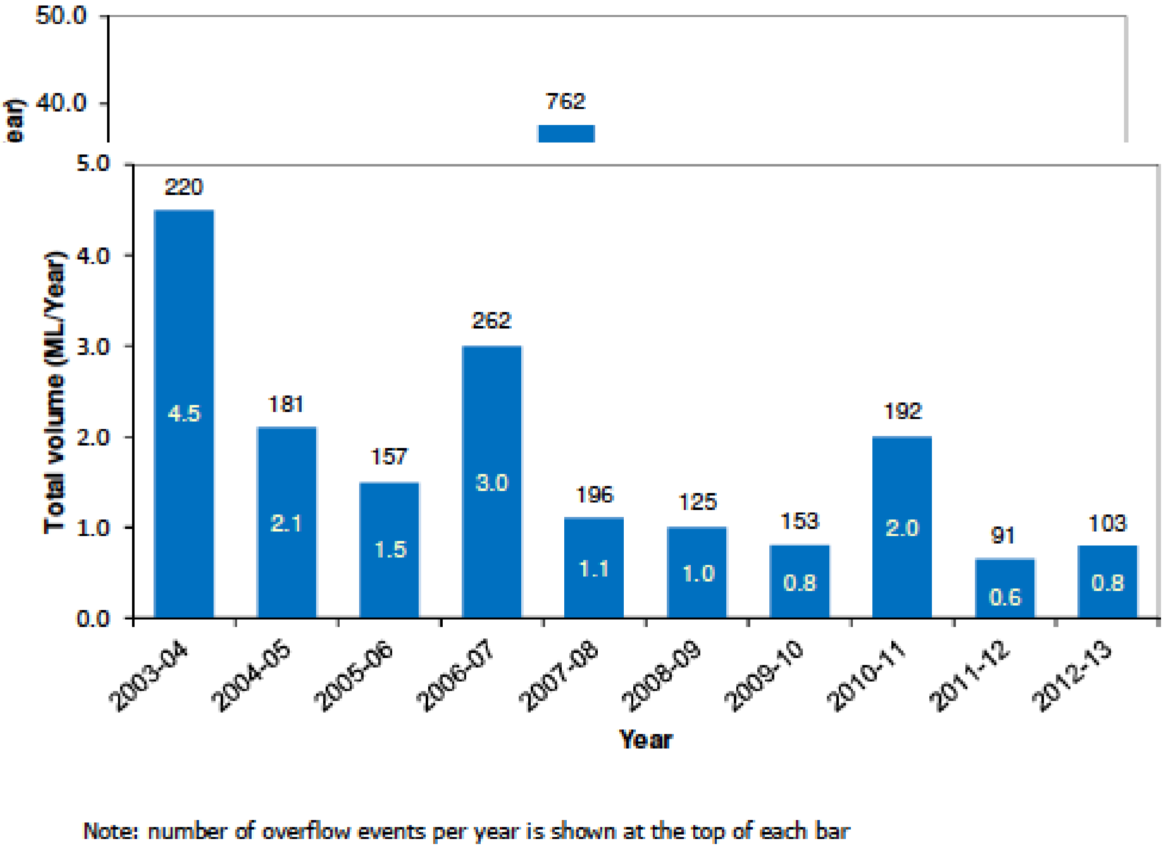


Figure 13: *Temporal trend in dry weather overflow volumes in ocean plant catchments (Sydney Water Corporation, 2013)*

Figure 14: *Temporal trend in dry weather overflow volumes in inland plant catchments (Sydney Water Corporation, 2013)*

Figure 13 also illustrates the effect of drought on dry weather overflows. Drought occurred between 2003 and 2007, with normal rainfall resuming in 2008, which then provided trees with an alternative water source to sewer pipes. The effect of these rainfall changes is evident in the dramatic decline in the frequency and volume of dry weather overflows between 2007-08 and 2008-09. The Sydney Water Sewerfix prioritisation program was also intensified in 2008, further reducing overflows in 2008-09.

The North Head and Malabar sewerage systems are responsible for nearly all wet weather overflows in coastal systems (see Figure 15), whilst Quakers Hill has the highest volume of wet weather overflows of the inland systems (see Figure 16).

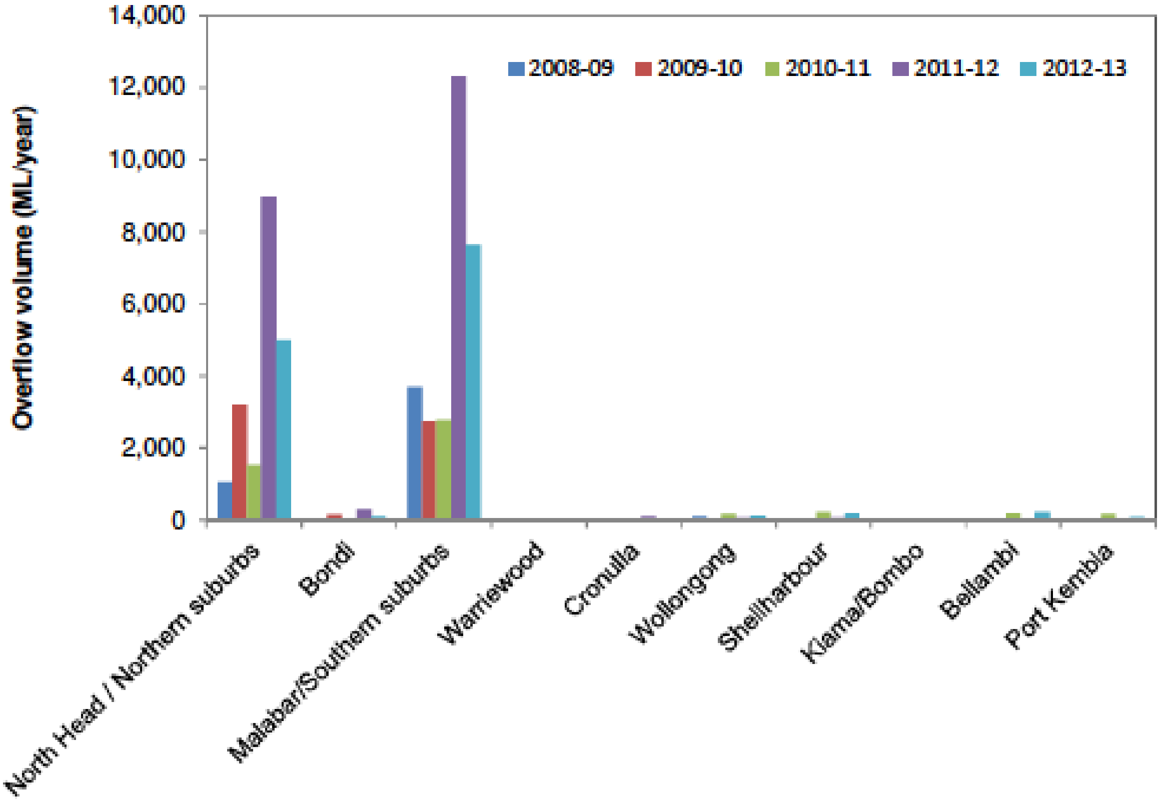


Figure 15: *Yearly trend in modeled wet weather overflow volumes by individual ocean wastewater systems (Sydney Water Corporation, 2013)*

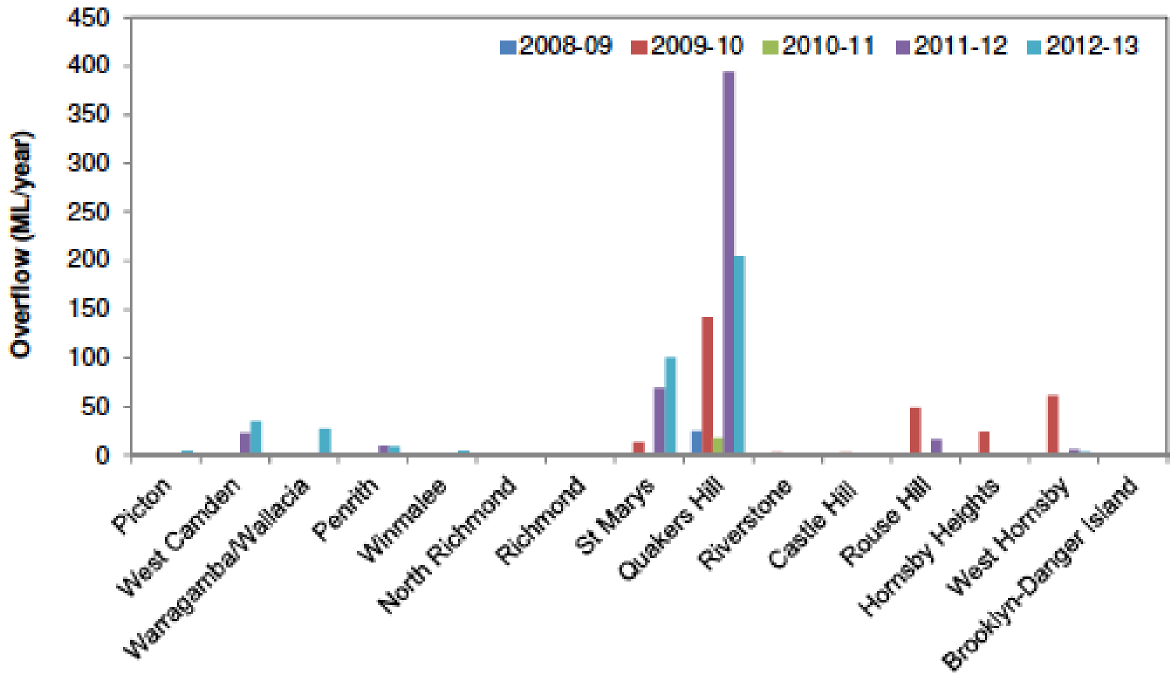


Figure 16: *Yearly trend in modeled wet weather overflow volumes by individual inland wastewater systems (Sydney Water Corporation, 2013)*

3.2.2 Impacts of sewer overflows

Abatement of sewage overflows is important because overflows have environmental, human health and economic impacts. The scale of these impacts depends upon the characteristics of the discharge (concentration of pollutants, and frequency, duration and volume of the overflow), and the characteristics of the receiving environment (presence of tidal action and the relative contribution of the overflow to total pollution in the receiving waterway) (Winder, 2003).

3.2.2.1 Environmental / ecological

Sewage overflows can contain a range of pollutants including:

- Sediment
- Turbidity
- Nutrients, particularly Nitrogen and Phosphorus
- Toxicants, including metals, pesticides and other chemicals
- Substances creating a biochemical oxygen demand
- Gross pollutants, including plastic and paper products

The potential impacts on the environment from these pollutants are outlined in Table 1.

Pollutants from Sewage Overflows	***Potential Environmental Impacts***
Suspended solids	Fine sediments and solids can silt up waterways and affect habitats of aquatic organisms
Turbidity	Reduces water clarity, which negatively impacts fish and aquatic plants
Nutrients including Phosphorus, Nitrogen and Ammonia	Stimulates growth of algae and undesirable aquatic plants, micro-organisms, and invertebrates (e.g., mosquitoes). Phytoplankton blooms occur in freshwater locations. Ammonia is toxic to the environment.
Detergents, pesticides, grease and oil, fat, colouring, solvents, cyanide, metals	Toxic to fish and aquatic insects at high levels. Bioaccumulates up the food chain.
Organic matter/ Biochemical oxygen demand	Reduces dissolved oxygen levels, which is detrimental to aquatic life including fish, insects, and micro-organisms, as oxygen is required for respiration.
Gross pollutants/ litter	Visually unattractive

Table 1: *Potential impacts on the environment of pollutants from sewage overflows (ARMCANZ and ANZECC, 2004b) (Winder, 2003).*

Wet weather sewage overflows may also impact aquatic environments by changing community structures as aquatic plants and animals are washed away and riverbeds are scoured by the fast flow of water (Winder, 2003).

In coastal regions of Sydney, waterways are flushed by tides, so overflows tend to be rapidly dispersed. As a result, water quality in coastal areas is more affected by faecal contamination (which limits swimming days), than by nutrients such as Nitrogen and Phosphorus.

Dry weather overflows of raw sewage can have substantial impacts on the environment due to high nutrient loads, which causes a dense growth of plant life and death of animal life from lack of oxygen. This is called eutrophication. The concentration of Nitrogen and Phosphorus in raw sewage is several hundred times higher than that likely to cause eutrophication in waterways. Therefore, whilst any overflow is likely to cause some localised impact in receiving waters, impacts are far more severe in dry weather when concentrations are much less diluted and low flow rates cause less nutrient dispersion (Winder, 2003).

3.2.2.2 Social / human health

As sewer overflows may contain raw sewage, they can carry pathogens, which have both adverse human health and social impacts. Pathogens present in sewage can include bacteria, viruses, protozoa (parasitic organisms), intestinal worms and inhaled moulds and fungi. The diseases they cause range in severity from mild gastroenteritis, to life threatening cholera, dysentery, hepatitis and severe gastroenteritis (ARMCANZ and ANZECC, 2004b). These impacts depend on the duration of exposure and the level of pathogens in the overflow. Some groups are more susceptible to the threat of microbial infection, including children, the elderly, tourists, those with compromised immune systems and people from culturally and linguistically diverse backgrounds (NSW Office of Environment and Heritage, 2014).

People are exposed to pathogens in overflows through direct contact in swimming and recreational waters and in public parks and streets. Other sources of exposure to pathogens in sewage overflows are consumption of shellfish from contaminated waters and inhalation or skin absorption. Overflows can create conditions encouraging increased mosquito breeding, leading to potential exposure to diseases such as Ross River Virus, Murray River Encephalitis and Arboviruses (ARMCANZ and ANZECC, 2004b).

Sewage overflows also have negative social impacts as the recreational value of waterways is diminished by making waters unsafe for swimming for several days after storm events. Degraded ecosystem health, sewage odours and litter that can result from overflows also reduce the recreational value of waterways. Noise from sewage pump station activities can also be a negative social effect, if located close to residential areas.

3.2.2.3 Financial

Sewage overflows also have adverse economic impacts for both Sydney Water and private property owners. The cost of containing overflows in Sydney is high due to the large size and age of the system. Whilst contemporary construction, materials and communications systems allow construction of new sewerage systems with minimal sewage overflows, achieving zero wet weather overflows is not cost effective for most existing systems. Therefore for existing systems, to minimise the financial costs of abating overflows, overflow targets should be set at an expected frequency that is acceptable to the community, matches the probability of overflow to the environmental value of the receiving water and takes into consideration financial costs, best practice technology and environmental and health benefits.

Often minimising the potential for overflows is more effective and economic than is minimising their future impacts (ARMCANZ and ANZECC, 2004b). To minimise the economic costs of abating overflows, source control or pollution prevention should be the focus of sewage overflow management, with downstream techniques like amplification and storage used only where source control cannot effectively mitigate adverse impacts. At source overflow prevention techniques include:

- Structural techniques to minimise inflow and leakage
- Appropriate management and maintenance of sewage systems
- Integrated water management such as recycling wastewater and/or stormwater at source for non-drinking purposes or water sensitive urban design (WSUD)

Reusing wastewater and/or stormwater reduces sewage overflows by reducing the flow of water in the sewerage and stormwater networks. WSUD is another stormwater management technique that reduces the volume of stormwater that can infiltrate into sewers during wet weather events. It includes elements such as raingardens, permeable paving and water tanks that capture and prevent or slow stormwater from entering the stormwater system during wet weather.

The cost of reducing overflows also depends on the level of reduction chosen. For example, recovering 92 percent of unsafe swimming days due to faecal contamination costs just 25 percent of the cost of removing 100 percent of unsafe swimming days. Similarly Sydney Water estimates that reducing overflows in the four coastal systems by 80 percent since 2000 has cost $1.5 billion, yet reducing the final 20 percent of overflows would cost an additional $5.5 billion (Sydney Water Corporation, 2015c)**.** This $5.5 billion figure includes downstream techniques for managing overflows such as amplification of 31 pumping stations and 900 kilometres of pipes, and construction of 48 storages. This high cost is driving Sydney Water's proposal to change overflow frequency targets to a risk based approach. Given this review is taking place it is timely that at source alternatives to reduce sewage overflows also be considered, such as water sensitive urban design (WSUD).

Sewage overflows in the private sewage system also have considerable financial impacts for private property owners, as rehabilitating private sewers can be expensive. For example fixing a private sewage overflow can cost over $10,000 in plumber fees and may require payment of additional council charges of over $1,000 if a local road is required to be closed whilst repairs take place. However the community is often unaware of actions they can take to minimise private sewage blockages, such as not putting wet wipes down toilets and not planting trees with invasive root systems near sewerage pipes. Public awareness campaigns are needed, such as the current Sydney Water "Keep wipes out of the pipes!" campaign.

3.2.2.4 Governance / Reputation

Most members of the public rarely consider the sewerage system unless it is brought to their attention by a private overflow, offensive odours, negative visual impacts, or media reporting of overflow events. The community simply expects sewage to be carried away from their properties in a safe and cost effective manner, with minimal adverse public health or environmental effects. However when made aware of sewage overflows, the public perception is that they are offensive and this can undermine public confidence in the effectiveness of sewerage management, even if the human health and environmental impacts are successfully managed.

Areas in Sydney where Beachwatch and Harbourwatch have identified that swimming sites are unsafe for swimming due to faecal contamination after heavy rain, have signage advising not to swim for certain periods after rainfall. These signs at numerous swimming sites can also undermine public confidence in the effectiveness of sewerage management.

3.2.3 Climate change risks

Climate change could affect the performance and condition of wastewater assets in numerous ways including:

- Increased risk of pipe cracks, due to increased variation in wet and dry spells and decreases in soil moisture
- Increased risk of wet weather overflows, due to higher rainfall intensity and peak flows
- Increased sewage concentrations and potential for corrosion and odours, due to water conservation measures, increased temperatures and longer travel times within the sewerage network
- Increased saltwater intrusion to sewerage networks and wastewater plants, due to rising sea levels
- Increased likelihood of inundation of low-lying water assets (such as drainage infrastructure and STPs), due to sea level rise and increased storms

These factors could hamper the ability of Sydney Water to provide reliable, safe service to customers and/or increase the costs of service provision and of maintenance and repair of sewage infrastructure assets (National Water Commission, 2012). To meet these challenges, Sydney Water will need to undertake robust risk assessment and implement appropriate risk management strategies to protect sewerage infrastructure.

3.3 Current management strategies and practice

3.3.1 Current management framework

3.3.1.1 Licensing

Each of Sydney Water's 24 wastewater treatment systems has an Environmental Protection Licence (EPL) regulated by the NSW EPA. The EPLs specify the performance standards and environmental monitoring required.

Since July 1999, the EPLs have included specific licence conditions for sewage overflows and leakage from the reticulation system, including targets for frequency of wet weather overflows and maximum limits for the number of dry weather overflows permitted. In order to meet these targets, Sydney Water has developed an Overflow Abatement Program to mitigate both dry and wet weather sewage overflows. A sewer overflow monitoring program has also been developed to track compliance against performance targets and to assess ecosystem response. This is called the Sewage Treatment System Impact Monitoring Program (STSIMP).

Licencing informed by Environmental Impact Assessments

When Sydney Water initially applied for licences for sewage overflows, the EPA required that Environmental Impact Statements (EISs) be prepared for each of the 35 sewerage systems. Workshops were held to allow the public to influence the EISs during the planning phase. By 1998, the EISs were complete for each sewer system (Sydney Water Corporation, 2010b). They identified the frequency, duration and volume of sewage discharges to sensitive locations, using time series modelling. They also included information on the number and types of pollutants in overflows, their impacts on waterways and the level of overflow reduction required to achieve the community's desired environmental objectives. Sydney Water used the EISs to identify priority overflows and to develop a program of works for dry and wet weather sewer overflows to reduce their environmental impacts. The EPA used the EISs to set licence conditions, including overflow targets and to select pollution reduction programs for overflows from each sewerage system.

3.3.1.2 License targets and conditions

Wet weather overflow targets

The EPLs for each sewerage system specify long-term frequency targets to reduce wet weather overflows to a defined number per 10 years, as predicted by a hydraulic sewer system model. Examples for different systems include:

- Cronulla: **40** wet weather overflows per 10 years by 2021 (NSW Environment Protection Authority, 2014)
- Bondi: **20** wet weather overflows per 10 years by 2021 (NSW Environment Protection Authority, 2014a)
- North Head: **20 to 54** wet weather overflows per 10 years by 2021 (NSW Environment Protection Authority, 2014b)
- Malabar: **5 to 44** overflows per 10 years by 2021 (NSW Environment Protection Authority, 2014c)

Dry weather overflow limits

The EPLs for each sewerage system also specify the maximum permitted number of dry weather overflows reaching waterways. Examples include:

- Cronulla: **18** dry weather overflows per reporting period (NSW Environment Protection Authority, 2014)
- Bondi: **19** dry weather overflows per reporting period (NSW Environment Protection Authority, 2014a)
- North Head: **142** dry weather overflows per reporting period (NSW Environment Protection Authority, 2014b)
- Malabar: **122** dry weather overflows per reporting period (NSW Environment Protection Authority, 2014c)

Modelling sewage overflows

The EPLs also require that Sydney Water develops and maintains a hydraulic sewer system model for each sewerage system. These models predict system performance in both wet and dry weather. The models are calibrated yearly using data from rainfall gauges and from gauges placed inside sewers. The sewer gauges measure the depth and velocity of wastewater flow. By comparing the results during wet weather to the baseline dry weather results, it is possible to determine the presence and location of wet weather overflows. Model runs are undertaken to determine overflow frequency and volume. The models allow comparison of system performance over time, given the same climatic conditions (Sydney Water Corporation, 2012).

For wet weather overflows the performance of each sewerage system as a whole is assessed by comparing the model's prediction for the current year's wet weather overflow frequency per 10 years, to that of the baseline year 2001. If a system's results are above the baseline range of allowable wet weather overflows, then that system is non-compliant and has breached its wet weather overflow limit for that year.

The performance of STPs is assessed by comparing the model's prediction for the current year's wet weather partial treatment discharges frequency per 10 years, to that of the 1994 baseline year. If results for a wastewater system are above the baseline year, then the STP is non-compliant for that year.

3.3.1.3 Capital works program

As at July 2014, approximately $1.5 billion has been spent since 2000 to improve wet and dry weather overflows in the four coastal systems (Sydney Water Corporation, 2015d).

Sydney Water's capital works programs are set every four years, with funding for each program determined by IPART. The existing Sydney Water capital works program runs from 1 July 2012 to 30 June 2016. Sydney Water's actual capital expenditure on wet and dry weather abatement during this period as compared to the IPART determination, is shown in Table 2.

Table 2 is an excerpt from Table A6-1 of the Sydney Water Price Plan 2016-20 Appendices (Sydney Water Corporation, 2015d). For both wet and dry weather abatement programs, the actual spending is below the IPART determination. $90m will be spent over the four-year period on wet weather overflow abatement, which is 55 percent of the IPART determination. Similarly $48m will be spent on dry weather overflow abatement, which is 73 percent of IPART's determination. The expenditure is below IPART determination because Sydney Water were able to achieve the outcomes required in the pollution reduction programs, for significantly less expenditure than the IPART determination.

Project or Program Description	2012-13	2013-14	2014-15	2015-16	TOTALS		
	Actual	Actual	Actual	Forecast	Actual/ Forecast	IPART determination	Variance
Wet Weather Overflow Abatement	47	11	15	16	90	164	-74
Dry Weather Overflow Abatement	15	11	10	12	48	66	-18
TOTAL of all Sydney Water Projects	647	560	676	696	2,580	2,827	-247

Table 2: *Actual / forecast capital expenditure by Sydney Water 2012-13 to 2015-16 ($m) on dry and wet weather overflow abatement and across all projects (Sydney Water Corporation, 2015d)*

Sydney Water advised that expenditure was below IPART determination was due to a range of factors including:

- Outcomes required by a pollution reduction program being achieved by undertaking less expensive alternatives than were priced by IPART, such as flushing sediments out of pipes, rather than replacement with larger pipes.
- A 'pain gain' incentive system utilised with contractors which incentivised efficient performance at least cost. Contractors tendered for projects (unaware of the IPART determination) and if those awarded the contract carried out the works for less than the IPART determination, they would receive half the difference as a bonus.
- The IPART determination included some expenditure items as capital expenditure, which were actually operating expenses.
- Some capital expenditure included in the IPART determination because it was initially forecast for the period 2012 to 2016, was brought forward and actually spent in 2011/12.

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3.3.1.4 Monitoring and reporting

Section 66 of the *Protection of the Environment Operations (POEO) Act 1997* requires that Sydney Water monitor and report to the EPA on sewage overflows and their impact on receiving waterways. The monitoring programs required are outlined in the "Sewage Treatment System Impact Monitoring Program" (STSIMP) (Sydney Water Corporation, 2010b). STSIMP programs have been developed jointly between Sydney Water and the EPA and have been used since 2008-09.

Monitoring

Elements that are required to be monitored include:

- Faecal indicator monitoring at recreational sites
- Biological indicators of ecological integrity and physical or chemical indicators to determine STP impacts on receiving waters, including:
    - Chronic or cumulative effects of primary treated effluent on marine sediments and benthic fauna
    - STP contribution to nutrients in ocean waters outside the dilution or mixing zone
    - Frequency and intensity of phytoplankton blooms in freshwater locations where Sydney Water STPs are the major contributor

Reporting to the EPA

Each year Sydney Water produces Annual Returns for each sewerage system. The annual returns include estimates of the total numbers of wet and dry weather overflows and their volumes and the proportion that reaches receiving waters. They also compare each wastewater system's wet weather overflow performance against the benchmark year or target system performance (Sydney Water Corporation, 2013). The Annual Returns are provided to the EPA, but are not publicly available.

However some information from the returns is available on the EPA's public register, including load-based licencing data and licence non-compliance (includes any non-compliance against overflow licence conditions). Following are instructions for how to find this information on the EPA website:

1. From the home page find "public register directory" and select "Environment protection licences'.
2. On the left hand side select "POEO Public Register".
3. Then on the left hand side select "Search for licences, applications and notices".
4. Under "Search for Environment Protection licences, applications, notices, audits or pollution studies and reduction programs", select "Licences".
5. Then search under "Licence Holder" by writing 'Sydney Water'. Alternatively search under the Licence number of the particular sewerage system you are researching.

Reporting to the public

Publicly available information about wet and dry weather overflows is included in STSIMP 'Interpretive Reports' and 'Annual Data Reports'. However the Sydney Water website has not been updated to include the most recent of these reports. The interpretive reports are produced every three years, with annual data reports provided each year in between. The interpretive reports contain additional detail than is included in the annual data reports.

Both annual data reports and interpretive reports include the following information related to overflows:

- Identification of any wastewater systems that did not comply that year with their EPL conditions, and which condition was breached (for example the wet weather overflow frequency limit)
- For wet weather overflows:
  - A graph of modelled trends in the *frequency and volume* of wet weather overflows, aggregated for ocean catchments and for inland catchments (see Figures 11 and 12).
  - A graph showing the yearly trend in modelled wet weather overflow *volumes* of individual wastewater systems for both coastal and inland systems (see Figures 15 and 16).
- For dry weather overflows:
  - A graph of modelled trends in the *frequency and volume* of dry weather overflows, aggregated for ocean catchments and for inland catchments (see Figures 13 and 14).

The additional information included in the interpretive report is:

- Explanation of the trends in the wet and dry weather overflow graphs
- Identification of the wastewater system with the highest volume and frequency of dry weather overflows.
- Wet weather overflow frequency, but only of those systems that failed to meet their frequency targets, for example "the Bondi wastewater network had a predicted overflow frequency in 10 years to 2010-11 of 174, above the limit of 154" (Sydney Water Corporation, 2012)

Neither report contains information on individual system's annual dry weather overflow volume or frequency over time.

Detail of mitigation measures and progress to prevent re-occurrence is reported in the *"Annual Sewage Treatment System Performance Report – Wet Weather Overflow 2012-13"*, which is provided to the EPA but is not made publicly available.

3.3.2 System capacity and performance

System capacity

As Australia's first colonial settlement, Sydney has the country's oldest and most intricate network of water mains, sewage pipes and stormwater pipes. Whilst it has coped with population growth and development since it was laid, a significant proportion of this water infrastructure is now reaching its structural life. With the population of Sydney predicted to increase by a further 1.5 million people, to reach 6 million by 2036 (NSW Office of Water, 2010), this ageing infrastructure is reaching its hydraulic capacity. For example the City of Sydney estimates that over 50 percent of its water infrastructure is over 70 years old and is reaching its ability to cope with future population growth and urban development (City of Sydney, 2012).

System performance

To objectively measure performance of any wastewater system, it is necessary to have a defined goal, with metrics measuring performance against the goal. Sydney Water has a legislative requirement to have a goal. Section 27 of the *Sydney Water Act 1994 (NSW)* requires Sydney Water "to adopt as an ultimate aim the prevention of all dry weather discharges of sewage to waters, including from ocean outfalls, except to the extent that this is necessary to safeguard public health or prevent environmental degradation, or both".

WaterPlan 21 was a plan devised in 1997 with goals, as a 20 year blueprint for ecologically sustainable wastewater management across the Sydney region. It included the long-term goal of "eliminating 80 to 90 percent of wet weather sewage overflows Sydney wide by 2020" (Sydney Water Corporation, 1997b). The plan was the result of investigations commenced in the late 1980s towards improving the sewerage system's performance. The cost in 1997 dollars was estimated at between \$0.5 billion and \$5 billion depending on the desired level of wet weather overflow reduction. The upper level was that required to reduce overflows to those resulting from one rainfall event per decade (Sydney Water Corporation, 1997b).

WaterPlan 21 is no longer referred to by Sydney Water. Sydney Water advised that this is because apart from the overflow target, its goals have been met and the due dates for the other programs have now passed (Kerr, 2015a). No broad environmental goal has replaced WaterPlan 21. Today the targets for overflows are those required for each sewerage system under their EPLs. However tracking the performance of individual wastewater systems against these target is difficult, due to the lack of publicly available data on the annual modelled frequency of wet weather overflows for each system. However Sydney Water advises that frequency of wet weather overflows per system in coastal Sydney has been reduced to an average of 4 overflows per annum (Kerr, 2015b).

Sydney Water estimates that wet weather overflows aggregated across the four coastal systems have been reduced by 80 percent since the year 2000, at a cost of \$1.5 billion. It is estimated that eliminating the final 20 percent of overflows would cost an additional \$5.5 billion (Sydney Water Corporation, 2015c). Sydney Water's proposal to IPART on prices to apply from 2016 to 2020 states "*We have invested \$1.5 billion since 2000 to meet the targets. This has dealt with about 80% of overflows in the four coastal systems, resulting in cleaner beaches and waterways that can be enjoyed by the community. However… Sydney Water estimated in 2012 that to meet the remaining 20% of (EPL) targets would require \$5.5 billion of additional expenditure, increasing wastewater customer bills by over a third for at least the next 50 years. This would involve building new structures and extensively upgrading existing facilities. Sydney Water would need to:*

- *Construct up to 48 storages with total capacity of over one billion litres*
- *Amplify over 900 km of pipes*
- *Amplify 31 wastewater pumping stations*
- *Improve over 1,700 km of wastewater pipes*
- *Reduce the number of illegal connections of stormwater to the wastewater system*

Construction on this scale in highly developed areas of Sydney would affect thousands of residents… and would have a significant impact on the community. In addition there are potentially diminishing benefits to the environment and community from such large additional expenditure because frequency targets do not take into account the volume, … (and) location of overflow and the resilience of the receiving waters" (Sydney Water Corporation, 2015c).

Sydney Water's solution to this problem is to propose a new risk based approach to managing wet weather overflows in Sydney. This approach will be discussed in section 3.3.4 of this report.

3.3.3 Sydney Water pricing and dividend

Sydney Water has proposed to IPART that customer water bills for the period 2016 to 2020, be lowered by an average of $100 per household per year (Sydney Water Corporation, 2015c). The media is also reporting that the State government has directed for the first time that all profit be returned to the government, delivering a $622 million dividend, a 75 percent increase on the dividend that had previously been predicted (Needham, 2015). Figure 17 shows the increase in dividend proposed for 2014-15. These actions will simultaneously lower the Sydney Water's revenue and pay out all profits.

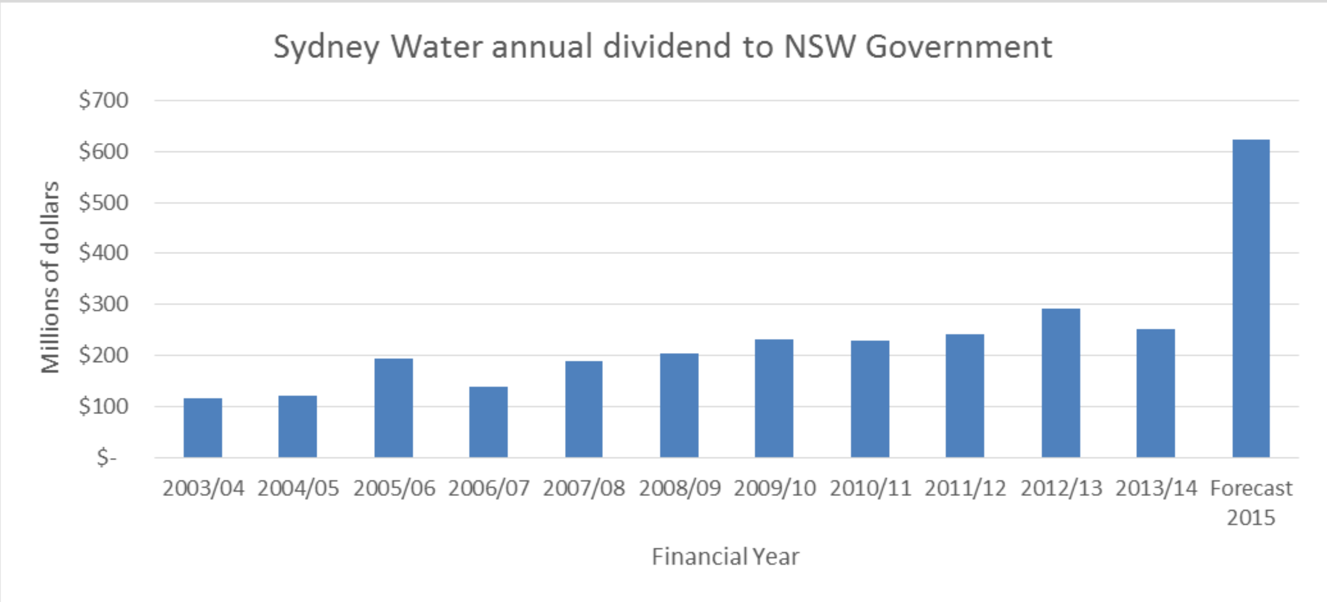


Figure 17: *Sydney Water dividend paid to NSW State government 2003/04 to 2013/14 (forecast) in $m.* Source: Sydney Water Annual Reports (Needham, 2015).

3.3.4 Proposed new licensing framework

Sydney Water has proposed changing the wet weather overflow frequency targets for the four main wastewater catchments of Malabar, North Head, Bondi and Cronulla, to a risk based approach that would replace the current frequency targets. This aims to achieve substantially lower capital costs, whilst having the same or better overall community and environmental outcomes. Whether the new approach delivers the same or better outcomes will be measured against the outcomes that would have been achieved had the current wet weather overflow targets been kept and met (NSW Environment Protection Authority, 2015). The final proposal will be submitted to the EPA before December 2015.

The EPA responded to a series of questions posed by the Sydney Coastal Councils Group to the EPA about the risk based approach in an email dated 25 November 2015. The full set of questions and EPA responses is included in this report in Appendix 4. The EPA advised that the new risk based approach is being developed with their close consultation and in principle the EPA supports the move.

A simplified outline of how the risk based approach would work will now be explained.

Each overflow is assigned a risk category rating from 1 (highest risk) to 5 (lowest risk), for each of three factors:

- Waterway ecosystem health
- Public health
- Aesthetics

The risk category for each of the three factors is determined as follows:

1. Assess the risk:
    - Risk = Likelihood (chance) X consequence (effect)

2. Determine potential for benefit if the overflow was prevented:
    - Would there be a significant benefit?
    - Are there any other contributors to the issue (e.g. does stormwater cause more pollution in the receiving waters than the overflow?)

3. Assign a risk category:
    - Risk categories are assigned from 1 to 5, based on the potential impact of the overflow.

This process is illustrated diagramatically in Figure 18.

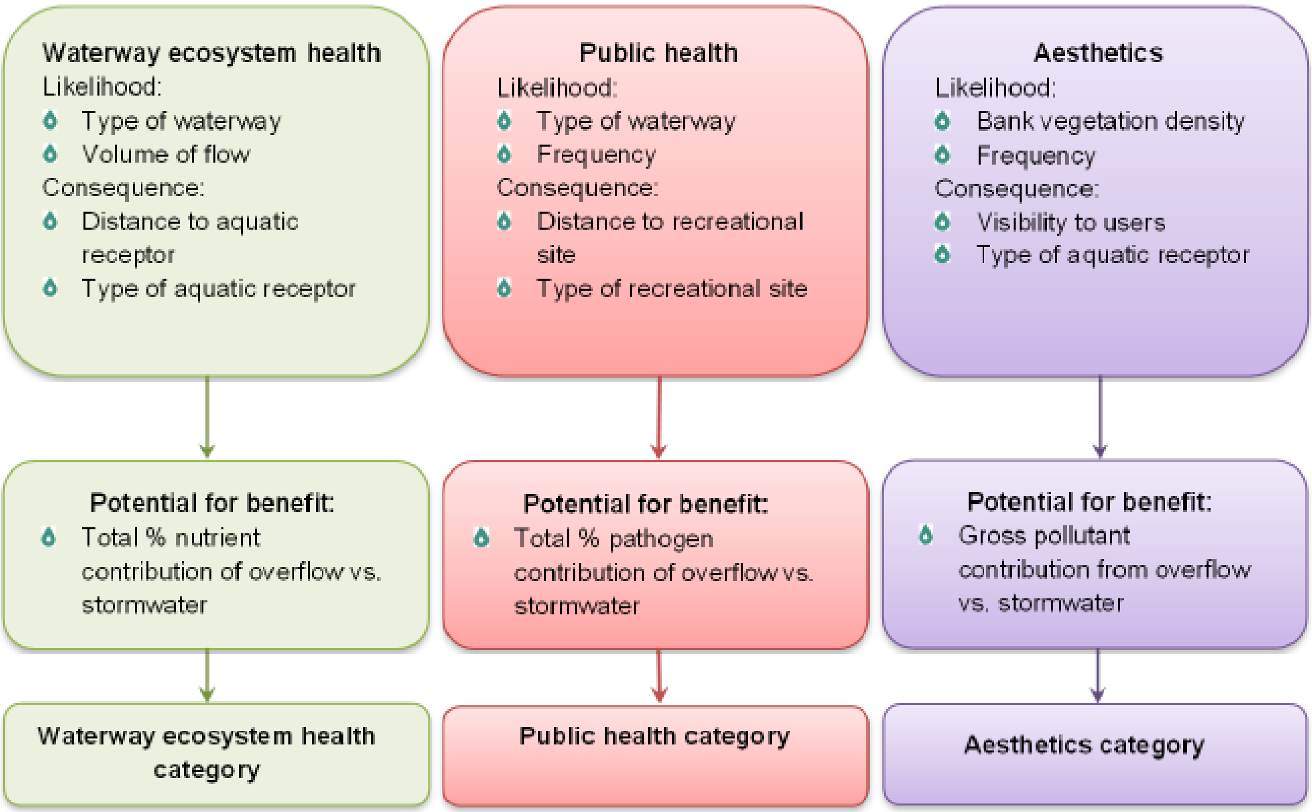


Figure 18: *The proposed risk based approach to managing sewage overflows (Sydney Water Corporation, 2015g)*

Once a risk category has been assigned for each of the three factors, whichever risk category had the highest risk, this becomes the overall risk category for the overflow. Across a catchment, these scores would be used to determine which overflows need further investigation. Overflows with as 1 or 2 are those with the highest risk and would be prioritised for investigation for abatement action.

Figure 10 in section 3.2.1 of this report shows the location of licenced overflows in Sydney, colour coded under the proposed new risk based approach to reflect each overflow's risk profile. For convenience this map has been included again in this section as Figure 19 below. The highest risk overflows are shown in red, followed by orange, yellow, green, down to blue which is of the lowest risk. The overall risk categorisation is determined based on consideration of risk to waterway ecosystem health, to public health and of aesthetics. Figure 20 shows a map of category 1 and 2 overflows. When compared to Figure 19, it is evident that whilst there are numerous overflows in the coastal areas of Sydney and that under the risk based approach they are mostly categorised with the lowest risk category of 4 or 5, indicating that they are of low risk to public health, waterway ecosystem health and aesthetics. Figure 20 shows that most overflows with the highest risk categories of 1 or 2 are located in the estuaries and inland. As a result Sydney Water will prioritise these overflows for the period 2016-2020.

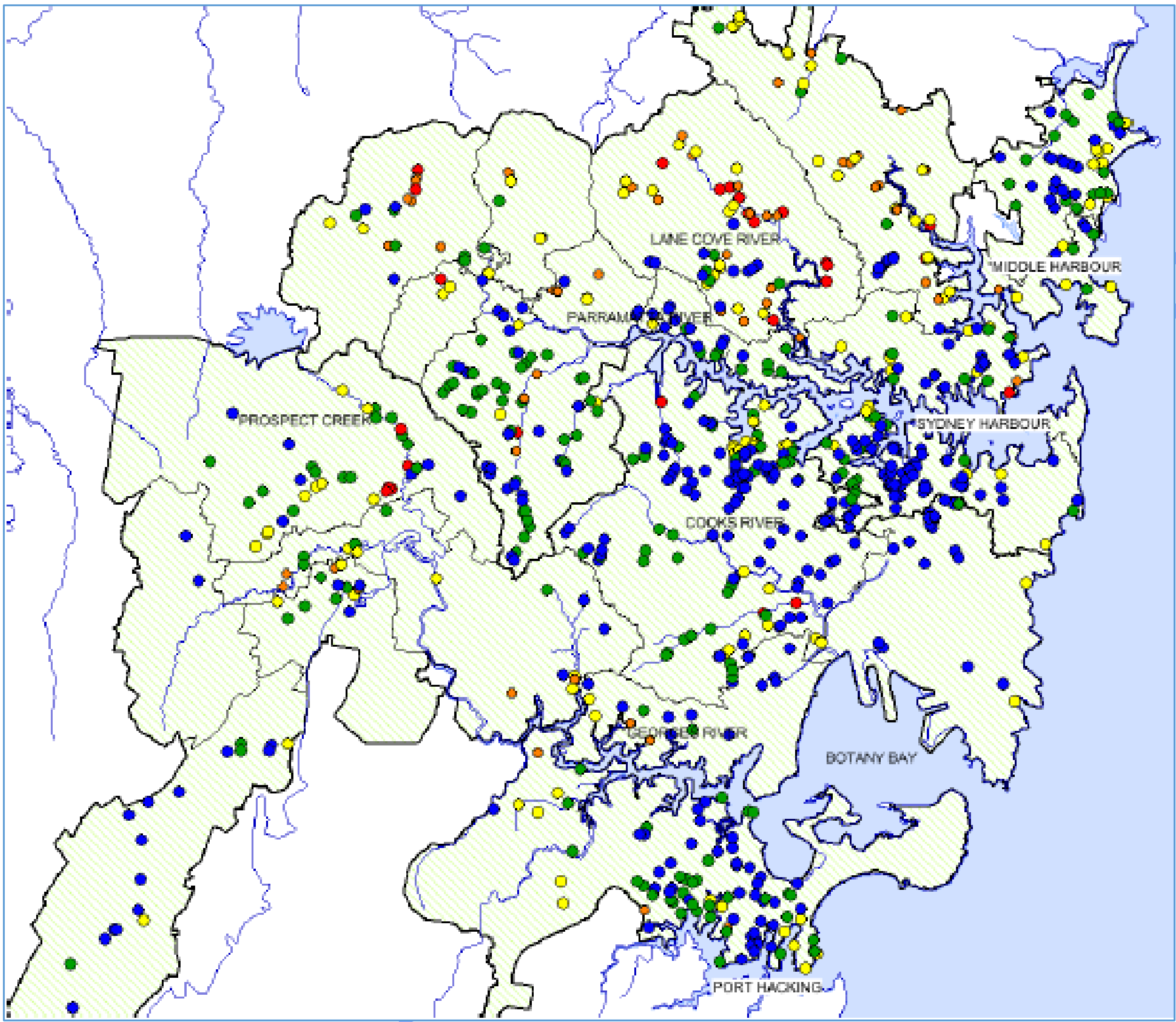


Figure 19: *Map of overflows in Sydney region, categorised for overall risk. Red is highest, then orange, yellow, green, with blue the lowest (Sydney Water Corporation, 2015g)*

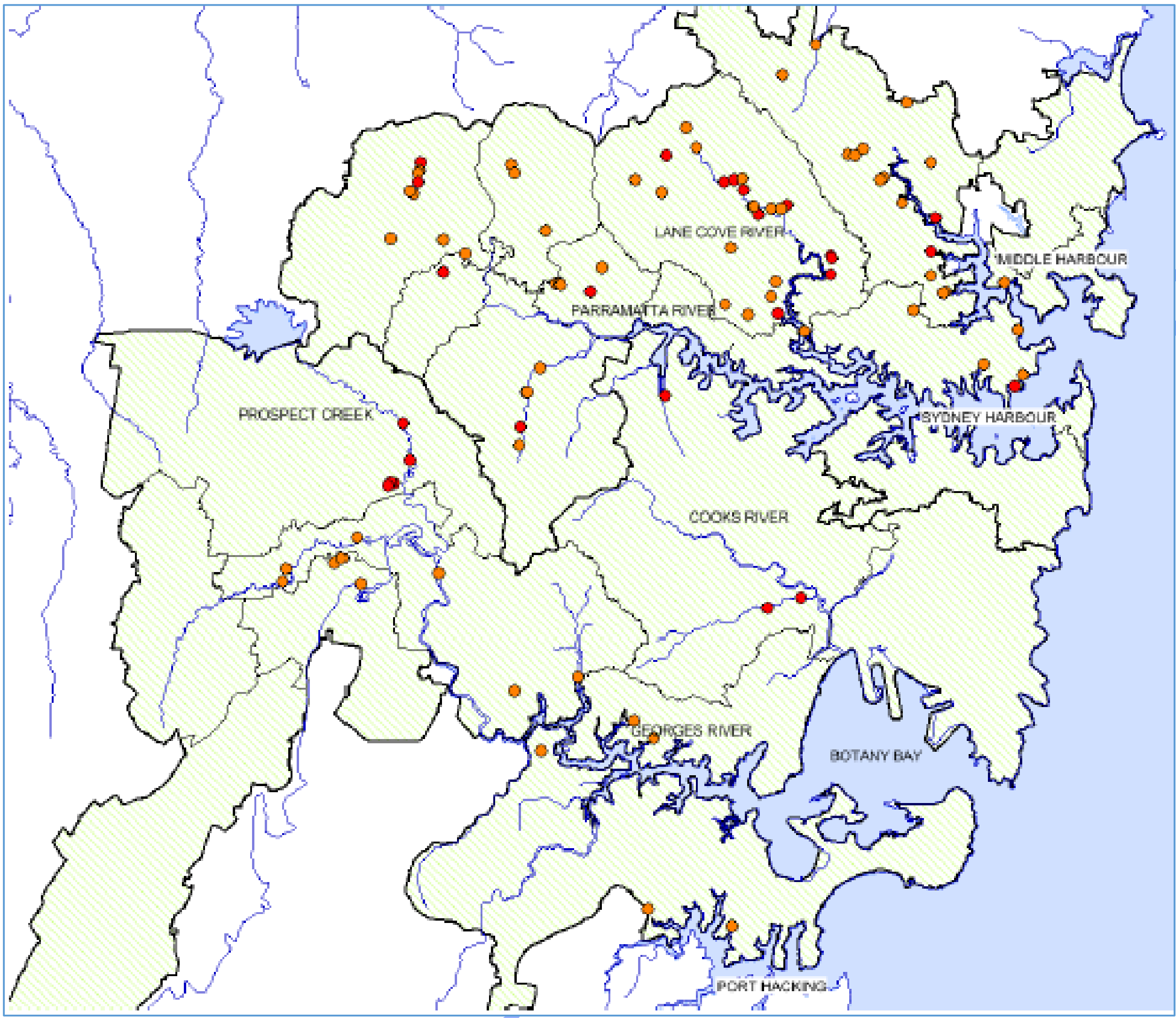


Figure 20: *Map of category 1 (red) and 2 (orange) overflows with the highest overall risk. These would be prioritised for abatement under a risk-based approach (Sydney Water Corporation, 2015g)*

The relative impacts of stormwater and sewage overflows to waterway pollution are central to allocating risk to licenced wet weather overflows under the proposed risk based approach. A two year CSIRO study in Brisbane provides a methodology that could be used to determine the correct allocation of pollution between stormwater and sewage overflows (Pollard et al., 2004, Pollard et al., 2005, Pollard, 2002). A summary will now be outlined.

Three sample sites were set for each overflow being assessed:

- One upstream of the overflow
- One at the overflow point
- One down stream of the overflow

A flap was installed at each overflow point, which triggered an alarm when a wet or dry overflow occurred. Each of the three points was sampled at different times, when there was:

- No rainfall and no overflow (to determine the ambient level and composition of waterway pollution)
- Rainfall and no overflow (to determine the level and composition of pollution in stormwater)
- Rainfall and overflow (to determine the level and composition of pollution from a wet weather overflow)
- No rainfall and overflow (to determine the level of and composition pollution from a dry weather overflow)

The relative effect on receiving waterways from pollution (including faecal contamination) under all these scenarios can then be determined and compared. This will identify what is the best outcome to reduce faecal contamination (and recover any unsafe swimming days) for each particular waterway. From this, the best approach to abate wet weather overflows can be determined.

3.3.5 Private sewer integrity 'Pipechecks'

'PipeChecks' was a 1999 program initiated by the Sydney Coastal Councils Group and environmental groups, to certify and rehabilitate sewers on private land. Initially funded by Sydney Water, the funding was withdrawn in 2002, so the program never eventuated.

PipeChecks aimed to identify faulty private sewer lines by requiring that plumbers undertake a new pre-purchase inspection of private sewers every time a property was up for sale. This would be recorded on title deeds. Just as a pest inspection identifies if there are any pest problems in properties listed for sale, similarly under PipeChecks, vendors could choose to fix the property's sewerage lines before selling, or if not, buyers would know whether their sewers needed to be renewed. As inspections of private sewers would be a part of the property sale process, rectification of faults would become a normal expectation. PipeCheck inspection information would be included in search documentation for conveyancing. Across the system as a whole, the program would create a low-cost, ongoing check of the integrity of the private sewer network and so reduce environmental damage from sewage overflows.

Property in metropolitan Sydney is sold on average every 7 years. So If councils required PipeCheck as a condition of planning consent for extensions and alterations, it was predicted that PipeCheck would result in around 80 percent of Sydney properties being inspected within 10 years (WME, 2001). This would have a significant impact on reducing wet and dry weather sewer overflows.

Sydney Water's current SewerFix program can only address problems in the parts of the sewerage system that are owned by Sydney Water. Given that an estimated half of wet weather overflows are caused by stormwater infiltration into private sewers, the urgent need for a program like PipeChecks remains. For example Sydney Water records from the time show that of nearly 95,000 inspections of private sewers, over half (49,400) had defects (Davies, 2003). It addition it is estimated that 40 percent of properties have illegal stormwater connections to the sewer (Davies, 2003). During wet weather these illegal connections increase the flow in the sewerage system, causing overflows. For example Sydney Water research suggests that when private lines are fixed at the same time as public lines, there is a 70 percent reduction in stormwater entering sewers, compared to a 30 percent reduction when only public lines are sealed (WME, 2001).

Without a program such as PipeChecks, homeowners usually neglect private sewers until significant failure. The resulting high cost to property owners to fix private overflows could be avoided if preventative maintenance of private sewers were undertaken.

3.4 Community and Media Perspectives

This section will examine community attitudes to sewage overflows as well as media coverage of sewage overflows.

3.4.1 Community attitudes

Community attitudes were referenced from Australian surveys where possible and overseas surveys in other cases.

Australian community attitudes to sewage overflows

Sydney Water recently conducted a series of three community workshops about a proposal for a new risk based approach to wet weather overflow management (Sydney Water Corporation, 2015b). There were 6 groups across Sydney and each group had 3 to 14 participants from a range of stakeholder groups including customers, water professionals, Sydney Coastal Councils Group, community and environmental groups, the EPA, councils and students. Participant’s comments included:

- Desire to be able to swim and surf after rain
- Northern Beaches (Brookvale) Storage Tank has made an improvement
- Sewer overflow into waterways should be minimised
- Bushland overflows should be made a priority for abatement due to time taken to detect overflows in these locations (weeks/months)
- The water quality in Lake Parramatta has improved in recent years
- Desire for WSUD and integrated water cycle management
- Interagency co-operation needs improvement
- Pollution and contamination of waterways such as Narrabeen Lagoon should be removed
- Desire to fish west of the Harbour Bridge

- Malabar has less pollution from stormwater now
- Desire for more transparent reporting of pollution levels
- A barrier to effective action is underpricing of water
- People are often unaware about their impact on the wastewater system and waterways

In 1997 participants in an EPA stakeholder's workshop (Sydney Water Corporation, 1997a) expressed views about wet weather overflow management including:

- The community wants 'no discharge' from sewers in the long term
- Desire for better outcomes
- Concern about engineering solutions

A CSIRO study into the relative impacts of sewage overflows and stormwater found that the public is generally unaware of overflows, their purpose or function. They are also unaware of the extent of stormwater runoff during wet weather events. However they strongly dislike the appearance of sewage and rubbish in waterways after heavy rain (Pollard et al., 2005), as the public expects waterways to be kept clean.

Community attitudes to sewage overflows in a comparable country

Canada is a developed country and has similar aged water infrastructure in its cities to Sydney, therefore it is likely community attitudes would be similar to those of Sydney residents.

In Canada the annual *RBC Canadian Water Attitudes Study* (GlobeScan Incorporated, 2015) includes a number of sewerage system related questions that are not found in Australian surveys. The 2015 survey found that Canadians are largely unaware of the condition of water infrastructure servicing their homes, with the exception of the pipes inside their own homes. Of those that do have an opinion, over three quarters believe the water supply, sewerage and stormwater infrastructure is in good condition with only minor regular investment required for upkeep. Two thirds believed aging leaky pipes should be repaired even if this costs more than letting them to leak, however the majority (83 percent) underestimated the actual cost required.

Australian community attitudes to other water related issues

A 2013 survey (MWH Global, 2013) of more than 1,000 people about urban planning and design found that water is the most important infrastructure element Australians value when choosing where to live. Water rated higher than electricity, roads or sewage, with 76 per cent of respondents valuing water supply infrastructure more than sewerage infrastructure. It also found there is still a major stigma associated with drinking recycled water. The study concluded that education around both the necessity and safety of different water supplies is a high priority to ensure the maintenance of a sustainable water supply. It found collecting rainwater, stormwater, grey water and recycled water and using these for fit-for-purpose applications will maximise efficient water use and minimise demand on fresh water drinking supplies.

3.4.2 Community preferred options

As no Australian surveys of preferred options for dealing with sewage overflows could be found, research from the US will be examined. Again as the US is a developed country with populations with similar needs, it is likely that Australian city residents would have similar preferences to options to abate overflows.

The public utilities department In Columbus, Ohio in the USA, surveyed community preferences for reducing wet weather overflows. The surveys were part of a review that compared traditional 'grey' infrastructure solutions (pipe amplification and storage) to a program called '*Blueprint Columbus'*, which included 'green infrastructure' using WSUD (Department of Public Utilities Division of Sewerage and Drainage, 2015). The main WSUD elements used in Columbus are pervious paving and bioswales (large scale rain gardens used in carparks and in streetscaping to slow, collect, infiltrate, and filter stormwater). The survey found 70% of polled residents supported the green infrastructure approach, 27 percent were neutral and less than 3% did not support the plan. Over three-quarters of the survey respondents particularly liked the green infrastructure component, as it results in additional benefits not provided by grey infrastructure. These benefits include neighborhood beautification, enhanced property values and jobs created for the ongoing maintenance of WSUD elements.

Similarly in Philadelphia in the USA, 92 percent of 700 participants in a "Green Neighborhoods through Green Streets" survey responded positively to a green infrastructure approach to addressing wet weather overflows. The Philadelphia Water Department found that stakeholders, including suburban watershed partners and residents living in wet weather overflow drainage areas, preferred a land-based approach that promotes multiple community benefits and creates sustainable watersheds and cleaner and more accessible waterways, over traditional grey infrastructure solutions (Philadelphia Water Department, 2011a).

3.4.3 Willingness to pay (WTP)

Willingness to pay for upgrades to wastewater system

Again reference is made to the previously discussed Canadian water attitudes study, as Australians could be expected to have similar attitudes. This survey found that given respondents have limited awareness of the high cost of sewerage system management and limited understanding of the poor state of the system, only one third of respondents were prepared to pay more to fund infrastructure upgrades to ensure safe treatment of wastewater/stormwater (GlobeScan Incorporated, 2015). Providing factual data on the need for sewerage system upgrades and their realistic cost would be needed to try to increase willingness to pay for upgrades to abate overflows.

Willingness to pay for water

A 2005 survey of 2021 households in Sydney, the Hunter, Wyong and Gosford was undertaken for IPART. The survey was called "*Household's Willingness to Pay for Water Service Attributes"* (Hensher et al., 2005).The following results are from Sydney residents only. 70 percent believed water and sewerage services are good value for money compared to other utilities. Although over half (56 percent) would not be happy to pay more for water, and only 34 percent were prepared to pay more. The participants most willing to pay more were households with less than 4 people.

These results are similar to a 2015 survey undertaken by Pittwater Council of 255 residents from a range of key demographics, called the 'Community water survey'. It found that even though most people in this area believe water is too cheap, they are not willing to pay more for water. Those living in units were less willing to pay more for water than those living in houses (Pittwater Council, 2015).

There have also been Australian surveys regarding willingness to pay for recycled water, including the 2010 *Waterlines* report commissioned by the National Water Commission. The survey found willingness to pay for recycled water depends on how it is priced relative to potable water (Centre for International Economics, 2010). If the relative price of recycled water is set too low, it encourages overuse of recycled water, as happened at Rouse Hill. In this case the price for recycled water was initially set by IPART at just 24 percent of the potable water price and needed to be increased to 82 percent within two years, to rectify the imbalance and reduce demand.

A 2013 Australian study found that due to Australian's strong resistance to drinking recycled wastewater, almost two thirds of respondents were willing to pay a 10 per cent premium to have drinking water without recycled sewage in the network (MWH Global, 2013).

3.4.4 Media

The media reports on a range of sewage overflow related issues in Sydney. The most common topics recently discussed include: blockages caused by wet wipes, sewage treatment plant bypasses, announcements of new 'grey infrastructure' and criticism/praise of Sydney Water's management of the sewerage system.

Many recent media articles have discussed the issue of sewer blockages caused by wet wipes, to improve public awareness. Facts are provided to explain the extent of the issue, for example that Sydney Water has removed over 1 million kilograms of wet wipes from its system over the past two years. Another issue discussed is that wet wipes are often marketed as flushable, but in fact should not be flushed into the sewerage system, as the blockages they create cause sewage overflows (Hatch, 2015).

When STP bypasses in Sydney occur, the media reports this so the public can make informed decisions about when to swim in waterways. Examples reported in the media include the 40 million litres of partially treated wastewater that bypassed North Head STP due to blackouts in a storm in April 2015 (Marks, 2015) and the bypass in August 2015 from a blackout which resulted in raw sewage entering Botany Bay (Daily Telegraph, 2015).

When new infrastructure to reduce the frequency of wet weather overflows is completed, this is usually reported in the media. For example articles were written announcing the completion of the $70 million Northern Beaches Storage tank that temporarily stores excess wastewater from the Narrabeen submain during storms (Utility Magazine, 2013) (Needham, 2013b).

The media also draws public attention to government / Sydney Water decisions. Media reports can be critical or supportive. For example the Sydney Morning Herald linked increasing bypasses at wastewater treatment plants to Sydney Water job cuts in 2013 (Needham, 2013a). The same article also reported the improvement in the Malabar beach grading by Beachwatch, after a $3 million stormwater diversion project (Needham, 2013a).

4. INTERNATIONAL (BEST) PRACTICE / INDEPENDENT RESEARCH

Areas of Sydney such as Rouse Hill and the City of Sydney, use recycled water at source, in a decentralised approach to urban water management. However for most of Sydney, water management is based on the traditional centralised approach where urban water supply, wastewater and stormwater systems are each separately designed and operated (Mitchell, 2006). This approach was designed to remove hygiene risks from waterborne diseases and to remove stormwater quickly to prevent urban flooding. It is a linear approach where water follows a one-way path from supply, to single use, to treatment then disposal to the environment. However this model has negative side effects including sewage overflows, poor waterway ecological health, increased waste disposal and pollution and high costs to replace aging water infrastructure.

Section 4 will examine alternatives to traditional sewerage management including integrated urban water management and water sensitive urban design. Current international best practice in sewerage system management will be outlined, as well as ideas yet to be implemented.

4.1 Integrated Urban Water Management

Water supply, wastewater and stormwater have traditionally been managed as separate systems, with a limited number of standard solutions. However it is recognised that integrated urban water management (IUWM) optimises the outcomes achieved by the water system as a whole (Mitchell, 2006). IUWM is a decentralised approach that recognises the connectivity of water resources, both natural and manmade, surface and subsurface, and allows for coordinated and flexible planning. Traditional and integrated urban water management is compared in Table 3.

IUWM allows the optimal combination of traditional grey infrastructure and new green infrastructure to be chosen to deal with complex urban water challenges. Grey infrastructure is made of concrete, metal or plastic (such as pipes, tunnels, storage tanks and treatment plants), whereas green infrastructure also includes soils and vegetation. Green Infrastructure describes an array of practices that use or mimic natural systems to manage urban stormwater runoff (NYC Environmental Protection, 2015). Alternative terms used for green infrastructure are ‘low-impact development technologies’ in the U.S., ‘Water Sensitive Urban Design’ (WSUD) in Australia and Canada, and ‘Sustainable Urban Drainage Systems’ in England (Askarizadeh et al., 2015). In this review the Australian terminology WSUD will be adopted.

Tools utilised in integrated water management include reuse of nonconventional water sources (such as roof runoff, stormwater, greywater and wastewater), and utilising a mix of WSUD and traditional, grey infrastructure.

The old paradigm	The emerging paradigm
Human waste is a nuisance. It should be disposed of after treatment.	Human waste is a resource. It should be captured and processed effectively, used to nourish land and crops.
Stormwater is a nuisance. Convey stormwater away from urban area as rapidly as possible.	Stormwater is a resource. Harvest stormwater as a water supply, and infiltrate or retain it to support aquifers, waterways, and vegetation.
Demand is a matter of quantity. Amount of water required or produced by different end-users is the only parameter relevant to infrastructure choices. Treat all supply side water to potable quality, and collect all wast water for treatment.	Demand is multifaceted. Infrastructure choice should match the varying characteristics of water required or produced for different end-users in terms of quantity, quality, level of reliability, etc.
One use (throughput). Water follows one-way path from supply, to a single use, to treatment and disposal to the environment.	Reuse and reclamation, Water can be used multiple times, by cascading from higher to lower quality needs, and reclamation treatment for return to the supply side of infrastructure.
Grey infrastructure. Infrastructure is made of concrete, metal, or plastic.	Green infrastructure. Infrastructure includes not only pipes and treatment plants, made of concrete, metal, and plastic, but also soils and vegetation.
Bigger/centralised is better for collection system and treatment plants.	Small/decentralised is possible, often desirable for collection system and treatment plants.
Limit complexity and employ standard solutions. Small number of technologies by urban water professionals defines water infrastructure.	Allow diverse solutions. Decision makers are multidisciplinary. Allow new management strategies and technologies.
Integration by accident. Water supply, wastewater and stormwater may be managed by the same agency as matter of historical happenstance. Physically, however, three systems are separated.	Physical and institutional integration by design. Linkages must be made between water supply, wastewater, and stormwater, which requires highly coordinated management.
Collaboration = public relations. Approach other agencies and public when approval or pre-chosen solution is required.	Collaboration = engagement. Enlist other agencies and public in search for effective solutions.

Table 3: *Characteristics of "old" and "emerging" paradigms of urban water systems (Pinkham, 1999)*

'Grey' infrastructure is the traditional solution to wet weather overflows. It requires construction of large capital works to create additional capacity in the wastewater system, through amplification and storage. Grey infrastructure includes capacity improvements to STPs, construction of storage tanks to transport and temporarily store stormwater, and construction of new tunnels and larger pipes. As it is focused on creating additional sewer capacity, grey infrastructure treats the symptom of the problem of too much water in the stormwater system.

4.1.1 Water Sensitive Urban Design

WSUD is an alternative approach to traditional methods used to abate wet weather overflows. It is a preventative rather than treatment measure, as it keeps stormwater out of the wastewater system in the first place. By diverting rainwater runoff out of the stormwater system, the volume of water that can infiltrate into defective wastewater system pipes during wet weather is reduced, which reduces sewage overflows. WSUD aims to manage stormwater runoff and its pollutants in a decentralised approach modelled after nature, by maximizing the reuse of stormwater and providing at-site water quality treatment. The general approach is to allow stormwater to flow through planted soil.

WSUD infrastructure includes:

- rainwater tanks used for stormwater harvesting and reuse
- rain gardens, rooftop greening and urban forests
- gross pollutant traps, wetlands and sediment ponds
- grassed or landscaped swales
- infiltration trenches and bio-retention systems
- grey water harvesting and reuse
- porous paving
- aquifer recharge and reuse (Melbourne Water, 2015)

Some of this infrastructure is illustrated diagrammatically in Figure 21.

Figure 21: *A range of treatments available to better manage stormwater (Melbourne Water, 2015)*

WSUD techniques can be used in car parks, roadsides, residential housing and commercial and industrial properties.

WSUD approaches work best when a number of treatments are distributed throughout the catchment, rather than constructing a single large treatment at the catchment outlet, for the following reasons:

- Provides opportunities for local harvesting benefits
- Better mimics the natural water cycle and improves receiving waterway health through natural treatment of stormwater
- Water quality is improved along a greater length of the waterway
- Localised treatment allows specific targeting of highly polluted sites or sewage overflow points
- Failure of a single treatment will not affect the overall system
- The total cost to the community is lower
- Implementation can be staged in line with available revenue
- Each WSUD element can be smaller than a single large one at the bottom of the catchment, thus saving space and reducing costs (Melbourne Water, 2015).

4.1.1.1 Comparison of performance of rain barrels and raingardens

Research is being undertaken to determine the best inexpensive WSUD techniques that can be implemented at a wide scale for reducing sewage overflows. The US EPA in collaboration with the University of Cincinnati, compared the performance of rain barrels (small water tanks) and rain gardens in reducing excess rainwater runoff in a 2009 study (Aad et al., 2009). See Figures 22 and 23 for illustration. The study found the rain gardens performed better than rain barrels in terms of both peak and volume reduction of stormwater flow.

Figure 22: *Typical US residential rain barrel (iTree, 2015)*

Figure 23: *Planter box raingarden (Melbourne Water, 2013)*

Studies have found that the size of a rain garden should be around 15 percent of the area of the impervious surface, to absorb all the stormwater and achieve a level of infiltration such that rainfall events do not contribute to overflows (Aad et al., 2009). Raingardens and bioswales (which are larger scale rain gardens) are therefore an inexpensive alternative to reducing wet weather overflows compared to using expensive, large-scale centralised stormwater sewer amplification or detention tunnels.

4.1.1.2 Permeable Paving

Permeable paving is another WSUD technique increasingly utilised internationally to mitigate sewage overflows. It allows stormwater to move through the surface to a storage layer below, with water eventually infiltrating into the underlying soil. Types of permeable paving include pervious concrete, porous asphalt, interlocking concrete pavers, and grid pavers. These pavement systems are ideal for car parks, driveways, alleys, footpaths and playgrounds. Permeable paving can be used on all soil types including clay. Maintenance involves using a regenerative air vacuum instead of a street sweeper. However permeable paving is only suitable for slopes up to 5 percent, as the pavers have a tendency to creep down steeper slopes. Figure 24 illustrates the more attractive appearance of WSUD elements, which can create enhance property values.

Figure 24: *Before and after images of an alley in Chicago which showed chronic signs of flooding until replaced by permeable pavers and surfaces that allow water infiltration (Economides, 2014).*

4.1.1.3 Limitations of WSUD and Integrated Urban Water Management

Slopes

Parts of Sydney, particularly areas North and East of the Cumberland Plain, have many hills. This can lead to the perception that WSUD is incompatible with Sydney’s steep slopes. However WSUD infrastructure can be effectively integrated into sites with slopes of 5 to 25 percent grade (US EPA, 2014a). Different strategies are required for different slope ranges. For example for slopes of up to 5 or 6 percent, the following techniques are suitable:

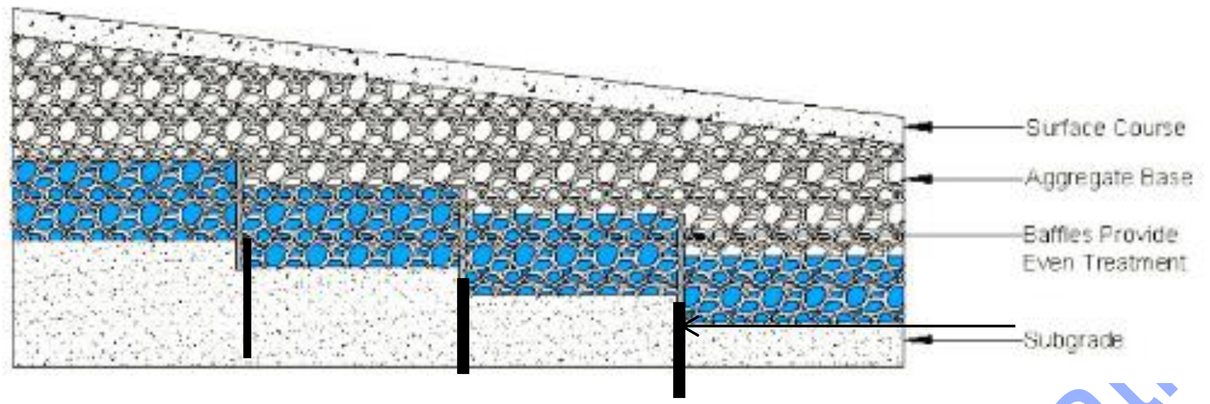
- Stepped pools (Fig. 25) or weirs (Fig. 26) used with bioswales/ planter boxes/ bioretention, to slow flows
- Dry wells (underground pits filled with gravel that slow stormwater and allow infiltration) (Fig. 27)
- Check dams used with grass channels (Fig. 28) to slow flows
- Baffles used with permeable paving (Fig. 29)
- Infiltration trench (Fig. 30)

Figure 25: *Stepped pools to slow flows Source: Seattle Public Utilities: www.seattle.gov*

Figure 26: *Weir used to slow flows (US EPA, 2014a)*

Figure 27: *Dry well*

Figure 28: *Grass swale with check dams*



https://www.youtube.com/watch?v=SzwRYma7W4c Photo courtesy Stormwater Maintenance and Consulting, LLC.

Figure 29: *Permeable paving with baffles to slow stormwater flow (US EPA, 2014a)*

Figure 30: *Infiltration trench (Pennsylvania Department of Environmental Protection, 2006)*

Techniques suitable for slopes up to 25 percent, are construction of diversion berms (Fig 31) and planting trees and vegetation to prevent erosion and absorb water. A diversion berm is a mound of compacted earth with sloping sides that is constructed along a contour. (US EPA, 2014a).

Figure 31: *Diversion berm, suitable for steep slopes (Pennsylvania Department of Environmental Protection, 2006)*

Clay soil

Where clay soil is present, WSUD structures should be lined with impermeable high density polyethylene (HDPE) geomembrane or a concrete box, with a pipe at the impermeable base connected to the stormwater system. WSUD structures connected to the stormwater system still provide the benefits of pollutant removal and evapotranspiration. In addition by providing temporary stormwater storage and reducing the runoff rate and volume of stormwater, they can contribute to avoiding overloading the sewerage system during wet weather.

Social licence

Community support is essential for the success of integrated urban water management. For example in the Gold Coast the award winning Pimpama Coomera Class A+ recycled water scheme introduced in 2009, is currently being discontinued. The dual reticulation systems installed in over 4000 homes are being disconnected over three years. The scheme provided highly treated Class A+ recycled wastewater through a separate network for toilet flushing and external use via purple taps. However the publicity from a small number of cross connections which exposed residents to drinking recycled water caused the public to lose confidence in the safety of water supplies. Many people then elected not to use the recycled water, which made the scheme unviable (Water Quality Research Australia, 2010, City of the Gold Coast, 2014).

4.2 International Best Practice

International best practice in mitigating wet weather overflows utilises WSUD stormwater management. For example the United States Environmental Protection Agency (US EPA) advises WSUD may provide ideal solutions for wet weather overflows caused by inflow problems, such as illegal stormwater connections. Here instead of simply redirecting the illegal sewer connections to the stormwater network, (transferring the water quality problem from one system to another) the US EPA advises the water should be redirected to rain barrels, water tanks, rain gardens, swales or other measures where the stormwater can be used to recharge groundwater, irrigate landscapes, or be used for other non-potable water uses (US EPA, 2014b). Where infiltration of stormwater into the sewerage system through cracks and faulty joints is the primary cause of wet weather overflows, the US EPA advises grey infrastructure combined with WSUD, is typically the best solution (US EPA, 2014b).

WSUD is preferred to grey infrastructure solutions alone because by reducing the amount of stormwater in the system, it can reduce the amount of expensive grey infrastructure required to prevent overflows. It also provides additional social and environmental benefits, such as reducing demand on drinking quality water, providing wildlife habitat and improving amenity and stormwater quality. Many cities around the world are already implementing WSUD. Case studies of best practice programs implemented in Sydney, Melbourne, Singapore, the US, Germany and the United Kingdom will now be examined. Figures 32 to 35 provide background information to compare the cities of Sydney, Melbourne, Singapore, New York, Philadelphia and Columbus in terms of average annual rainfall, land area, population and population density.

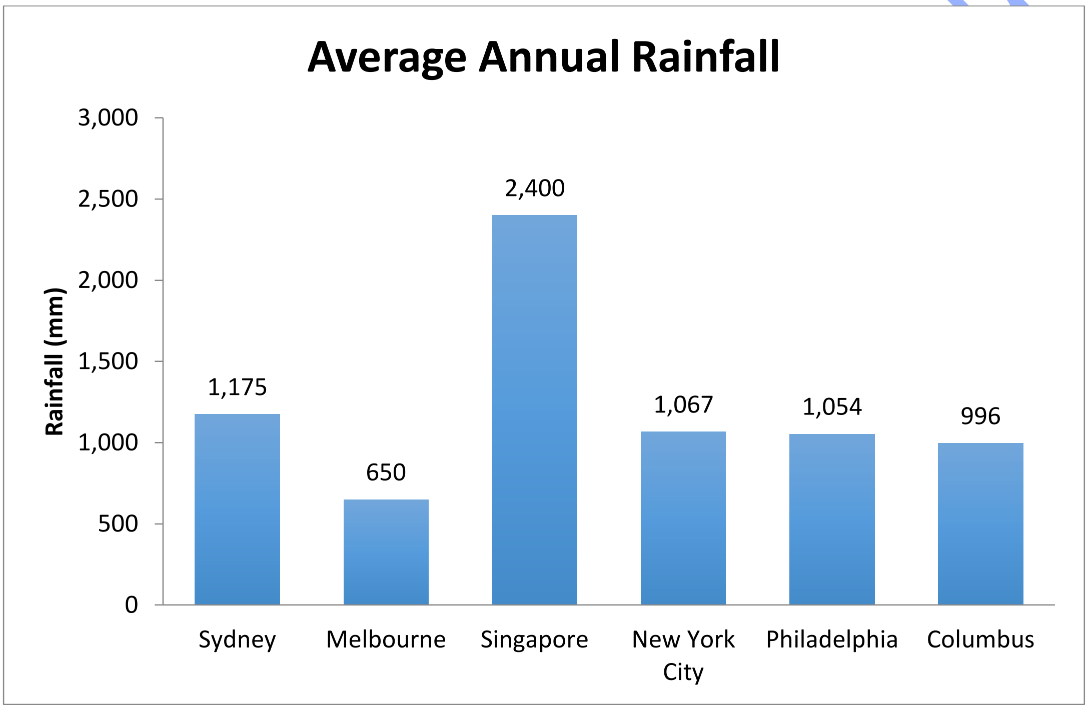


Figure 32: *Average annual rainfall in comparison cities implementing WSUD*

Figure 32 shows that Sydney has less than half the annual rainfall of Singapore, but nearly double that of Melbourne, and similar rainfall to the comparison US cities implementing WSUD programs (Figure 30). In terms of area, Sydney and Melbourne are spread over a much larger area than the other cities (Figure 33) so Sydney and Melbourne's wastewater and stormwater pipe reticulation systems are much longer.

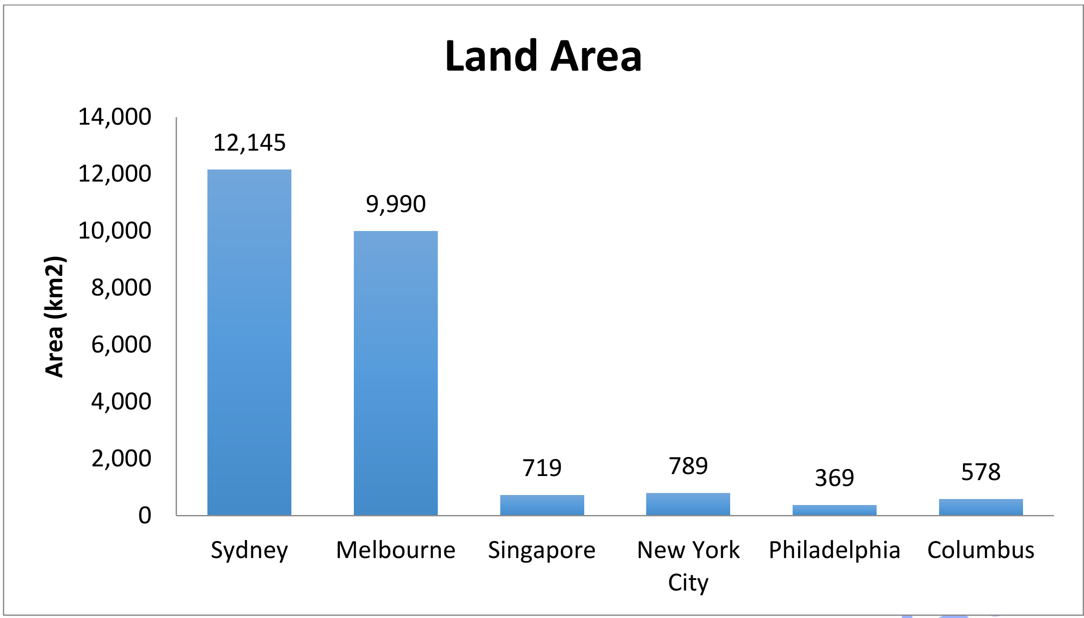


Figure 33: *Land area of comparison cities implementing WSUD*

In terms of population size, Sydney and Melbourne are much larger than Philadelphia and Columbus, but less than Singapore and nearly half the size of New York's population (Figure 34).

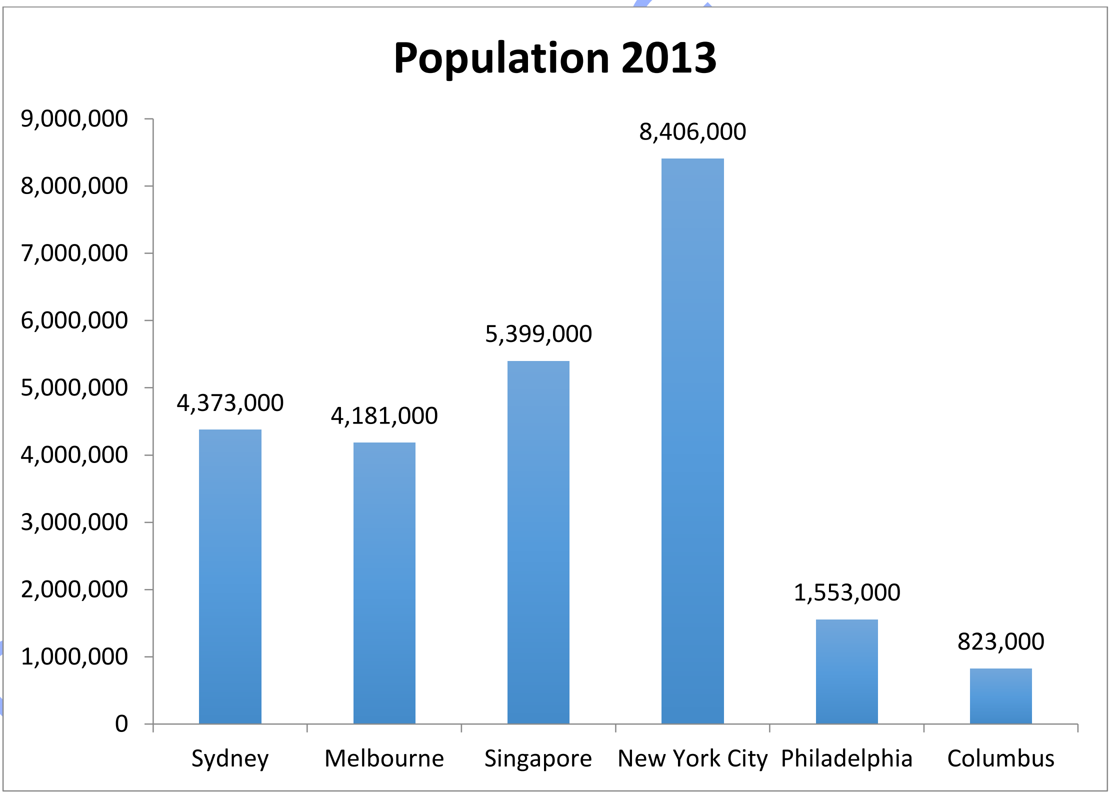


Figure 34: *2013 Population for comparison cities implementing WSUD*

Sydney and Melbourne are also significantly less densely populated than Singapore and the comparison US cities (Figure 35).

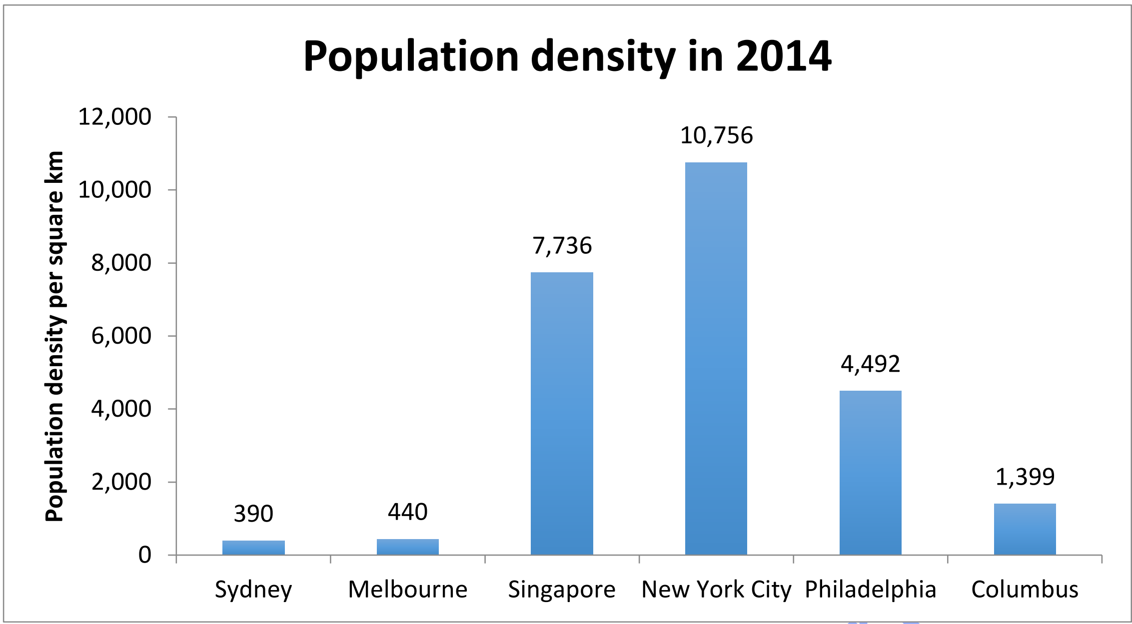


Figure 35: *2014 population density of comparison cities implementing WSUD*

It is evident that Sydney's large land area presents a challenge in managing wet weather sewage overflows, as the sewer system's extensive size will potentially have more leaks and also a greater number of illegal connections (due to the low population density with many people living in detached housing). A large number of WSUD elements will be required in such a spread out city to significantly reduce stormwater runoff. However international experience indicates the implementation cost would still be significantly lower than grey infrastructure solutions alone (see section 4.2.4). The cost of implementing WSUD in Sydney could be reduced by implementing some of the innovative financing ideas used in Philadelphia and Germany, where incentives are created for privately funded WSUD development (see sections 4.2.4.2 and 4.2.5).

The WSUD programs being implemented in Sydney, Melbourne, Singapore, New York City, Philadelphia, Columbus and Germany will now be outlined.

4.2.1 Sydney

4.2.1.1 City of Sydney Decentralised Water Master Plan

The City of Sydney has prepared a 'Decentralised Water Master Plan' to treat and reuse water at source. The plan incorporates water efficiency, recycled water and stormwater quality measures. The recycled water and stormwater quality measures will reduce wet weather overflows by reducing the volume of stormwater flowing through the stormwater system during wet weather. Key targets of the plan include:

- Recycled water:
  - Reduce mains water consumption in Council's own buildings and operations to 10% below 2006 levels by 2030 through water efficiency and connection to non-potable water supplies.
- Stormwater quality:
  - Reduce 50 per cent of sediments and suspended solids and 15 per cent of nutrients currently discharged into the waterways from stormwater run-off generated within the City of Sydney by 2030 (City of Sydney, 2015).

Recycled water and WSUD is being incorporated into all new developments as well as some renewals of public open space and streetscape projects. Recycled water projects include two precinct scale stormwater harvesting schemes at Green Square, Town Centre and Sydney Park. At these locations stormwater is collected, stored and treated so it is fit for purpose for non-potable uses such as toilet flushing, laundry use, irrigating parks and gardens and in air conditioning cooling towers. Sydney Park uses a bioretention system and wetlands to treat the stormwater. In addition 12 park-scale water-harvesting schemes have been implemented to recycle stormwater for irrigation of the parks.

WSUD elements already introduced include 130 raingardens, 53 green roofs and 30 green walls (City of Sydney, 2015). The goal is to retrofit public open space with a combination of raingardens, swales and wetlands in at least 10 percent of opportunities and to incorporate WSUD into at least 10 percent of renewals of roads and other streetscape projects (City of Sydney, 2015).

4.2.1.2 Sydney Water decentralised community systems

In Bingara Gorge and Rouse Hill in NSW, decentralised systems have been constructed at a precinct scale. Rouse Hill is the biggest reuse system in the Southern hemisphere (Kerr, 2015b). These decentralised systems use sewer mining (recycling of wastewater) to provide an alternative water source. Households and businesses use recycled wastewater that has been treated at a local treatment plant for toilet flushing and for outdoor uses such as garden watering and washing cars. This water is provided in purple pipes so it is clear to users that it is recycled non-potable water. Use of the two types of water is separately metered and billed, with the recycled water priced lower than potable water. Such decentralised local use of wastewater eliminates the traditional transport of wastewater in long sewers to coastal treatment plants. This reduces the possibility of water infiltrating into the long network of aging and leaky pipes, which can cause sewage overflows.

4.2.1.3 Sydney – Stormwater Trust

The now defunct Stormwater Trust in NSW funded an urban stormwater program that was a world first in cleaning stormwater before reached waterways (Peatling, 2004). The Stormwater Trust was established in 1997 by the NSW government and was allocated $60 million in funding for the first three years. The objective of the Stormwater

Trust was to encourage and support better stormwater management to improve the condition of receiving waterways. The program had three main elements:

- A stormwater trust grants scheme that allocated $51 million primarily to local councils to undertake 252 stormwater projects.
- A state-wide urban stormwater education program to educate the community, industry and local councils about ways to reduce stormwater pollution
- A stormwater management planning process that required local councils to prepare stormwater management plans for their urban areas. The plans were jointly prepared on a catchment basis by councils with participation of relevant state agencies.

The Urban Stormwater Program was successful in reducing stormwater pollution in a cost effective manner and in raising public awareness (Stormwater Trust, 2000). The program ran from 1997 to June 2006, at which time the Stormwater Trust was closed, due to funding cuts to the Department of the Environment and Conservation (Peatling, 2004).

Another innovative project was run between July 2002 and September 2003, to build the capacity of local councils to implement WSUD. It was a collaboration between Sydney Coastal Councils Group, Western Sydney Regional Organisation of Councils, the Upper Parramatta River Catchment Trust and the Stormwater Trust. Workshops and a competition were held where councils presented their achievements in WSUD to other entrants. The project was successful in encouraging free exchange of WSUD knowledge and in facilitating implementation of WSUD across Sydney councils.

4.2.2 Melbourne

In 2008 Melbourne Water launched the ‘10,000 Raingarden Program’ which called for 10,000 rain gardens to be built across the Port Phillip and Westernport regions, a target reached by 2013. Rain gardens reduce runoff as they are placed between stormwater runoff sources (roofs, driveways, carparks) and runoff destinations (storm drains, streets, and streams). By reducing stormwater flow, infiltration into sewer pipes is reduced during wet weather, which reduces sewage overflows.

4.2.3 Singapore

Singapore is an example of world’s best practice in integrated water management at a regional scale. The driver was Malaysia dramatically increasing the price charged to Singapore for potable water, resulting in a 2003 decision to set a goal for water self-sufficiency by 2061. The integrated water management plan designed to achieve this includes both water recycling and construction of two desalination plants. The management of water supply, wastewater and stormwater was brought together so they could be managed by a single agency, the Public Utilities Board, in an integrated and coordinated manner.

Like Sydney and Melbourne, Singapore has separated wastewater and stormwater systems. The Public Utilities Board made the decision in the late 1990s to replace the nation's entire wastewater system with a new infrastructure system called the Deep Tunnel Sewerage System (DTSS). The A$3.6 billion DTSS is considered one of the most visionary water projects in the world and has received numerous awards for innovative sewerage management (Sipes, 2010). It collects, treats and reclaims wastewater using a large deep water tunnel and a network of cross-island tunnels to intercept all wastewater and convey it by gravity to two new centralised tertiary sewage treatment plants at either end of Singapore. The large tunnel is located 50 metres below ground and has diameter up to 6.5 metres. Much of the two STPs is located underground. The use of gravity to convey wastewater through the deep-water tunnel eliminates the need for pumping stations, which reduces the chance of sewage overflows from pumping station failures. The Public Utilities Board has recently been experimenting with projects incorporating a totally sealed sewer system, thus eliminating I&I altogether and the potential for wet weather overflows.

After treatment the wastewater is either discharged to the ocean through deep-sea outfalls, or further treated using microfiltration, reverse osmosis and ultraviolet disinfection, to potable quality. This water is called NEWater in Singapore and exceeds World Health Organisations for drinking water. Most of the NEWater is used for industrial and air-cooling purposes, with the balance fed into reservoirs during dry months. This blended water then undergoes filtration before being supplied to customers for potable use. NEWater currently meets 30 percent of Singapore's total water demand and is planned to meet 55 percent of future water demand by 2060 (Singapore Public Utilities Board, 2015).

Urban stormwater is also harvested on a large scale for treatment to add to drinking water supply. At source WSUD techniques, such as green roofs, rain gardens, porous paving and retention ponds are used to slow stormwater down (Public Utilities Board, 2014).

4.2.4 United States

Major cities in the US demonstrate varying levels of effort in promoting WSUD. Leading cities include New York City, Philadelphia (Pennsylvania) and Columbus (Ohio). In the US one of the prime motivations for WSUD is to bring systems into compliance with the US *Clean Water Act (US EPA, 2014b)*. The EPA strongly encourages WSUD (green infrastructure) solutions to abate sewage overflows from both combined and separated sewerage systems (US EPA, 2014b). Combined overflows occur in cities with combined sewer systems (where wastewater and stormwater are collected in the same pipe network). NYC has a largely combined sewer system, Pennsylvania's system is 48 percent combined and 52 percent separated, and Columbus has a mostly separated system (only the downtown and university areas of the city are combined). Columbus' system therefore most closely resembles Sydney's separated system.

4.2.4.1 New York City

In 2010 NYC began the 20-year "New York City Green Infrastructure Program", which is managed by the New York Department of Environmental Protection (DEP). The goals are to:

- Reduce combined sewer overflow (CSO) volume by an additional 3.8 billion gallons (14.4 billion litres) per year, or approximately 2 billion gallons (7.6 billion litres) more than the 'all grey infrastructure' strategy
- Capture rainfall from 10 percent of impervious surfaces in CSO areas through green infrastructure (WSUD) and other source controls
- Provide substantial, quantifiable sustainability benefits that the previous grey strategy did not provide including:
    - Cooling the city
    - Reducing energy use
    - Increasing property values
    - Cleaning the air (Economides, 2014)

The green infrastructure program is projected to reduce combined sewer overflow volumes by 60%. The estimated cost of the Plan is US$1.5 billion, significantly less expensive than the $3.9 billion needed to achieve the same level of overflow abatement by grey infrastructure alone. In addition to a lower cost, the green infrastructure plan will produce greater sustainability benefits over time (Figure 36) (Economides, 2014).

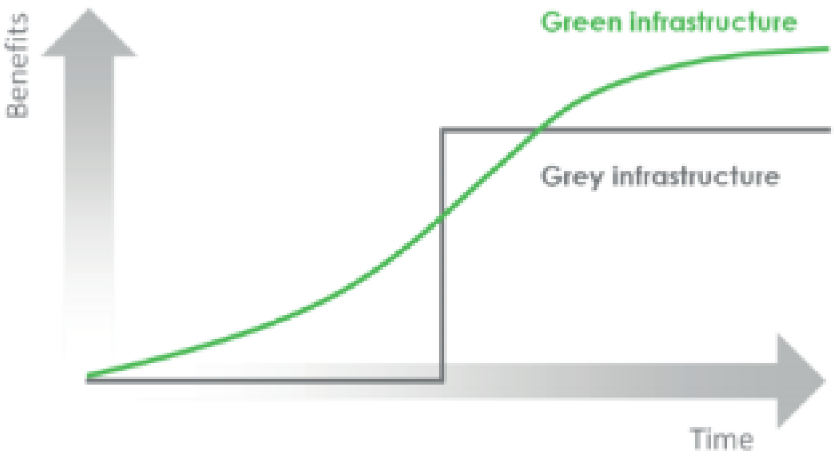


Figure 36: *Predicted benefits from the green (WSUD) and grey infrastructure combined sewer overflow management strategies for New York City (Economides, 2014)*

WSUD strategies implemented in New York City (NYC) include green roofs, permeable paving, engineered wetlands, street trees and bioswales. A bioswales is a vegetated depression or trench that receives stormwater runoff and slows water filtration. NYC expects to eventually have the largest number of bioswales in the world (NYC Environmental Protection, 2015). See Figure 37 for an illustration of a NYC bioswale. Each NYC bioswale is 1.52 metres deep and can absorb 7,570 litres of water each time it rains. The kerb directs stormwater to the swale, where it gets treated by the vegetation and is absorbed by the sandy soil at the top (engineered soil) and stone layer at the bottom. The stone layer stores the water until it can infiltrate into the subsoil and replenish groundwater. Water absorbed by the trees and plants or on the surface of the bioswale is released into the air as water vapour, in the process called ‘evapotranspiration.’ Whilst most of the curb runoff is being directed into the bioswale, during heavy storms if the bioswale reaches capacity, the water will overflow at the outlet and enter the combined sewer system (NYC Environmental Protection, 2015).

In March 2013, the New York Department of Environmental Conservation and DEP announced an agreement to increase the level of investment to US$2.4 billion in WSUD and US$1.4 billion in grey infrastructure to target the City’s most sewage impaired waterways over the next 18 years. This will save US$1.4 billion in grey infrastructure substitution projects and an additional US$2 billion in deferred costs. The estimated savings are viewed favourably by stakeholders, assisting in public acceptance of green infrastructure programs in NYC (Economides, 2014).

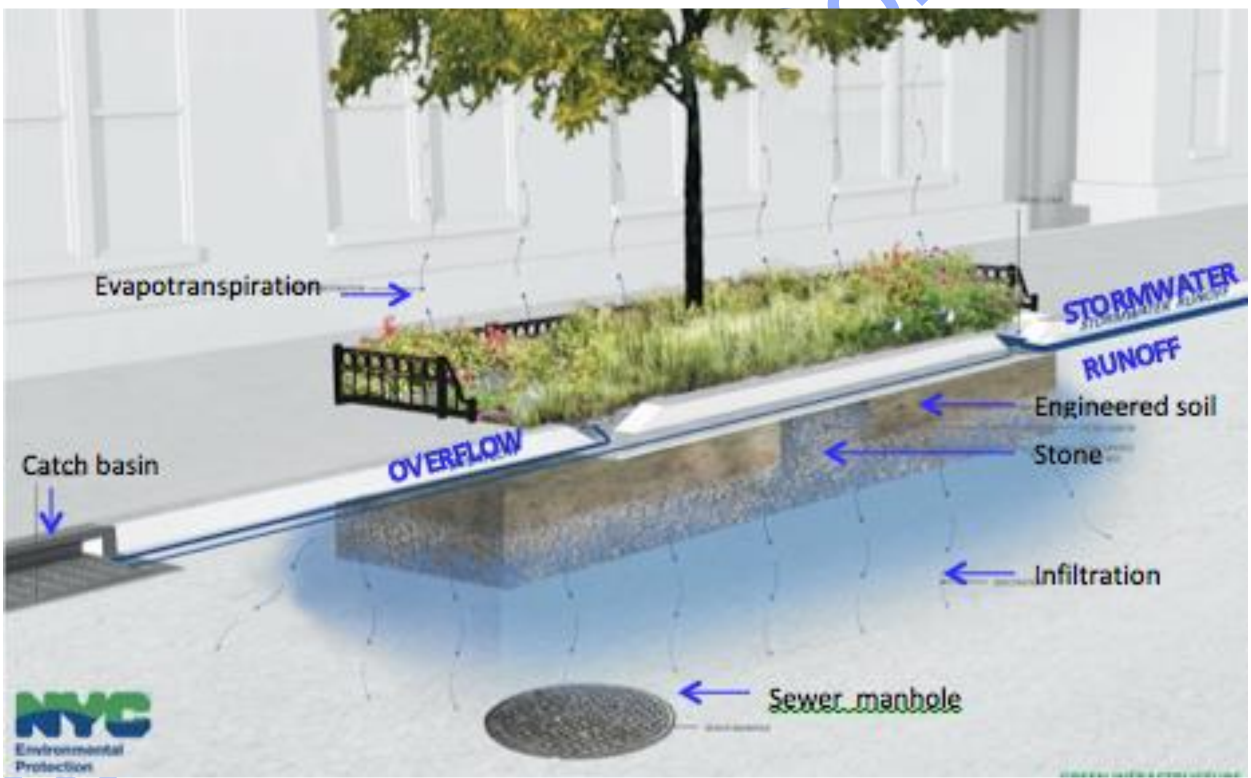


Figure 37: *Typical New York City kerb-side bioswale* (NYC Environmental Protection, 2015)

4.2.4.2 Philadelphia, Pennsylvania

The largest green stormwater program in US is in Philadelphia. The program began in 2011 and is a 25-year, US$2 billion program called “Green City, Clean Waters”. The program is managed by the city’s water utility, the Philadelphia Water Department. Its aim is to mitigate stormwater issues and abate sewer overflows primarily through

WSUD. Specifically the target is to green at least 1/3 of the existing impervious cover in their combined sewage drainage areas within 25 years. It is estimated that this will prevent 85% of the current levels of pollutants that are entering waterways from sewer overflows on a system wide average basis (Philadelphia Water Department, 2011b). Tools utilised include raingardens, green roofs, pervious paving, rain barrels, stormwater basins, vegetated curb extensions, stormwater planters, stormwater tree trenches, stormwater treatment wetlands and bioswales (Economides, 2014).

Philadelphia has implemented innovative financing ideas to fund the WSUD implementation. For example the 'Stormwater Management Incentives Program', offers credit incentives to private owners of impervious commercial properties, to build and maintain green stormwater management projects. Private development has shown to provide the most green infrastructure, with 79 percent of constructed new green impervious areas in Philadelphia coming from private development (Economides, 2014).

Additional funding for WSUD projects comes from stormwater fees, which are charged to commercial properties based on the area of impervious surfaces the properties cover, rather than on the amount of stormwater runoff. Owners of carparks (which were not previously charged for stormwater runoff) are also now charged a similar rate to commercial customers. The water utility provides free design assistance and site evaluation to identify WSUD stormwater management opportunities. If the recommended work is undertaken to retrofit the property to manage the first inch (2.5cm) of runoff, the commercial customer is given 'stormwater credits' that reduce the cost of their water bills. A free cost-benefit analysis is also provided by the utility to weigh the cost of the retrofit against the annual water bill savings (Philadelphia Water Department, 2011b). Philadelphia expects to receive US$ 1 – 1.5 billion over the 25 years due to this program, which will help fund the Green Cities, Clean Waters program (Economides, 2014).

In addition, all new development and redevelopment of properties over 4,500 square metres must manage the first inch (2.5cm) of water runoff on the site. Green infrastructure is also implemented every time any street work is done on water, gas, cable, and phone lines, or when routine repaving work is undertaken (Philadelphia Water Department, 2011b).

4.2.4.3 Columbus, Ohio

The city of Columbus' largely separated sewer system most closely matches Sydney's system. Their program to address wet weather overflows is called "Blueprint Columbus" and is a 20 year US$1.7 billion program. This program replaces the previous grey infrastructure plan, which was to cost US$2.5 billion and take 30 years to achieve the same level of wet weather overflow abatement (Department of Public Utilities Division of Sewerage and Drainage, 2015). The Blueprint has four main elements.

- Rehabilitation of the entire private sewer network by lining residential sewer lines at the utilities expense (private sewers otherwise would be likely to be neglected by homeowners until significant failure). This is expected to reduce I/I by 30 percent.

- Whilst at private properties, the utility will redirect any illegal stormwater connections from sewers to the stormwater network or to private lawns.
- Voluntary installation of sump pumps (not relevant to Sydney).
- Investment of US$373 million in WSUD green infrastructure to allow water to drain through the soil in otherwise impervious areas. This will reduce total runoff quantity, improve stormwater quality, create local jobs, improve home values and create wildlife habitat.

The main WSUD elements are pervious paving and bioswales in streetscaping and in carparks. Compared to the grey infrastructure alternative of building increasing numbers of new assets to control overflows, the Blueprint Columbus plan is estimated to require significantly fewer tunnels to meet EPA overflow requirements and these goals will be met 10 years earlier. It also has the additional social and environmental benefits outlined above. The higher maintenance costs of WSUD infrastructure compared to new grey infrastructure have been built into the models used to choose between the two alternatives. To assist with affordability for ratepayers, a 20 percent discount on usage charges in water bills is in place for low-income customers.

4.2.4.4 California

Six Californian cities that discharge sewage into San Francisco Bay (Alameda, Albany, Berkeley, Emeryville, Oakland and Piedmont) phased in a ‘Regional Private Sewer Program’ from 2011. The program was introduced in response to an EPA requirement that private sewer lines be repaired to prevent sewage overflows into San Francisco Bay. Legislation was passed that requires private property owners to obtain a ‘Compliance Certificate’ when they sell their property, or carry out renovations over US$100,000, or request a change in the size of their water meter. Compliance Certificates officially declare that a private sewer line has been tested and meets the following standards:

- Is free from roots, grease deposits, and other solids that could disrupt flow
- All joints are watertight
- All pipes are sound and free of fractures, cracks, breaks, openings or missing portions
- There are no stormwater connections to the sewer

Property owners may also voluntarily choose to have their private sewer lines tested and certified. The property owner hires a plumber to assess the condition of their pipes and undertake any remedial work required. Then an inspection is scheduled with the utility to test that the repaired pipes meet the requirements. Once the test is passed, a Compliance Certificate is issued.

These certificates last for 7 years, or where the sewer line has been entirely replaced with modern plastic pipes, they last for 20 years (East Bay Municipal Utility District, 2014). The Compliance Certificate costs US$225 and property owners who do not obtain a certificate after receiving a violation notice are fined US$350 initially, then US$87 per month thereafter (East Bay Municipal Utility, 2014).

4.2.5 Germany

Innovative incentives for private investment in WSUD have been implemented in Germany by changing the way households are charged for stormwater. The majority of households are now charged based on an estimate of the stormwater burden generated from their properties. This is calculated based on the proportion of land area covered by impervious surfaces. Therefore land-use decisions (such as paving a driveway or installing a green roof) directly affect households' stormwater charges, creating incentives to incorporate WSUD infrastructure on private properties (Buehler et al., 2011). In Berlin, charging residents in this way has been found to increase public awareness of the connections between land-use decisions and environmental problems in waterways, such as sewage overflows (Buehler et al., 2011).

Another innovation implemented in Germany is decentralised wastewater recycling on a precinct scale.. This project began in 2006 in a new residential development area in the town of Knittlingen, near Pforzheim. The project is called DEUS 21 (Decentralised Urban Infrastructure System) and aims to treat both wastewater and stormwater on site for local reuse. Wastewater is treated at a local treatment plant called the 'water house,' which from the outside resembles a house. Both wastewater and ground biological kitchen waste can be treated at the water house by an anaerobic treatment process. It is converted into biogas for use in a combined heat and power plant for the generation of energy, heat or cold. The sludge is used to produce fertiliser. The treated effluent can then be discharged to receiving waters or used for other purposes.

Rainwater is collected in tanks, stored in underground cisterns, and then treated using a membrane process to a drinking quality standard. Legally it cannot be used for drinking, but it is supplied via a dual reticulation system for all other household purposes including showers, sinks, washing machines, flushing toilets and watering gardens (Fraunhofer Institute for Interfacial Engineering and Biotechnology, 2015). See Figure 38 for an illustration of the process.

The small scale of the project means that wastewater and stormwater travel only short distances in modern plastic pipes, reducing the potential for infiltration of stormwater into the sewer pipes and for sewage overflows.

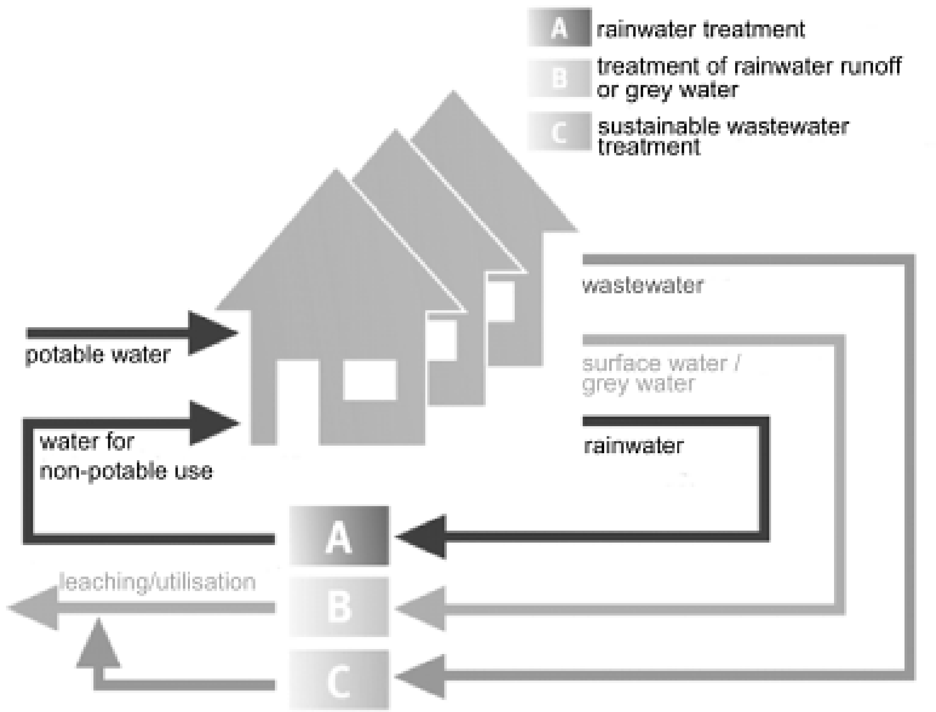


Figure 38: *The water cycle in the DEUS 21 concept (Beck and Speers, 2006)*

4.2.6 United Kingdom

To reduce infiltration/inflow (I/I) in the private sewer network, the United Kingdom recently adopted a new approach. There are ten UK authorities responsible for water and sewerage. In 2012 they took over responsibility for the private part of the sewerage system from private property owners. This is because when this part of the system is privately owned, it is usually neglected until there is significant failure and a private overflow occurs. This is a positive step towards reducing I&I as the responsibility for the network is now under the control of one body (Ramsay, 2012), which will regularly maintain the system. This action should significantly reduce the frequency of wet weather overflows.

4.3 Innovations yet to be implemented

4.3.1 Networked Infrastructure National Architecture System

In Australia a system called 'NINA' (Networked Infrastructure National Architecture system) has been developed and the designer is currently in discussion with the NSW State government to obtain funding for a trial in Sydney. NINA is a decentralised system for the capture and treatment of some stormwater for reuse for non-potable purposes. The dirtiest stormwater (the 15 percent that has runoff roads and which contains 90 percent of the pollution) is separated from the rest, which is relatively clean (Fig.39). The dirtiest contaminated stormwater is captured and stored in buried tanks under local parks and ovals. This water is then treated on-site using a passive filter system that removes heavy metals. Once treated, the water is reused on-site to irrigate the parks and ovals it is stored beneath (Fig. 40).

The clean stormwater is separately captured and can be reused locally by industry, or by households for flushing toilets and watering gardens, or can be discharged to waterways in the usual way. This stormwater would have only a very small level of pollutants compared to current stormwater, so would significantly reduce stormwater pollution of waterways.

By reusing stormwater, the NINA system reduces the volume of water currently flowing through the stormwater system, thus reducing the potential for stormwater infiltration into sewers and therefore for wet weather overflows.

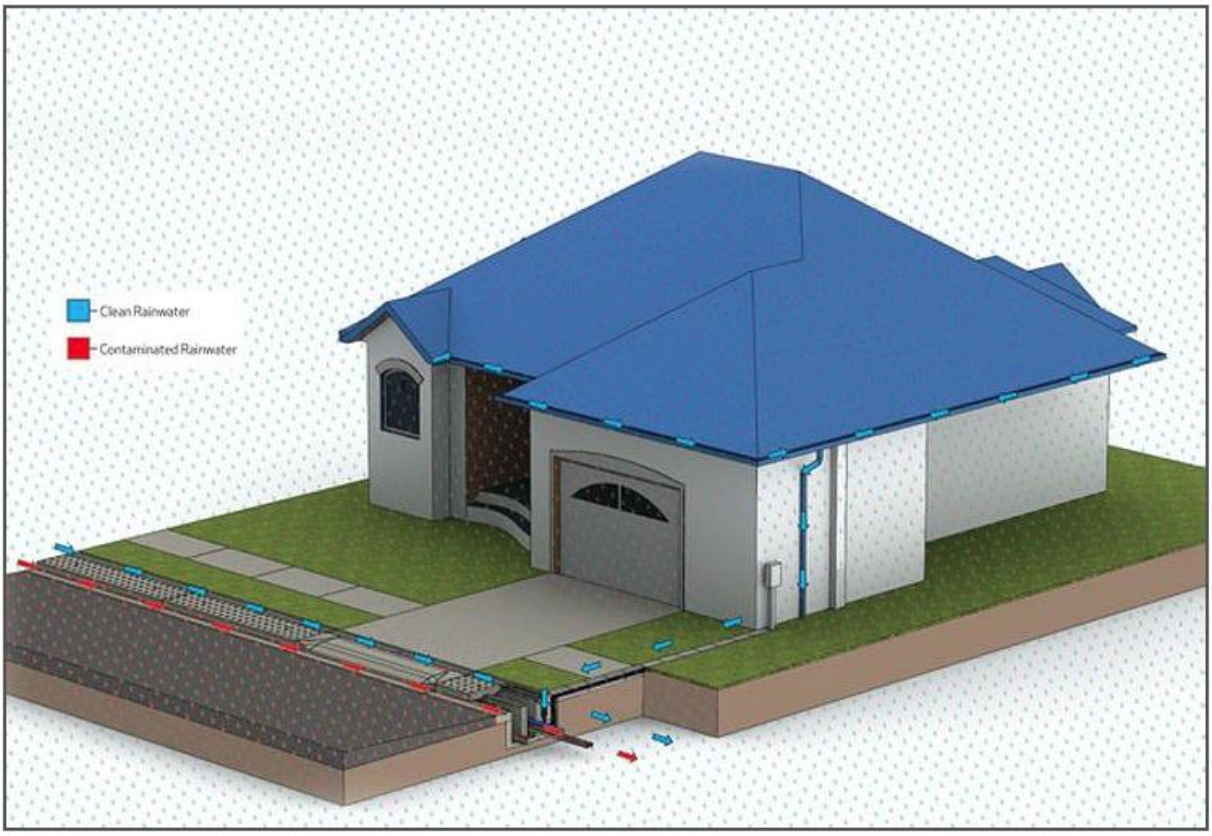


Figure 39: *In the NINA system, the heavily polluted road stormwater (red) is collected separately from the clean stormwater (blue) (Dixon, 2015)*

Figure 40: *The contaminated stormwater (brown) is collected, stored and treated separately from the clean runoff (blue) (Dixon, 2015)*

4.3.2 First Flush Diversion

An idea proposed by Sydney Water is diverting the first flush of stormwater into the sewer network during rainfall events, as a way to reduce stormwater pollution in Sydney's waterways. First flush is the initial surface runoff of a storm that contains the high initial pollutant load. The stormwater that runs off later after the rainfall has 'cleansed' the catchment, is usually less polluted. So if at the beginning of a rain event, the most contaminated stormwater were diverted into the sewerage network, the remaining stormwater that reaches waterways from stormwater outfalls would be much cleaner. These diversions to the sewer would have to be controlled to ensure that the levels of stormwater did not exceed the capacity of the sewerage network. This would be best done by diverting small volumes of stormwater at multiple points across the catchment, rather than at one point at the bottom of the catchment. This idea is relevant as the ultimate point of reducing wet weather overflows is to reduce the levels of sewage pollution reaching receiving waterways. As stormwater can also contain faecal contamination, diverting the first flush of stormwater could also contribute to reducing pollution of receiving waterways.

5. KEY ISSUES AND FUTURE MANAGEMENT OPTIONS

5.1 Key Issues and Future Management Options

Recommendations for future management of sewage overflows in coastal Sydney are summarised in Table 4. As future management options constitute the majority of the Issues Paper that accompanies this Literature Review, they have simply been summarised here.

Key Issues	Future Management Options
Management of sewage overflows	• Proposed new risk based approach for wet weather overflow management
System performance	• Operations and maintenance • Addressing poor state of private sewer network and illegal private stormwater connections to the sewerage system • Integrated urban water management (recycling and WSUD)
Governance framework	• Consider changing the institutional/regulatory arrangements for the management of stormwater
Communication / Engagement / Transparency	• Collaboration between Sydney Water and councils to implement WSUD • Improved information access • Studies to determine allocation of waterway pollution between sewage overflows and stormwater

Table 4: *Key issues and future management options for the management of sewage overflows in coastal Sydney.*

6. POLITICAL ADVOCACY & POLICY POSITIONS

Different stakeholders have different perspectives on the management of sewage overflows in Sydney and the contribution that wet weather overflows make to faecal contamination of waterways in coastal areas of Sydney. These perspectives will now be outlined.

6.1 Sydney Water perspective

The information in this section is from an interview with Sydney Water on 30 October 2015, the Sydney Water Price Plan 2016-2010 and its Appendices, as well as Beachwatch reports.

Sydney Water advised that their annual expenditure on infrastructure maintenance is in line with the industry standard, which is 0.5 percent of asset replacement value. Their wastewater infrastructure has a replacement value of about $29.7 billion and in the 2008 to 2012 IPART period they annually spend about $160 million on maintenance of this infrastructure (Kerr, 2015b).

Since 2000, Sydney Water has spent $1.5 billion on wastewater system improvements in the coastal areas of Sydney (Sydney Water Corporation, 2015c).

During the period 2012 to 2016, Sydney Water will have spent $90 million during on wet-weather overflow abatement (Sydney Water Corporation, 2015d).

Abatement works 1995 to 2002

Sydney Water advised that between 1995 and 2002 about $180 million was spent on source control. This involved using sewer flow gauging to study how the flow in the sewer responds to rainfall and using this data to identify stormwater entry “hot spots”. Further investigation to find stormwater entry points and repairs were then done across the hot spot areas. The problems included stormwater downpipes incorrectly connected to the sewer, low overflow relief structures (yard gullies) and cracked and faulty pipelines. The areas included Circular Quay, Darling Harbour, Woolloomooloo, Walsh Bay, Rozelle, Burnt Bridge, Allambie, Maroubra, Bondi, Bronte, Hornsby, Manly, Brighton and North Sydney.

Abatement works from 2000

Wet weather overflow abatement works have been prioritised by benefit and cost and for this reason much of the work has been done in coastal areas, to improve the suitability of beaches for swimming. In these areas source control was not pursued because the stormwater entry to the sewer tended to be dispersed. Instead the works involved amplification of pipes and pumping stations, and inclusion of storage tanks.

As a result overflows to northern, central and southern Sydney ocean beaches, northern coastal lagoons, Lane Cove River, Middle Harbour and North Sydney, middle Georges River and Port Hacking have been reduced. The performance achieved being as per the long term targets recommended in the Sewerage Overflow Licencing Environmental Impact Statements (SWC 1998) and ranging from not more than 2 to not more than 4 per year, depending on the location (Kerr, 2015b).

Evidence for the effectiveness of the overflow abatement works and stormwater quality improvement works conducted by Councils may be reflected in the high number of ocean beaches and baths that are classified as “good” or “very good” for Sydney Water’s area of operation, when compared to the rest of the state. The number of “good” and “very good” beaches in Sydney Water’s area of operation is 57 of 58, while for the rest of the state it is 85 of 90. The single site in Sydney with lesser water quality is Boat Harbour on the Kurnell Peninsula, an area that is not sewered (Appendix 3).

Stormwater in perspective at ocean beaches

Stormwater pollution is an issue and needs to be addressed if we are to realise the full benefits of wet weather overflow abatement. Most people believe stormwater runoff is clean, this is not the case. Typical levels of enterococcus in stormwater runoff is about 2,500 cfu/100mL, levels that are greatly in excess of those for safe swimming.

The suitability of our beaches for swimming deteriorates during wet weather due to stormwater runoff and sewage overflow. Most beaches recover quickly after rainfall and this is the basis of the Beachwatch advice to not swim during rainfall and for 1 day after at ocean beaches and 3 days after at estuary beaches.

To understand the number of days stormwater runoff and sewage overflow elevate the microbes at an ocean beach we can do a simple sum. Stormwater runoff occurs when about 5mm of rainfall occurs in a day and this occurs about 30 times a year on average. This would elevate levels at the beach on about 60 days of the year ie 30 x (1 + 1). Sewage overflows occur about twice per year on average. This would elevate levels at the beach on about 4 days of the year ie 2 x (1+ 1). Given this, sewage overflows only elevate levels of microbes for a small number of days compared to stormwater runoff and these days are the days when the most intense rainfall occurs.

Example of where stormwater improvement has fixed a problem

Sydney Water provided the following real life examples to highlight the benefit to suitability for swimming of stormwater runoff management. Malabar beach had a large number of days where the levels of microbes were elevated due to wet weather. Sydney Water conducted scientific studies to determine the source of the microbes and this was found to be the main stormwater drain at the Northern end of Malabar Beach and not the sewage overflow on the south side of Long Bay. To solve the problem, Sydney Water partnered with Randwick Council to divert the stormwater to a discharge outfall located at the Malabar headland, well away from the beach. Consequently, the suitability for swimming changed from ‘very poor and poor’ to ‘good’ (Appendix 3). The marked reduction in the levels of microbial pollution at the beach in response to the diversion is readily apparent in Figure 41.

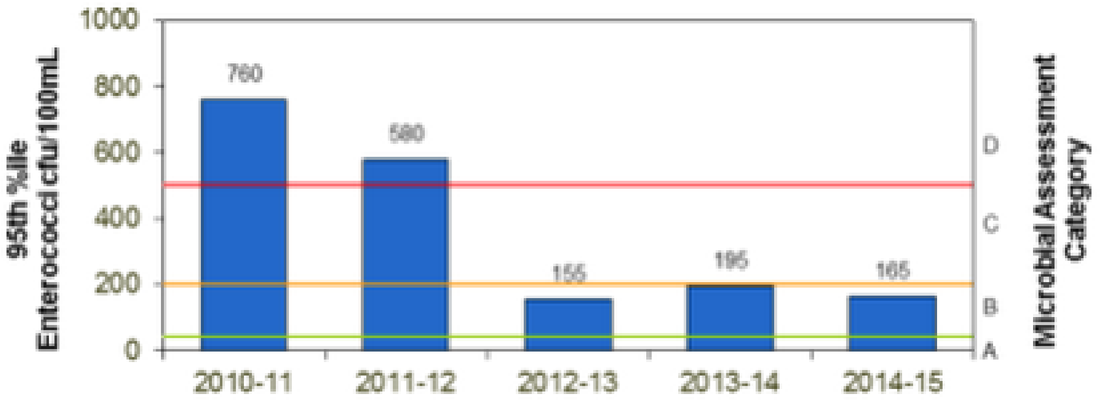


Figure 41: *The 95% ile level of Enterococcus at Malabar Beach (Kerr, 2015b)*

Risk based approach

Sydney Water hopes to implement a risk based approach to addressing sewage overflows. Under this approach public health, ecosystem health and aesthetics would be considered and based on the nature of the risk, and a cost effective solution implemented. Solutions could include screens to capture gross pollution similar to what is being done for stormwater discharges, Treatment and discharge, pipeline and pumping station amplification, storages and source control.

Between 2016 and 2020 the corporation is forecast to spend a further $127 million (Sydney Water Corporation, 2015d), with the expenditure targeted primarily for abatement efforts in estuarine and inland areas of Sydney, including Prospect, Fairfield, Parramatta and Duck Creek, as well as in Sydney City.

Education

Sydney Water stated that to maintain the good performance achieved in abating wet weather overflows on the coast there needs to be an improvement in private property owner's understanding of the wastewater system and what constitutes good practice to stop the gains that have been achieved from being eroded. There is an opportunity for councils and Sydney Water to work together in this area to achieve a collaborative solution to the common goal of environmental improvement.

6.2 Member Councils' perspective and projects

Councils are concerned at the levels of faecal contamination of coastal waterways after rainfall events, as evidenced by Beachwatch data. As Sydney Water is responsible for wet and dry weather sewage overflows, further action is required to abate sewage overflows. The coastal areas are key tourist areas for Sydney and unsafe swimming days at beaches are not acceptable.

Projects

To address sewage overflows from the private sewer network, a joint project between the NSW EPA and Sydney Water is being undertaken called the NSW Environmental Trust Grant Project. It is a sewer leak investigations training course for council officers to detect, investigate and regulate private sewer leaks. This course is important as the private sewer accounts for 50% of Sydney's sewer network and councils are the appropriate regulatory authority for the private sewer.

Manly Environment Centre

The Manly Environment Centre was consulted for input into the literature review. Concern was expressed in three areas: unsafe swimming days, lack of transparency and concern about the proposed move to a risk based approach.

It was felt that it is unacceptable that swimming days are still being lost due to faecal contamination of beaches. It was their position that this contamination was from sewage overflows, not from stormwater. Independent testing by the EPA in a number of catchments would need to be provided to prove that the contamination was from stormwater.

Why dry weather overflows still occur was questioned, including 3 at Balgowlah Heights. A letter by the then NSW Minister for the Environment Robyn Parker was tabled at Manly Council's Community Environment Advisory Committee Meeting on 10th April 2013. The letter was in reply to concerns raised by Clean Oceans Foundation. This statement is quoted from the letter: "there have been several licence non-compliances for the Northern Suburbs STS, mainly relating to overflows from the sewerage network. Dry weather overflows in the network system prior to reaching the treatment plant are usually the result of blockages and breaks in sewer pipes, often caused by tree roots or pipe failure due to age." The Manly Environment Centre believes this statement supports the view that Sydney Water's North Head sewerage system is still a significant source of faecal contamination.

There was concern that the previous testing of waterways in Manly, Curl Curl, Dee Why and Narrabeen Lagoon that was undertaken six times per annum during wet weather has now ceased. The results of this testing were made publicly available and enabled the public to assess the health of waterways. It was felt that generally the amount of publicly available information relevant to sewer overflows has decreased over time. For example it is difficult to get a detailed map of the exact locations of licenced sewage overflows in Sydney.

The question was asked whether under the proposed risk based approach to setting targets for wet weather overflow abatement, will Sydney Water be required to meet standards for water quality that can be independently verified? The view was expressed that the only way to have a risk-based approach is if the risk is assessed by concrete data, not by modelling performed by Sydney Water.

6.3 NSW Environment Protection Authority perspective

A list of questions related to sewage overflows in Sydney was emailed to the EPA on 5 November 2015. These questions and their responses are given in Appendix 4. A summary is presented below.

Dry weather overflows

Whilst Sydney Water is not required to notify the EPA every time a dry weather overflow occurs, it must notify the EPA, councils and others (including the NSW Health) when overflows threaten or cause material harm to the environment (including public health). Sydney Water is responsible for determining whether an incident constitutes material harm. Material harm is defined in section 147 of the *Protection of the Environment Operations Act 1997* (POEO Act). For these significant incidents, Sydney Water must provide detailed information to the EPA within 7 days about action taken or proposed to prevent such an event reoccurring. The EPA uses these reports to determine whether further investigation is warranted. This information is not publicly available. If Sydney Water did not report significant incidents to the EPA, the EPA would take regulatory action.

An exception to the above process is made for dry weather overflows from pumping stations that reach or are expected to reach waterways. Under Sydney Water's licences all such incidents must be reported to the EPA.

Wet and dry weather overflows with significant impact

For the calendar year 2015 to date there have been approximately 160 reports to the EPA related to Sydney Water. These are a combination of:

- Sydney water self reports (notifications of dry weather pumping station overflows expected to reach waterways and wet and dry weather overflows with 'significant' impact)
- Community reports
- Council reports

These reports include wet weather overflows (WWOs), dry weather overflows (DWOs), STP discharges not treated in accordance with licence requirements, odour issues, burst water mains and chemical spills. Information about each overflow incident causing environmental harm is not publicly available. However Beachwatch provides updated daily pollution forecasts based on information from Sydney Water including WWOs and DWOs that impact recreational water quality and pose a risk to public health. The EPA is currently working with Sydney Water to improve public notification of sewage discharges that may pose a public health risk.

Annual returns on the Environment Protection Licences on each wastewater system

Each year Sydney Water compares each wastewater system's wet weather overflow performance against the benchmark year or target system performance. This data is reported in the Annual Returns on each licence provided to the EPA. These annual returns are not publicly available, however information from the returns including licence non-compliance and load-based licencing data is available on the EPA's public register. This includes any non-compliance in relation to dry weather overflow related licence conditions. See section 3.3.1.4 of the Literature Review for how to search for this information on the EPA website.

Proposed change to risk based approach to wet weather overflows for Sydney Water EPLs

Sydney Water has developed its proposal in close consultation with the EPA, and in-principle the EPA supports the move to a risk based approach for wet weather overflows. However Sydney Water has not yet submitted its formal detailed proposal to the EPA, so the EPA is not in a position yet to answer questions about the approach. However whether the new approach delivers "same or better" outcomes for the environment and community overall will be measured against the outcomes that would have been achieved had the WWO frequency targets been kept and met.

Stormwater

Stormwater is not regulated by the EPA except to the extent that holders of EPLs are required to ensure that stormwater that leaves their licenced premises is managed in such a way that it leaves the site unpolluted (s120 of POEO Act).

6.4 NGO perspective

The Total Environment Centre was consulted for input. Sewage overflows were still regarded as an issue in Sydney, for example it is undesirable to have STPs on bypass.

The view was expressed that the solution to overflows should work with stormwater, by recycling effluent and stormwater. Although this may not be financially viable compared to the existing system, especially given the desalination plant is there as an alternative water source. Both stormwater and wastewater need to be tackled together as they are inextricably linked. At the moment stormwater management is hampered by fragmented responsibility.

It was noted that IPART is now moving towards less prescriptive licences for Sydney Water generally. For example previously there was a target of keeping water use below a daily average of 329 litres per customer (including both residential and commercial). This target has now been removed. Even though Sydney Water was meeting the target, it was felt that maintaining it would have ensured that water conservation remains a priority in the future.

Regarding the proposed risk based approach it is impossible to make an assessment without seeing both approaches modelled and the differing impacts on the environment compared. Although it was felt that the risk based approach can only work if something is also done about stormwater, given that the 'potential for benefit' component used to assess risk is determined based on contribution of the overflow to pollution versus pollution from stormwater.

Consideration of changing the current regulatory arrangement may be needed, so that a single organisation is responsible for stormwater management in Sydney. For example if Sydney Water were responsible for both sewage and stormwater, then whole of catchment proposals could be undertaken to tackle pollution. The least cost, most effective mix of stormwater and sewerage infrastructure solutions could be implemented for each catchment. Sydney Water would approach IPART for additional funding to manage stormwater and to be able to bill customers for stormwater management.

It was suggested that other alternatives could include the government appointing a new body that is responsible for stormwater management across Sydney and to fund this body. Or the state government could provide councils with the funds required to fix stormwater or alternatively allow councils to apply to IPART for the ability to increase stormwater levies to fund new stormwater programs. A difficulty with the current arrangement of councils having responsibility for stormwater is that different councils have different priorities, so developing a catchment wide approach can be difficult.

7. CONCLUSION

Swimming days are still being lost in coastal Sydney beaches due to faecal contamination after wet weather events. There is dispute whether this contamination is primarily the result of sewage overflows or stormwater. However it is reasonable to assume that the community would expect that action be undertaken to continue to attempt to reduce waterway pollution, regardless of the source. Therefore there is opportunity for Sydney Water and local councils to work collaboratively to identify the source of contamination and to find solutions. This is particularly important, as the allocation of pollution between stormwater and sewage overflows is a key part of the proposed risk based approach to setting wet weather overflow targets for Sydney Water's wastewater system. In addition, international best practice in managing wet weather overflows focuses on WSUD, which both reduces wet weather overflows and cleans stormwater. This kind of integrated management of stormwater and wastewater is required to provide the clean coastal waterways that support Sydney's lifestyle, environment and economy.

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Appendix 1 Acronyms & Abbreviations

CSO	Combined sewer overflow
DWO	Dry weather overflow
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EPL	Environment Protection Licence
I/I	Infiltration / inflow
IPART	Independent Pricing and Regulatory Tribunal
NINA	Networked Infrastructure National Architecture system
POEO	Protection of the Environment Operations Act 1997
STSIMP	Sewage Treatment System Impact Monitoring Program
STP	Sewage treatment plant
WSUD	Water sensitive urban design
WWO	Wet weather overflow
US EPA	United States Environmental Protection Agency

Appendix 2 Glossary

Bioswale

A long channelled depression or trench that receives stormwater runoff, that has vegetation and organic matter to slow water filtration and filter out pollutants. They provide an alternative to the stormwater pipe system. They absorb low flows and where fitted with subdrains can carry runoff from heavy rains to the stormwater system. Bioswales improve water quality by infiltrating the first flush of stormwater runoff and removing silt and pollution from stormwater.

Bypass

A STP bypass is a discharge from a STP that has not been treated, or is only partly processed by the designed treatment process of the plant.

Choke

A blockage in a wastewater pipe, usually caused by tree roots, or inappropriate items that have been flushed down the toilet, or a build up of oil, grease and debris in pipes.

Combined sewer

A system of pipes and tunnels designed to collect both sewage and stormwater runoff together.

Dry weather overflow

Overflows from the sewer that occur during dry weather. Such overflows are of undiluted sewage and are typically caused by chokes, or sewage volumes beyond the capacity of the sewers or pumping stations, or power failures in pumping stations.

Dual reticulation system

Series of pipes and fixtures that provides recycled water to properties for use in toilet flushing, laundry and garden watering. The pipes are separate to those providing potable water to the property and are coloured purple to indicate that the water they contain is non-potable.

Grey infrastructure

The traditional infrastructure for managing water made of concrete, metal and plastic including pipes, tunnels, storage tanks and treatment plants.

Infiltration

The entry of groundwater to a sewerage system through cracks and/or leaks in the sewer pipes.

Inflow

The entry of stormwater to a sewerage system at points of direct connection to the system.

Integrated urban water management

The integration of water supply, sewerage and stormwater, so that water is used optimally at a catchment/regional scale. It includes long-term water resource management and planning in a state and national policy context. It promotes the coordination of urban water, land and energy management and the application of WSUD principles within the urban built environment.

Main sewer

A large diameter sewer, usually not available for direct connection of property sewer/drains.

Nutrients

Compounds required for growth. Nitrogen and phosphorus are the most common.

Overflow point

A structure that is intended to provide relief, in a controlled manner, from potential hydraulic overloading of a sewerage system during an emergency situation.

Pathogen

Microorganisms that can cause disease in humans and animals, such as bacteria, viruses and parasites.

Primary Sewage Treatment

The process that removes a substantial amount of suspended matter but little or no colloidal and dissolved matter from sewage.

Reticulation sewer

A small diameter sewer that receives flows from property sewers/drains and feeds main sewers.

Secondary Sewage Treatment

A level of sewage treatment higher than primary, that uses biological activity to break down organic matter and remove nutrients. The separated solids form sludge, which can be reused for fertiliser.

Sewage

The used water from domestic, commercial and industrial sanitary appliances containing dissolved and suspended matter. Sewage may also contain approved trade wastes.

Sewage pumping station

Facilities that pump sewage from a lower level to higher level to assist normal gravity flow towards the sewage treatment plant.

Sewer mining

The process of tapping into a wastewater system, (either before or after the wastewater treatment plant), and extracting wastewater, which is then treated and used as recycled water.

Sewerage

A system of pipes, maintenance holes, pumps, treatment plants and other items for handling sewage.

Stormwater

Water flowing over ground surfaces and in natural streams and drains as a direct result of rainfall over a catchment.

Tertiary sewage treatment

The final stage of sewage treatment after secondary treatment that includes filtration to remove remaining nutrients and solids, and disinfection to remove pathogens.

Trade waste

The liquid waste generated from any industry, business, trade, or manufacturing process. It does not include domestic wastewater.

Trunk sewer

A very large diameter pipe that carries large flows directly to treatment plants or major pumping installations.

Water Sensitive Urban Design

An integrated approach to urban water management to manage stormwater runoff to protect the health of aquatic ecosystems. It aims to mimic the natural water cycle as closely as possible, by using rainfall at its source using decentralised management techniques. WSUD commonly uses vegetation, soils, and natural processes to manage stormwater. Also known as 'green infrastructure', 'low impact development (LID) technologies' or 'Sustainable Urban Drainage Systems.'

Wet weather overflow

The spillage of untreated sewage and stormwater from sewer pipes that occurs in wet weather where the hydraulic capacity of the sewer is exceeded due to infiltration and inflow (I/I) of rainwater. These overflows are controlled to discharge from designated overflow points to waterways so that wastewater does not back up in pipes and discharge to properties.

Appendix 3 Beachwatch Beach Suitability Grades

2009/10 – 2013/14

Beachwatch Beach Suitability Grades

		2009/10	2010/11	2011/12	2012/13	2013/14
	Sydney Ocean Beaches			9th wettest summer on record	High level rainfalls in many areas	Driest summer in almost 30 years
Northern Sydney	Palm Beach	Good	Very Good	Very Good	Very Good	Very Good
	Whale Beach	Very Good	Very Good	Very Good	Very Good	Very Good
	Avalon Beach	Very Good	Very Good	Very Good	Very Good	Very Good
	Bilgola Beach	Very Good	Very Good	Very Good	Good	Very Good
	Newport Beach	Good	Very Good	Good	Good	Very Good
	Bungan Beach	Very Good	Very Good	Very Good	Good	Very Good
	Mona Vale Beach	Very Good	Very Good	Very Good	Good	Very Good
	Warriewood Beach	Good	Good	Good	Good	Good
	Turimetta Beach	Good	Good	Good	Good	Good
	North Narrabeen Beach	Good	Good	Good	Good	Good
	Collaroy Beach	Good	Good	Good	Good	Good
	Long Reef Beach	Good	Good	Good	Good	Good
	Dee Why Beach	Good	Good	Very Good	Good	Very Good
	North Curl Curl Beach	Good	Good	Good	Good	Good
	South Curl Curl Beach	Good	Very Good	Very Good	Good	Very Good
	Freshwater Beach	Good	Good	Good	Good	Good
	Queenscliff Beach	Good	Good	Good	Good	Good
	North Steyne Beach	Good	Good	Good	Good	Good
	South Steyne Beach	Good	Good	Good	Good	Good
	Shelly Beach	Good	Good	Very Good	Good	Very Good
Central Sydney	Bondi Beach	Good	Good	Good	Good	Good
	Tamarama Beach	Good	Good	Good	Good	Good
	Bronte Beach	Good	Good	Good	Good	Good
	Clovelly Beach	Good	Good	Good	Good	Very Good
	Gordons Bay					Good
	Coogee Beach	Good	Good	Good	Good	Good
	Maroubra Beach	Good	Good	Very Good	Very Good	Good
	South Maroubra Beach			Very Good	Good	Good
	Malabar Beach	Very Poor	Very Poor	Poor	Good	Good
	Little Bay	Good	Good	Good	Good	Good
Southern Sydney	Boat Harbour	Good	Good	Good	Poor	Poor
	Greenhills Ocean	Very Good	Very Good	Very Good	Very Good	Very Good
	Wanda Beach	Good	Very Good	Very Good	Good	Very Good
	Elouera Beach	Very Good	Very Good	Good	Good	Very Good
	North Cronulla Beach	Good	Very Good	Good	Good	Very Good
	South Cronulla Beach	Good	Very Good	Good	Good	Good
	Shelly Beach	Very Good	Very Good	Good	Good	Very Good
	Oak Park	Good	Very Good	Very Good	Very Good	Very Good

Beachwatch Beach Suitability Grades

	Sydney Estuarine Beaches and Baths	2009/10	2010/11	2011/12	2012/13	2013/14
Pittwater	Barrenjoey Beach	Very Good	Very Good	Very Good	Good	Good
	Paradise Beach Baths	Good	Very Good	Good	Good	Good
	Clareville Beach	Good	Good	Good	Good	Good
	Taylors Point Baths		Good	Good	Good	Good
	Bayview Baths	Good	Good	Good	Good	Poor
	Elvina Bay	Good	Very Good	Very Good	Good	Good
	North Scotland Island	Good	Good	Good	Good	Good
	South Scotland Island	Good	Good	Good	Good	Good
	The Basin	Very Good	Good	Good	Good	Very Good
	Great Mackerel Beach	Very Good	Very Good	Very Good	Good	Good
Sydney Harbour	Watsons Bay	Good	Good	Good	Good	Very Good
	Parsley Bay	Good	Good	Good	Good	Good
	Nielsen Park	Very Good	Very Good	Very Good	Very Good	Very Good
	Rose Bay Beach	Fair	Good	Good	Good	Poor
	Redleaf Pool	Good	Good	Good		
	Dawn Fraser Pool	Good	Good	Good	Good	Good
	Murray Rose Pool				Good	Good
	Chiswick Baths	Good	Good	Poor	Good	Good
	Cabarita Beach	Fair	Fair	Fair	Good	Good
	Woolwich Baths	Fair	Fair	Poor	Fair	Good
	Tambourine Bay	Poor	Poor	Poor	Poor	Poor
	Woodford Bay	Fair	Good	Good	Good	Good
	Greenwich Baths	Good	Good	Good	Good	Good
	Hayes St Beach	Good	Poor	Poor	Good	Good
	Clifton Gardens	Good	Good	Good	Good	Good
	Balmoral Baths	Good	Good	Good	Good	Good
	Edwards Beach	Good	Good	Good	Good	Good
	Chinamans Beach	Good	Good	Good	Good	Good
	Northbridge Baths	Fair	Fair	Poor	Poor	Poor
	Davidson Reserve	Poor	Poor	Very Poor	Poor	Poor
	Gurney Crescent Baths	Fair	Fair	Fair	Poor	Fair
	Clontarf Pool	Good	Fair	Fair	Fair	Fair
	Forty Baskets Pool	Good	Good	Good	Good	Good
	Fairlight Beach	Good	Good	Good	Good	Good
	Manly Cove	Very Good	Good	Good	Good	Good
	Little Manly Cove	Good	Good	Good	Good	Good

Beachwatch Beach Suitability Grades

	Sydney Estuarine Beaches and Baths	2009/10	2010/11	2011/12	2012/13	2013/14
Botany Bay and lower Georges River	Silver Beach	Good	Good	Good	Good	Good
	Como Baths	Poor	Fair	Poor	Good	Good
	Jew Fish Bay Baths	Fair	Good	Good	Good	Good
	Oatley Bay Baths	Poor	Good	Poor	Poor	Good
	Carss Point Baths	Fair	Fair	Poor	Fair	Good
	Sandringham Baths	Good	Good	Good	Good	Good
	Dolls Point Baths	Good	Good	Good	Good	Good
	Ramsgate Baths	Good	Good	Poor	Good	Good
	Monterey Baths	Good	Good	Good	Good	Good
	Brighton-Le-Sands Baths	Fair	Good	Good	Good	Good
	Kyeemagh Baths	Poor	Poor	Poor	Fair	Good
	Foreshores Beach	Very Poor	Poor	Very Poor	Very Poor	Very Poor
	Yarra Bay	Fair	Fair	Good	Good	Good
	Frenchmans Bay	Poor	Poor	Poor	Good	Good
	Congwong Bay	Good	Good	Good	Good	Very Good
Port Hacking	Jibbon Beach	Very Good	Very Good	Very Good	Very Good	Very Good
	Horderns Beach	Good	Poor	Poor	Poor	Good
	Gymea Bay Baths	Poor	Poor	Poor	Poor	Poor
	Lilli Pilli Baths	Good	Good	Good	Good	Good
	Gunnamatta Bay Baths	Fair	Fair	Fair	Good	Good

Sydney Lagoon/Lake					
Narrabeen Lagoon	Poor	Poor	Poor	Poor	Good

Appendix 4 NSW Environment Protection Authority response to questions

Dry weather overflows

- ***Is there a goal of eliminating all dry weather overflows in Sydney?***

The EPA's environment protection licences (licences) for Sydney Water's sewage treatment systems do not contain a goal of eliminating all dry weather overflows in Sydney, however the licences set out overall objectives to:

a) Require practical measures to be taken to protect the environment and public health from sewage treatment plant effluent and sewer overflows;
b) Require proper and efficient management of the sewage treatment system to minimise harm to the environment and public health;
c) Require no deterioration and continuing improvement in the sewage treatment system environmental performance relative to existing conditions; and
d) Minimise the frequency and volume of overflows and sewage treatment plant bypasses.

The licences contain a number of dry weather overflow-related conditions that promote these objectives and are used to measure or determine Sydney Water's environmental performance and compliance with the above objectives.

- ***Does Sydney Water have to notify the EPA every time a dry weather overflow occurs?***

No, Sydney Water does not have to notify the EPA every time a dry weather overflow occurs.

Part 5.7 of the Protection of the Environment Operations Act (POEO Act) establishes the legislative requirements regarding duty to notify pollution incidents causing material harm to the environment (as defined by section 147). Under section 148 of the POEO Act, Sydney Water is required to immediately notify all relevant authorities (including EPA, local Council, Fire and Rescue NSW, NSW Health and WorkCover) of incidents, including those that are sewage-related, causing or threatening material harm to the environment (including public health). Condition R2 of Sydney Water's licences reiterate the Part 5.7 notification requirements.

Sydney Water is responsible for determining whether an incident constitutes material harm to the environment and hence ensuring notification in accordance with the requirements of Part 5.7 of the POEO Act. This includes the notification of any dry weather overflow that causes or threatens material harm to environment. As it is a legal requirement for Sydney Water to notify under section 148 of the POEO Act, there are penalties for non-compliance and the EPA can take regulatory action if warranted in accordance with the EPA's Compliance Policy (http://www.epa.nsw.gov.au/legislation/130251epacompl.htm).

In addition to section 148 pollution incident notifications, the licences require other notifications by Sydney Water under licence condition R4, which include any dry weather sewage overflow from a sewage pumping station that reaches (or is expected to reach) waterways to be reported to the EPA.

EPA investigates all reports it receives regarding sewage discharges, including dry weather overflows, to determine the impact of discharge and that the cleanup undertaken by Sydney Water is timely and effective. The EPA also assesses whether the discharge / incident is compliant with the EPLs and the POEO Act and takes regulatory action if warranted in accordance with the EPA's Compliance Policy (http://www.epa.nsw.gov.au/legislation/130251epacompl.htm).

- ***Do they have to submit corrective action that will be undertaken when a dry weather overflow occurs?***

The environment protection licences (including Sydney Water's) require the licensee to provide written information to the EPA about the incidents causing or threatening material harm to the environment.

For significant incidents, the EPA requests written reports (under licence condition R3) from Sydney Water for more detailed information about the incident which enables the EPA to determine, amongst other things, the adequacy and timeliness of Sydney Water's incident response and cleanup. These reports are required to include information on actions taken by the licensee in relation to the event and details of any measures taken or proposed to be taken to prevent or to mitigate against a recurrence of such an event. The R3 reports are an important source of information and are reviewed by the EPA as part of its investigation of the incident and determination of whether any regulatory action is required.

All licensees under condition R2.2 require that written details of the notification of environmental harm is provided to the EPA within 7 days of the date on which the incident occurred. Sydney Water's 7 day reports include details about the actions taken in relation to the event and details of any preventative or mitigation measures taken or proposed to be taken. The EPA reviews each of these reports to determine whether further investigation is warranted.

- ***Is this information made publicly available?***

This information is not publicly available. As they are Sydney Water's documents I would encourage you to discuss your request for the public availability of these documents with Sydney Water.

Information

Is there any possibility that the Annual Returns on the EPLs on each of the wastewater systems could be made publicly available, so councils and others could see detailed information about overflows in each catchment?

Annual Return information, including licence non-compliances and load-based licensing data, regarding Sydney Water's EPLs is publicly available on the EPA's public register. This includes any non-compliances in relation to dry weather overflow –related licence conditions.

In addition to the Annual Return, the EPLs require Sydney Water to submit an Annual System Performance Report, which includes the number of dry weather overflows from chokes and sewage pumping stations from each system and its associated system's SCAMPs (sewer catchment asset management plans or sewer sub-catchments) and identification of any exceedances of the sewerage systems' dry weather overflow limit at condition L7.4 and or SCAMP target(s) specified in the licences.

Sydney Water is also required to submit to the EPA an annual report on the dry weather overflow performance of its sewerage systems which provides further detail of those systems which have exceeded its dry weather overflow limits and / or SCAMP targets, including details of any dry weather overflow abatement investigations works and activities currently being undertaken or proposed to be undertaken and associated timing.

These reports are not publicly available and as they are Sydney Water's documents I would encourage you to discuss your request for the public availability of these documents with Sydney Water.

Proposed change to 'risk based approach' on Sydney Water EPLs

- ***The change away from frequency targets on EPLs will provide "same or better"***

outcomes. Is 'same or better' measured from the overflows performance now, or from where they would have been if frequency targets to 2021 were kept?

- ***Weren't the other factors that the new targets will take into account (such as how the community uses the waterway, or the volume of the overflow), already taken into account in prioritising which overflows to target to fix first?***
- ***Looking at the diagram below (from Sydney Water's community consultation on the new risk based approach):***
- ***How will the nutrient/pathogen/gross pollutant 'contribution of overflow vs. stormwater' be determined? Will the EPA determine this for each overflow, or Sydney Water? If it is Sydney Water, won't the lack of transparency of the determination create opportunities for conflict between stakeholders? But alternatively could the EPA realistically make such an assessment for every overflow? If Sydney Water makes the determination, will the modeling or investigation used to make the determination be publicly available, so councils and others can decide if they agree with the assessment?***
- ***If the contribution to pollution is found to be largely from stormwater, does this mean that the overflow will receive a high score (indicating a low risk) and therefore the overflow not be prioritised for investigation by Sydney Water? If so, does that mean that overflows into receiving waters where it is determined there is significant stormwater pollution, under the proposed risk based approach, no longer be required to be abated?***

As the Sydney Coastal Council Group is aware, Sydney Water is proposing an alternative framework for regulating and managing the impacts of wet weather overflows (WWOs) from its sewerage systems, to change from the current frequency based approach to a risk based framework. While Sydney Water has developed its proposal in close consultation with the EPA, and the EPA supports in-principle the move to a risk based approach for WWOs, Sydney Water has not yet submitted its formal detailed proposal to the EPA via a licence variation application. Therefore without having all the details of the proposal at hand, the EPA is not in a position at this time to make informed consideration of your very valid questions, and as such recommends that Sydney Coastal Council Group refers its questions to Sydney Water.

Alternatively, the Sydney Coastal Council Group also has the option of waiting until Sydney Water submits its formal detailed proposal to the EPA. The EPA will be putting the application on exhibition and inviting submissions from interested stakeholders. As a known interested stakeholder the Sydney Coastal Council Group will be notified when exhibition commences (likely early 2016) and the EPA encourages the Group to make a submission at that time.

Having said that, the EPA can answer the Group's first question in relation to the concept of "same or better". "Same or better" will be measured against the overall environmental and community outcomes that would have been achieved had the WWO frequency targets been kept and met.

Reporting of overflows with significant risk to public or waterway health

When Sydney Water decides that an overflow is significant enough to require reporting to the EPA, is there a standard criterion that they must apply given to them by the EPA, or is it up to them?

Section 147 of the POEO Act defines material harm to the environment if:

- *it involves actual or potential harm to the health or safety of human beings or to ecosystems that is not trivial, or*
- *it results in actual or potential loss or property damage of an amount, or amounts in aggregate, exceeding $10,000 (or such other amount as is prescribed by the regulations),and*

- *loss includes the reasonable costs and expenses that would be incurred in taking all reasonable and practicable measures to prevent, mitigate or make good harm to the environment.*

The EPA does not stipulate a standard criterion, other than section 147 of the POEO Act, for Sydney Water to determine whether an overflow or any other incident constitutes environmental harm.

As mentioned above, it is a legislative requirement under section 148 of the POEO Act for Sydney Water to immediately notify all relevant authorities (including EPA, local Council, Fire and Rescue NSW, NSW Health and WorkCover) of incidents, including those that are sewage-related, causing or threatening material harm to the environment (including public health).

Sufficient detail of the incident must be reported to enable appropriate follow-up action. The relevant information required is listed in section 150 of the POEO Act, including:

- the time, date, nature, duration and location of the incident
- the location of the place where pollution is occurring or is likely to occur
- the nature, the estimated quantity or volume and the concentration of any pollutants involved, if known,
- the circumstances in which the incident occurred (including the cause of the incident, if known,
- the action taken or proposed to be taken to deal with the incident and any resulting pollution or threatened pollution, if known,
- other information prescribed by the regulations

Any required information that is not known when the incident is notified must be notified immediately once it becomes known.

The EPA often requests R3 written reports from Sydney Water for significant incidents to provide further information about the incident which can assist the EPA's investigation in determining the environmental impact, whether Sydney Water's incident response and clean-up was adequate and timely and whether regulatory action is warranted.

- ***How frequently are overflows with significant impacts reported to the EPA?***

To date for 2015 (calendar year) there has been approximately 160 reports to EPA's Environment Line for Sydney Water related incidents. These are a combination of Sydney Water self-reports (including notifications of environmental harm incidents under s148 of POEO Act and other notifications under licence condition R4), community reports, and council reports. These reports include dry weather overflows, wet weather overflows, sewage treatment plant discharges that have not been treated in accordance with its licence treatment requirements, odour issues, burst water mains and chemical spills.

- ***Is this information made publicly available?***

Currently information about each overflow incident causing environmental harm is not publicly available. However, provides the public with an updated daily pollution forecast based on information provided by Sydney Water (including information on any dry or wet weather overflow that may impact recreational water quality and pose a risk to public health); the EPA can issue media releases for significant overflow incidents; and the EPA also encourages Sydney Water during its response to incidents to place signage in appropriate locations to alert the community of the incident and to restrict access to polluted areas.

As discussed at the meeting on 24 September 2015 with Sydney Coastal Council Group, EPA is currently working with Sydney Water to improve public notification of sewage discharges which may pose a public health risk. The EPA is also supportive of Sydney Coastal Council Group's recommendation, as requested in its letter to EPA dated 28 October 2015, to convene an interagency meeting to discuss options to improve communications, notifications and response in relation to Sydney Water pollution incidents.

- ***Is there any reason stormwater is not regulated, as overflows are?***

Stormwater assets/infrastructure or stormwater management is not an activity that triggers the requirement for an environment protection licence under the POEO Act, although s120 of the POEO Act applies regarding the pollution of waters, including permitting pollution to enter infrastructure designed to receive or carry rainwater. In relation to activities the EPA regulates, licensees are required to ensure that stormwater on their licensed premises' is managed in such a way that it leaves the site unpolluted. Stormwater management generally is a whole-of-government responsibility with the majority of stormwater pipes and structures owned and managed by Councils.