DAWESVILLE CHANNEL:

Environmental impacts and their management

Working Paper 1994

Peel Inlet Management Authority
Waterways Commission
Report 50
1994

WATERWAYS COMMISSION

16th floor
216 St Georges Terrace
PERTH
Western Australia 6000
Telephone: (09) 327 9777
Fax: (09) 327 9770

Peel Inlet Management Authority

Sholl House
21 Sholl Street
MANDURAH
Western Austraia 6210

Telephone: (09) 535 3411
Fax: (09) 581 4560

Postal Address:
PO Box 332,
MANDURAH
Western Australia 6210

ISSN 0814 – 6322
ISBN 0 – 7309 – 5986 – 4

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SUMMARY

The Peel-Harvey Estuary lies 70 kilometres south of Perth in southern Western Australia. The two shallow coastal lagoons are connected to the ocean by a narrow inlet channel which restricts tidal exchange. In recent decades, the estuary has become severely degraded through excessive input and accumulation of nutrients from its 11 000 square kilometre catchment. High nutrient levels support blooms of the toxic blue-green alga *Nodularia* and excessive growth of macroalgae (seaweed), which have negative impacts on the ecology and human use of the estuary.

A management strategy, developed after many years of studies and public review, was released in 1988. The Peel Inlet and Harvey Estuary Management Strategy: Environmental Review and Management Programme Stage 2 sets out a three-pronged approach:

- catchment management to reduce nutrient input,
- construction of the Dawesville Channel to increase estuary and nutrient flushing to the ocean,
- increased weed harvesting to reduce the weed nuisance while the other measures have time to work.

The Dawesville Channel was opened in April 1994. It will speed up restoration of the estuary by increasing nutrient outflow and changing conditions in the estuary so that the damaging cycle of algal blooms and nutrient release from the sediments is stopped. One of the main benefits will be the control of *Nodularia* blooms. Marine conditions are expected to virtually eliminate *Nodularia* from the basins of the estuarine system.

The Dawesville Channel is not a total solution, however, long-term success of the management strategy will depend on significantly reducing nutrient inputs. Water quality targets have been set and stated in an Environmental Protection Policy (Environmental Protection Authority (EPA, 1988), and catchment planning measures and catchment management are contributing to reducing nutrient input.

Reduction of nutrient input, combined with the effects of the Dawesville Channel, will significantly improve the environmental health of the Peel-Harvey estuary. Overall the estuary is expected to become more like the marine environment, because there will be a greater exchange of water with the ocean and increased tidal exchange. The plants and animals will establish a different balance over time. In the long-term, the estuary will be healthier and more resilient to change.

The Dawesville Channel will cause profound changes to the estuary's water movement, water quality and ecology. Impacts considered to be beneficial to the long-term health of the estuary include:

- increased tidal range;
- improved water clarity;
- increased water salinity, inhibiting growth of *Nodularia* blooms;
- increased flushing of nutrients, suspended sediments and detritus from the estuary;
- reduced length of time water and nutrients remain within the system;
- increased levels of dissolved oxygen in water, improving conditions for animal life, breakdown of organic matter and better phosphorus adsorption to the sediments; and
- improved mixing of the water column, so reducing the length and frequency of stratification events. (EPA, 1988)

In the short to medium term, these changes may also lead to a number of potentially adverse impacts. These include:

- increased macroalgal (seaweed) growth and accumulation due to improved water clarity and residual nutrient levels;
- changes in the shoreline and water levels, particularly at low tide, which may affect boating, recreation, fringing vegetation and wildlife;
- the possibility of increased mosquito numbers;
- the possibility of increased rates of formation and exposure of river deltas at the junctions of waterways and the estuary;
- regular inundation of low-lying land; and
- continued algal blooms (including *Nodularia* blooms) in the freshwater reaches of the Serpentine, Harvey and Murray Rivers.

Other changes may arise as a result of the complex alterations to the hydrology and ecosystems of the estuary. Many of the biological changes, for example to the fishery, are hard to predict accurately and it may be a number of years before a complete picture of the changes is available. Environmental changes to the estuary are being monitored, including catchment nutrient inputs, estuarine water quality, phytoplankton and macroalgal growth, changes to the shoreline and fringing vegetation, tides and water levels, saline intrusion into drainage channels, and impacts on the adjacent marine environment. Selected areas of vegetation and bird rookeries were surveyed by the Department of Conservation and Land Management in 1994. It is anticipated that monitoring of impacts on water birds and both the commercial and recreational fishery will be undertaken in the next financial year.

The environmental changes caused by the Dawesville Channel are likely to affect people who live around or use the estuary in a number of ways. Positive impacts include the improved water quality and long-term environmental health of the estuary, which will have benefits for lifestyles, recreation and tourism. Potential negative impacts are likely to be related to increases in mosquito numbers, changes in water levels, the possible short-term increase in weed growth, and changes to foreshore habitats.

The potential adverse impacts need to be viewed in the context of the long-term benefits to the environment and the community as a whole. A social impact program began before the channel opened to identify peoples concerns and involve them in developing management measures to reduce negative impacts. An information program has also been set up to inform the public about the environmental changes, results of monitoring, and the development of management strategies. The program includes publications, school talks and a telephone "hotline" to answer public enquiries.

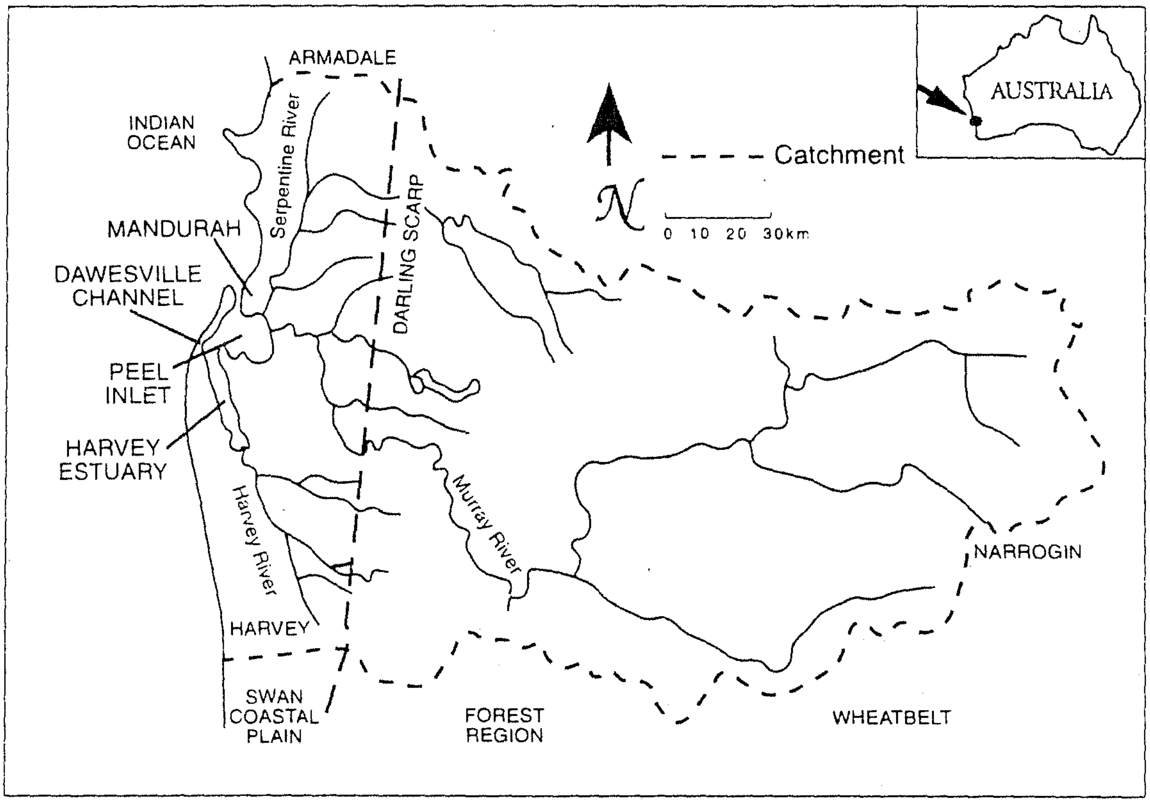

Figure 1. the Peel-Harvey estuary and its catchment.

1 INTRODUCTION

The Dawesville Channel is one of the largest environmental projects ever undertaken in Australia. It has been built to significantly increase the marine flushing of the Peel-Harvey estuary, in order to reduce the adverse impacts which have arisen from severe nutrient enrichment, in particular the blooms of the cyanobacteria (known as blue-green algae) *Nodularia*. The decision to build the channel was made because there was serious concern that unless action was taken, rotting algae could lead to total collapse of the biological systems in the estuary (Environmental Protection Authority, 1988).

The Peel-Harvey estuary lies near the city of Mandurah, approximately 70 kilometres south of Perth, Western Australia. The estuary consists of two shallow coastal lagoons, Peel Inlet and Harvey Estuary, with an area of about 133 square kilometres, and a catchment of 11 000 square kilometres (Figure 1). Its deepest basins are around 2.5 metres deep, with large areas around the margins being no more than 50 centimetres deep. Peel Inlet is connected to the ocean by a narrow inlet channel (Mandurah Channel) which restricts tidal exchange with the sea. In recent decades the Peel-Harvey estuary has become severely degraded by excessive inputs of biologically available nutrients. These nutrients, predominantly phosphorus and nitrogen, are transported to the estuary from catchment water runoff and are responsible for the regular accumulations of nuisance macroalgae (seaweed) and blooms of the highly toxic blue-green alga *Nodularia*. The excessive algal growth has damaged the health of the ecosystem, recreational use of the estuary and the quality of life of people living around it.

A three-pronged approach to solving the problems in the Peel-Harvey estuary has been developed:

- reduce nutrient run-off from the catchment,
- increase estuary (and nutrient) flushing to the ocean (Dawesville Channel); and
- continue harvesting macroalgae as necessary.

This approach was documented for environmental assessment in the Peel Inlet and Harvey Estuary Management Strategy: Environmental Review and Management Programme (ERMP) Stage 2 (1988).

The Dawesville Channel has been designed to increase marine flushing of the estuary. One of the main objectives of the channel is to control the toxic blooms of *Nodularia*. This undesirable and toxic species does not tolerate marine conditions and is expected to be virtually removed from the basins of the estuarine system following completion of the channel.

The channel is not a total solution, however. The channel will not be able to return the estuary to a healthy state without the other measures being successfully carried out. A comprehensive management plan aimed at reducing the level of nutrients entering the system will be critical to the success of the Management Programme. This was recognised in the ERMP (Kinhill Engineers, 1988), which stated that unless there were significant reductions in nutrient inputs, the Dawesville Channel may provide little benefit other than to virtually remove *Nodularia* blooms.

The Environmental Protection Authority (EPA) concluded in its assessment of the 1988 ERMP that, in conjunction with the Dawesville Channel:

- annual phosphorus input to the system shall not exceed 85 tonnes in more than four years out of ten (on average) and shall not exceed 165 tonnes in more than one year out of ten (on average). [These are based on 60 and 90 percentile loads]; and

- average phosphorus concentration in estuary water shall not exceed 0.02 milligrams per litre in nine years out of ten (on average).

However, the Environmental Protection Policy for the Peel Inlet-Harvey Estuary 1992, states that the environmental quality objective to be achieved and maintained in respect of the Estuary is a median load (mass) of total phosphorus (TP) flowing into the Estuary of less than 75 tonnes, with the median load of TP flowing into the estuary from the Serpentine River being less than 21 tonnes; from the Murray River being less than 16 tonnes; amd from the Harvey River and drains being less than 38 tonnes.

Several other water quality targets were set, and are stated in a statutory Environmental Protection Policy (EPP) (EPA, 1992), which requires all government and private activities in the catchment to contribute to reaching these targets. The EPP is supported by a Statement of Planning Policy (SPP), which details necessary catchment planning measures (Department of Planning and Urban Development, 1992).

There have been a number of difficulties in monitoring total phosphorus flow into the estuary, however, catchment managment since 1990 is known to have directly reduced the tonnage of phosphorus entering the Estuary by over 35 tonnes and aditional significant but unmeasurable reductions from diffuse sources are known to have also occurred (EPA, 1994).

Reduction of nutrient input combined with the increase of nutrient output and nutrient immobilisation caused by the Dawesville Channel, will significantly improve conditions in the Peel-Harvey estuary.

The Dawesville Channel was opened in April 1994. There will be profound changes to the character of the estuary and the lower reaches of associated rivers, over both the short and long term. Predicted changes to the estuary arising from the construction of the Dawesville Channel were outlined in the Environmental Review and Management Programme Stage 2 (ERMP) (Kinhill Engineers, 1988) and the subsequent assessment report by the Environmental Protection Authority (EPA 1988). Both documents recognised that there would be positive and negative impacts as a result of the Dawesville Channel. They concurred that the potential adverse impacts were acceptable when measured against the net benefit to the system, provided that appropriate monitoring and management strategies were implemented.

The EPA recommended that the proponents, the Ministers for Waterways, Transport and Agriculture, instigate a monitoring and management programme which would evaluate and maximise the success of the project. This report provides a discussion of potential environmental impacts from the opening of the Dawesville Channel, based on the information available at the time of opening, and the monitoring and management programme which has been put in place.

Management strategies will be developed to deal with adverse impacts as they arise. A social impact assessment and community consultation program has been set up to ensure community involvement in determining management strategies. They will also ensure that the community stays well informed.These will aim to reduce negative impacts while the estuary returns to an ecologically healthy and resilient state.

2 ENVIRONMENTAL IMPACTS OF THE CHANNEL

2.1 Water quality

Before the opening of the Dawesville Channel, the Peel-Harvey estuary was a poorly flushed coastal lagoon and flooded interdunal waterbody, with a single shallow channel to the ocean at the northern end of Peel Inlet. The Dawesville Channel now allows more than three times greater exchange of water between the estuary and the ocean than before.

Increased tides will help to improve water clarity by increasing the rate at which suspended sediments and phytoplankton are removed from the estuary. The increased input and mixing of marine water in the estuary will improve estuary water quality. In effect 10% of the estuary's volume will be flushed each day. The marine water will:

- increase the amount of dissolved oxygen in the water;
- increase water salinity for much of the year to a level similar to seawater;
- reduce the salinity range between dry and wet seasons;
- improve water clarity; and
- flush phosphorus to the ocean where it will form biologically unavailable compounds (apatites).

2.1.1 Dissolved oxygen

Abundant growth and subsequent death of algae, particularly in the Harvey Estuary, has led to an accumulation of a black organic layer over much of the sediments in the estuary. Microbiological breakdown of this layer consumes oxygen, which can create a state of anoxia (no oxygen present) in the sediments and surrounding water. This can be fatal to aquatic fauna, especially sedentary bottom dwelling (benthic) species such as worms and mussels which cannot move away from these conditions.

The regular inflow of oxygenated marine water through the Dawesville Channel will increase oxygen levels throughout the estuarine waters. This will result in phosphorus precipitating as calcium, iron and aluminium phosphates - apatites, so becoming biologically unavailable,. The higher oxygen levels will also lead to more rapid breakdown of the organic sediments, while maintaining oxygen in the water for marine fauna.

2.1.2 Stabilised salinity

Approximately 90% of the region's rainfall occurs between June and September each year. Consequently, the salinity of water in the Peel-Harvey estuary has been low in winter due to freshwater runoff and direct rainfall and high in late summer and autumn due to minimal runoff, high rates of evaporation and increased input of marine water. Salinity has ranged from less than 3 parts per thousand (ppt) in winter to over 40 ppt in autumn, which is an extreme environment for organisms to survive in.

With the Dawesville Channel, the estuarine waters will reach a stable salinity range closer to sea water (i.e. 35 ppt) for most of the year. This will inhibit the growth of *Nodularia* blooms and so improve water clarity (see 2.3.1).

2.1.3 Stratification

During winter and early spring, two distinct layers form in the water column of the estuary. River run-off is much less dense than saline estuary water so it forms a layer on the surface. Frequently these layered (stratified) conditions have remained throughout summer.

The lower saline water layer, particularly in the Harvey Estuary, becomes depleted in oxygen because it is trapped and cannot become reoxygenated by contact with air at the surface. Aquatic life which depends on oxygen has at times been adversely affected and even killed. Stratified conditions, and subsequent anoxia, also lead to the release of more phosphorus from the sediments.

With the Dawesville Channel open, the overall period of stratification may be reduced by about two months. Stratification is still likely to occur in the Harvey Estuary in winter and early spring. Since saline water will flow into the lower water layers from the Dawesville Channel rather than from Peel Inlet, stratification at these times will be stronger.

The benefits are:

- stratification during winter and early spring will enhance flushing of the surface flow of Harvey River water from the estuary by reducing the mixing of nutrient-laden river water in the estuary; and

- the Channel will greatly reduce the distance Harvey River water will have to travel to reach the ocean.

In summer, reduced rainfall and runoff and an increased tidal range will improve the mixing of estuarine waters, so that the salinity of the estuary will be similar to that of seawater. Stratification during summer will occur less frequently and this will reduce the likelihood of deoxygenation of sediments and water in the deeper portions of the estuary.

Stratified conditions are likely to remain in the lower reaches of the Serpentine, Harvey and Murray Rivers. Increased tidal movements in the lower reaches of the major rivers should carry saline waters further upstream for much of the year. This may strengthen the stratified conditions already experienced in spring. The lower layer of saline water may develop earlier, the bottom waters may be without oxygen for increased periods of time and the salinity differences between the two layers may be greater, inhibiting mixing. Tides may carry this deoxygenated, saline water further upstream. As a consequence, sections of the river upstream may be prone to anoxia, particularly if there is an event such as a sudden input of fresh water from a summer storm.

2.1.4 Sediments

Many problems in the Peel-Harvey estuary have arisen from excessive levels of organic matter and nutrients in the sediments. These are largely derived from dead and decaying algae.

As discussed in 2.1.1, the breakdown of large amounts of organic matter depletes the sediments and surrounding water of oxygen. As well as being unfavourable to aquatic animals, anoxic conditions increase the rate at which nutrients are released from the sediments.

The release of nutrients supports growth of more algae; consequently nutrients, particularly phosphorus, are recycled in the system and there is little nutrient loss to the ocean. As phosphorus is often the limiting nutrient in estuary plant growth, this cycle means that algal blooms can be self-perpetuating and algal population size is unrelated to recent inputs of phosphorus.

Nitrogen has not been such a major problem. There are significant losses of nitrogen via denitrification in anoxic sediments, which leads to production of atmospheric nitrogen.

Reduction of nutrient levels in the sediments, particularly phosphorus, is likely to take many years because current levels are so high. However, they will diminish provided catchment inputs continue to decrease. The channel will gradually flush resuspended sediments to the ocean and phosphorus will be immobilised into biologically unavailable forms.

It is expected that the increased inflow of marine water will have minimal direct impacts on the rivers, so there will be no significant reduction in river sediment nutrient levels. Fresh water input, occasional anoxic conditions and current levels of nutrient inputs will promote *Nodularia* growth. Algal blooms in the rivers can be expected until catchment management strategies reduce nutrient inputs.

2.2 Water levels

The aim of the Dawesville Channel is to increase marine flushing of the estuary. This flushing will be driven mainly by the tidal cycle. It is anticipated that the water exchange per tide cycle will be at least three times greater than the previous flow through the Mandurah Channel.

2.2.1 Tidal

Water levels in the estuary are affected by a number of factors: astronomic tides, seasonal river inflows, weather conditions such as barometric pressure, high winds and long-term fluctuations in sea level. Detailed numerical modelling was undertaken by the Department of Transport in order to predict changes to estuary water levels. The changes are being monitored by the Department of Transport. There are tidal gauges operating in the centre of both the Harvey Estuary and Peel Inlet, and at the ocean entrance of the Dawesville Channel.

Daily tidal range

Before the channel, the tidal range in the estuary was approximately 10% of the ocean tide. The new connection to the ocean will increase the tidal effect in the estuary. Tidal range in the Peel Inlet will increase to about 45% to 50% of the ocean tidal range and the Harvey Estuary will increase to about 60% to 70% of ocean tidal range.

On average, Mean Higher High Water Levels (the long-term average of the highest tide each month) in the Peel and Harvey are predicted to rise by 9 centimetres and 12 centimetres respectively. Some low-lying areas next to the estuary will be inundated at high tide. These areas will tend to be flooded more frequently (daily) and to a higher level but for shorter periods than before.

The Mean Lower Low Water Levels (the long-term average of the lowest tide each month) in the Peel and Harvey are predicted to drop by 9 centimetres and 17 centimetres respectively. More shallow flats may be exposed at low tide, but for relatively short periods each day.

In summary, water levels will be higher more frequently, but water will also recede more quickly than before. The opposite will also be true for low water tides. Furthermore, figures quoted are annual averages; there will be some variation in the daily, semi-annual and annual tidal ranges, water levels and channel flows.

Agricultural drains

Saline water may move up to 300 metres further into agricultural drains during high tide. Tide gauges have been placed in three agricultural drains to find out how they will be affected by the new tidal pattern. If necessary, control structures such as gates will be built on drains and protective earthworks will be installed.

Water residence time in the estuary

The average time water spends in the estuary will be significantly reduced, which means that much greater volumes of nutrient-laden river waters will be flushed to sea before they can contribute to excessive growths of algae. This will be helped by the fact that the distance Harvey River water has to flow to reach the sea will be approximately halved.

2.2.2 Flooding from river flow

Flood risks will be reduced by the Dawesville Channel. The estimated 100 year flood level (from rainfall which is so severe that it is only likely to occur, on average, once every hundred years) of the Peel-Harvey estuary, which results from major river flows in the Murray and Serpentine Rivers will fall from 1.6 metres AHD (Australian Height Datum) to approximately 1.1 metres AHD, a drop of 0.5 metres.

The time it takes for flood waters to recede will be significantly reduced, with the 100 year flood levels falling to tidal levels within 5 days compared with 10 to 14 days prior to the channel.

2.2.3 Storm surges and cyclones

The infrequent combination of onshore cyclonic weather, wet coastal and inland catchments and high astronomic or barometric tides has resulted in flooding of low-lying areas on previous occasions.

Cyclone Alby struck the southwest in 1978. This provided valuable data as to what can be expected during such rare natural events. It is predicted that a similar storm would produce ocean tides 20 centimetres higher with the channel in place but water levels would also depend on other weather conditions such as low pressure systems and winds. Like river floods, the high water levels resulting from extreme ocean surges will recede more rapidly with the channel in place - in about 1.5 days instead of three days.

Several nearby freshwater wetlands, such as Lake McLarty and Lake Mealup are important nature reserves. They are not expected to be affected except in extreme flood conditions, as would have been the case before the channel was constructed. However, if there is evidence of saltwater entering them, protective measures will be undertaken.

2.3 Estuarine plants

In recent decades, the Peel-Harvey estuary has been dominated by a succession of algal species. Excessive accumulations of green macroalgae were first reported in the mid 1960s and continued until the early to mid 1980s. *Nodularia* then became the dominant species and *Nodularia* blooms have been an almost annual occurence since 1978. Management strategies aim to improve the health and resilience of the estuarine system so it can again support a rich diversity of aquatic plants, including phytoplankton, other macroalgae and seagrass species.

2.3.1 Phytoplankton

In recent years the phytoplankton of the estuary has been dominated by *Nodularia*, which has appeared in massive blooms in late spring almost every year since 1978. These blooms, with algal cell densities in excess of 100 000 per millilitre (cubic centimetre), have been the principal symptom of nutrient enrichment. At the peak of a bloom, algal cells accumulated around the estuary margins in a blue-green paste. The *Nodularia* paste is highly toxic to mammals. The toxins within *Nodularia* cells may accumulate in the gut and tissues of filter feeding mussels and oysters and in the tissues of fish and crustaceans.

There is increasing evidence that these toxins can result in necrosis (death) of the liver and are associated with liver cancer (Falconer, 1994). As the blooms are so offensive, humans tend to stay away from affected areas and there have been no reports of people suffering such effects due to ingesting *Nodularia* in Western Australia. However contact with blooms can lead to skin irritation.

Because *Nodularia* blooms represent a serious health hazard to the human community, the Peel Inlet Management Authority and the Health Department of WA issue warnings to avoid direct contact with estuarine waters and avoid consumption of estuarine seafood when *Nodularia* blooms are present. Although *Nodularia* algal cells are highly toxic, they degrade in a matter of days.

Regular blooms of phytoplankton also occur in the lower reaches of the Serpentine and Murray Rivers. The blooms, coupled with anoxic conditions, have led to numerous recordings of fish and crab deaths, particularly in early spring. Blooms have also led to stock deaths.

Nodularia akinetes (i.e. spores or seeds) reside in the sediments and require several days of near fresh conditions in suitably warm water to germinate. In spring, water temperatures and salinities less than 15 ppt have favoured *Nodularia* germination in most years. It is expected that *Nodularia* blooms will be virtually eliminated from the Peel-Harvey estuary following the completion of the Dawesville Channel (Huber, 1985) because of the increase in salinity of the estuary in spring to at least 20 ppt. A further increase in the salinity (to around 35 ppt by the end of November) will retard *Nodularia* growth and prevent massive blooms.

It is possible that the more saline conditions and absence of *Nodularia* will enable marine species of phytoplankton (i.e. blue-green algae, dinoflagellatesor diatoms) to bloom and dominate the estuary. Blooms of marine phytoplankton, some potentially toxic, may occur in the short term until nutrient levels in the estuary are reduced.

In the long term, it is expected that the estuary will support an increased diversity of marine species, at lower levels of abundance, provided catchment input of nutrients has been effectively reduced. These are key indicators of a healthy ecosystem.

In the near future it is expected that run-off water entering the rivers will continue to be high in nutrients, which will favour the germination and growth of *Nodularia* in suitable regions of the rivers. The nutrient-rich sediments of the riverine reaches are likely to contain an abundant supply of *Nodularia* akinetes. Therefore it is highly probable that *Nodularia* will remain in the lower reaches of the Serpentine, Harvey and Murray Rivers.

2.3.2 Macroalgae

A large number of macroalgal (or seaweed) species, including red, green and brown varieties, with no one dominant species, usually inhabit healthy estuaries. High nutrient levels in the Peel-Harvey estuary have disrupted the natural balance of macroalgal species, so that at present only a few species flourish in far greater quantities than would normally occur.

Current nuisance macroalgal accumulations consist principally of *Chaetomorpha* (ropeweed), and to a much lesser extent, *Enteromorpha* and *Ulva* species.

A clear succession process occurred as the system became increasingly eutrophic. Macroalgae blooms were first noticed in the 1960s. *Cladophora* (goatweed) dominated until the late 1970s. In the 1970s macroalgal biomass reached its highest levels, particularly in the southeast region of Peel Inlet.

In the 1980s and early 1990s there was a general reduction in the size of the macroalgal population, due to an increase in the frequency of *Nodularia* blooms. High *Nodularia* cell densities and suspension of sediments and detritus reduced water clarity in spring. These factors appear to have reduced light and inhibited the growth of macroalgae.

Macroalgal accumulations have been harvested since the mid 1970s from shallows and beaches where they are trapped under the influence of wind and tidal currents. Drifting wracks of algae have been harvested using conveyor harvestors in deeper water (greater than 50 centimetres) since 1984.

In the short term, high levels of nutrients and improved water clarity, due to the lack of *Nodularia* blooms and more rapid flushing of coloured river water, will be likely to favour the growth of macroalgae.

It is anticipated that there will be substantial accumulations of macroalgae in shallow waters, particularly along the south eastern shoreline of Peel Inlet. It is possible that macroalgal populations could reach the proportions currently found in Princess Royal Harbour at Albany within a relatively short period.

It is strongly suspected that the thick macroalgal blanket which currently covers the organic sediments of Princess Royal Harbour is enhancing nutrient cycling. Any significant growths of macroalgae in Peel-Harvey estuary will be intensively harvested, thereby attempting to minimise nutrient cycling similar to that in Princess Royal Harbour.

At present there are relatively small accumulations of macroalgae in the three canal developments entering the estuarine system and lower reaches of the Serpentine and Murray Rivers. Increased tidal movements in the canal developments may favour the growth and accumulation of macroalgae. However, macroalgal populations in the Serpentine and Murray Rivers should remain low, partly because continued *Nodularia* and other phytoplankton blooms in these regions will reduce water clarity (see Section 2.3.1) and because of their average lower salinities.

The State Government has provided additional funding for the construction of harvesting equipment to be deployed in shallow waters. Macroalgae may develop in the deeper waters of the estuary and the lower reaches of the Serpentine and Murray Rivers. If this occurs, harvesting efforts will need to be increased and redirected to those areas of greatest need. Deep water harvesting will help to inhibit nutrient recycling by preventing the formation of a macroalgal blanket overlying organic sediments.

Monitoring and mapping of the macroalgae in the estuary will provide information on the distribution of macroalgae and locate areas where harvesting may be needed. Off-shore weed harvesters take a non-targeted catch of crabs and fish. Any proposal to increase harvesting will take this into consideration and specific studies to minimise this impact may be undertaken.

2.3.3 Seagrasses

The deterioration in Peel-Harvey estuary water clarity, and thus light available for photosynthesis, has severely impacted the once common seagrasses *Halophila ovalis* (paddleweed) and *Ruppia megacarpa*. High *Nodularia* cell densities, macroalgal blooms and excessive amounts of suspended fine organic matter have reduced light penetration into the water column. This has led to the death of large areas of seagrass beds over the last 20 to 30 years.

The return of seagrasses will depend on reduction of the extent and duration of all types of algal growth: benthic (on the bottom), free-floating and epiphytic (attached to other plants). Macroalgae are dependent on sustained high levels of nutrient-enriched water, which catchment management is working to reduce.

In the long term, it is possible that seagrasses will be able to recolonise sediments in the Sticks and Dawesville Channels, the river deltas, the south eastern Peel Inlet flats and the sub-littoral margins of the Peel and Harvey estuaries. The reduced salinity range and more marine conditions may lead to an extension of the restricted patches of *Zostera* and *Heterozostera* species.

Existing *Ruppia* stands may disappear from marginal shallows which become regularly exposed by the change in tidal fluctuations, but are expected to move to the slightly deeper marginal zone which is permanently inundated.

2.3.4 Fringing vegetation

The two main factors influencing the distribution of fringing estuarine plant species are foreshore salinity and the level of inundation by tidal and flood waters. Under the pre-Dawesville tidal regime, the fringing vegetation of the Peel-Harvey estuary was inundated for several days and subsequently exposed for a similar period.

The opening of the Dawesville Channel is expected to result in a pattern of frequent inundation and exposure in areas between the high and low water marks (i.e. the intertidal zone). Increased tidal range will also increase the extent of the intertidal zone. Fringing plant communities will gradually adjust to local changes in the size and nature of the intertidal zone.

In areas where erosion is already a problem, or where only a narrow band of vegetation remains, tree deaths and shoreline erosion may occur. Rehabilitation work will be undertaken as necessary.

In some areas, particularly the extensive, shallow mud flats of the Peel Inlet, plant colonisation could be on a large scale. Once fringing vegetation is established in exposed intertidal areas there may be natural colonisation of other plant species and increased sediment deposition. Studies of the Swan, Leschenault and Wilson estuarine systems have indicated that colonisation of bare substrate may continue over five to twenty years, following a change in environmental conditions (Luke Pen, unpublished data).

There is expected to be increased growth of fringing vegetation, particularly saltmarsh, which is an extremely productive part of an estuarine ecosystem and can contribute up to 25% of an estuary's energy cycle. Saltmarsh (and other fringing plants) provide a very effective nutrient, suspended sediment and pollutant filter and wave buffer, thus helping to stabilise the shoreline and improve water quality. The movement of sediments and increase in saltmarsh may promote the formation of stagnant, temporary pools which are suitable mosquito habitat. This is discussed further in Section 3.4.

There is likely to be loss of animal habitat for some species and creation of habitat for others. There may initially be reduction of fringing vegetation used by waterbirds, but in the longer term there is likely to be increased areas of some types of fringing plant assemblies that will offset original losses of bird habitat.

It is possible that opportunistic introduced species, such as pigface (*Carpobrotus edulis*), *Atriplex hastata* and Watsonia (*Watsonia bulbilifera*) might invade the shoreline. PIMA will monitor and manage such changes as required.

2.4 Estuarine animals

The Peel-Harvey estuary supports a dense population of invertebrates, crustaceans, fish and waterbirds. Some of these crustaceans and fish are prized by recreational and commercial fishermen (e.g. blue manna crab, king prawn, whiting and mullet), and some migratory waterbird populations are of international significance.

As a result of the profound changes arising from the Dawesville Channel, it is expected that the distribution and abundance of a range of animal species will change. Marine aquatic species will be likely to benefit, while some estuarine aquatic species may decline in abundance. The stabilised salinity may allow a greater range of animals to inhabit the estuary. Overall, more species will be able to use the estuarine waters both on a seasonal and permanent basis.

2.4.1 Invertebrates

The invertebrate community of Peel-Harvey estuary includes species of zooplankton and benthic or sediment-dwelling invertebrates. Zooplankton are microscopic to small animals that live suspended in the water column. They feed principally on phytoplankton, detritus and other zooplankton. They are primarily fed upon by small fish. Benthic invertebrates are small animals that live on or in the estuarine sediments and include worms, molluscs and small crustaceans. Zooplankton and benthic invertebrates are important food items in the diets of many fish, crustaceans and waterbirds.

The invertebrate community of Peel-Harvey estuary experienced extreme seasonal changes in salinity prior to the Dawesville Channel. *Nodularia* blooms and macroalgal growth, and subsequent periods of anoxia (see 2.1.1), severely stressed the invertebrate community and often resulted in mass mortality of animals throughout areas of the estuary .

Because of the harsh environmental conditions of the Peel-Harvey estuary, it has supported a relatively small number of invertebrate species. Invertebrate species found in the estuary tended to be small, short-lived, produced a large number of offspring and were tolerant of a wide range of salinity and oxygen levels. These attributes have allowed these species to opportunistically recolonise disturbed areas created by *Nodularia* and macroalgae blooms.

Invertebrate populations tended to reach their highest density in autumn and early winter. This was probably because of improved environmental conditions following the collapse of *Nodularia* blooms in summer and macroalgal decomposition in summer and early autumn.

Before construction of the Dawesville Channel, marine invertebrates could only enter the estuary through the Mandurah Channel, which is shallow, relatively long and narrow. Movement of marine species into the estuary was restricted to the summer and early autumn months, when river flow was minimal and marine conditions were established in the estuary.

The Dawesville Channel will create marine conditions in the estuary for longer periods throughout the year. Reduction of blue-green algal blooms and increased mixing of the water column should reduce the frequency of anoxic conditions in the sediments and lower water layers. Reduction in *Nodularia* blooms will favour the growth of a wide variety of other species of phytoplankton (diatoms and dinoflagellates). Zooplankton generally did not graze on *Nodularia* so they may have a greater range of food sources in the more marine conditions.

The new channel should allow a greater passage of marine invertebrates into the estuarine system. Marine organisms will be able to enter the estuary earlier in the year, persist longer and extend further into the estuary than at present. Seasonal changes in salinity and periods of anoxia may still occur, albeit for shorter periods. However, the current dominant estuarine species are likely to remain important components of future invertebrate communities.

It is likely that fresh and brackish water organisms will retreat upstream in the inflowing rivers. It is also likely that large and longer living bivalve molluscs and polychaete worms will return to the estuary, provided anoxic episodes are infrequent and do not affect large regions of the estuary. The large and longer living estuarine mollusc and worm species are expected to be similar to those found in the lower and middle regions of the Swan Estuary and the Leschenault Inlet.

Increased tidal ranges will expose areas previously submerged and inundate areas formerly exposed. New invertebrate habitats will be created in this process, but old habitats may be subject to stresses such as dessication, heat and increased exposure to predators.

Invertebrates are a major source of food for many prawn, crab, fish and waterbird species in the estuary. Any changes in the invertebrate community may affect other animals in the system. These changes are likely to be subtle, complex and occur over an extended period of time.

2.4.2 Fish and large crustaceans

About 60 fish species have been recorded in the Peel-Harvey estuary, which is approximately half the number recorded in the Swan Estuary. The macroalgal blooms in the Peel-Harvey, particularly in the 1970s, were strongly associated with an increase in fish numbers. However, eutrophication of the estuary proved to be detrimental when the *Nodularia* blooms became commonplace. Juvenile fish and fish in general have been reported to be adversely affected by *Nodularia*. The blooms also hindered fishing (Lenanton *et al.*, 1985; Potter *et al.*, 1983).

The more marine conditions in the estuary will favour habitationby species which mature or only occur at marine salinity. This may include commercially important species such as yellow-eye mullet (*Aldrichetta forsteri*), cobbler (*Cnidoglanis macrocephalus*), tailor (*Pomatomus saltator*) and blue manna crabs (*Portunus pelagicus*, which were common before the opening of the Dawesville Channel). It is expected that these already abundant species, many of them seasonally abundant, will increase. Whiting, mulloway, Australian herring and trevally may also benefit and become more regular visitors to the estuary during winter.

The few species which live only in estuarine conditions or systems are unlikely to be severely impacted because they can tolerate a wide range of salinities. These include black bream, yellow tail trumpeter and several species of hardyheads and gobies. However, the changes are likely to be unfavourable to species such as sea mullet, whose young are often abundant during low salinity periods in the estuary during winter and spring..

Evidence from work done in the Peel-Harvey estuary during the mid 1980s (Potter *et al.*, 1991) suggests that the abundance of juvenile king prawns (*Penaeus latisulcatus*), is positively correlated with salinity, with preferred salinities being greater than 30ppt. The change to this fishery will depend on a number of factors. Increased marine flushing is likely to prevent the formation of greater than seawater salinity levels in parts of the estuary, which may make these areas of the estuary less attractive to this commercially important species. Other factors include how recruitment from the adjacent ocean is affected and the availability of suitable nursery habitats in the estuary. Possible increases in weed growth could adversely affect their habitats because juvenile king prawns prefer to live over shallow sandy areas along the shoreline margin. Exposure and drying out of these sands on warm summer days may affect use of these areas. In addition, these prawns are detrital feeders and improved estuarine conditions may not be favourable to them if their food supply is reduced.

The regular tidal exposure of shallow feeding areas may not favour certain fish, crabs and prawns. Higher oxygen levels in the estuary should prevent mass mortality of fish and crabs and increase the food supplied by aquatic invertebrate prey. In the short to medium term, the expected increase in macroalgal biomass will also probably favour certain species of fish and crustaceans. However, increased weed harvesting operations may impact species such as cobbler and crabs, although this has to be carefully considered because of the confounding effects of fishing pressure, and the total amount of algal biomass harvested compared to what is in the estuary.

Further subtle and complex effects on fish and large crustacean populations, due to changes in food types and their availability, cannot be predicted with confidence. However, conditions are likely to more closely resemble those of Leschenault estuary, which is one of the most productive estuaries for its size in the southwest, as measured by fish catches.

Recent research (Potter *et al.*, 1989) has revealed that the highest densities of Western school prawns (*Metapenaeus dalli*) are found in the Murray River over the summer months. Apparently prawns move from Peel Inlet and Harvey Estuary into the Murray River to breed. Thus the anticipated changes to estuarine salinity should not adversely affect school prawn numbers. However effects of the anticipated changes to patterns of water movement remain unclear.

For further details, see Department of Conservation and Environment Bulletin 195, 1985 and Bulletin 242, 1986.

2.4.3 Birds

The Peel-Harvey System is one of nine sites in Western Australia recognised as being a wetland of international importance under the Ramsar Convention. It is the most important waterbird habitat in the southwest of Western Australia and is listed by the Australian Heritage Commission.

To date over 80 species of birds have been sighted, with counts of up to 100 000 individuals. This includes 27 waders which are listed on the Japan-Australia Migratory Birds Agreement (JAMBA) and China-Australia Migratory Birds Agreement (CAMBA). A number of species which are regularly observed on the Peel-Harvey estuary, such as the white-winged tern *(Childonias leucoptera)*, are rarely seen on other southwest estuaries. One of the rarest birds in the world, the freckled duck *(Stictonetta naevosa)*, has been sighted at the southern end of Harvey Estuary and on adjacent freshwater swamps. Fringing trees and saltmarsh are home to many other bird species.

At present, wading birds feed in shallow waters that persist for many days. These areas may be especially important for pre-migratory fat deposition in late summer/early autumn, since feeding opportunities between the estuary and Shark Bay are limited at this time of year.

Changes to the aquatic and foreshore environment of the Peel-Harvey estuary may affect waterbird populations by altering food sources, roosting and/or breeding habitats. The increase in tidal range and frequency is of particular relevance to a number of species which are resident in the southwest region and are known to favour shallow inland waters in preference to estuaries with strong tidal influences (e.g. banded stilts, *Cladorhynchus leucocephala*). The reason these birds have frequented the Peel-Harvey estuary prior to the opening of the channel is thought to be because of the previous lack of tidal variation.

The new tidal regime is not expected to adversely impact the trans-equatorial migratory waders that visit the region, because these birds are generally opportunistic and many of the estuaries they frequent in other parts of the world experience even greater tidal regimes than that of the Peel-Harvey estuary.

At high tide, the inundation of roosting areas, such as rocks, sandy cays and spits, may affect wading and fish-eating birds (i.e. cormorants, pelicans and terns). Higher tides will also allow boat access to previously shallow areas and this may lead to increased disturbance of birds which favour quiet sections of the estuary.

Breeding habitats may be gained or lost for a range of waterbird species. There are also likely to be changes in the amount, composition and availability of food. Some bird populations will be able to adapt to the new environment and even increase in numbers while others may decline or disappear from the estuarine system.

It is extremely difficult to predict changes in bird abundance and diversity that may result as a consequence of the Dawesville Channel. Many species are resilient and opportunistic. However, because the site is of regional and international significance, it is important that all necessary actions are taken to ensure the integrity and value of the Peel-Harvey system is not compromised in any way.

If existing feeding, roosting and breeding habitats become degraded or diminish as a result of the Dawesville Channel, alternative habitat sites may need to be created. Options include planting fringing vegetation and use of flood gates to prevent saltwater intrusion into freshwater wetlands such as Yalbanerup Pool, Lake Goegrup, Lake McLarty and Robert Bay.

For further details on how bird populations may be affected see Department of Conservation and Environment Bulletin 242, 1986 pp.16-18 and EPA Bulletin 363, 1988 pp.59-60.

2.4.4 Mosquitoes

It has been recognised since the preparation of the ERMP and subsequent EPA report (Kinhill, 1988; EPA,1988) that there may be increased numbers of mosquitoes once the Dawesville Channel is open. This is because there will be an increase in inundation of fringing saltmarsh, particularly during summer when this did not previously occur. Current breeding areas will be inundated more frequently and so will be likely to produce greater mosquito populations.
In the short term, increased mosquito breeding will be the direct result of the increased tidal range. In the longer term, mosquito numbers may slowly increase through the formation of new breeding areas, such as salt marshes. The accumulation of sediments in intertidal areas may create slight levees which trap tidal water, inhibit drainage and ultimately form salt marshes. Small natural troughs in the intertidal zone will contain pockets of permanent water.

Increased growth of fringing plant communities may further enhance the formation of isolated pools which are suitable for mosquito breeding.

A range of salt marsh mosquitoes can carry two non-fatal but seriously debilitating viruses: Ross River virus (RRV) and Barmah Forest virus. For more details of the viruses, the role of mosquitoes and potential control strategies see Appendix 1 and Dawesville Topic Sheet No.6. RRV and Barmah Forest virus are notifiable diseases.

2.5 Nearshore marine areas

The Dawesville Channel will increase the passage of river waters to the ocean. As nutrients currently stored in organic-rich estuarine sediments are oxidised and used by resident phytoplankton, both nutrients and plankton will be carried to nearshore marine areas. In the short to medium term there should be an increase in the level of dissolved and particulate nutrients in nearshore marine areas throughout the year. It is expected that phosphorus will be immobilised by reacting with calcium, iron and aluminium in seawater to form biologically unavailable compounds called apatites.

In the long term, nutrient export from the estuary will occur predominantly in the winter months, when river flow is highest, or during any phytoplankton blooms.

The Department of Transport has undertaken a program to monitor the levels of nutrients in the nearshore marine area adjacent to the channel before and after channel construction. It is also determining ocean current flows to establish nutrient dispersal paths, or plumes.

These results will be integrated into the *South Metropolitan Coastal Waters Study*, which will be completed at the end of 1994. Current data indicate that marine water near the channel will frequently flow north into the Sepia Depression, as the channel mouth is near the southern end of a longshore underwater hollow. Water flow from here is currently being determined by the EPA, but it is thought that the water remains in the coastal vicinity for extended periods (Chris Simpson, pers. comm.).

The assimilative capacity of coastal waters is being determined in the above study. This includes quantifying how different nutrient loads affect marine biology, including algal blooms. Nitrogen is often the limiting nutrient for many marine algae species. Until significant progress is made in reducing nutrient run-off from the catchment, large volumes of nitrogen and phosphorus will continue to enter nearshore areas, however, less total nitrogen is expected to enter the nearshore coastal region overall, because of the reduction in *Nodularia* blooms.

There have been *Nodularia* blooms in the estuary in 11 of the last 13 years. It is estimated that each bloom fixed up to 2000 tonnes of atmospheric nitrogen. Because the more saline conditions of the Estuary now inhibit *Nodularia* blooms, considerably less nitrogen will enter coastal waters. Monitoring and management of catchment run-off and the nearshore coastal region is on-going.

3 SOCIAL IMPACTS OF ENVIRONMENTAL CHANGES

The environmental changes caused by the Dawesville Channel are likely to affect the human community and tourism values of the estuary in a number of ways. These are discussed below. A project team has been set up by the State Government to investigate how the environmental changes in the Peel-Harvey estuary affect the community, and to involve people in developing management strategies to minimise any adverse affects.

3.1 Water quality

The improved water clarity and reduced *Nodularia* blooms in the short term, and reduced weed growth and improved environmental health of the estuary in the longer term, will have benefits for local residents, recreation and tourism in the region. The intrusion of the more saline estuary water further into agricultural drains, and possibly freshwater wetlands, is of concern and is being monitored so that management measures (for example gates on drains) can be put in place.

3.2 Water levels

The change in tidal regime and water levels in the estuary may effect people living around the estuary shoreline and those using the banks and waters for recreation, fishing or boating. Issues associated with higher tides include concern about possible damage to homes or tourist facilities, shoreline erosion, changes to fringing vegetation, changes to the water table (and hence impacts on bores and septic tanks), flooding of agricultural land, effects on canal developments, and foreshore planning. Issues associated with lower water levels at low tide include maintenance of navigation channels and exposure of tidal flats and sandbars. Changes in currents will affect boating, and the safety of small boat use, skiing and swimming in the Channel also needs to be considered.

Department of Transport monitoring together with existing hydrological data will allow the development of inundation control strategies for low-lying urban, rural and conservation areas. Studies indicate that the changes in tides will not affect homes. Future planning, development and use of land around the estuary will need to consider the increased tidal range and associated changes in water levels.

The increased tidal range will affect fishers and boating operators in the region, however no major navigation channels have been affected. Fishers will need to adjust their activities to adapt to the new tidal regime and pattern of water movement. For example, commercial tide prawn fishers who use the outgoing tide in late summer and autumn to catch their prawns may be adversely affected by increased tide velocities.

The Dawesville Channel now provides unimpeded ocean access for small boats; the channel is permanently open, and the bridge has a clearance height of 19 metres. In the longer term, there may be increased numbers of boats using the estuary because of improved water quality and increasing population in the region. The altered tidal regime may slightly reduce navigable areas at some times.

3.3 Weed growth

The reduction in toxic *Nodularia* blooms will improve recreational and fishing conditions in the estuary in spring and early summer, when the blooms have usually appeared. However, the expected increase in weed growth until the nutrient levels in the estuary drop may cause some inconvenience due to weed accumulation and odours. This will be monitored and harvesting effort by the Peel Inlet Management Authority will be increased if necessary.

3.4 Mosquitoes

It is possible that the altered tides and marine conditions will create new and better breeding places for mosquitoes and extend the potential breeding season for some species further into summer. The more marine conditions will favour saltmarsh species, which can carry the non-fatal but seriously debilitating Ross River and Barmah Forest viruses.

A Contiguous Local Authority Group (CLAG) has been established to manage mosquito problems in the region. This group consists of representatives from the Department of Health, Local Government Authorities, and the Peel Inlet Management Authority. It aims to ensure that mosquito management is efficient, effective and environmentally acceptable. The management programme includes applied research, use of larvicides, habitat modification and public education.

Numbers and types of mosquitoes have been monitored to establish baseline data and allow the effectiveness of control measures to be assessed. Much of this research was undertaken by the University of Western Australia Department of Microbiology and was funded by the Health Department of WA.

Mosquito larvae are monitored and controlled when necessary using the chemical larvicide "Abate". The Health Department of WA in collaboration with Mandurah, Murray, Waroona and Rockingham Councils, is responsible for their control.

Runnels (shallow channels which connect mosquito breeding pools to open water) have been investigated as a way to reduce suitable breeding areas in saltmarsh. They increase tidal flushing, rather than draining the marsh. In the longer term, this may prove to be preferable to chemical options or other forms of habitat modification such as filling or draining. This research has been undertaken by Murdoch University and was funded by the Health Department of WA.

Mosquito breeding habitats will need to be regularlsurveyed, as the shoreline and fringing plant communities adjust to the greater tidal range.

It is important to recognise that some species, including migratory waders (especially greenshanks) and ducks (especially teal), use mosquito larvae as a food source, and that mosquitoes should not and cannot be eliminated from the ecosystem.

Effective control of mosquito numbers combined with public education should minimise rates of viral infection in the community.

3.5 Fisheries

Issues include changes in fish, crab and prawn availability, fishing conditions and navigation. Some predictions can be made about changes in species composition and abundance of the estuary's fish, crab and prawn populations (see 2.4.2). However, the estuary ecosystem will take a number of years to adjust to the changes due to the Dawesville Channel. Short-term changes in catches will be difficult to interpret because populations vary from year to year depending on seasonal conditions and marine recruitment. The Fisheries Department will monitor commercial fishing catches, and the community will be encouraged to report changes in recreational catches (see 4 below).

The more marine environment, improved water clarity and reduced *Nodularia* blooms will improve recreational fishing conditions. Shore-based rock walls in and around the channel, as well as increasing local population, will add to fishing pressure.

The increased tidal range will affect fishers, who will need to adjust their activities to the new tidal regime and pattern of water movement (see 3.2).

4 MONITORING AND MANAGEMENT

The Dawesville Channel has been constructed to improve environmental health of the Peel-Harvey Estuary. However it will not immediately rectify all the current water quality problems of the estuary. Although there will be rapid changes on channel completion, particularly improved water clarity and reduction in the highly toxic *Nodularia* blooms, it may be some years before mosquito numbers, macroalgal accumulations, and water quality have stabilised to acceptable levels. In order to assess changes in the estuarine system, baseline data of pre-channel conditions, particularly the water quality of estuarine, canal, river and nearshore marine areas have been collected.

An environmental monitoring program has been set up to monitor the changes. The program involves a number of government agencies:

The *Peel Inlet Management Authority* will monitor water quality, algal growth and changes to the shoreline and fringing vegetation. Work will continue on auditing nutrient loads from the catchment into the Peel Inlet and Harvey Estuary. The water quality of the estuary will be regularly monitored. This will include nutrients as well as growth of microscopic algae. The abundance, distribution and species composition of macroalgae (seaweed) will be surveyed, as weed growth may increase for a few years following the Dawesville Channel opening, before decreasing with the reduction of the bank of nutrients found in sediments of the estuary.

The *Department of Conservation and Land Management* will continue a program to monitor the impact of the new water level regime on water birds and fringing vegetation in conservation reserves. The *Health Department of WA* will continue its collaborative program with local government to monitor and manage mosquito nuisance and associated Ross River virus. The *Fisheries Department of WA* is responsible for monitoring the effects of the Dawesville Channel on the commercial and recreational fisheries. The *Department of Transport* will continue its tidal monitoring and study of the adjacent marine environment. The *Water Authority* is combining with the Department of Transport to look at the issue of intrusion of estuarine waters into drainage channels. The results of the monitoring programs will be made available as the research proceeds.

The community will also have an important role in monitoring changes to the estuary. Local people will be encouraged to report their observations, and the Peel Inlet Management Authority has prepared a recording sheet for this purpose. These observations will be a valuable addition to the formal monitoring programs.

The changing environmental conditions, including daily tidal regime, will affect some people who live around the estuary. A social impact program began before the Channel opened, with the aim of finding out about people's concerns and involving the community in developing management measures to reduce any negative impacts. The Peel Inlet Management Authority will continue this program.

Adverse environmental impacts which can be managed, for example foreshore erosion, excessive weed growth, increased mosquito numbers or saline water intrusion into drains, will be minimised by appropriate management. Some changes, such as gradual establishment of a different balance in fringing plant communities and the estuary's animal life, are less easy to manage. Such impacts need to be viewed in the light of the overall long-term benefits to the Peel-Harvey estuary. Careful management of affects on boating areas, important foreshore areas and seaweed populations, and control of mosquito numbers, should counter any potential adverse impacts on tourism or the number of holiday makers in the region. The social impact program will give the community an opportunity to be involved in determining appropriate management strategies through a Community Consultative Committee. People will also be able to express concerns or opinions through public forums, community surveys or direct comment to the Peel Inlet Management Authority.

It is essential that residents of the Peel-Harvey region have a good understanding of possible beneficial and adverse impacts of the channel and are informed of likely and actual the changes to the estuary, as well as the management actions taken which may affect them. The State Government has instigated a Dawesville Channel public information program, which includes a series of information sheets (Dawesville Topics) on various aspects of the environment that will be affected by the channel, talks to schools and a "hotline" phone service to answer people's queries and concerns (phone (09) 535 9112).

Information on the results of monitoring and development of management strategies will be made available through regular publications and media releases.

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APPENDIX: MOSQUITO-BORNE VIRUSES

Ross River Virus (RRV) causes the disease epidemic polyarthritis. A WA survey of the 1988-1989 epidemic revealed that symptoms frequently persist for six to twelve months. RRV only rarely causes disease in the southwest in winter months. Barmah-Forest virus produces similar symptoms to RRV, but appears to be more likely to surface in winter months than RRV. They are different viruses, and require separate blood tests.

In general, each year around 100-200 cases of RRV are confirmed in the whole state. However, in 1989 and 1992 environmental conditions were favourable for viral transmission and over 600 cases were notified in both years.

There were ten reported cases of Barmah-Forest virus in 1993 and one in 1994 in the Peel region. These were the first cases to have been recorded in the area. The Health Department of WA is monitoring both diseases. The Department is also working to identify key vertebrate hosts and whether vertical transmission can occur (when a female mosquito can pass the virus to her offspring).

The salt marsh mosquito species *Aedes Camptorhynchus* is the main vector of both viruses in the southwest. It can travel three to five kilometres in a night. *Coquillettidea linealis* is a minor vector of the disease; its main breeding sites are reed beds (especially *Baumia*) in freshwater wetlands.

Although *Aedes vigilax* is a vector of the disease elsewhere in the state, it is important to note that this species does not appear to be a vector in the southwest, and is likely to be a separate sub-species. However, this species can breed in enormous numbers in the Peel-Harvey area, has been known to travel over 50 kilometres from its breeding site and is the main nuisance species in the region.

At present the organophosphate "Abate" is the only larvicide available in granular form suitable for aerial application. The Health Department of WA has recently conducted trials of *Bacillus thuringiensis israeliensis*- sp (Bti.). Results have been promising, and it may be possible to use this alternately with "Abate". This would reduce resistance build-up in mosquitoes to both larvicides.

Public education will be an integral part of disease minimisation. The Health Department of WA has published an informative pamphlet on Ross River Virus. People need to understand that personal protection is esential and the critical times of day vary with the season. This is because mosquitoes are extremely vulnerable to dessication, and hot dry conditions are lethal for them.

During the hotter months, between October and April, mosquitoes are most likely to be active at dawn and one to three hours after sunset. This form of bimodal activity is known as crepuscular. Between the cooler months of May and September mosquitoes are most likely to be active during the day, because of wet and higher humidity conditions. People should be particularly encouraged to minimise exposure during the peak periods of mosquito activity.

ACKNOWLEDGEMENTS

This report was compiled by Tom Rose (Peel Inlet Management Authority), David Deeley (Waterways Commission) and Luke Pen (Water Authority of Western Australia).

Useful discussions were held with a number of colleagues during the preparation of this document. They are sincerely thanked for their contributions.

Vas Hosja	Waterways Commission
Geoff Bastyan	Centre for Water Research, Murdoch University
Prof Arthur McComb	Centre for Water Research, Murdoch University
Dr Hugh Kirkman	CSIRO, Watermans
Dr Rod Lenanton	Fisheries Department of W.A.
Jim Lane	Department of Conservation and Land Management
Brian Devine	Health Department of W.A.
Sue Harrington	Health Department of W.A
Tony Wright	Health Department of W.A
Dr Stuart Halse	Department of Conservation and Land Management
Dr Robert Humphries	WA Water Resources Council
Dr Chris Simpson	Department of Environmental Protection
Nello Siragusa	Department of Transport
Jane Latchford	Murdoch University
Colleen Henry	Department of Commerce and Trade
Robert Atkins	Waterways Commission

Editorial assistance was provided by Karen Majer (Waterways Commission) and Shona Kennealy.