

Department of Environment, Water and Natural Resources

Adelaide Dolphin Sanctuary



Reference Paper 3: Water Quality

This document is a companion to the Adelaide Dolphin Sanctuary Management Plan and provides background information for the development of the Plan.



Government
of South Australia



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This paper is available on the ADS website: www.adelaidedolphinsanctuary.sa.gov.au

1 Scope and purpose

In 2005 the South Australian Government proclaimed the Adelaide Dolphin Sanctuary Act (the Act) to establish the Adelaide Dolphin Sanctuary (ADS). The purpose of the ADS is to protect the dolphins and their habitat in the Port Adelaide River and Barker Inlet.

The Sanctuary is 118 km² located along the eastern shore of Gulf St Vincent. It includes the Port River and Barker Inlet and from there it stretches around to North Haven Marina, then north around Outer Harbor and up the coast to the Port Gawler Conservation Park. (See Attachment 1 – Map of the ADS). Estimates of the number of dolphins resident in the ADS range from 30 to 60.

The area includes mangroves, seagrass, saltmarsh, tidal flats, tidal creeks and estuarine rivers all combining to provide the necessary habitat for the ADS dolphins and their food resources.

The Act requires the preparation of a Management Plan. The Management Plan must address the priorities for the achievement of the objects and six objectives of the Act.

The objects of the Act are in section 7:

- (a) to protect the dolphin population of the Port River estuary and Barker Inlet: and*
- (b) to protect the natural habitat of that population.*

The purpose of this Reference Paper is to identify information relating to the third objective in the Act - section 8(1)(c):

Water quality within the Port River estuary and Barker Inlet should be improved to a level that sustains the ecological processes, environmental values and productive capacity of the Port Adelaide River estuary and Barker Inlet (Government of South Australia 2005).

For the purpose of this paper, the following definitions are used:

Water quality - the chemical, physical and biological characteristics of water required to sustain the dolphin population, and maintain the environmental value of the ecosystem, its ecological integrity, and all associated native flora and fauna.

Ecological processes - the dynamic biological and physical processes affecting the abundance and distribution of organisms, eg natural cycles,

currents, sediment movements, nutrient cycling, community and trophic structures and migratory species movements.

Environmental values - values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health and which require protection from the effects of pollution, waste discharges and deposits (ANZECC 2000).

1.1 Methodology

This paper has been collated from a study of local, Australian and international research and describes specific ADS water quality characteristics. This is one of a series of Reference Papers compiling information to support the development and implementation of the ADS Management Plan. Other papers supply information about key habitat features and dolphins. While each paper focuses on one specific subject, topics in each overlap. To gain a full understanding of the issues to consider for management of the area, the papers are best considered together.

2 Introduction

This Reference Paper describes characteristics of ADS waters and identifies environmental issues that affect the water quality of the ADS and, consequently, the dolphin population. It can be suggested that dolphins will not remain in an area without sufficient food, a healthy ecosystem and physical safety. A healthy ecosystem is an environment that maintains biodiversity, is stable over time and is resilient to change (Rapport *et al.* 1995). The dolphins not only rely on ADS waters to maintain the healthy ecosystem for themselves, but also for the maintenance of their food resources and supporting habitat.

Clean water is also vital for producing fish and shellfish for human consumption. Recreational fishing occurs within ADS waters, and although limited, commercial activities also take place. Commercial fishing outside ADS waters is also affected by the water quality in the ADS.

The ADS environment has changed significantly since European settlement. The environmental and water quality prior to these changes will never be returned. However, it is still possible to make current practices better to support the improvement of the environment.

2.1 Cumulative impacts and water quality in the ADS

Cumulative impacts are those created by successive actions causing minor to major impacts taking place over a period of time. Cumulative impact is a major water quality issue in the ADS due to the many and varied influences

that affect it, such as industrial, recreational, commercial and residential inputs.

Cumulative inputs can cause a range of habitat effects. For example, excess nutrients in the water may cause increased growth of native algae, which in turn, can affect the growth of mangrove seedlings. Extra nutrients may also increase the growth rate of introduced species causing broad impacts on seagrasses and, consequently, the fish that rely on them.

Bottlenose dolphins are particularly vulnerable to cumulative long-term impacts. They are long lived, take a number of years to reach sexual maturity, have few offspring, with typically two to three years or longer between giving birth. Population declines may take many years to become evident, by which time it may be too late to address the impacts causing the decline. This makes it important to look at the full range of impacting activities together to really understand their ecosystem impacts. While the system may be able to absorb the impacts of a single given activity, it may not be able to absorb the impacts of this activity multiplied or combined with others.

3 Characteristics of ADS waters

The risks to ADS waters vary from short to long-term. They can be localised, for example directly adjacent to outfall sites, or widespread throughout the ADS. Risks can be relatively minor, or cause major environmental impacts.

3.1 Configuration of ADS waters

The topographical features of the Port Adelaide estuary have a significant influence on the water quality issues facing the area. The Port area is the lowest lying area of the northern Adelaide plains. Consequently, natural run-off gravitates to this area (Harbison 1986), bringing with it pollutants from natural, industrial, and domestic sources.

The historic accumulation of sand and silt from the run-off has produced a very large area of intertidal mudflats within the Barker Inlet Aquatic Reserve. Aerial surveys show that approximately 90% of this Reserve, including 1000 hectares of mangrove forest, is exposed to low spring tides (Harbison 1986).

The shape of the Barker Inlet results in a parting tide, with the tidal front divided by Torrens Island. The western section moves up the Port River flowing around the southern end of Garden Island, through North Arm and to the mouth of Swan Alley Creek. The eastern section of the tide moves into Barker Inlet on the eastern side of Torrens Island.

The phenomenon of a dodge tide is a feature of Gulf St Vincent, and results in extended periods of standing water in Barker Inlet, when intertidal mudflats

are covered by a layer of very shallow water for up to 24 hours. During the summer, this water can reach temperatures of 30°C. This can result in severe oxygen depletion, and the possible remobilisation of pollutants from the sediments (Harbison 1986).

Although the ADS area is referred to as an estuary, by environmental and water quality reporting definitions it could be considered as a predominantly marine environment. Inflows of freshwater from industries and stormwater have altered the mixing of fresh and marine water entering the area to some degree.

It is likely that the construction of Breakout Creek in the early 1900's reduced discharges from the Torrens River. Since then, urbanisation and development of the Port Adelaide and surrounding region have also had a major impact. The construction of the West Lakes flow-through system in the 1970's has had an impact on salinity levels, with today approximately 600 Megalitres (one Megalitre is 1000 cubic metres) of marine waters entering the Port River daily (EPA 2005b) in addition to normal tidal flows.

In addition, less fresh water enters the Port River from groundwater discharges. However, more is entering via stormwater, as rainwater runs off pavement and roof tops rather than passing through natural surfaces to the groundwater table (EPA 2005b).

3.2 Turbidity and sedimentation

3.2.1 Definition and environmental impacts

Water turbidity is a measure of the light transmitted through water, and indicates the amount of particles and dissolved substances such as organic matter, pollutants and suspended sediments that are present in the water column. Sedimentation is a naturally occurring process that happens when materials such as soil and organic matter are transported from the land to the sea.

Human activity can increase turbidity and sedimentation through a range of activities including vegetation clearance causing soil erosion, dredging leading to disturbance of the sea floor, and from vessel movements causing wave action and sea floor disturbance. Other human contributors to turbidity and sedimentation include particles and pollutants transported in stormwater from urban and industrial sites, and pollutants such as rubber particles, oil and grease from roadways, also transported in stormwater. Industrial discharges containing particles and pollutants, and wastewater discharges from the waste water treatment plant also contribute.

It is difficult to differentiate between the amount of turbidity and sedimentation caused by natural processes and the amount caused by human activities. Climatic events such as storms and high rainfall often lead

to water run-off from the land, and disturbances of the sea floor by strong wave action. These can be described as natural contributions. However, the run-off may contain higher than natural levels and types of soil particles from areas cleared of vegetation, and industrial and urban sites, that are greater than or different to natural contributions. In addition, intensive activities such as dredging can cause significant short-term turbid conditions, beyond what is likely to occur naturally.

Turbidity and sedimentation impact the marine environment in several ways. Turbidity reduces the amount of light reaching marine plants, impairing photosynthesis and plant growth and survival. As a result of reduced light, marine plants may become restricted to areas of shallow water where the light can still penetrate. Suspended particles may also settle on marine organisms and smother them. The particles may also impair filter-feeding organisms by impeding their ability to search for food (EPA 2002). Plant loss caused by turbidity may also cause the reduced stability of seabeds, which increases turbidity even more. Turbidity and sedimentation may influence not only the location and abundance of marine plants and animals, but also species composition and habitat complexity.

Turbidity and sedimentation can also cause additional impacts if the particles include toxic pollutants such as oils, heavy metals or PCB discharges, which may be harmful to marine life. Although the sediments eventually become stabilised on the sea bed by bacteria, micro-algae and other marine organisms, disturbances can re-occur and release the particles again, including any pollutants they may contain.

3.2.2 Turbidity and sedimentation in the ADS

Much of the ADS waters can be described as turbid for parts of the year (EPA 2006), with particles entering the waters as a result of a number of sources and activities. These include: stormwater carrying urban, agricultural and horticultural run-off; discharges from the wastewater treatment plant; a range of industrial discharges carrying solid particles; vessel movements; and dredging activities.

Consequences of turbidity and sedimentation may include a reduction in marine plants and plant communities. For example, seagrass communities have significantly reduced in area, and this is thought to be due to a combination of environmental impacts, including turbidity and sedimentation. Near the SA Water Bolivar waste water treatment plant, the total cover of *Posidonia sp* decreased from 26.3% to 6.2% between 1949 and 1993 (Edyvane 1999). In addition, seagrass loss can lead to more turbidity as the sea bed erodes without the protection of the vegetation. See Reference Paper 2 for further information on seagrass.

Dredging can significantly increase turbidity, and localised activities can potentially cause damage to seagrass beds (Harbison 2006 pers. comm.).

Sedimentation, and sediment contents, can also affect marine life by influencing species composition and abundance. For example, the high organic content of the sediments within the ADS supports a diverse community of bacteria. Some of these reduce the sulfate from seawater, producing high concentrations of sulfide, which further depletes oxygen, is toxic to fish, and gives the mangrove forest its characteristic smell (Harbison 1986).

Turbidity and sedimentation within the ADS also contribute to chemical and heavy metal risks to the environment and marine life. Due to the sheltered nature of the Inlet, the sediments of the intertidal edges of the Barker Inlet, particularly in the southern region, are more highly polluted than other regions of the Inlet. This is where the fine grain sediments, which present the largest surface area for surface absorption of pollutants, are found (Harbison 1986).

Sediments within the ADS have been reported to contain copper, mercury, zinc, lead, cadmium, tributyltin (TBT), organochlorines, polychlorinated biphenyls (PCBs) and herbicides (Coastal CRC undated; EPA 2000). The possible impacts of the pollutants are discussed further in the relevant sections of this paper and Reference Paper 2.

In ADS waters, significant point source discharge activities are licensed by the EPA. The EPA works with the licence holders to reduce discharges using the provisions of the *Environment Protection Act 1993*, including through environmental improvement programs.

3.3 Thermal properties

3.3.1 Definition and environmental impacts

Water temperatures in estuary environments vary naturally due to daily and seasonal weather conditions, tidal flows and inputs from rivers and creeks. Temperatures will also be cooler in the winter, during the night, and become increasingly cooler with depth. Water temperature affects growth, reproduction, energy use and mobility of marine organisms. Marine species have adapted to these natural conditions, with species composition, population numbers, and ecosystem functions expected to vary seasonally. In addition to natural variations, water temperature may also be altered by human activities, such as wastewater outflows from industries.

Changing water temperature by human activities is called thermal pollution, and can cause environmental risk. Warm water discharges can magnify natural variations in species composition and population densities. These changes may happen because water temperature affects the speed of chemical reactions and biological processes. An increase in water temperature by 10 °C can double the rate of biochemical reactions. Changes in temperature can impact directly by causing loss of habitat, changing the dissolved oxygen in the water, influencing the extent to which

metal contaminants and other toxins are assimilated, and influencing the persistence of pathogens (Australian Government undated).

In addition, warmer waters may have lower levels of dissolved oxygen available for marine life and this can cause fish to die from suffocation. Also, exposure of fish to low oxygen levels can cause an immune suppression effect that may elevate their susceptibility to disease for several years (Australian Government undated). Juvenile fish are affected by even slight increases in water temperature. Increases in temperature may cause more mobile species to migrate to cooler waters. Warmer waters may also provide an opportunity for tropical invasive species, from ballast waters or other accidental release, to establish.

3.3.2 Thermal pollution in the ADS

Port River water temperatures are coolest in winter months. For example, EPA data (EPA 2002) indicate they are lowest in July at 12°C, and highest in February at approximately 25.5°C (median of several monitoring sites).

Power stations located at Pelican Point, Torrens Island and Osborne take in water, use it as part of the turbine cooling process, and discharge warmer water back into the waterway (EPA 2002; EPA 2003). This results in water near the power stations being warmer than elsewhere. For example in 2001-2002 the TRUenergy (formerly TXU) Torrens Island power station discharged a total of 660,000 Megalitres, with temperatures typically 1.5 - 5°C warmer than Inlet water, with a maximum recording of 8°C warmer (EPA 2002).

Industrial wastewater outflows may also contribute to thermal pollution of ADS waters. For example, in 2000, Penrice Soda Holdings Ltd discharged approximately 70 Megalitres per day, with weekly water temperatures averaging 36.6°C in June and 47.4°C February (EPA 2002).

An EPA assessment of the impacts of thermal pollution concluded that thermal discharges did not contribute to changes in the overall water temperature, and that buffering from unaffected water appears to keep the impacts of thermal discharges localised to the outflow sites (EPA 2002). Further, the impacts of thermal discharges in the Port River appear to be localised to the areas surrounding the power stations (EPA 2003).

However, these localised impacts appear to have contributed to the creation of noticeable differences in species composition and abundance in areas immediately surrounding the outfall sites compared to the wider area. This is thought to be because the warmer water creates an improved environment for introduced marine pests originating from tropical waters, encouraging their rapid spread. For example, *Zoobotryon verticillatum*, a bryozoan, typically dies back when the water gets cold. Where water is warm all year round this animal will continue to expand (Coleman 2006 pers. com.). Additionally, the diversity and abundance of native species decreases if they

cannot tolerate the warmer waters (Johnston and Harbison in Daniels and Tait 2005) and cannot compete with the introduced species.

Near the Torrens Island outfall site, changes in the intertidal mudflat communities were found. Several populations of bivalve mollusc and worm species had reduced in abundance or been eliminated, while other previously rare or absent species had become more common (Thomas *et al.* 1986). Fish may also be affected. Yellow eye mullet appeared to avoid the inner estuary during summer and autumn months (Baker *et al.* 1996).

The impacts of thermal pollution can be exacerbated when combined with excess nutrients. For example warm, nutrient rich water creates an ideal environment for algal growth. It is not certain how far these localised impacts extend.

3.4 Nutrients

3.4.1 Definition and environmental impacts

Sea water contains a range of elements including carbon, hydrogen and oxygen which are usually abundant and, in appropriate amounts, are necessary for plants and animals to survive. Other elements are classed as nutrients and are required by aquatic organisms for survival, growth and reproduction. These include nitrogen, phosphorus, sulfur, sodium, magnesium, calcium, manganese, iron, copper, and zinc. Of these, nitrogen and phosphorus are the most influential in supporting plant growth. They are required in larger amounts than the other elements and can become limited in the marine environment, particularly in the spring-summer period, from high demand by plants in their main growth stage, along with losses to the sediments and to the atmosphere (EPA 2005b). Consequently, plant growth is normally limited by the amounts of nitrogen and phosphorus available (UNEP/GPA Coordination Office 1999).

As naturally limited amounts of nitrogen and phosphorus normally constrain algal growth, when these nutrients are in excessive amounts, rapid growth may occur. Excessive amounts of nitrogen can also cause negative impacts on seagrasses with the possibility of eventually causing the death of the plant (Devlin 1999).

Organic matter, including bird droppings, is the main natural source of nitrogen and phosphorus. Other sources include human inputs from fertilisers, detergents, stormwater and industrial discharges.

Excessive nutrients in marine waters can lead to eutrophication which occurs when increased levels of nutrients encourage rapid growth of primary producers, especially algae (Nixon 1995). This can result in algal blooms, with algae reaching population densities of up to 900 million cells per litre (Cannon

1991). Blooms limit light to the plants on the seabed, reducing their ability to photosynthesise, and limiting their growth.

Algal blooms resulting from eutrophication also affect the amount of dissolved oxygen available in the water. Oxygen levels are typically high during the day as plants produce oxygen through photosynthesis, and low at night when it is dark and photosynthesis is not occurring. During an algal bloom, the little oxygen that is available at night is used very quickly by the large mass of algae, and when levels become too low, bottom dwelling organisms, fish and crustaceans may die from lack of available oxygen (Horrigan *et al.* 2002). Further, in conditions of depleted oxygen, toxin producing bacteria may increase, which can affect both plants and animals. These bacteria can enter the food chain, and lead to human poisoning through consumption of contaminated organisms. Eutrophication may alter an ecosystem and cause losses of biodiversity, and change the distribution of plants and animals.

3.4.2 Nutrients in the ADS

A number of studies have identified nutrients as the most significant problem occurring in the Port River and Barker Inlet system (Connolly 1986; Edyvane 1991; Kinhill Delfin 1991; PPK Consultants 1992; Steffensen *et al.* 1989). The EPA has released a Water Quality Improvement Plan (WQIP) for the Port River and Barker Inlet waters. The WQIP focuses on reducing nutrient discharges into these waters by assessing input sources of nutrients and working with dischargers to reduce them.

Nutrient enrichment has impacted on the ADS by contributing to:

- large-scale loss of seagrass meadows with effects on associated animals, biodiversity and fisheries;
- loss of mangroves and altered mangrove habitat;
- increased occurrence of low oxygen conditions resulting in occasional fish kills;
- increased occurrence of nuisance insect problems;
- toxic algal blooms, causing depleted oxygen levels in the water resulting in fish deaths, reduced plant growth, and public health risk due to contamination of edible marine organisms (EPA 2005b).

Algal blooms in the Port River estuary and Barker Inlet are a risk during spring-summer, when algal growth is highest due to the warm waters and fine weather. At this time of year there is also greater use of reclaimed water from the Bolivar WWTP for domestic and horticultural irrigation, resulting in a decrease in discharges of wastewater (EPA 2006) thus reducing some of the risk.

Currently there is very little seagrass remaining in the Port River. The largest and most devastating disturbances to seagrass meadows have been caused

by the nutrient enrichment of the River (Kirkman 1995). The EPA (2005b) suggests that seagrass and mangroves are in continuing decline in the Barker Inlet northwards towards the Gawler River and that the remaining nutrients in the system may be sufficient to maintain this trend.

Nutrient pollution may also have adverse impacts on animal species. For example, a study comparing nutrient contaminated areas directly adjacent to Bolivar outfall sites with distant, less contaminated and non-contaminated sites, showed a progressive decrease in abundance of both western king prawn and blue swimmer crab the closer to the outfall (Baker 2000).

The main nutrient sources from human activities in the ADS are industrial discharges from Penrice Soda Holdings Ltd (ammonia and nitrogen) and effluent discharges containing nitrogen and phosphorus from the SA Water Bolivar wastewater treatment plant (WWTP). There are a number of other nutrient sources with a comparatively low impact (EPA 2006) (See Table 1).

Table 1. Sources and amounts of nitrogen and phosphorus loads entering the Port River Estuary.

Source	Annual Nitrogen Load (t/year)			Annual Phosphorus Load (t/year)		
	1995	1998	2004	1995	1998	2004
Torrens catchment	33	9.5	9.5	9	4	1.3
Northern Adelaide Barossa catchment						
Dry Creek – Little Para River	40	40	29.5	10	10	1.5
Smith Creek catchment	ND	ND	ND	ND	ND	ND
Local stormwater	2	2	2	<0.2	<0.2	<0.2
Regional groundwater	10	10	10	0.25	0.25	0.25
West Lakes	30	30	41	3	3	6
Bolivar WWTP	1265	1000				
Low salinity plant	-	-	373	215	215	188
High salinity plant	-	-	104	-	-	44
Port Adelaide WWTP	511	511	-	105	105	-
Penrice Soda Holdings Ltd	1300	1100	820	3	3	0.7
Bulk handling	2	2	2	>0.2	>0.2	>0.2
Fertiliser industry	2	2	2	<0.2	<0.2	<0.2
Recreation	10	10	10	2	2	2
Wingfield Waste Management Centre	2	2	2	<1	<1	<1
Garden Island landfill	1	1	1	<1	<1	<1
Internal sources	<100	<100	<100	<10	<10	<10
Atmospheric fallout	32	32	32	2	2	2
TOTALS	3340	2851.5	1538	361.9	356.9	257.4

Source: EPA (2006).

Although both the SA Water Bolivar WWTP and Penrice Soda Holdings Ltd have reduced their nitrogen and phosphorus outputs in recent years, significant amounts still continue to be released and further reductions are expected as part of the EPA's WQIP (EPA 2005b).

EPA (2005b) modelling suggests that under particular tide and wind-driven currents, treated effluent from the Bolivar WWTP spreads mainly southwards through the Central Barker Inlet and North Arm, with a smaller measurable effect on the Port River.

Wetlands have been constructed to reduce nutrients entering ADS waters, including those at Barker Inlet, Magazine Creek and the Range. The Barker Inlet wetlands are fed by four stormwater drainage systems carrying urban and industrial stormwater from surrounding areas. Monitoring indicates these wetlands remove approximately 80% of nutrients in the stormwater (EPA 2005b). Other wetland systems, including the Little Para wetlands at the mouth of the Little Para River, the Greenfields and Connector wetlands, and Edinburgh wetlands are also removing nutrients from stormwater. (See Attachment 2 - Map of ADS Wetlands, Catchments and Watercourses.)

In addition to recent and on-going nutrient sources, the historic accumulation of nutrients and the resulting algal debris has enriched the sediments in decaying organic matter, which imposes a high oxygen demand on overlying shallow waters (Harbison 1986). It is possible that it may take some time after the major sources of nutrient pollutants entering the ADS waters are reduced, before sediment nutrient levels decrease.

3.5 Chemicals

3.5.1 Definition and environmental impacts

Organochlorines are synthetic, carbon based chemicals that contain bound chlorine and enter the environment mainly through industrial and agricultural applications (Gales *et al.* 2003). They are also produced in chlorination processes such as chlorine pulp bleaching (Zann 1995). Since they are human made, there are no natural levels of them in the marine environment. Organochlorine compounds have been widely used in Australia as herbicides (2,4-D - dichlorophenoxyacetic acid, 2,4,5-T - trichlorophenoxyacetic acid), insecticides (DDT, lindane, chlordane), fungicides (hexachlorobenzene, chlorinated phenyls) and as insulating fluids (polychlorinated biphenyls or PCBs). These and other chemical pollutants enter the marine environment through stormwater from agriculture, horticulture, road and industrial site run off, leaching from waste dumps and industrial discharges.

Of concern to marine mammals are polychlorinated biphenyls (PCBs) and dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyldichloroethane (DDD) (Borrell and Aguilar 1993; Reijnders 1994). They are a risk because they can affect the immune,

endocrine and nervous systems, resulting in impaired growth, development, reproduction, and lower resistance to disease (Beland *et al.* 1993; Reijnders 1994; Reijnders and De Ruiter-Dijkman 1995; Ross *et al.* 1996; Skaare *et al.* 2000).

PCBs have been banned in many countries since the late 1970s. In Australia, PCBs were never manufactured or imported for use in manufacturing goods, (Richardson 1995). However, they were widely used within goods imported to Australia as heat transfer fluids, hydraulic fluids and fluids in capacitors and transformers. Common articles containing PCBs were plastics, wrapping papers, carbon paper, printing inks, paints and vehicle tyres. PCBs affect organisms by disrupting hormonal functions, and have been known to cause cancers, memory distortions, growth deformities, and reduced reproduction (Keith 1997).

Tributyltin (TBT) is a chemical used in anti-foulant paint, which is used on vessels, fish nets and buoys to discourage the growth of marine organisms (for example: barnacles, tubeworms, mussels, bacteria and algae). TBT is a hormone disrupter and impacts are specifically observed on gastropod (snail) species. It may also impact on the immune system. TBT antifouling paint can also affect non-target species including mussels, clams and oysters by damaging their structure and growth, and it is highly toxic to crustaceans (US EPA 1985).

The use of antifoulants on vessels in South Australia, including TBT, is regulated under the *Environment Protection (Water Quality) Policy 2003*, section 22 - Antifoulants. Users must comply with the *Code of Practice for Antifouling and in-water Hull Cleaning and Maintenance 1997* prepared by ANZECC. In addition, there are specific provisions to follow concerning types of antifoulant, and the size and location of vessel when being treated. Antifoulant residues must not be allowed to enter any waters and must be collected and disposed of appropriately.

Most of the synthetic toxic pollutants known to be of serious environmental concern have been banned in first world countries. However, they may still be produced in developing countries, and in addition, if already present, are persistent in the environment for many years. These pollutants may be present in landfills and the possibility of toxins leaching from landfill sites exists.

3.5.2 Chemicals in the ADS

Chemical pollutants reported in the Port River include those found in organochlorine pesticides (for example: chlordane, DDT, dieldrin, heptachlor, lindane, aldrin), PCBs, herbicides (atrazine), and organotines (tributyltin, dibutyltin and monobutyltin) (Coastal CRC undated). At present there is little information on the effects of these contaminants on dolphins or their habitat in ADS waters.

The EPA (2003) has reported high levels of PCB contamination in the ADS. Dolphins in the ADS have been found to have PCBs (as detected by the presence of the PCBs - arochlor 1260 and arochlor 1254) present in blubber tissue samples tested by the EPA (2000). Similarly, sediment samples have also tested positive for PCBs (arochlor 1260, but not arochlor 1254). A site at Bolivar also tested positive, but this may indicate historical contamination from the 1960's and 1970s (EPA 2000).

Testing for the presence of organochlorines is a difficult process. Separate tests must be undertaken for each specific substance, and there are hundreds of them. Concentrations may be localised either in the environment or in animal tissues and so multiple tests may be required over an area or for one animal.

3.6 Heavy metals

3.6.1 Definition and environmental impacts

Heavy metals (mercury, cadmium, lead, copper, nickel, chromium and zinc) occur naturally in mineral deposits and enter the environment from the weathering of rocks and ores. In a well functioning ecosystem, they are present at levels tolerable, and in some instances essential, to marine life.

When heavy metals are present at higher levels from pollution from industry and urban populations, they can be toxic. The effects on individual marine organisms can be acute, causing immediate harm or death, or chronic causing longer-term effects such as reduced reproductivity, increased susceptibility to disease or predation and decreased ability to adapt to environmental change (Edwards *et al.* 1999).

Marine mammals can be exposed directly to heavy metals by breathing air, from the water by contact through skin or tissue, and by passing water through their bodies for feeding. However, the main source of metal accumulation is through the diet of the mammal (Butterfield and Gaylard 2005). Heavy metals may accumulate in an animal's tissue if the absorption rate exceeds the animal's capability to excrete the heavy metals. This is referred to as bio-accumulation. Metals can travel up the food chain from plants to higher order animals. Concentrations of heavy metals are typically greater in organisms at the top of the food chain than those at the bottom. This is referred to as bio-magnification.

Environmental conditions, such as the pH, salinity, and temperature of the water can affect the availability of heavy metals to organisms. For example, an increase in pH increases the toxicity of cadmium and zinc, while lead and mercury toxicity decreases (Wang 1987).

The bio-accumulation of heavy metals in fish and dolphins can be assessed by analysing tissue samples of these organisms. Dolphins are particularly

useful as indicators of heavy metal accumulation due to their high position in the food chain and relatively long life span (Butterfield and Gaylard 2005).

3.6.2 Heavy metals in the ADS

In addition to natural sources, heavy metals enter the ADS waters from the atmosphere, from wastewater treatment plant discharges, industrial effluents, stormwater containing road and household run-off, run-off from gardens and farms, and run-off from sites where metals and products containing metals are corroding.

Elevated lead and mercury have been reported in sediments in the Barker Inlet (EPA 2000). However, Maher (1986) found that cadmium was undetected in fish, and lead and zinc were low in invertebrates and fish from Gulf St Vincent. Similarly, Olsen (1983) reported low mercury in invertebrates and fish from Gulf St Vincent. More recently, Edwards *et al.* (2001) also reported low cadmium but high lead in fish from the Barker Inlet. Similarly, the EPA reported an improvement in metal concentrations since 1995-96 and found moderate zinc and low concentrations of cadmium, lead and mercury in the Port River estuary waters (EPA 2002) and in fish (EPA 2000). A later EPA study showed that there may have been an increase in zinc concentrations in Gulf St Vincent waters between 1995 and 2002 (EPA 2004).

The EPA conducted research to assess heavy metal concentrations in dead dolphins collected along the South Australian coastline, and compared the results between the regions of the Gulf St Vincent, Spencer Gulf, and the Southern Ocean (Butterfield and Gaylard 2005). Key results included:

- Overall, cadmium, lead and zinc concentrations were low. However, there were some individuals with high concentrations. The differences between individuals are thought to be due to natural variations within the population. Likely sources are from both natural sources and pollutants (Butterfield and Gaylard 2005);
- Lead concentrations were significantly higher in individuals from Gulf St Vincent than those in Spencer Gulf, with the results indicating long-term rather than recent exposure, possibly as a consequence of the use of leaded petrol and further studies are recommended to determine if lead levels decline over time as a result of the ban on using leaded fuels (Butterfield and Gaylard 2005); and
- Mercury concentrations were classified as high in all bottlenose dolphins collected. However, the results suggest that the mercury had minimal effects on dolphins' health, and that the source was likely from natural origins. It is thought that mercury in the animals had bound together with selenium, largely neutralizing the mercury's toxic effects (Butterfield and Gaylard 2005).

Additional data also obtained by the EPA on the Port River dolphins specifically show the following:

- Mercury levels found in liver samples from Port River dolphins were not unusual compared to those found in dolphins elsewhere around the State. Elevated levels of mercury were found in sediment samples taken from five sites. The contamination at some of these sites could have been due to past practices, but the possibility of recent contamination was not excluded (EPA 2000);
- Cadmium levels in kidney samples from the Port River dolphins were generally lower than dolphins found elsewhere around South Australia (EPA 2000);
- Lead and zinc were found in high concentrations in sediment. The source of the lead and zinc is likely to be road runoff and indicates that more needs to be done to stop these pollutants from entering the River (EPA 2000);
- Copper and nickel were found in higher levels near ship or boat building activities, or areas where boats are repaired or maintained. Copper levels may also be elevated in wastewater due to corrosion of hot water services and pipes (EPA 2000).

The EPA study on the fish species within the Barker Inlet found that mean levels of mercury, cadmium and lead in the fish flesh met food standards and are safe to eat (EPA 2000). Although safe levels have been established for human consumption, it is not known if the same standards apply for dolphin consumption. However, potential accumulation over time would be far greater for a dolphin consuming fish and other animals containing these metals, as they are its primary food source, compared to an individual human occasionally eating this food.

3.7 Marine debris

3.7.1 Definition and environmental impacts

Debris has been recognised by the International Oceanographic Commission as one of the five major marine pollutants (National Oceans Office undated). The environmental risk of marine debris in Australian waters has also been recognised under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth of Australia 1999) as a key threatening process, specifically the, "injury and fatality of vertebrate marine life caused by ingestion of, or entanglement in, harmful marine debris" (Department of the Environment, Water and Natural Resources 2003).

Typically marine debris is from land based plastics, and fishing gear from recreational and commercial fishing. Fishing lines, fragments of trawl nets and synthetic ropes pose the most risk to dolphins. For dolphins, the possibility of ingestion of marine debris is not considered to be a threat. The most

significant risk from debris is from entanglement which can cause physical impairment affecting the animal's swimming, breathing and feeding ability, and, in addition, wounds caused by attached gear can become infected.

Debris can also cause secondary environmental impacts by increasing shade and limiting light transmission and plant photosynthesis. An additional consequence of debris and rubbish is the diminishment of the aesthetic value of an area. If an area looks untidy due to rubbish, people are less likely to value the area, possibly leading to further littering and degradation.

3.7.2 Debris in the ADS

To date, post mortems conducted on hundreds of dolphins collected from South Australian and ADS waters have not found any debris in the stomach contents of deceased dolphins (Gibbs 2006 pers. comm.).

Since 1998, SA Museum records show one ADS dolphin death due to infection from discarded fishing gear embedded in its body. One young animal was also rescued from entanglement three times and there are reports of other entanglements where the animal has either freed itself or been freed by human intervention.

ADS conservation officers and volunteers from Project Dolphin Safe currently conduct regular rubbish clean ups in the ADS and a litter monitoring program has been established. Clean ups will be regularly conducted in the same places and the litter counted and categorised to discover if there are any regular sources of the debris.

3.8 Pollutant sources and remedial strategies

3.8.1 Penrice Soda Holdings Ltd

Penrice Soda located at Osborne, uses ammonia to produce sodium carbonate. A proportion of the ammonia is discharged into the Port River, and consequently the company is a major industry contributor to nutrients in the Port River (EPA 2005b).

According to the EPA, Penrice Soda discharges 70,000 kilolitres (one kilolitre is one cubic metre) of wastewater per day into the Port River, with weekly average concentrations of 57 milligrams per litre (minimum 22 milligrams per litre and maximum 177 milligrams per litre) of ammonia (EPA 2002; EPA 2005b). The current discharge rate equates to 820 tonnes of nitrogen per year (EPA 2006).

A solids recovery plant completed in 2001 enabled Penrice Soda to reduce solids in the wastewater by 98% (100,000 tonnes per year). Additional improvements include changes to the processing, the containment of ammonia, replacement of areas of the plant, and monitoring to identify

further areas for improvement. Penrice has committed to reduce nitrogen to 575 tonnes per year by 2010 (EPA 2006).

3.8.2 SA Water Bolivar Wastewater Treatment Plant

SA Water operates four wastewater treatment plants (WWTP) in metropolitan Adelaide, processing a total of 250 Megalitres of wastewater daily (SA Water 2005b). These plants are at Glenelg, Christies Beach and two on the Bolivar site. The Bolivar WWTP has discharged into Gulf St Vincent since it was commissioned in March 1967.

These discharges had a rapid impact on the adjacent marine environment, with some 130 hectares of intertidal seagrasses lost within 18 months of commissioning (Steffensen *et al.*, 1989). In 1989, that figure had risen to 500 hectares, with another 500 hectares of sub-tidal *Posidonia* sp. lost since then (EPA 2005b). Seagrass loss is examined further in the Habitat Reference Paper.

The SA Water Bolivar Environment Improvement Program completed in 2005 involved the construction of a dissolved air flotation filtration plant to provide quality reclaimed wastewater for use in irrigation, replacing biological filters with a new activated sludge treatment process, and constructing a pipeline and new treatment plant at Bolivar to replace the outdated Port Adelaide WWTP that ceased operation in late 2004. These improvements resulted in a discharge reduction from 1265 tonnes of nitrogen to 477 tonnes and 320 tonnes of phosphorous to 232 tonnes (EPA 2006).

3.8.3 Marina and boating waste

Marina and boating waste include both chemical and nutrient pollutants from a variety of substances which may enter the water from normal vessel operations, and also from normal maintenance activities including oils, anti-foulants, fuels, engine discharges and paints. In addition, substances may enter the waterway from accidental discharges. The most frequently reported water pollution from the marine and boating industry is from fuel and oil. Spills from vessels, slipways and refuelling service facilities are of concern due to the adverse impacts on marine life and the amenity of aquatic environments (EPA 2005c).

Marina and boating waste discharges (black and grey water) have been identified as direct sources of nutrients to the Port River and Barker Inlet. The EPA's *Draft Code of Practice for Vessel and Facility Management: Marine and Inland Waters* (EPA 2005c) includes the requirement of zero black water (sewage) discharges and the future requirement for zero grey water discharges.

3.8.4 Ballast and bilge water

Ballast water – Ballast water is water taken on a ship directly from the sea to stabilise the vessel. This water may be increased or decreased according to the needs of the vessel and the weight loads it is carrying. As water is pumped in, whatever is in the water column including sediments, plants and animals is also taken on board. This water and its contents may then be discharged thousands of kilometres away introducing species of plants and animals into an environment where they don't belong. Discharges of ballast water are one of the main avenues for exotic plant and animal species to enter a waterway.

Australia introduced mandatory ballast water management requirements in 2001. All internationally trading vessels are required to manage their ballast water in accordance with the requirements of the Australian Quarantine and Inspection Services (AQIS). The discharge of high-risk ballast water in Australian ports or waters is prohibited (Australian Quarantine and Inspection Service undated).

Domestic ballast water discharges have the potential to cause significant adverse impacts by distributing invasive species between Australian ports. Under the proposed National System for the Prevention and Management of Marine Pest Incursions, domestic ballast water will be managed on a day to day basis by a Commonwealth agency through the Single National Interface (SNI). However, it is likely to be administered under South Australian legislation and some minor elements will be the responsibility of the States. Management and legislative arrangements for this issue are still under development.

Bilge water - Water may collect in the deepest part of a ship's hull, the bilge, from normal ship operations. This bilge water may contain oily waste including some hydrocarbons that are carcinogens implicated in disease of aquatic organisms. The EPA's *Draft Code of Practice for Vessel and Facility Management: Marine and Inland Waters* states that vessels operating in state waters must install and maintain oil filtration devices on bilge pumps, place commercially manufactured oil absorption material in bilges, not use detergent or emulsifier in bilge water, keep bilge water separate from other wastewater, and dispose of bilge water absorbent materials in accordance with the EPA's guidelines: *Disposal of Used Hydrocarbon Absorbent Materials*. The draft Code also states that, engines should be maintained regularly to prevent oil and fuel leaks, install non-spill vacuum systems for engine oil changes, and use polypropylene bilge socks in preference to biodegradable items (EPA 2005c).

3.8.5 Material handling practices

Poor material handling practices, spillage and waste run-off from cargoes such as live sheep exports, bulk fertilizer and grain, and from wharfs can contribute to nutrient pollution of the Port River.

The EPA's draft Code of Practice for Materials Handling on Wharves is being prepared to address these issues (EPA 2005d).

3.8.6 Stormwater

According to the EPA, 130 Gigalitres (130,000,000 cubic metres) of stormwater are produced in South Australia annually, with 110 Gigalitres discharged directly into the sea (EPA 2003). Stormwater discharges from eight major drains have emptied into the Port River and Barker Inlet system over a long period. This stormwater may contain a wide variety of substances, including heavy metals and hydrocarbons from vehicles and their fuel, nutrients from organic matter and run-off from agriculture and horticulture, industrial and residential chemicals, sediments, and other pollutants (EPA 2003). A number of initiatives are in place to manage the impacts of stormwater on ADS waters.

The Councils of Port Adelaide-Enfield, Prospect, and Charles Sturt are implementing an Urban Stormwater Master Plan (USMP) for all catchments within the north west Adelaide region. The USMP uses detailed studies of water flows and volumes, land use and development projections and environmental issues to devise management strategies including wetlands, detention and retention basins, on-site controls, potential aquifer storage and recovery locations and gross pollutant traps, to develop catchment specific management strategies (City of Port Adelaide-Enfield undated).

Other initiatives include Stormwater Prevention Projects managed by the Natural Resources Management Boards (formerly Water Catchment Management Boards) and Councils. These stormwater projects aim to raise awareness of the human impacts on stormwater quality and improve the stormwater management practices of industries so that the quality of stormwater can be improved. Specific focus is given to small and medium industries and businesses not licensed by the EPA and mobile business operators (Torrens Catchment Water Management Board 2004).

The Port Adelaide Enfield Council manages a series of constructed wetlands including the Barker Inlet, Range and Magazine Creek Wetlands and the City of Salisbury manages the Greenfields and Connector Wetlands. These wetlands intercept stormwater and run off before it reaches the waterways. Over 50 species of plants have been planted in the 337 hectares, including mangroves. These wetlands provide a range of environmental benefits from bird habitat, to tidal areas for mangrove growth and saltmarsh regeneration, to provision of habitat for aquatic invertebrates, fish and crustaceans.

3.8.7 Atmospheric sources

Although not typically considered a major source of pollution, the atmosphere can contribute to water pollution of ADS waters by transporting

pollutants from land-based sources. Fine particles of pollutants and dust may be carried by the air and deposited in the sea, contributing to turbidity and sedimentation, and degrading the water quality if they contain chemicals, heavy metals, or nutrients and organic matter. Although accurate measurements are difficult to obtain, the EPA suggests that 32 tonnes of nitrogen will be deposited from the atmosphere into ADS waterways every year (Christy 2004 in EPA 2006).

4 Conclusion

This paper discusses one component of the management issues facing the Adelaide Dolphin Sanctuary. The topics raised here must be considered in conjunction with issues centering on protecting the dolphins themselves, their habitat and food sources, and furthering ecologically sustainable development principles. In addition, existing and historical relationships in the area must continue to be acknowledged and respected.

The Adelaide Dolphin Sanctuary environment is complex and diverse. Despite the human activities and processes impacting the water quality, the area retains considerable environmental importance. The dolphins in the ADS are widely appreciated, and it is clear most community members want them to remain in ADS waters.

The challenge for those who use and value the area in so many different ways is to make sure on-going activities do not cause further damage, and, to make sure that future activities improve the existing habitat, water quality and safety of the dolphins.

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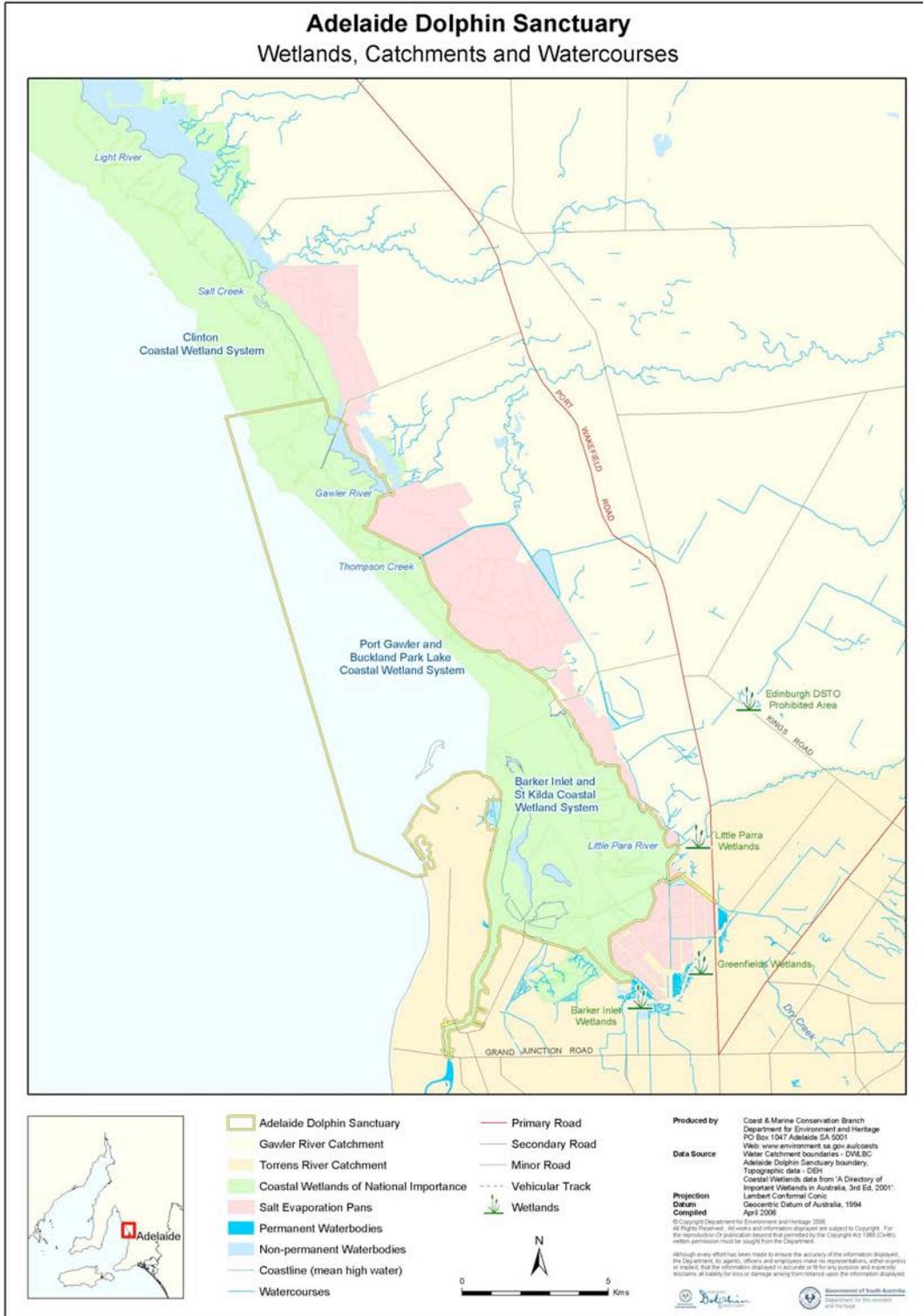
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6 Attachment 1 – Map of the ADS



7 Attachment 2 – Map of ADS Wetlands, Catchments and Watercourses



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