

PLOOM



10 years of
protecting Perth's
coastal waters



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SUMMARY

This document has been produced to mark over 10 years of commitment to research, monitoring and management of Perth's coastal waters through the Perth Long-term Ocean Outlet Monitoring (PLOOM) programme. The majority of this work has been undertaken over and above any regulatory obligations. It has enabled informed decisions required to protect our marine environment and demonstrated the value of improved environmental performance at Perth's wastewater treatment plants (WWTPs).

Disposal of Perth's wastewater

Approximately 320 ML (i.e. 320 million litres) of wastewater is discharged to Perth's sewers every day from homes, businesses and industry. The collection, treatment and safe disposal (and reuse) of wastewater is a major task entrusted to the Water Corporation and carries with it a significant responsibility to protect our health, the health of the environment and to increase opportunities for wastewater recycling. At present, about 98% (314 ML per day) of Perth's wastewater is ultimately discharged to the ocean.

Re-use of Perth's wastewater

The Water Corporation acknowledges that there are compelling reasons to increase re-use of treated wastewater and to this end has a stated target of achieving at least 20% reuse of WA's wastewater stream by the year 2012. However, it is important to note that, for the foreseeable future, there will be a need for some form of ocean disposal of the wastewater from the re-use processes and also the need to dispose of treated wastewater that cannot be reprocessed or allocated for other uses due to lack of demand (e.g. due to seasonal effects).

Perth's Long-term Ocean Outlet Monitoring (PLOOM) programme

In light of the public health, environmental and water resource management issues wastewater disposal raises, responsible management of WA's wastewater disposal is of significant value to the community. The PLOOM programme has underpinned responsible management for the past 10 years and will continue to do so, with an increasing component being the management of wastewater re-use.

The key to designing a sustainable wastewater disposal system is a good understanding of the environmental setting where disposal occurs. The work undertaken from 1991 to 1994 by the Water Corporation for the Perth Coastal Waters Study (PCWS) forms the basis for much of this understanding. A key outcome was the finding that excessive nitrogen loads posed a threat to Perth's marine environment and that one of the most important tasks for the Water Corporation was to ensure that nitrogen loads are not causing environmental harm, especially in summer months.

Key findings

Results obtained during the past 10 years of the PLOOM programme show that although treated wastewater discharge has caused some measurable nutrient and bacterial related effects in the vicinity of the outlets, there have not been any harmful effects on the marine environment or loss of recreational amenity at beaches near any of the three outlets. Effective protection of human health and the marine ecosystem is achieved by treating wastewater to a high level, and discharging it through well designed diffusers located in deep waters well offshore in an open coastal environment. Key findings are:

- Elevated nutrient concentrations occur downstream of outlet diffusers, but there are no harmful effects due to nutrient enrichment.

- There are occasional slight elevations in phytoplankton production downstream of the outlets.
- The outlets do not promote potentially-harmful algal blooms, with no increases in the types or amounts of potentially harmful algae near outlets.
- There is a low risk of harmful effects on natural reefs, either because there are no reefs located close enough to the outlets (Swanbourne, Sepia Depression) or, in the case of Ocean Reef, at the depths where periphyton results show nutrients enhancing growth.
- There are no harmful effects on seagrass density or coverage due to wastewater-discharge at Ocean Reef, with seagrass density actually being higher near the outlets. Changes (losses and gains) in coverage at Ocean Reef are dominated by natural factors such as sand movement and storm damage.
- Any risk to human health at Perth beaches due to wastewater discharge is negligible.
- There is a very low risk of harmful effects on marine biota, with no toxicity observed at the wastewater dilutions that occur in the marine environment.
- There is no measurable contamination of sediments or marine biota due to wastewater discharge.


PLOOM informs and underpins wastewater disposal strategy

The PLOOM programme is an important component of the Water Corporation's wastewater disposal strategy as it provides a strong understanding of the effects of disposing of treated wastewater to the ocean. The PLOOM programme is vital for four key aspects of Water Corporation's operations.

1. Retaining the 'social licence' (communi-

ty approval) to discharge to the ocean by demonstrating the benefits of high levels of treatment and appropriate disposal in minimising impacts on the environment and public dissemination and discussion of the findings. Maintaining community confidence in the Water Corporation's judgement with regard to wastewater disposal is a core requirement of its wastewater treatment strategy.

2. Meeting the Water Corporation's corporate social and environmental obligations by:
 - Providing feedback on the sustainability of various flows and levels of treatment (current flows and levels of treatment are resulting in sustainable ocean disposal).
 - Demonstrating that current levels of activity (disposal to sensitive marine environment) are not having an adverse impact.
 - Enhancing understanding of the ecosystem and the effects of wastewater disposal, allowing for better management and conservation based decision making with respect to future wastewater disposal.
3. Informing strategic planning with regard to options and constraints on wastewater treatment, disposal and re-use. The understanding gained through the PCWS and PLOOM has directly guided and reinforced key investment decisions resulting in significant environmental improvements to our coastal ecosystems. Examples include:
 - A decision to cap nitrogen loads to 1994 levels.
 - Expenditure of nearly \$200 million on upgrading of Perth's WWTPs.
 - Decisions regarding ocean disposal for Alkimos WWTP.

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- The decision making process for the Kwinana Water Reclamation Plant.
 - Studies and strategies for Aquifer Replenishment.
4. Meeting regulatory obligations and informing future regulatory management approaches. The information generated by the PLOOM programme also informs the Water Corporation's strategy in light of regulatory changes and pressures, for example, in negotiating the development of Environmental Quality Management Frameworks for the metropolitan ocean outlets.

Future

The Water Corporation is committed to:

- Sustainable (environmentally, socially and economically) solutions for treated wastewater disposal.
- Ensuring that disposal of treated wastewater to the ocean is well managed and environmentally responsible.
- Seeking re-use alternatives for treated wastewater (target 20% re-use by 2012).
- Best practice management of the marine environment around ocean outlets.
- Meeting its regulatory requirements with regard to treated wastewater disposal.

The PLOOM programme is continually being reviewed so that it meets and, where possible, anticipates, the Water Corporation's requirements. It is intended that the PLOOM programme will become more aligned with other WA marine compliance programmes and also draw on a recently completed international best practice review of treated wastewater monitoring and management.

BACKGROUND

Approximately 320 ML (i.e. 320 million litres) of wastewater is discharged to Perth's sewers every day from homes, businesses and industry. This volume of wastewater is equivalent to filling Subiaco Oval to the top of the goalposts every day. Most of this wastewater is from homes (showers, baths and washing machines) and comprises of 99.97% water; the wastewater carries high concentrations of nutrients and faecal bacteria, mainly due to toilet wastes.

The collection, treatment and safe disposal (and re-use) of wastewater is a major task entrusted to the Water Corporation of WA (the Water Corporation) and carries with it a significant responsibility to protect our health, the health of the environment and to increase opportunities for wastewater recycling. At present, about 98% (314 ML per day) of Perth's wastewater is ultimately discharged to the ocean. The Kwinana Water Reclamation Plant (KWRP) has recycled 17 ML/d (5.4%) of this wastewater once prior to discharge, reducing industry use of scheme water by a similar amount.

The wastewater is discharged through three ocean outlets managed by the Water Corporation. The greatest amount is discharged at the Sepia Depression (43%), followed by Ocean Reef (38%) and Swanbourne (19%). The location of the wastewater treatment plants (WWTPs) and their associated outlets are shown in Figure 1.

The treated wastewater flow includes small amounts of wastewater accepted from light industry (1.5% of Beenypup WWTP inflows, 4.2% of Subiaco WWTP inflows and 8.2% of Woodman Point WWTP inflows) while 2% of the Woodman Point WWTP inflows come from heavy industry. As most wastewater is from households, the primary form of toxicant contamination comprises:

1. trace amounts of metals introduced as water flows through metal pipes and appliances; and

2. organic contaminants from detergents and personal care products.

The history of treatment and disposal of wastewater has been influenced by increased scientific understanding and changing community concerns.

- The original role of sewage treatment and disposal was to protect the public from water-borne diseases, as historically, public concerns about wastewater disposal to the ocean have centred on health issues (e.g. is it safe to swim at the beach?).
- In the 1970s and 1980s—particularly with the passing of the Environmental Protection Act in 1984—concern broadened to include the environmental impacts of ocean disposal.
- More recently, declining water levels in dams and groundwater aquifers due to population growth and reduced annual average rainfall has focused public concern on management of freshwater resources, including recycled wastewater as a potential source of freshwater.

In summary, responsible management of WA's wastewater is of significant value to the community in light of the public health, environmental and water resource management issues wastewater disposal raises. The PLOOM programme has underpinned this responsible management for the past 10 years and will do so into the foreseeable future.

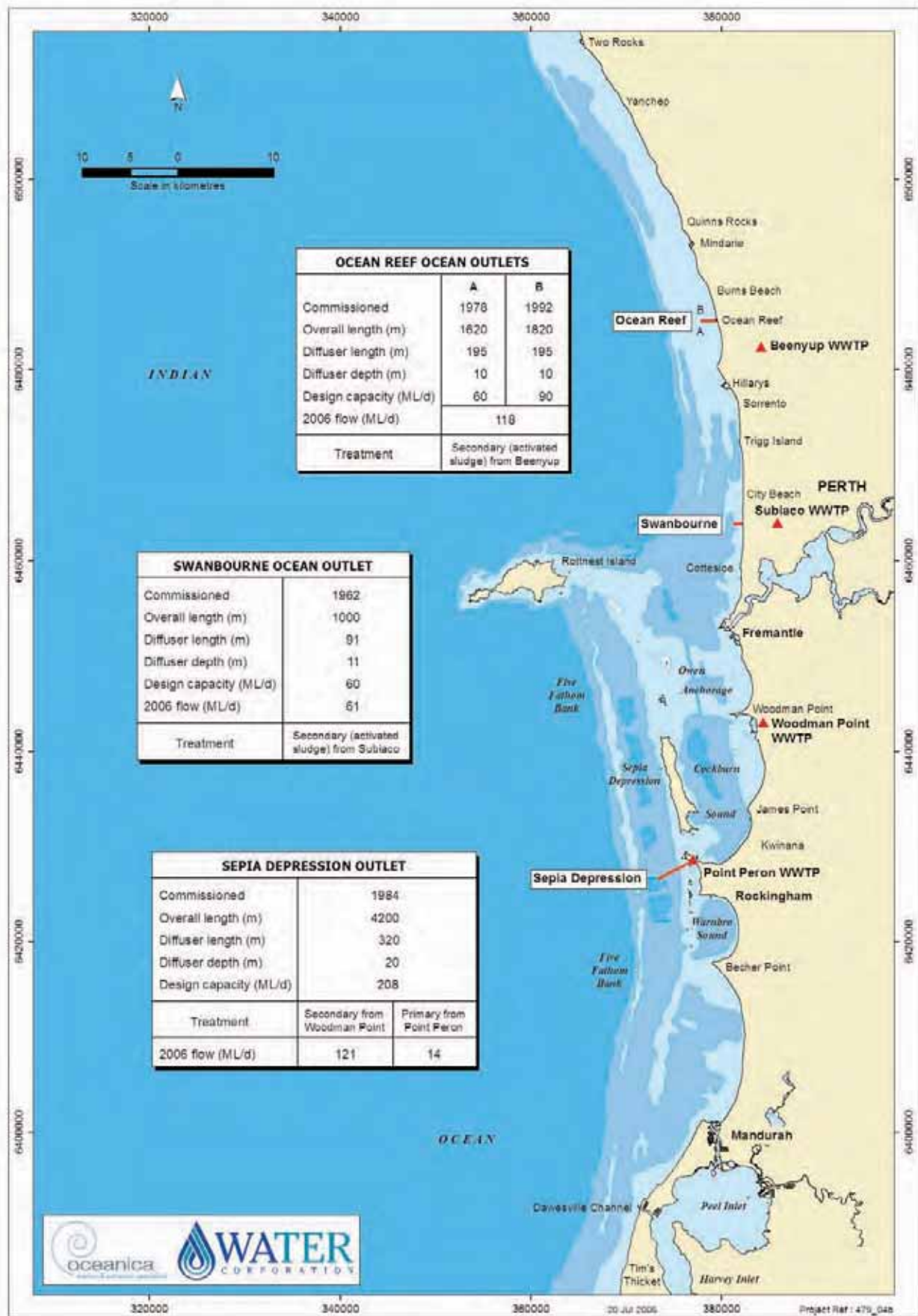


Figure 1: Perth's ocean outlets and major wastewater treatment plants

Wastewater treatment, re-use and disposal

Wastewater treatment is a staged process that is often described by the terms 'preliminary', 'primary', 'secondary', 'tertiary' and 'advanced', according to the increasing level of treatment involved (Table 1).

Treatment Level	Description
Preliminary	Screening to remove large objects and grit
Primary	Settling out of solid material
Secondary	Use of specific microbes to reduce the amount of organic material and nutrients following primary treatment
Tertiary	Further settling and/or filtration to remove organic material from secondary treated wastewater, it can also involve disinfection
Advanced	Can include chemical treatment, use of granular activated carbon, or membrane filtration (e.g. reverse osmosis)

Table 1: Levels of wastewater treatment

The Water Corporation has a stated target of at least 20% re-use of WA's wastewater stream by the year 2012. The level of treatment required for wastewater re-use depends on how the water is to be re-used (e.g. industrial process water, irrigation, drinking water) and where it will be disposed (e.g. sporting ovals, farms, lakes, rivers, oceans). As the level of treatment increases, so too does the amount of equipment, energy, chemicals and money required, while every stage of treatment produces a reject or concentrate stream that ultimately requires disposal. In addition, there are large seasonal changes in demand for re-used wastewater as irrigation, with low demand in winter.

Depending on the nature of the re-use, there may not be an equivalent drop in ocean disposal as the treated wastewater may still require ocean disposal after re-use. For example, about 17 ML/d of wastewater is recycled for industrial use by the Kwinana Water Reclamation Plant (KWRP), reducing industry use of scheme water by a similar amount, however the resulting discharge from industry returns to the Sepia Depression Ocean Outlet Landline for disposal via the Sepia Depression outlet.

While there are compelling reasons to continue to increase re-use of treated wastewater, it is important to recognise that, for the foreseeable future, there will always be a need for some form of ocean disposal for the re-use reject streams and also to 'overflow' treated wastewater that cannot be reused due to lack of demand (e.g. due to seasonal effects).

Table 2: History of wastewater plant and ocean outlet improvements

Year	WWTP	Outlet
Subiaco WWTP/Swanbourne outlet		
1927	Subiaco WWTP commissioned. Plant consisted of two septic tanks, with the treated wastewater from these tanks being carried in a tunnel to the ocean and discharged out to sea through a 100-metre ocean outlet.	0.1 km outlet
1936	Upgrade to primary treatment. Claisebrook plant closed and flow diverted to Subiaco WWTP. Primary treated wastewater discharged.	
1961	Upgrade to secondary treatment, using activated sludge treatment and heated sludge digestion	1.1 km outlet at 11 m depth
1981	Redeveloped and expanded to provide a modern treatment process capable of serving more than 300,000 people.	
1985	Upgrade number of aeration tanks and further nutrient removal. Waste from Swanbourne WWTP diverted to Subiaco WWTP.	
2003-04	Upgrade number and type of aeration tanks and installation of recycle pumps in aeration tanks to reduce nutrients. Shift to advanced nitrogen removal with nitrification/denitrification.	
2004-05	Odour control systems installed.	
Beenyup WWTP/Ocean Reef outlets		
1962	Beenyup WWTP commissioned with on-site disposal.	
1977	Upgrade to secondary treatment using activated sludge treatment.	Discharge via 1.6 km outlet at 10 m depth (Outlet A)
1978 -90	Upgrades to increase capacity and Outlet B constructed.	Discharge via 1.8 km outlet at 10 m depth (Outlet B)
1996	Expansion of secondary treatment capabilities.	Majority of discharge via Outlet B
2001	Expansion of primary treatment capabilities.	
2002-05	Upgrade number of aeration tanks and clarifiers. Shift to advanced nitrogen removal with nitrification/denitrification.	Majority of discharge via Outlet B increasing discharge from Outlet A
Woodman Point WWTP/Sepia Depression outlet		
1966	Woodman Point WWTP commissioned. Primary treatment facilities.	1.8 km outlet into Cockburn Sound at Woodman Pt.
1970	Point Peron WWTP commissioned. Upgraded to secondary treatment in 1975 Downgraded to primary treatment in 1986.	Primary treated wastewater discharged at Pt Peron.
1984	Woodman Point WWTP upgraded and discharge diverted from Woodman Point to Sepia Depression.	4.2 km outlet at 20 m depth into Sepia Depression, Woodman Pt outlet decommissioned.
2001-02	Upgrade to secondary treatment using activated sludge treatment with nitrification/denitrification.	
2005	2005 Industrial wastewater reuse commenced. Decreases discharge by $\approx 11\text{ML day}^{-1}$.	

A brief history of Perth's wastewater treatment and disposal

Centralised wastewater management for Perth and Fremantle began in 1910 in response to a typhoid outbreak, with a large septic tank at Fremantle discharging to the ocean. The Perth system started in 1912 with septic tanks at Claisebrook discharging to the Swan River. Since this time, WWTPs and disposal methods have evolved rapidly in response to population growth and significant increases in knowledge regarding public health and environmental impacts. The history of development of Perth's wastewater treatment and disposal system is summarised in Table 2.

How does ocean disposal work?

Treated wastewater is piped offshore (1 km at Swanbourne, 1.6 km at Ocean Reef and 4 km at Sepia Depression) to a section of pipe called a diffuser. The diffuser discharges wastewater through holes or 'ports' spaced over a length of pipe hundred metres of pipe (Figure 2). The diffuser is designed to ensure maximum dilution for the volume of wastewater discharged.



Figure 2: Examples of diffusers: Swanbourne outlet (left), which has been in place for decades, and is heavily covered in marine growth. Bunbury outlet (right) shown within 6 months of construction in 2001, the outlet is now also extensively covered in marine growth. Outlet pipes function as artificial reef structures, attracting fish and crustaceans.

The majority of dilution occurs within minutes of discharge because wastewater is significantly less salty than seawater and therefore less dense. Because of this, the wastewater initially rises rapidly as a buoyant plume, entraining seawater as it rises until it either reaches the surface (Figure 3) or has mixed to the point where there is no longer any significant density difference between the plume and the surround seawater. As a general rule-of-thumb, fresh wastewater dilutes about 10-fold for every metre it rises in sea water. This 'initial dilution' is followed by horizontal transport

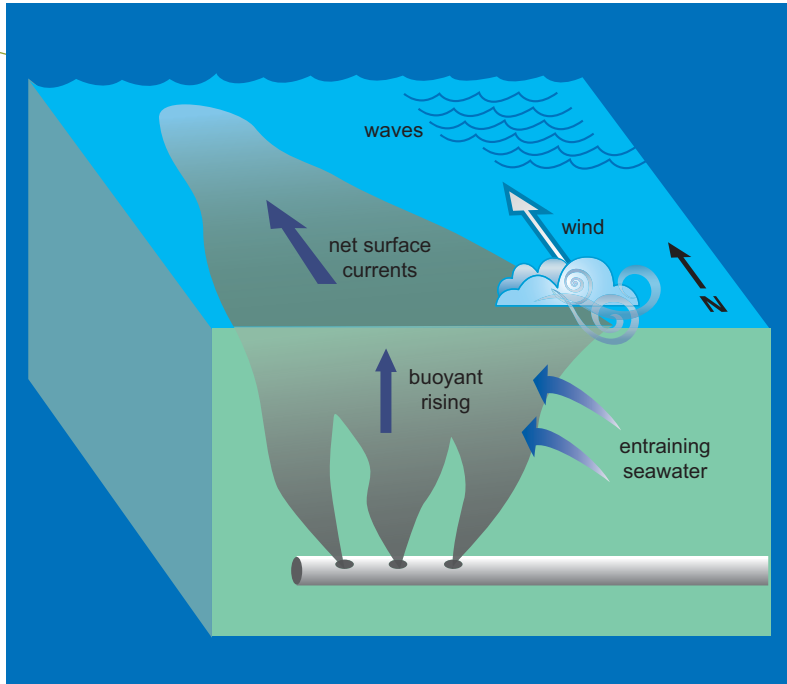


Figure 3: Plume dilution processes

and further dilution of the plume by waves and currents.

The length and location of an outlet plays a major part in determining how rapidly a plume is diluted. A well designed and located (deepwater, high mixing energy and open ocean) outlet can ensure rapid reduction of the contaminants in wastewater with distance from the outlet so that environmental impacts are localised and minimal (conversely, poorly designed systems have caused significant human health impacts and environmental degradation). Ocean disposal also uses other natural processes in the ocean to further 'treat' wastewater, including

- Breakdown of organic material by bacteria in oxygen-rich waters;
- Uptake of nutrients by marine plants; and
- Salt and sunlight (especially UV light) disinfecting bacteria.

The key to designing a sustainable wastewater disposal system is to have a good understanding of the environmental setting where disposal occurs.

Environmental setting

The Water Corporation's "Perth Coastal Waters Study" (PCWS) (1991-1994) was a significant achievement in that it developed a comprehensive understanding of Perth's coastal waters (the environmental setting). Many of the following findings are drawn from the PCWS results.

Nutrients in Perth's coastal waters

Perth's coastal waters include the 150 km region between Yanchep in the north and Tim's Thicket in the south, and out to the 50 m isobath. These waters are shallow, clear, low in nutrients, and exposed to low to moderate wave energy. Two river systems enter the ocean in this region; the Swan-Canning, and Peel-Harvey, both of which provide freshwater flows in winter. Nutrient supplies from offshore waters are limited as the warm Leeuwin Current is also very low in nutrients (unlike the cold 'upwelling' currents found on the west coasts of South America and Africa). Therefore plants and animals of the WA coast have evolved in a low nutrient environment.

The productivity of any area depends on the growth of plants, and the most important factors affecting plant

growth are usually light, temperature and nutrient supply. The amount of growth that can occur is 'limited' by that factor which is in least supply. In Perth's shallow coastal waters, it is nitrogen supply that limits the growth of the rapidly growing phytoplankton (microscopic plants that float in the water column) and some algal species, but for slower growing seagrasses and macroalgae (seaweeds), light is more important.

Nutrient enrichment is an important problem in many estuarine and some coastal ecosystems. Examples of impacts caused by nitrogen loading in our waters include the loss of seagrasses in Cockburn Sound and Princess Royal Harbour in the 1970s and 1980s. This impact mechanism is called 'eutrophication'. The process of eutrophication occurs when the 'limiting' nutrient in an ecosystem is supplied (whether through natural or man-made influences) to such an extent that excessive growth of 'opportunistic' species of plants is stimulated, and slower growing plant species are out-competed, thus changing the diversity and array of species. Nitrogen is considered to be the nutrient which limits plant growth in most coastal waters and studies have shown that nitrogen availability is naturally highly limited in the coastal waters of Western Australia.

In most natural waters, the bulk of nitrogen is contained within particulate and dissolved organic material in the water column (90% or more), with the remainder in a dissolved inorganic form as ammonium and nitrate. It is this dissolved inorganic nitrogen (DIN) that is readily used by plants. The sum of all the forms of nitrogen is termed 'total nitrogen' (TN). The nitrogen bound in particulate and dissolved organic material only becomes available for plant uptake when it is released as DIN via the process of microbial decomposition; a process occurring continuously albeit at a slow rate.

Land-based sources provide significant loads of DIN to Perth's coastal waters. These sources include treated wastewater, drains, groundwater, the Swan River and the Peel-Harvey estuaries. All of these sources have been significantly contaminated with nitrogen since human settlement. Estimates of the nitrogen loads from these systems for 2006 are summarised in Table 3 and Figure 4. With the commissioning of the Water Corporation's Kwinana Water Recycling Plant, direct discharge of nutrients by industry is now negligible. Table 3 does not include natural processes such as ocean exchange and benthic nutrient cycling processes. Estimates derived for the PCWS found that ocean exchange is unlikely to contribute significant DIN loads, and that although the net contribution from benthic sources is also small (an order of magnitude less than wastewater and swan river loads). The natural benthic turnover (recycling) will be significantly higher than those loads in Table 3 as the benthic ecosystems in Perth's

Source	Estimated tonnes per annum	% of total
Groundwater	420	9.5%
Treated wastewater	1900	42.8%
Surface Drainage	40	0.9%
Atmosphere	170	3.8%
Swan River	1185	26.7%
Peel-Harvey	725	16.3%
Totals	4440	100%

Table 3: Estimated external loads of dissolved inorganic nitrogen to Perth's coastal waters (2006)

coastal waters have evolved such that essential nutrients tend to be retained in the system and losses (exports) are relatively low.

In WA, the seasonality of the loads is a significant factor as loads from river discharge, drains, and groundwater are generally insignificant in summer, while in winter, loads from these factors will dominate due to increased rainfall. In addition, studies have found that winter storms promote nutrient release from sediment resuspension and generate wrack which adds nutrients to the system as it breaks down. All these sources will have loading maxima in winter or early spring. Wastewater disposal occurs all year round and as such, outlet discharge is the major external source of DIN to our coastal waters in summer.

Therefore, one of the most important tasks for the Water Corporation is to ensure that nitrogen loads are minimised and that increased nitrogen loads are not causing environmental harm, especially in summer months. The latter task is addressed by the PLOOM programme.

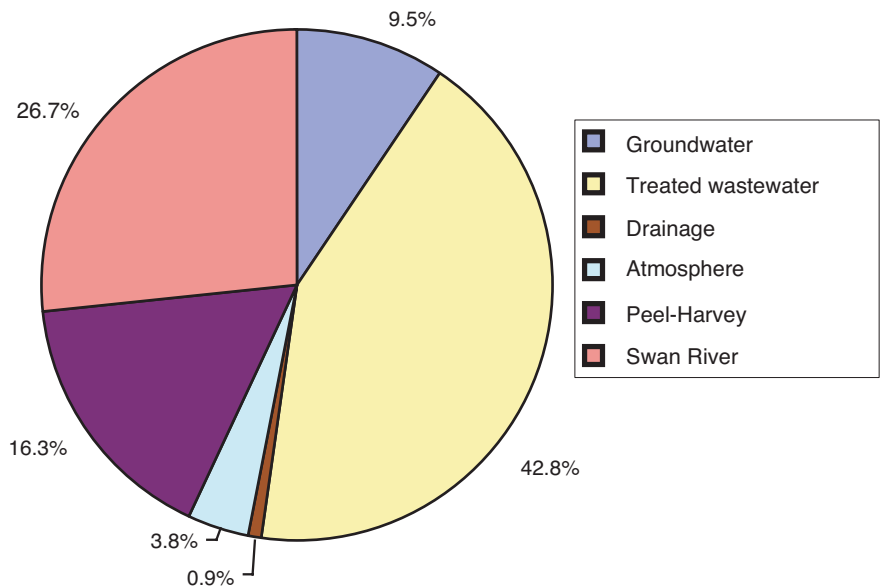


Figure 4: Estimated external loads of dissolved inorganic nitrogen to Perth's coastal waters (2006)

Oceanographic features

Perth's ocean outlets are located in a 'high energy' open coast environment that helps the dilution and mixing of wastewater. Inshore water movements are invariably wind-driven, while water movements further offshore (~5-10 km offshore) are influenced by the southward flowing Leeuwin Current. The Leeuwin Current does not play a significant role in the fate of waters over the ocean outlets. The coast tends to channel inshore water flows to be parallel with the shore. Under light wind conditions, currents are more vari-

able and shoreward flows from outlets will occur under light westerlies.

Our coastal winds are dominated by winds from the south-west quarter, meaning that net inshore water movement is northwards. PLOOM studies have continually shown that the greatest extent of any nutrient related changes occurs parallel to the shore north of the outlets.

The advantage of WA's climate of strong winds and open ocean waves is that rapid 'flushing' occurs at the outlets, and PLOOM studies to date have found that there is no excessive build up of nutrients or contaminants around the outlets as a result of this.

Benthic habitat

The shallow nearshore waters near the ocean outlets contain a variety of habitats, from seagrasses that are dominant in sheltered sandy areas, to exposed sandy areas, and limestone reefs and platforms that support a variety of algal communities and tend to be found in the more exposed areas. The PCWS and the PLOOM programmes have examined the habitats around all three outlets.

The main focus has been on the Ocean Reef outlets (Figure 5) as the other two outlets are located in bare sand habitats (Table 4). Ocean Reef outlet is surrounded by reef and seagrass habitat types as well as bare sand.

