# WATER QUALITY MONITORING PROGRAMME FOR THE PEEL-HARVEY COASTAL CATCHMENT

## A GUIDING DOCUMENT WITH STRATEGIES FOR ESTABLISHING A MONITORING NETWORK CAPABLE OF ACCURATELY MEASURING NUTRIENT LOADS

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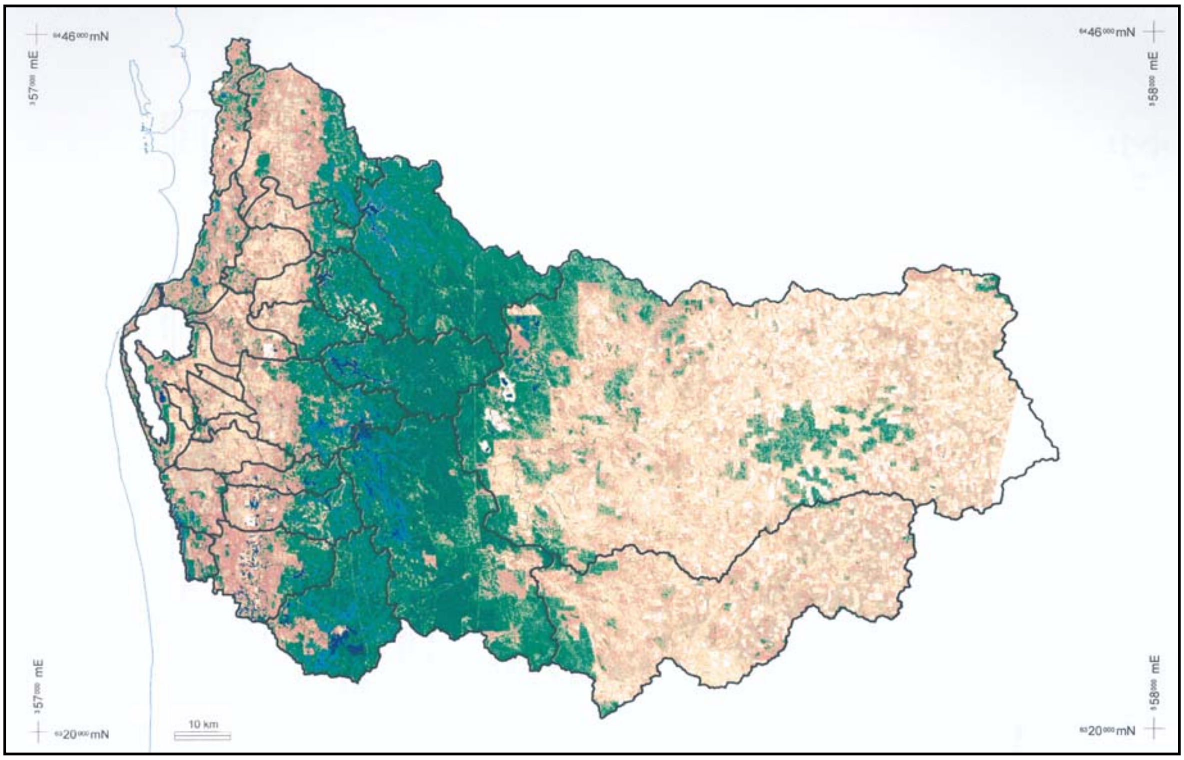

Prepared by Dr Tom Rose and the Aquatic Sciences Branch of the WA Department of Environment

Coastal Catchment Initiative – Environment Australia

Water Quality Monitoring Program and Infrastructure Project for the Peel-Harvey

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# PREAMBLE

The shallow waters of the Peel-Harvey Estuary support extensive stands of macroalgae and some seagrass, and these plants, in combination with high phytoplankton productivity, support large populations of small invertebrate animals. The high plant and invertebrate productivity is the basis of a food chain that supports large numbers of fish, crabs, birds and prawns. The fringing vegetation and the shallow intertidal flats are also important feeding and shelter areas for waterbirds. The Peel-Harvey estuarine system (PHES) has the largest professional and recreational estuarine fisheries in Western Australia and it is one of the most important estuarine habitats for waterbirds in south-western Australia, particularly for summer migrant species whose breeding-grounds are in the northern hemisphere (McComb *et al.* 1995).

The PHES is also an important recreational and tourism resource due to a combination of its biological features, sheltered waters, scenic surrounds and close proximity to the Perth metropolitan area. There is considerable recreational use of the system, the most popular being passive recreation (eg. walking), prawning, crabbing, fishing and boating (O'Brien Planning Consultants *et al.* 1994).

This document outlines a strategy to develop a water quality monitoring program for the coastal catchment of the Peel-Harvey estuarine system that can measure nutrient loads from a monitoring network established in the next two years.

The document concentrates on the coastal portion of the whole Peel-Harvey catchment. It is recognised that any coastal catchment water quality monitoring program must also compliment and support a holistic approach to water quality issues that affect the total catchment. This document has a strong nutrient focus because nutrient enrichment has a long history in the region and has been recognised as the major environmental issue affecting the ecology of the system. However, a robust load measuring network will be able to be adapted to measuring other water quality parameters in the future, if need arises.

The network that will be established from this program will provide good catchment monitoring data to answer questions of performance required by State Ministerial Conditions and a regional Environmental Protection Policy (1992). Because of the need to provide data suitable to test performance over time, the document emphasises the problems detected in historical catchment nutrient data and outlines what is needed to measure water quality and flow so that load calculations and trend analyses are computed with known precision. Only then can among year differences be determined and monitoring data be used as a performance or compliance measure.

The ANZECC/ARMCANZ (2000) documents stress that development of a water quality monitoring program can take time if it successfully engages the whole community. Engagement and support of the community is critical if a monitoring program is to be used to measure changes in water quality over a period of time. The document outlines over 120 questions and sub-questions to help develop a water quality monitoring program so that the relevant issues and requirements for a successful program are included. This water quality monitoring program has been expedited because of the exigencies of the Coastal Catchment Initiative program (CCI).

In short this document outlines a strategy to develop a load measuring capacity around which a comprehensive water quality monitoring program is being developed. The monitoring program will compliment the development of the Water Quality Improvement Plan, whose objective is to guide this project, other CCI projects, and community initiatives. This core program will support additional monitoring and evaluation efforts under NAP/NHT2 funded strategies.

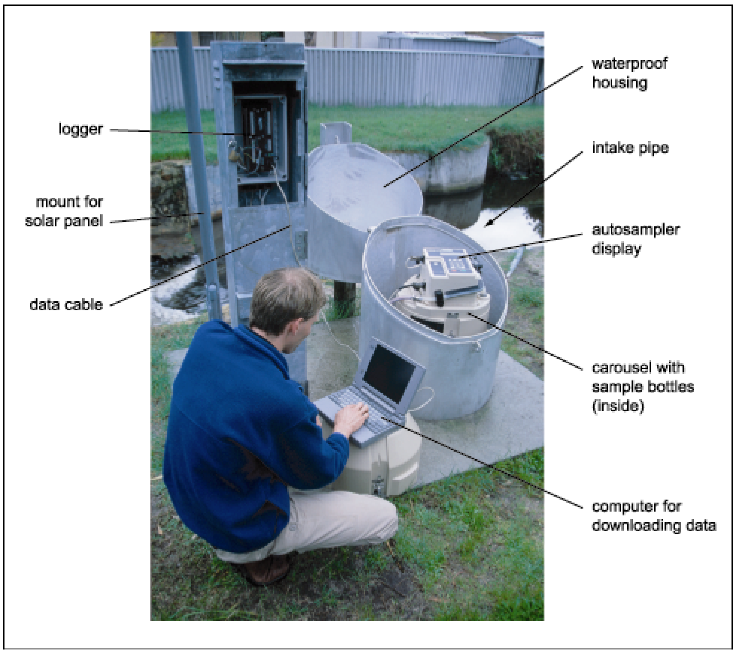
# 1.0 INTRODUCTION

Since the late 1960s the Peel-Harvey Estuarine system became known for its large-scale eutrophication problems. The system used to experience extensive macroalgal blooms in the Peel Inlet and after 1978, toxic blue-green algae *Nodularia* blooms in the Harvey Estuary and its tributary rivers. More recently, the construction of the Dawesville Channel in 1994, to improve flushing with the Indian Ocean and reduce algal blooms, has also been notable for being one of the largest environmental remediation projects in the Southern Hemisphere. Despite improved water quality in the estuarine basins, poor water quality and algal blooms still persist in the lower tributary rivers (Rose, 1998).

A common local perception is that poor water quality conditions are increasing in frequency as nutrient rich catchment water combines with weak tidal flushing in the lower rivers, all of which is felt to be exacerbated by the Dawesville Channel. However, to determine the extent of the current problem, a monitoring program is required that samples water quality at appropriate temporal and spatial scales, ie frequently enough at the right places, so that statistically significant trends can be shown. Currently, there is little monitoring of this scale in the tidally affected lower tributaries and more importantly, upstream catchment tributaries. In fact, the lack of monitoring on appropriate scale in the upstream catchments of the coast has also meant authorities are unable to tell whether nutrient discharges to the estuary have increased or decreased since the construction of the Dawesville Channel. The lack of a functional network has also meant that nutrient load targets established by an Environmental Protection Policy in 1992 can not be properly tested or evaluated.

A recent initiative by Environment Australia for the Coastal Catchment Initiative Program (CCI) has led to the opportunity for sufficient resources to be invested in existing Department of Environment water quality monitoring infrastructure and gauging station network on the Peel-Harvey coastal plain catchment, ie in the upstream catchment tributaries and drains. Existing infrastructure includes gauging stations that measure stage height and therefore flow and in some cases contain instruments for continuous recording of conductivity.

**Figure 1.** Autosampler components



Three operational gauging stations are located on the Serpentine River, Harvey River and Meredith Main Drain but they are decaying sites that require maintenance to become fully operational. These sites have been used to measure nutrient loads and verify progress with catchment initiatives, red mud program, and statutory acts (eg. Peel-Harvey Environmental Protection Policy (1992) and State Ministerial environmental conditions. Thirteen other sites representing defunct monitoring and measurement programs since the late 1960s also exist but housing and water flow control structures (weirs) are in various stages of disrepair and are essentially non-functional for future monitoring. Critical rating curves that estimate flow are also now too inaccurate for proper hydrological and hydrographic assessments. The sites with decaying infrastructure were established for a number of defunct programs. For example, to quantify water volumes and quality for the North and South Dandalup River water supply dams. Other extinct programs included estimating flows associated with deep drainage and irrigation, or, were associated with extinct nutrient monitoring programs prior to and shortly after the construction of the Dawesville Channel was built in 1994. There is one other possible exception to this situation provided by the gauging station located at Dirk Brook on the Serpentine River, which is maintained by Water Corporation. It is believed Water Corporation has either dismantled the autosampling and logger instrumentation from this site or is not using it.

A large number of other sites have more recently been established that just take water quality “grab” samples to estimate nutrient concentrations, ie using extendable poles with containers at the end dipped into the water. Grab sampling has been mainly associated with the Ribbons of Blue Program (ie. Water watch), catchment monitoring groups, LCDC monitoring or Local Government and State agency initiatives. Theses sites are really no more than road intersections and GPS localities where staff may safely take water samples. Many locations are not suitable for establishing monitoring housing with intake pipes that can hold autosamplers and loggers or allow flow control structures to be built. Sites used to measure nutrient loads ideally require housing to hold autosamplers and computer loggers that are connected to flow control structures such as v-notched weirs or other structures that allow authorities to measure river flow at various stage heights and water depths (ie. establish accurate flow rating curves). These sites also have to pump in and store water samples for later water quality including nutrient analyses.

# 2.0 WATER QUALITY MONITORING PROGRAM OBJECTIVES

The objectives of this water quality monitoring program for the Peel-Harvey catchment are:

Develop a network that can measure nutrient loads and concentrations with known precision in order that changes over time can be described using a known level of statistical significance or quantitative estimate of uncertainty.

Provide an umbrella or guiding document that primarily establishes strategies to better estimate nutrient loads entering the Peel-Harvey Estuary from its coastal catchment. It is intended the approach of this document will allow loads for other solutes, such as salt and sediments, to be incorporated if management directions turn to studying those variables in greater detail or if they become issues in the future.

Measurement of phosphorus and nitrogen loads entering the Peel-Harvey Estuary for use in management to assess trends and detect improvement and, to provide a basis for assessing existing State Ministerial and environmental conditions made in the early 1990s.

Compliance with and major support for the master Water Quality Improvement Plan (WQIP) and the other seven CCI projects, but particularly for the information requirements of the Decision Support System model currently being developed. This program will form a regional basis for a Monitoring and Evaluation framework under NAP/NHT2.

# 3.0 PHYSICAL SETTING

## 3.1 Location and climate

The Peel-Harvey estuarine system (PHES) is located 75 km south of Perth on the western edge of the Swan Coastal Plain. The region has a Mediterranean climate, characterised by mild wet winters and hot dry summers, with an average annual rainfall of 880 mm (McComb 1995; James and Dunn 1996). Runoff from the total catchment area of 11,378 $km^2$ enters the PHES via three rivers and 15 agricultural drains. The rivers are the Murray, the Serpentine and the Harvey (Hillman *et al.* 1990).

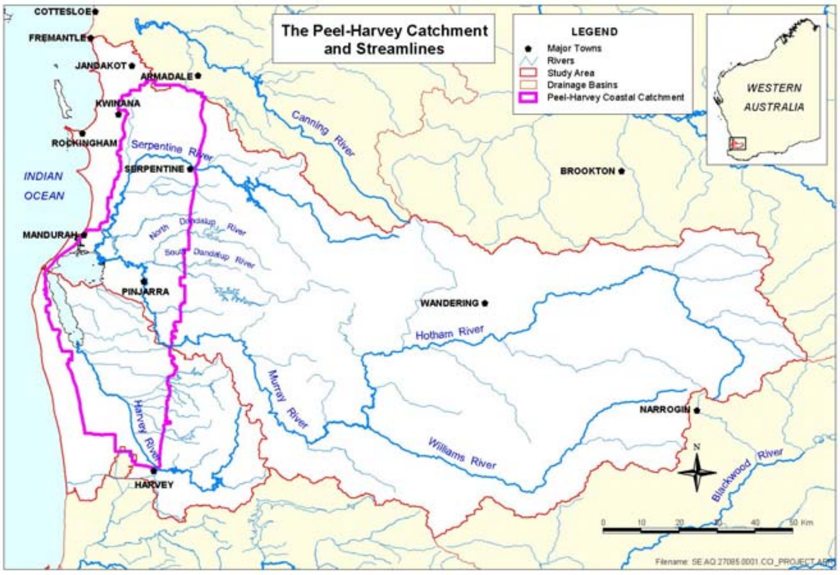
## 3.2 Catchment Features

The Harvey catchment has been extensively cleared and drained for agriculture. Irrigated pastures in the southeast portion support a major dairy industry and some intensive horticulture, while clover-based pastures in the central and western portions support beef cattle, sheep and hay production (Water and Rivers Commission 1996). The Murray catchment contains mostly wheat and sheep farms. The

Serpentine catchment has undergone the least clearing for agriculture but contains some productive horticulture and grazing areas, intensive agricultural uses (eg. piggeries) and hobby farms associated with the outer Perth suburbs (Water and Rivers Commission 1996). Waters from the largely pristine forested upper catchment of the Serpentine have been diverted for potable water supplies (upstream of the dam).

The whole Peel-Harvey catchment contains 27 recognised large sub-catchments with 21 identified in the coastal plain portion within the statutory boundaries as defined by the Peel-Harvey Environmental Protection Policy (1992)(DA Lord Associates and JDA Consultant Hydrologists, 2001)(See Fig. 2 and Fig. 7 at the end of Appendix One).

**Figure 2.** Total catchment of the Peel-Harvey with the gazetted coastal plain portion outlined in purple.



Catchment land-use has been described in detail by Jakowyna (2000), and is summarised in the following table.

**Table 1.** Catchment characteristics for areas discharging into the Peel-Harvey Estuarine System

| REGION | CATCHMENT | AREA (km²) | APPROX. TOTAL ANNUAL SURFACE INFLOW TO PHES | LAND USE |
|---|---|---|---|---|
| Serpentine | Serpentine River | 1,128 | 12% | • Several large townships, including Mandurah.<br>• Commercial and industrial areas.<br>• Undergoing rapid urbanisation.<br>• Stock grazing, pasture production, horticulture, stock holding yards, piggeries, poultry farms, dairies, floriculture.<br>• Woodland, parkland, cleared and forested areas. |
|  | Peel Main Drain | 121 | 1% | • Undergoing rapid urbanisation.<br>• Some industry and commercial centres.<br>• Stock grazing, pasture development, piggeries, horticulture, stock holding yards, poultry farms. |

| REGION | CATCHMENT | AREA ($km^2$) | APPROX. TOTAL ANNUAL SURFACE INFLOW TO PHES | LAND USE |
|---|---|---|---|---|
| | Dirk Brook/ Punrack Drain | 138 | 1% | • Stock grazing, pasture development, turf farming, piggeries, horticulture. |
| | Gull Road Drain | 7 | <1% | • Piggery.<br>• Pasture development and grazing. |
| | Nambeelup Brook | 115 | 1% | • Stock grazing, pasture development, dairies, horticulture, plantation. |
| Murray | Murray River | 7,180 | 60% | • Several large townships, including Pinjarra.<br>• Some commercial areas and industry (refinery).<br>• Stock grazing, horticulture, pasture development, dairies.<br>• Forested areas and plantations. |
| | South Dandalup River | 670 | 3% | • Stock grazing, pasture development, dairies, horticulture.<br>• Forested area |
| Small Drains to Estuaries | Caris Drain | 23 | <1% | • Stock grazing, pasture development, dairies. |
| | Coolup Main Drain | 52 | <1% | • Stock grazing, pasture development, piggeries. |
| | Mealup Main Drain | 25 | <1% | • Stock grazing and pasture development. |
| | South Coolup Main Drain | 32 | <1% | • Stock grazing, pasture development, turf farming, dairies. |
| Harvey | Harvey River | 1,185 | 20% | • Several townships.<br>• Some commercial areas and industry (mining).<br>• Dairies, horticulture, turf farming, pasture development and stock grazing.<br>• Forested areas and plantations. |
| | Mayfields Main Drain | 112 | 2% | • Stock grazing, pasture development, turf farming, dairies. |
| | Mayfields Main Drain – SubG | 10 | To Mayfields M.D. | • Stock grazing, pasture development, dairy. |
| | Samson Brook North | 19 | To Harvey River | • Stock grazing, horticulture, dairy and pasture development.<br>• Some industry (mining). |
| | Meredith Main Drain | 49 | To Harvey River | • Stock grazing and pasture development.<br>• Plantation. |

## 3.3 Soil and water in the coastal catchment

The Peel-Harvey coastal plain is flat with low undulations of up to 3m. Soils are generally of alluvial deposition overlain by deep weathered sands that form low parallel dunes running north to south. Over 60% of the catchment has coarse sandy surfaces of varying depths on top of impermeable layers of ironstone or clay. Inundation is common during winter because of the flat landscape and short but relatively wet and intense winter rainfall season. Winter rainfall is in excess of evaporation and when combined with ground saturation and soil types of the area helps contribute to as much as 30% run-off. Consequently there are many lakes and some areas of permanent water logging. A large drainage network has been constructed since the 1930s and this greatly reduces inundation (Summers *et al.*, 1999).

Despite the drainage network, stream flow rises and peaks over several days following rain events as water pools and is stored on the flat landscape. Run-off from clay soils is predominantly over the surface while sandy soils have combined subsurface drainage through the topsoil and surface flow when the soils, ie overlaying sands become saturated. The sandy soils have a predisposition to become saturated because of the relatively impermeable ironstone and clay underlayers (Summers *et al.*, 1999).

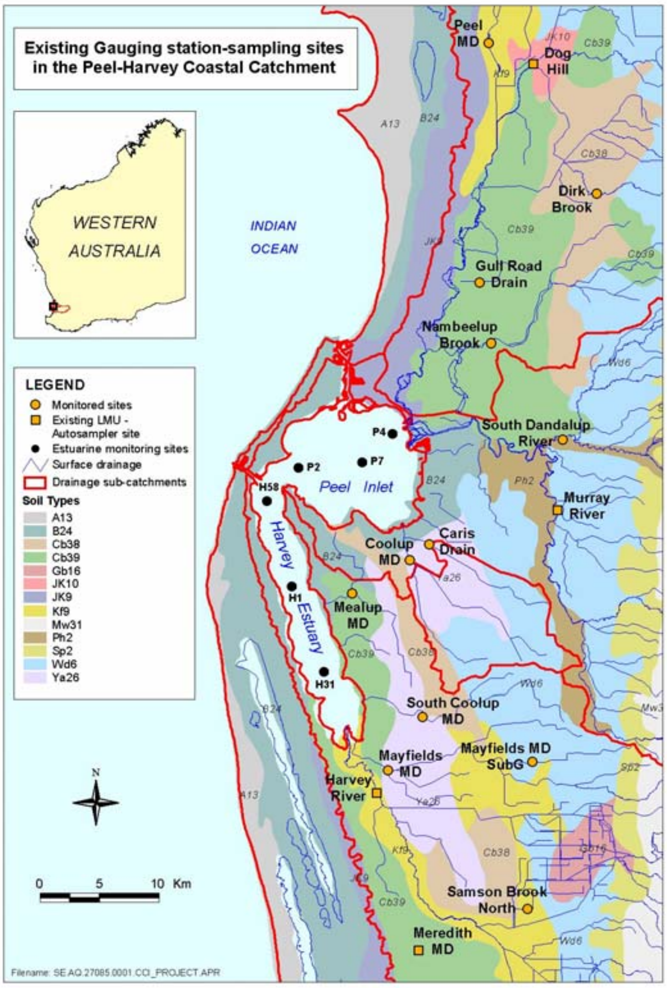


**Figure 3.** Location of gauging sites and sediment types on the coastal plain portion of the Peel-Harvey estuarine system. Note that A13 - Coastal dune formations backed by the low-lying deposits of inlets and estuaries, mainly calcareous sands; B24 - Undulating dune landscape underlain by aeolianite, frequently exposed with small swales of estuarine deposits including siliceous sands, brown sands and leached sands in the wetter sites; Kf9 – in hilly areas, metasediments with narrow ridge crests and peaks, narrow valleys, some rock outcrops, soils are shallow loamy soils; JK9 – dune soils mainly of brown, siliceous and leached sands; JK10 - coastal dunes with aeolianite outcrops, caves, and sink holes, soils mainly brown sands; Cb38 - Sandy dunes with intervening sandy and clayey swamp flats: chief soils are leached sands; Cb39 - Subdued dune-swale terrain, chief soils are leached sands; Wd6 - soils sandy acidic yellow mottled soils, some contain ironstone gravel; Ph2 - River levees and terraces, chief soils hard acidic red soils on the levees associated upper terraces of neutral red and yellow earths; Ya26 - undulating calcareous mounds or rises, chief soils sandy alkaline yellow mottled soils; Mw3 - Plateau remnants: undulating to low hilly areas of acid leached red earths with small, wet flats and upland valleys of undescribed soils; and, Gb16 - Alluvial fans: chief soils are dark porous loamy soils and possibly buried profiles of older soils occurring at shallow depths.

### *3.4 The Peel Harvey Estuary*

Estuaries are characterised by seasonal and spatial differences in the salinity of their waters, and are also naturally enriched due to the accumulation of nutrients and sediments from catchment runoff. Few species of animals and plants are adapted to the changing and variable salinities of estuarine waters, but those that are benefit from the nutrient-enriched conditions, and consequently, estuaries are usually extremely productive (Day 1981; McComb 1995).

The PHES is a broad shallow waterbody with a large catchment, strongly seasonal river inflow and, prior to the opening of the Dawesville Channel, limited exchange with oceanic waters. Like all estuaries it is an accumulation site for sediments and nutrients. The natural enrichment of estuaries is a slow process, which gives the biota time to change and adapt. However, rapid changes in nutrient inputs can produce extreme responses in estuarine biota, such as massive algal blooms.

The Peel-Harvey coastal catchment has been highly modified over the last 160 years. These changes have altered the flushing characteristics of the estuarine system and greatly increased the amount of nutrient inputs (James and Dunn 1996).
The major changes are as follows:

- Large-scale clearing of land, principally for agriculture (clearing for timber and mining industries has also occurred, and in more recent years for urban development);
- Water management practices, such as swamp drainage, drainage networks, dam construction, river diversion, dredging removal of sandbars and modification of river mouths; and
- Massive increase in nutrients (especially phosphorus) in catchment run-off, associated with agricultural land use.

## 4.0 ENVIRONMENTAL ISSUES

As outlined previously, the clearing of native vegetation, construction of dams and drains, increases in broad acre and intensive farming combined with increased use of phosphatic fertilisers has laid the basis for the many environmental issues facing the coastal Peel-Harvey region. These issues have been exacerbated by rapid population growth, which has increased pressures for multiple uses of the land and waters in a sandy low relief high groundwater table and poorly flushed estuarine system.

### *4.1 Nutrients and the algal problem*

Previous nutrient studies conducted between the late 1970s, and 1998 indicated that a large percentage of phosphorus entering the Peel-Harvey Estuary was in dissolved inorganic form (ie non-apatite or phosphate) rather than adsorbed to sediments or in particulate form although this varies seasonally and between river systems (Black *et al.*, 1981; ERMP 1988). Estuarine and catchment studies have also shown that although the estuary is highly nutrient enriched with phosphorus and nitrogen, ie eutrophic, phytoplankton and particularly *Nodularia*, and to a certain extent macroalgae were phosphorus limited. The phosphorus was shown to enter the system mainly during winter and spring when rainfall generated river flow. Work by McComb *et al.* (1995) indicated that when rainfall and/or river flow volumes exceeded a certain threshold enough phosphorus was transported into the system to stimulate phytoplankton blooms and create conditions conducive for subsequent *Nodularia* blooms in late spring and summer, including maintenance of long periods of brackish water conditions.

The algal problem in the PHES is relatively recent, and its onset has been linked to clearing of extensive areas of deep grey sandy soils on the coastal plain catchment in the 1960's and 1970's and subsequent application of phosphate fertilisers in these areas (Hodgkin *et al.* 1980). Phosphorus was readily leached from the sandy soils of the catchment, and this led to a considerable increase in phosphorus inputs to the PHES, particularly from the Harvey River (James and Dunn 1996) and also from the Serpentine River, which also drains effluent from intensive piggeries and feedlots.

The earliest account of superphosphate fertiliser from farms being washed into the PHES by the winter rains appeared in the Mandurah Fisheries Inspector's Annual Report for 1957 (Waterways Commission *et al.* 1994). Ten years later the Shire of Murray started complaining about the accumulation of algae on the shores of the Peel Inlet and the smell from decomposing algae and, in 1970, a massive bloom of the toxic alga *Nodularia* occurred in the Serpentine River (Bradby 1997). The problem intensified in 1978 with the appearance of the first large-scale bloom of *Nodularia* in Harvey Estuary (*Nodularia* blooms also occurred in the Harvey Estuary in 1973 and 1974), but aroused little comment: (Hodgkin *et al.* 1985).

Most of the phosphorus entering the PHES is associated with catchment runoff in winter, and a complicated sequence of nutrient cycling events was responsible for the algal problem. Nutrient levels have been found to be particularly elevated in the first flushes when drains and rivers begin to flow, usually in late autumn and early winter. Prior to the opening of the Dawesville Channel a large proportion of the phosphorus carried in winter river inflow was taken up by phytoplanktonic diatom blooms. When these died and settled to the sediment surface, at least part of the phosphorus store trapped in decaying organic matter was released and became available for the growth of macroalgae and *Nodularia* in spring and summer.

Over the years the store of phosphorus in the sediments also accumulated, and under conditions of low oxygen levels this sediment phosphorus was released into the water column. The macroalgal accumulations and *Nodularia* blooms also caused low oxygen conditions, causing further release of phosphorus from sediments. Oxygen is consumed by living plants during the night, and the decomposition of decaying plant material also consumes oxygen. The sediments therefore became an important *in situ* source of phosphorus, complementing the external sources (rivers and drains), and helping to maintain nuisance levels of algal growth during years of low nutrient input (i.e. lower catchment run-off due to dry winters).

**Figure 4.** Satellite photograph showing a *Nodularia* bloom during the late spring of 1989 in the Peel-Harvey system. Note the export of *Nodularia* into Comet Bay.

## 5.0 ENVIRONMENTAL MANAGEMENT AND GOVERNMENT RESPONSE

An Environmental Review and Management Plan developed by the Environmental Protection Authority of WA concluded in 1988 that the best way to improve environmental conditions and excessive eutrophication occurring in the estuary was to undertake a three part management strategy (Peel Inlet and Harvey Estuary Management Strategy). This involved undertaking a comprehensive catchment management program targeting rural phosphorus use (particularly on the sandy soils where it identified the majority of phosphorus was coming from), maintaining the macroalgae harvesting program including the use of mechanical harvesters on the shores and navigational channels, and lastly, to construct the Dawesville Channel in the Northern Harvey so that oceanic flushing and export of nutrients from the system would improve. Between 1989 and 1993, a total of 21 Ministerial conditions and proponent commitments were imposed on the Peel-Harvey coastal region to support the proposed management program. The Ministers for Transport (now the Minister for Planning and Infrastructure), Waterways (now the Minister for the Environment) and Agriculture (now the Minister for Agriculture, Forestry and Fisheries) were made proponents of the Peel Inlet and Harvey Estuary Management Strategy, and are legally bound to carry out to the satisfaction of the Environmental Protection Authority Ministerial Conditions and proponents' commitments that were set between 1989 and 1991. These conditions also imposed drain and clearing moratoriums, nutrient concentration limits for total phosphorus concentrations in estuarine waters and a range of other conditions including responsibilities for the construction of the Channel and highway overpass bridge.

An Environmental Protection Policy for the Peel-Harvey (PH EPP) was gazetted in 1992 which contained percentile nutrient targets for total phosphorus based on loads or tonnes per year. The targets were for the estuary and the three major tributaries and stated that total phosphorus loads to the estuary in six and nine years out of ten (ie. in 60 or 90% of years) were not to exceed 85 and 165 tonnes respectively (PHEPP, 1992; WRC, 1998). This policy was preceded and complimented by a Statement of Planning Policy (SPP) gazetted by the WA Planning Commission in 1990. This spelt out development and planning controls for the coastal plain such as set back distances from foreshores and waterways, the minimum lot size allowing septic systems and depth to groundwater for septic leach systems.

## *5.1 The Dawesville Channel and management*

The Dawesville Channel was opened in April 1994 and connects the PHES to the ocean close to the junction of the Peel Inlet and Harvey Estuary. It is 2.5 km long, 200 m wide and from 4.5 to 6.5 m deep, and was constructed with the principle aim of enhancing nutrient transport from the PHES.

It was recognised that the $65 million Channel and bridge overpass would cause profound changes to the physical, chemical and biological characteristics of the system over both the short and long terms and that some negative impacts would result. The five-year Dawesville Channel Monitoring Programme (DCMP) was therefore approved by the State Government to determine how well the Channel was achieving the purpose for which it was designed and to ensure that positive and negative environmental impacts associated with its construction were properly understood and managed. Approval of the DCMP included requirements to review the DCMP after two years of data collection, and again after five years of data collection, to assess and report on changes to the ecology of the PHES since the opening of the Channel.

Overseeing, coordinating and reviewing the numerous projects associated with the DCMP are the responsibility of the Peel-Harvey Senior Officers Group (SOG), comprising representatives of the proponent Ministers and led by the Water and Rivers Commission (WRC). The SOG is supported by the Peel-Harvey Project Managers group (PHPMG), which brings together all government departments undertaking monitoring. A subgroup of the PHPMG, led by the WRC, was also established to consider social impacts and public information needs associated with construction of the Channel, and this team liaises closely with the PHPMG. Management of the DCMP has become more informal since 1998; the WRC remains the lead agency, and initiates interaction with other members of the SOG and PHPMG on an 'as needed' basis.

A general ecological pattern has become established in the estuary since the Channel was opened. Water quality in the estuary is generally good all year round, there is less phytoplankton biomass, no blue-greens and generally less dinoflagellates and much greater densities of diatoms. Unfortunately and as stated earlier in this document, the lower tidal rivers have not experienced improvements in water quality with the worst water quality occurring during late spring, summer and early autumn. Phytoplankton blooms are dominated by toxic blue-greens and dinoflagellates in the Serpentine River and nuisance dinoflagellates and other algae in the Murray River while the Harvey River which is isolated from the public is reported to also undergo regular blue-green blooms.

## 6.0 WATER QUALITY MONITORING

Attention created by the Peel-Harvey estuarine systems environmental problems and because of the need for potable water supplies, there is a long history of catchment water quality monitoring.

## *6.1 Historical monitoring*

In brief:

1. During the 1970s Local Government Authorities-Department of Conservation and Environment-Fisheries and Wildlife-Public Works Department and environmental consultants (eg. for the Yunderup Canals) undertook all catchment water quality sampling, but this was mainly targeted at the tidal rivers and some catchment tributaries.
2. Between 1983 and 1990 – the Environmental Protection Authority undertook sampling in up to 21 sites than handed this over to the Waterways Commission. The WA Water Authority (WAWA) also undertook sampling at a number of tributary and main drain sites.
3. Between 1990 and 1993 the Waterways Commission (WWC) undertook sampling but was extremely under-resourced to maintain the sampling frequency (short staffed) and chemistry costs expected to measure change over time.
4. No money was identified for catchment monitoring when State Cabinet allocated money (*ca* $400k over five years) to WWC. This money was identified to monitor changes to the estuary, including estuarine water quality, estuarine peripheral vegetation, water quality changes to the lower tidal rivers (changes to the nearby ocean were deemed the responsibility of Department of Marine and Harbours), measure social impacts and communicate changes to the community.
5. Between 1994 and 1995 the WWC undertook monitoring of the catchment on a very minimal budget targeting only four sites.
6. Between 1996 and 1998 the Water and Rivers Commission (WRC) amalgamated with the WAWA and regional budgets were immediately put under extreme pressure such that minimal catchment and flow monitoring occurred.
7. Between 1999 and 2003 the WRC (with very minimal resources) amalgamated with the Department of Environmental Protection (now called Department of Environment - DoE) to maintain minimal sampling.
8. There is now a very patchy record of flow measurements and nutrient concentrations with a large amount of mismatch such that when concentration data is available there is often no flow data. Conversely when flow data is available there is no concentration data. Minimal monitoring and supervision of the process has led to weak quality control and custodianship of the overall database.

**Table 2.** Existing and historical sampling sites where water flow has been gauged on the Peel-Harvey coastal plain. * indicates no AWRC code

| # | Site Name | Other names/functioning status | AWRC Reference Code (WRC Reference Code) |
|---|---|---|---|
| 1 | **Serpentine River *autosampler*** | Dog Hill/partially functioning needs work/ministerial requirement | 61430 (PHS2) |
| 2 | **Peel MD** | Folly Road/Zig Zag Road non functioning needs work | 614096 |
| 3 | **Dirk Brook** | Yangedi Swamp near Hopelands/Punrac Rd (Water Corporation operated – no control with poor flow ratings, site sampling location has varied over years) | 614028 (PHS5) |
| 4 | **Gull Road Drain** | Gull Rd Drain (non-functioning) | * (PHS4) |
| 5 | **Nambeelup Brook** | Kielman (non-functioning) | 614063 (PHS3) |
| 6 | **Murray River *autosampler*** | Pinjarra (non- functioning needs work, ministerial reqmt) | 614065 (PHM1) |
| 7 | **South Dandalup River** | Patterson Rd (non-functioning, decommissioned) | 614022 (PHM3) |
| 8 | **Harvey River *autosampler*** | Clifton Park (functional but poor ratings, ministerial reqmt) | 613052 (PHH1) |
| 9 | **Mayfields MD** | Old Bunbury Rd (decommissioned>1995) | 613031 (PHD1) |
| 10 | **Mayfields MD SubG** | Mayfield Sub G Drain (de-commissioned) | 613054 (PHD2) |
| 11 | **Meredith MD** | Johnston Road (functioning but needs upgrade) | 613054 (PHH2) |
| 12 | **Samson Brook North** | Somers Road (decommissioned) | 613014 (PHH3) |
| 13 | **Caris Drain** | Greenlands Rd (de-commissioned) | 613029 (PHD5) |
| 14 | **Coolup MD** | Paull Rd (de-commisioned) | 613030 (PHD4) |
| 15 | **Mealup MD** | Mealup Rd (de-commissioned) | 613032 (PHDM) |
| 16 | **South Coolup MD** | Yackaboon (de-commissioned) | 613027 (PHD3) |

## 6.2 Existing water quality monitoring

A registry of sampling projects capturing very recent and current effort has revealed a number of State, local government, community, industry and education groups undertake nutrient sampling for a range of purposes in the Peel-Harvey coastal catchment (See Appendix One). Without exception these water quality programs are measuring concentrations of nutrients or micro-organisms. If this registry was expanded to be more comprehensive it could be used as a reference to identify and outline all sampling programs. It has the potential to be used to assist in calculating general nutrient load budgets or concentration trends for the system and to avoid duplication in effort. It could also help locate the most problematic catchments and areas where improved catchment management would reduce nutrient export.

**Table 3.** Registry of recent water quality sampling programs in the Peel-Harvey

| **Who** | **Number of programs** |
|---|---|
| State Government Agencies | |
| Department of Environment | 2 (estuarine/tidal rivers and catchment) |
| Agriculture WA | 4 (catchment water quality and metals/pollutants) |
| Local Government | |
| City of Mandurah | 4 (Bacteriological, nutrient, estuarine beaches) |
| Shire of Murray | 3 (monthly bacteriological and biannually and annually for 2 tips as per license requirements) |
| Shire of Waroona | Unknown (presumably at least one, eg. bacteriological) |
| Catchment Groups/Catchment Council | 1 (Catchment nutrients) |
| Schools (Primary and Secondary schools) | 6 (nutrients) |
| University | 2 (water quality for fish & nutrients) |
| Greenskills | 1 (13 sites) |
| Alcoa (see Table in Appendix One) | 1 (large monitoring program for license conditions) |
| **Total** | **25 projects** |

Currently the Department of Environment (ex WRC & DEP, ie the new DoE) sample 11 sites taking grab samples using extended pole samplers. The sites are previously listed in Table 2 with the addition of one new site situated upstream in the headwaters of Gull Rd Drain, ie PHS7. This site is ungauged. Samples are taken fortnightly all year round reflecting the strong groundwater influx and contribution groundwater provides to base flows in the drains and tributaries of the Peel-Harvey coastal catchment.

Sampling is sometimes weekly during the first flush periods of rainfall in late autumn and early winter. A total of 55 samples are generated per sampling run where total phosphorus and nitrogen, as well as filterable reactive phosphorus, nitrate-nitrite and ammonia nutrient species are measured. Data for $No_x$ and $NH_4$ is problematical because much of it is not entered into the DoE water information database. The reasons for this are currently unknown. The only autosampling that occurs is at Meredith Main Drain where Department of Agriculture subsidise the DoE to collect and analyse nutrient samples to monitor the effects of red mud applications in the sub-catchment. Samples at Meredith are taken six hourly and composited to create one daily sample. The samples are collected every 2-3 weeks and analysed for nutrients. There currently is no flow rating review or surveys being undertaken.

# 7.0 WATER QUALITY MONITORING ISSUES

## 7.1 Review of recent water quality and nutrient reports on the Peel-Harvey catchment

Water quality monitoring of catchment streams is supposed to be the basis of auditing catchment nutrient inputs as required under ministerial conditions for the Peel Inlet and Harvey Estuary Management Strategy. Compliance in the past has been made against interim targets set by the EPA for phosphorus input to the PHES. The interim targets are:

"Annual phosphorus loads to the system shall not exceed 85 tonnes in more than four years out of ten (on average); nor 165 tonnes in more than one year out of ten (on average). (These are based on 60th and 90th percentile loads)."

The WRC carried out a detailed statistical analysis of trends in total phosphorus (TP) and total nitrogen (TN) concentrations in PHES catchment waters monitored between 1983 and 1998 (Donohue *et al.* 1998; Jakowyna 2000). Nutrient data series contain several sources of variation, including flow and seasonal variations, and trend and random components. Changes brought about by human activity will usually be superimposed on natural sources of variation. In the WRC's detailed statistical analysis, the Mann - Kendall test was used to determine the statistical significance of the trending periods. Some of the important findings evident from these analyses were as follows:

- TP concentrations in the Harvey River showed no evidence of a trend over the monitoring period (1983 to 1998), with the current nutrient status indicating moderate phosphorus enrichment. No detection of a trend may be due to insufficient flow data available for the analyses;
- Nutrient concentrations in the (upper) Serpentine River have not changed over the monitoring period, with the current nutrient status indicating moderate phosphorus enrichment. The main source of phosphorus to the river is diffuse, derived from agricultural properties and much of it transported via groundwater;
- There has been little change in water quality of the Murray River over the monitoring period, with phosphorus and nitrogen concentrations indicating low enrichment;
- TP concentrations in the Gull Road Drain, which drains into the Serpentine River, fell dramatically (by 2.1 mg/L per year) between 1985 and 1987, and there was an unconfirmed trend (i.e. not statistically proved) of a slower decline (0.26 mg/L per year) between 1988 and 1998. However concentrations remained extremely high (median values from 1990-98: 3.8 mg/L), indicating the influence of a point source, and were a significant source of phosphorus to the Peel Inlet;
- TP concentrations in the Meredith Main Drain, which drains into the Harvey River, changed little between 1982 and 1998 (Jakowyna, 2000). It was noted that large-scale soil amendment programs were implemented to improve nutrient retention in the Meredith subcatchment in the early 1990s, and AgWA monitoring data observed decreases in TP concentrations between 1990 and 1995, although there was little further change after 1995 (Rivers 1997); and
- Although the records are incomplete, TP concentrations increased in Nambeelup Brook, which drains into the Serpentine River, by 0.04 mg/L each year over the monitoring period.

A critique by Wittenoon *et al.* (1998) points out that load-based compliance testing requires accurate measures of total catchment inputs, and this is impossible to achieve with either the past or present network coverage and sampling regimes of the PHES catchment monitoring program as currently conducted by the DoE. Nor can the performance of the catchment management program be assessed from catchment nutrient loads or the validity of the original management targets re-tested (see ministerial conditions in WRC, 1998). Wittenoon *et al.* (1998) recommend a change in the nature of the targets and compliance testing, and suggest trend analysis of nutrient concentrations in the waters of the catchment drainage network could be an alternative performance indicator for the integrated catchment management program instead of nutrient loads.

## 7.2 Catchment nutrient data pre-1989

Bearing the above comments in mind, in the period up to 1989 the DCE/EPA estimated that streamflow into the PHES catchment ranged from 370 to 1,200 x $10^6$ $m^3$, and estimates of total phosphorus input varied between 96 and 237 tonnes (WRC, 1998). Over this period the Harvey River contributed 30%–40% of stream inflow to the PHES, but up to 50% and 75% of the annual phosphorus load. The Murray River contributed large volumes of stream inflow, but had low nutrient concentrations and therefore contributed less total phosphorus (*ca* 10-20%). The Serpentine generally contributed less than 25% of stream inflow but its nutrient concentrations were much higher than those of the Murray, and its contribution to total phosphorus loads was therefore higher (20-40%).

## 7.3 Catchment nutrient data post-1989

Water and Rivers Commission nutrient input data for 1990-95 were more reliable than estimates for earlier years. Available data, summarised in WRC (1998) indicate that over this period the relative importance of Harvey nutrient inputs to the PHES declined and those of the Serpentine increased.

Concentration data is available but there is no nutrient load information for the period 1996 to 1999, and so compliance with the nutrient loads set out in the Ministerial conditions cannot be determined as the conditions are expressed upon the basis of ten years of data. When the period between 1990 and 1993 was calculated phosphorus loads exceeded both the 60th percentile (85 tonnes) and 90th percentile (165 tonnes) loads of the conditions on two occasions (1991 and 1992).

The EPA (1988) also proposed interim targets for total phosphorus concentrations in rivers as follows:

- Serpentine River: 0.135 mg/L (50th percentile), 0.137 mg/L (90th percentile);
- Murray River: 0.046 mg/L (50th percentile), 0.047 mg/L (90th percentile); and
- Harvey River: 0.104 mg/L (50th percentile), 0.107 mg/L (90th percentile).

These would be classified as low-to moderate under a recent classification outlined by Jakowyna (2000). The median concentrations measured for the Harvey and Serpentine Rivers in 1990–95 did not meet the interim targets.

Load-based compliance testing is effectively impossible, as accurate estimates of total catchment inputs cannot be made. However, there are good long-term data sets for nutrient concentrations at a number of key sites in the PHES catchment monitoring program. Analysis of long-term trends in measured nutrient concentrations provides a far more reliable record of changes in catchment inputs than estimated loads (Wittenoom *et al.* 1998).

At the time the Dawesville Channel was about to be opened the following changes in catchment practices had also been implemented:

- All major point sources in the catchment had put effluent management systems in place to the satisfaction of the EPA (Bradby 1997), which was estimated to prevent 34 tonnes of phosphorus per year from entering the region's waterways;
- The amount of fertiliser applied in the catchment was reduced through market forces from 27,000 tonnes/annum in the late 1960s, to 17,000 tonnes/annum by 1975, and further reduced to 9,500 tonnes/annum by 1987 due to improvements in fertiliser efficiency throughout the catchment (Bradby, 1997; James and Dunn, 1996);
- Considerable progress in LandCare (environmental repair) had been achieved; and
- Wetland drainage had been severely curtailed.

A consistent theme in reports written between 1995 and 2000 eg. Donohue *et al.* 1998; Wittenoon *et al.* 1998; WRC, 1998; Jakowyna, 2000, has been that there is little link between observed water quality-nutrient levels in catchment streams and land use changes or practices which can explain trends observed in the data. Many of these authors felt that this diminished the value of just looking at water quality data without this catchment understanding.

One other theme that was stated about past catchment water quality sampling was that "bottom end" sampling as represented by the 16 gauged sampling sites on the coastal plain did not reflect whole sub-catchment nutrient export characteristics. Rather sampling sites reflected nearby nutrient losses and not necessarily the whole sub-catchment nutrient loss since the placement of these sites could not measure assimilation and assimilation processes that would naturally occur along the course of the waterways before reaching the sampling sites.

Summers *et al.* (1999) monitored a number of coastal Peel-Harvey sub-catchments to assess the influence of soils and land use on phosphorus discharge to the estuary. Five parameters out of 11 were shown to be related to phosphorus discharge but only two were found to be suitable for prediction because the rest had very low regression coefficients, ie coefficients of determination. They found the area closest to the drainage system had an influence on the concentration of phosphorus discharged and the presence of native vegetation was related to lower discharge. They cautioned that great care must be taken to relate the effectiveness of catchment management practices measured in flows based upon soil characteristics from small parts of the catchment to the whole catchment. Mismatched measures of scale and impact and inconsistent soil characteristics across a sub-catchment exacerbated the relationship between land use and catchment soil characteristics.

## *7.4 Loads and sources of error in their calculation*

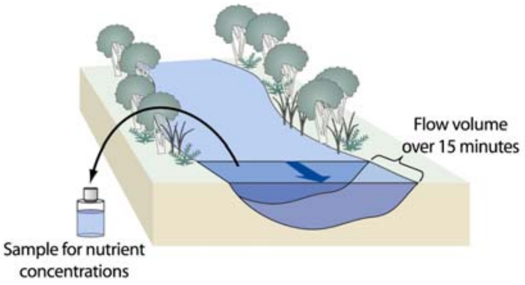
Measurement of nutrient loads in rivers and streams is important to provide reliable information for catchment and estuarine management and can be a measure of catchment impact on waterway condition. The load of a substance is the total amount of the substance that is transported past a particular point, and is measured as concentration x flow. Loads are typically measured at the bottom of a catchment to estimate the total amount of a nutrient or other substance that is delivered to a receiving water body.

Reliable estimates of nutrient loads are important to calculate long-term nutrient budgets for estuaries and catchments in the Southwest. Like all water quality data, mass load estimates are subject to errors, and these must be known to effectively use information for management decisions. Where large undefined measurement errors are involved it may be impossible to detect differences among years, or determine whether observed changes reflect a real change in environmental conditions or merely imprecision in the estimates. Load data is also used to calibrate catchment and estuarine models to evaluate the impacts of future land use changes on nutrient delivery to the estuary. The predictive power of these models depends on the magnitude of errors involved if load estimates are used to underpin them.

**Box 1:**

**Annual Nutrient Load** is the sum of instantaneous loads (estimated for all flows) over the year. Usually tonnes or kilograms.

**Instantaneous Load** = concentration of nutrients in river flow x volume of water occurring when the concentration was measured.



Measuring nutrient loads in the simplest sense is merely a matter of calculating flow estimates over time multiplied by nutrient concentrations taken during various flow conditions. This calculates nutrient load over time. This approach has a number of significant technical shortcomings that can drastically affect accuracy and precision of load estimates unless the issues are carefully managed, controlled and defined.

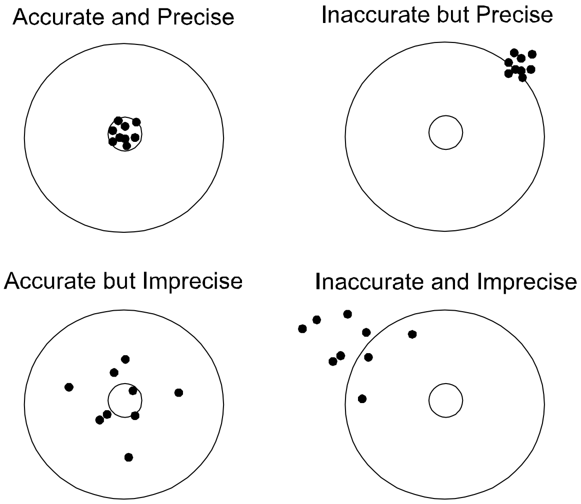
Precise and accurate load measurements are complicated and difficult to obtain since they require both frequent measurements of flow and a detailed knowledge of the relationship between flow and concentration in a particular catchment. Loads are estimated through a combination of measuring different flows (ie. gauging) in rivers for that catchment and taking samples of nutrient concentrations at these different flow levels often at different flood stage heights. Lack of precision in either of these measurements results in load estimates that misrepresent the true load occurring. In particular, sampling at fixed intervals (typically weekly or fortnightly) tends to miss the peaks and variations in nutrient concentrations that occur during such flow events. It thus produces imprecision – this is because it tends to be flow *events* that are the major influence on nutrient loading. Minimisation of these errors is only attainable using automated techniques – involving automated water samplers and gauging of flows with well-designed and maintained structures. This is prohibitively expensive in many situations.

**Box 2:**

Errors can be summarised into two main types:

**Precision –** causing load measurements to occur across a greater range (increasing the variation in measurements about the true target, see illustration below)

**Accuracy –** causing consistent over- or under-estimation in load measurements (missing the target).



The full list of causes that can account for error, uncertainty or variability, including those as sources of imprecision and inaccuracy associated with calculating loads, can be summarised and generally related to:

1. Calculation errors including mistakes and use of inappropriate statistics
2. Sampling errors including inappropriate timing of sampling that misses significant flow events or periods
3. Failure to include ungauged portions of catchments or not including estimates of this contribution, particularly if this portion contributes substantially to nutrient inputs into a receiving waterbody like the Peel-Harvey Estuary (eg. in Peel-Harvey coastal catchment this is estimated to cover about 24% of the area, all close to the estuary)
4. The actual sediment profile exposed to water when other strata may also be contributing nutrients
5. Poor estimates of flow (ie. poor rating curves)
6. Poor or unspecified laboratory analysis, particularly if analytical procedures are too insensitive or techniques inappropriate, also includes lack of Quality assurance procedures
7. Poor handling and consequent contamination and loss of samples

### 7.4.1 Using PlaNet

PlaNet is a Microsoft Windows software system that uses historical flow, stage and concentration data to design and simulate field sampling to obtain results with a specified level of precision and accuracy. It uses these simulations to dynamically update parameters in a template Campbell Scientific logger file to control autosampling frequency with the logger, autosampler, housing and intake pipes collectively known as a load measuring unit (LMU). PlaNet will be the driving analytical tool, through use of simulations, combined with some statistical approaches to help identify future secondary load measuring sites and to set sampling frequency for all monitoring sites. It has been tested and its utility refined on Swan-Canning catchment tributaries.

### 7.4.2 Determining Measurement Errors

Measurement errors are determined through a process of collecting high quality information about nutrient concentrations and flows from rivers and using this to develop a flow-concentration relationship. This relationship is then used to determine load measurement errors for different sampling scenarios, and thus to develop efficient sampling programs for measuring loads. This process can be achieved in several stages:

1. **Data collection**. Detailed information about the patterns of nutrient and suspended sediment concentrations (eg. TN, TP, TSS) that occur over a range of river flows is collected using computer-controlled automatic water samplers coupled with precise flow-gauging stations. The autosamplers take water samples in response to changes in water flows to ensure that more samples are taken during high flows (flow events) than low flows (ie. flow-stratified sampling).
2. **Model development**. A purpose built software package known as PlaNet is used to construct a computer model using several years of water quality and flow information. This model enables the patterns of nutrient concentrations to be predicted for any flows (rising and falling) in the river or drain. The relationship between measured nutrient concentrations and the flow rates at which the concentrations occur is the basis of this model.
3. **Load simulation for different sampling frequencies**. PlaNet is used to simulate the fluxes of nutrients that would be measured for a river if sampled continuously, at different fixed intervals (from daily to monthly) and using the autosampler control program. For each year, numerous Monte-Carlo (randomised) simulations are performed to determine the loads estimated if sampling occurred at the same intervals, but on different days. For each flow volume that is ‘sampled’ by the program, a corresponding concentration is generated using the flow-concentration relationship. A random factor is also included based on the residual variation around the flow-concentration curve. This process generates a range of possible load estimates, which vary according to which flow events are ‘hit’ or ‘missed’ by the particular sampling regime and due to the degree of scatter in the flow-concentration relationship.
4. **Evaluation of errors**. The load estimates obtained by simulating different fixed-interval sampling strategies and automated sampling are compared with the accurate estimates obtained with the “continuous” sampling scenario to evaluate the measurement errors (precision and accuracy – see Box 2) involved in each strategy. This enables the comparison of different sampling scenarios.
5. **Optimising load measurement**. Quantifying the errors associated with different sampling scenarios enables an optimal load measurement strategy to be developed based on the requirements of the monitoring program. Taking into account the conflicting demands of cost and exactness of data, an evaluation of the errors involved in different fixed-interval sampling strategies can ensure that mass load measurements are sufficiently exact to meet the needs of the monitoring program.

PlaNet is also used to refine the process of automated water sampling over time. The computer program is optimised to collect the minimum number of samples needed to represent every runoff event occurring in the waterway. The PlaNet software is used to repeatedly test errors associated with different sampler control programs to minimise the number of samples collected while maintaining the desired high precision and accuracy.

### 7.4.3 Causes of inaccuracy and imprecision

The main cause of inaccuracy in load measurements is missing events that are short in duration but where most of the load occurs (peak flux). Because fixed-interval grab sampling generally captures few of these events, fixed-interval load measurements are often underestimated to some extent.

Imprecision errors are due to inadequate sampling of the variations in nutrient concentrations during storm events. In several catchments of the Peel-Harvey, total nitrogen and phosphorus concentrations generally increase with increasing discharge. Therefore the precision of load measurements can be improved by ensuring that sampling adequately targets the increases in concentrations occurring during run-off events. Intense sampling of these initial fluctuations is important to maximise the precision of load measurements.

The only effective way to minimise imprecision – if loads are used to detect year to year changes for instance – is using automated sampling of nutrient concentrations. Where this is not realistic, reducing the interval of nutrient sampling can achieve some gains in precision of subsequent load estimates. Through the process described above, the modelling of data derived from program controlled automated sampling enables the extent of these gains to be quantified, which is important to ensure that the fixed-interval sampling strategy meets the needs of the monitoring program in terms of both cost and information quality.

Critical to all of these estimates is the precise and accurate measurement of flows. Measurement of flows using sub-standard structures can result in imprecision and bias in load measurements that add to the errors due to sampling concentrations. Errors in flow gauging may be of similar magnitude as for water quality sampling particularly for rivers and drains where routine calibration of flow gauging or installation of stable gauging structures has not occurred.

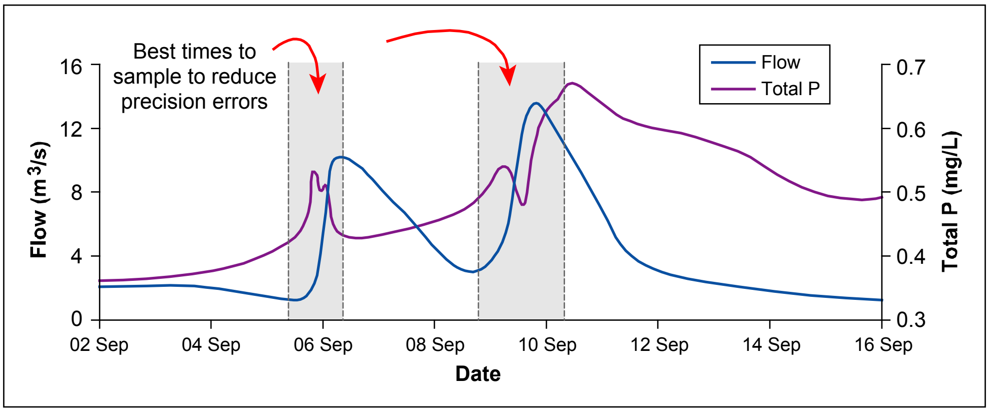
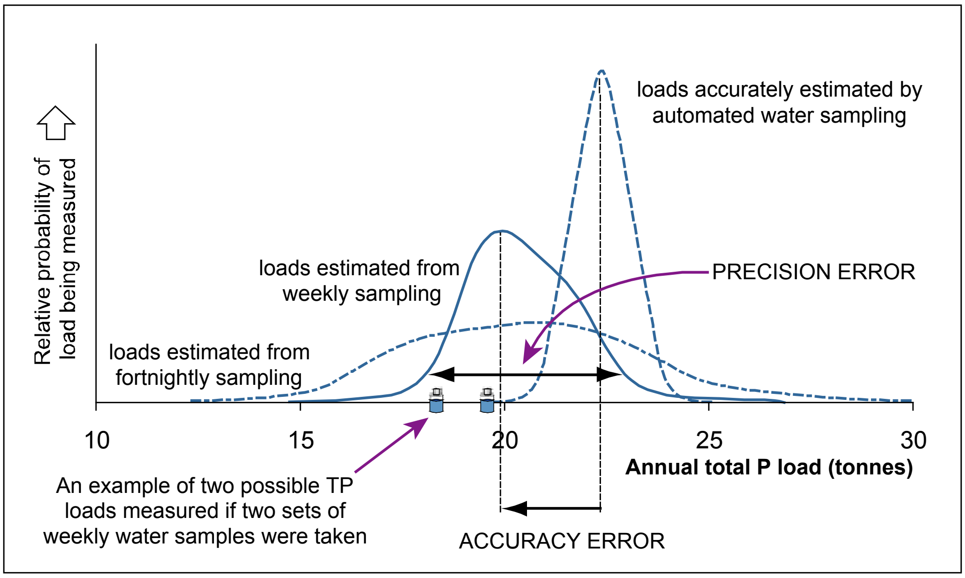


**Figure 5.** Changes in total phosphorus concentrations and water flows during a storm event in Ellen Brook illustrating timing of sampling to improve precision of load estimates.

### 7.4.4 Accurate load estimates favour reliable nutrient budgeting

Loads can be used to calculate nutrient budgets to understand the flow of nutrients through the ecosystem. Reliable nutrient budgeting and modelling in the Peel-Harvey catchment and estuary depends upon knowing the reliability of the initial loading information used to undertake these projects. Since such analyses are conducted using long-term patterns of nutrient loading, the cumulative effects of errors are of most interest. In this case accuracy errors could be a major problem, since they indicate a systematic bias and are additive. Precision errors, in contrast, tend to cancel out over the long term.

**Figure 6.** Distributions illustrating the possible ranges of annual total P loads in Ellen Brook in 1999 for different sampling scenarios. These distributions define where actual load estimates from a single set of samples could occur for each sampling scenario.



## 7.5 Loads versus Concentrations

Loads are generally unreliable for monitoring changes over time. Detecting changes in nutrient loads over time in tributaries such as Serpentine River and Harvey River is complicated by the large precision errors occurring during measurement of nutrient concentrations by fixed-interval sampling. Improvements or deterioration of nutrient export from the catchments can only be detected once these exceed the 'noise' caused by precision errors, which can take a considerable time. Automated sampling can improve the precision, but is not a realistic option for widespread use due to the expense and expertise required.

Changes in water quality over time that may be reflective of changes in catchment management are most reliably measured by trends in flow-corrected concentrations. This approach is more certain in detecting early improvement or deterioration in river water quality using fixed-interval sampling than can be achieved by monitoring changes in nutrient loads.

The technical and operational difficulties of measuring an external mass load to a system as complex as the Peel-Harvey estuary is immense (see Littlewood 1992 for discussion of measuring natural systems). In fact, the complexities of measuring river loads probably invalidate their use for *routine* compliance monitoring (Ellis 1989). Nevertheless, the nutrient concentration data series that have been generated by the compliance effort do provide indicators of changes in loading in the sense that long-term decreases in loading will usually be accompanied by decreasing trends in nutrient concentration (Sanders *et al* 1987). Data series collected in fixed time-intervals result usually in biased and imprecise loading estimates but are ideal for the detection of trends in concentration using standard statistical techniques (Ward *et al* 1990). The data series deal principally with the longer-term steady state condition of the waterways, rather than short-lived episodic events, such as storms or accidental spillages.

**Box 3: Loads vs Trends**

There is much debate about whether to use loads, or trends in concentration, as measures of change over time – particularly to identify a reduction in nutrient delivery that can be attributed to management actions. Both methods are useful but they provide different information, for different purposes:

- Trends in concentration over time provide a useful and robust measure of change especially when corrected for variations in flow. Sampling is less frequent than is necessary for precise load measurements.
- If load calculations are to be used as a measure of change over time or achievement of a target then automated sampling from well-maintained gauging stations is a requirement.
- Loads are better used to calculate nutrient budgets to understand the flow of nutrients through an ecosystem. Load information calculated from the same fixed-interval sampling data collected for calculating trends is often of sufficient resolution for this nutrient budgeting.

## 7.6 Comments on Fixed Interval Sampling

Donohue *et al.* (1998) note that most samples collected in fixed intervals of time, for example, greatly bias sampling effort toward the longer-term steady state condition of the river, rather than short duration episodic events such as storm fluxes. Any coincidence between sampling and storm flows was a largely a matter of chance (about 18 percent of weekly samples from the Peel-Harvey network were collected on the rising limb of storm hydrographs). In relatively pristine streams draining vegetated catchments these samples are probably responsible but even in relatively natural catchments, the sample nutrient level will be elevated Rivers draining relatively natural catchments, such as that of the Dandalup that exceeded 0.1 mg/L probably reflected a chance coincidence between sampling and storm fluxes.

Given this sampling effort progressive clearing of catchments of vegetation could work in a variety of ways to increase the rate of excursion above any concentration value. For example, in catchments that contain areas of cleared land the probability that intense rainfall events falling on cleared agricultural land increases proportionally.

In addition, clearing of vegetation elevates watertables, and increase the duration of storm flows. It is therefore more likely that storm flows are sampled by fixed-interval sampling regimes. In the early stages this pathway would result in an increase in the excursion rate and may not be accompanied by major change in other statistical measures of the data series, such a median concentration

A major source of nutrients to waterways on the Swan Coastal Plain is via influx of shallow groundwater to surface channels. For management, it may be more useful to describe water quality in periods between storm events (Sanders *et al* 1987), especially in agricultural catchments with well drained sands and shallow aquifers that supply significant water and nutrients to surface drainage (Ruprecht and George 1993, Schofield *et al.* 1985). When enriched groundwater is an important source of nutrients to surface drainage it will have a major effect on data series collected in fixed intervals because sampling effort is biased towards these flow strata. The groundwater signature will also be seen in seasonal patterns (Schofield *et al* 1985).

# 8.0 STRATEGY TO DEVELOP THE PROGRAM AND SHORT TERM PLAN

It is not known what monitoring sites are required to help accurately measure loads leaving the Peel-Harvey coastal catchment with known precision. Simulations using PlaNet will be undertaken first to establish where in the hydrograph sampling will be undertaken to estimate mass loads of nutrients. Approximately six to nine sites can be accommodated in the current budget assuming expenditures on chemistry are as per the contract agreement. Any savings achieved in the establishment of the LMU sites will be invested in the secondary LMU sites so that the most comprehensive picture as possible will be obtained for nutrient loads into the Peel Harvey estuary.

## *8.1 Reviewing all data and analysing it for utility and predictiveness*

Analysing and reviewing existing nutrient and flow data based on PlaNet simulations and data analysis for trend and loads combined with identifying where problematic land uses are occurring (from nutrient concentration snapshot surveys) will help establish a robust network of existing and new sampling sites. This network should be able to provide a known level of accuracy and precision for loads. This general process will occur over the next two years based on the funding provided by the Coastal Catchment Initiative.

## *8.2 Strategy stages*

### 8.2.1 Primary LMU's

1. Assess original existing gauging sites for load measuring units (LMUs) capacity from the Serpentine River, Murray River and Harvey River, to upgrade these sites to a standard suitable for effective load measurement.
2. Undertake necessary works to bring these three primary sites up to standard.
3. Provide staff training in PlaNet so that its use will help refine future sampling frequency.

### 8.2.2 Secondary network

1. Establish Secondary LMU sites.
2. Review previous snapshot data and undertake additional snapshot survey to identify where secondary nutrient load measuring sites (sites) should be situated.

3. The choice of these secondary sites will need to reflect a common overlap between viable defunct measuring sites, have reasonable flow rating curves, location on sub-catchments identified as problematic from previous nutrient concentration snapshots and hopefully overlap with other CCI projects to help establish the affect of catchment work on nutrient exports. They will also have to be located so that they can provide data that assists the CCI Decision Support modelling (DSS) project so it is accurate and lastly, be practically located with relatively easy establishment work, given the financial and physical limitations to constructing or refurbishing new sites. For example, six secondary sites were budgeted in the original project proposal but this number may be arbitrary depending on site specifications and LMU requirements.
4. Develop a sampling and analysis plan that outlines sampling sites, variables to be measured, quality assurance protocols, data management and data reporting requirements.
5. Use snapshot data to identify "hotspots" that will focus catchment management work on problematic sub-catchments.
6. Refine and develop the steps required to develop a longterm robust and dynamic water quality monitoring program as defined by ANZECC 2000 (see next section).

### *8.3 Study Design*

The scope of this water quality monitoring program is determined by the boundaries of the gazetted Peel-Harvey coastal catchment as defined in the DEP's EPP (1992). This is an area of approximately 2,000 km$^2$. Water quality monitoring will be undertaken for two years, most likely on a fortnightly basis during flow periods (but this will determined by PlaNet), as per the project life as funded through the Coastal Catchments Initiative. Sampling will reflect that required to validate or improve PlaNet simulations and output.

- The ultimate choice of field sampling sites will reflect spatial variability, frequency, precision and accuracy issues dependent upon PlaNet simulations and the potential to compliment the five criteria as listed in the previous section.
- Water quality parameters will initially be restricted to five parameters (TP, TN, FRP, $NO_x$, $NH_3$) but may include total suspended solids (TSS), total dissolved solids (TDS), pH and conductivity.
- Specific data requirements as determined by the review of existing water quality data and PlaNet simulations.

## 9.0 FIELD SAMPLING FOR NEXT TWO YEARS

1. Undertake field work to establish or refurbish LMU sites.
2. Undertake sampling according to the frequency determined by PlaNet simulation results to validate simulations.
3. Ensure adequate site and field sampling safety procedures are followed. For example, two people will sample together and have staff carry a mobile phone or radio to call in regularly or report problems and need for assistance.

Conditions encountered during sampling should be such that the risk to the health and safety of personnel is minimised. In addition to the standard safe field work practices, particular caution should be taken when dealing with potentially hazardous materials (both solids and liquids) and caution should be taken when sampling potentially toxic forms of algae, particularly where a scum as formed. Direct body contact with the water containing the algae should be avoided, since toxins may cause allergic reactions on the skin or in eyes. The field sampling safety plan should include the use of appropriate personal protective equipment. This includes gloves made of an appropriate resistant material. Other personal protection equipment including gumboots, coveralls, safety glasses etc. should also be considered when sampling in areas suspected to be contaminated with organic compounds. All safety equipment should be checked prior to its use.

**Table 4.** Analytes for measurement as part of the water quality monitoring program, both in next two years and in future.

| ANALYTE | COMMENTS |
|---|---|
| Total Phosphorus (TP) | Collect now and in future |
| Filterable Reactive Phosphorus (FRP) | Collect now and in future |
| Total Nitrogen (TN) | Collect now and in future |

| | |
|---|---|
| Dissolved Inorganic Nitrogen (DIN) | Collect in future |
| Ammonia ($NH_3$) (actually ammonium in water) | Collect now and in future |
| Nitrate-Nitrites (NOx) | Collect now and in future |
| Dissolved Organic Carbon (DOC) | Collect in future |
| Total Suspended Solids (TSS) | Collect now and in future |
| Total Dissolved Solids (TDS) | Collect now and in future |
| pH (or total acidity – alkalinity) | Collect now and in future |
| Conductivity - salinity | Collect now and in future |
| Dissolved Organic Nitrogen (DON) | Collect in future |
| Miscellaneous compounds such as tannins and mineral complexes | Collect in future |

A proper sample analysis plan will be developed after PlaNet simulations have been undertaken. An example of what kind of information would be provided is shown in Table 5.

**Table 5.** EXAMPLE ONLY - Peel-Harvey catchment monitoring program and sampling methods. Sampling since 1990 was concentrated in the winter flow period, which was generally between the first flush with the onset of rain (May/June) the cessation of surface flow at the end of spring (Nov/Dec). (TCS = Time-composite Sampling). The sites with bold text are those for which reliable streamflow data were available.

| Major River / Tributary Systems | Tributary (and Site code) | Site Location | Catchment Area ($km^2$) * | Sampling Method | Sampling Frequency | Analytes |
|---|---|---|---|---|---|---|
| Serpentine River System | 1. Serpentine River / Main Drain | Dog Hill | 1128.00 | Auto-sampler | Weekly grab samples, 1L TCS; 250 mLs/6 hours | TN, TP, FRP, NOx, NH3, others |
| | 2. Nambeelup Brook (PHS3) | Patterson Rd | 114.81 | Grab sample Review | Weekly | Review |
| | Gull Rd Drain (PHS4) | Serpentine Grazing Co. | 4.87 | Grab sample Review | Weekly grab samples 1L TCS; 250 mLs/6 hrs | Review |
| | 3. Punrack Drain / Dirk Brook (PHS5) | Punrack Rd Bridge | 138.05 | Grab sample Review | Weekly | Review |
| | 4. Peel Main Drain (PHS6) | Karnup Rd Bridge | 120.98 | Grab sample Review | Weekly | Review |
| Murray River System | Murray River (PHM1) | Pinjarra Rd Weir | 7180.35 | Auto-sampler | Weekly grab samples 1L TCS; 250 mLs/6 hrs | TN, TP, FRP, NOx, NH3, others |
| | South Dandalup River (PHM3) | Patterson Rd Bridge | 455.68 | Grab sample Review | Weekly | Review |
| Peel Inlet Tributaries | Coolup Main Drain (PHD4) | Paul Rd | 54.91 | Grab sample Review | Weekly | Review |
| | Coolup A / Caris Drain (PHD5) | Greenlands Rd | 16.05 | Grab sample Review | Weekly | Review |
| Harvey River and Tributaries | Harvey River (PHH1) | Clifton Park | 597.45 | Auto-sampler | Weekly grab samples. 1982-84 - 1L TCS; ≈330mL/8hrs. 1985-95 - 1L TCS; 250mL/6hrs. | TN, TP, FRP, NOx, NH3, others |
| | Meridith Main Drain (PHH3) | Johnston Rd | 53.95 | Both | Weekly grab samples. 1982-84 - 1L TCS; ≈330mL/8 hrs. 1985-95 - 1L TCS; 250mL/6 hrs. | Review |
| | Samson Brook | Sommers Rd | 18.91 | Grab sample | Weekly | Review |

|  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|
|  | Nth (PHH3) |  |  |  |  |  |
|  | Mayfields Main Drain (PHD1) | Old Coast Rd | 111.75 | Grab sample | Weekly | Review Note Red mud program |
|  | Mayfield Drain Sub- G (PHD2) | Sommers Rd | 12.44 | Grab sample | Weekly | Review Note Red mud program |
|  | Sth Coolup Main Drain (PHD3) | Yackaboon (Old Bunbury Rd) | 6.21 | Grab sample | Weekly | Review |

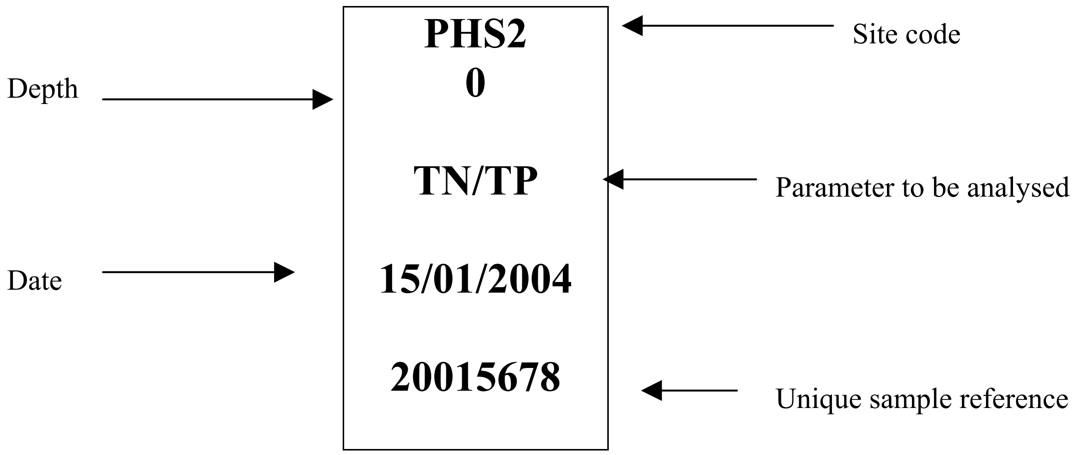
* Catchment area calculated includes the portion draining the Scarp.

## 10.0 LABORATORY ANALYSIS AND QUALITY ASSURANCE

### *10.1 Labelling of bottles*

Bottles will need to be labelled by staff prior to the field trip. The bottles can be pre-ordered by Mandurah or Aquatic Sciences Branch staff.

Each sample bottle for each site must be labelled with the date, the unique site code (eg PHS2), the depth method (eg 0 (zero)), the parameter to be analysed (eg TN/TP), and the unique sample reference number (eg 20015678). As shown below:



### *10.2 Chain of Custody forms*

The Chain of Custody (COC) Forms are used to keep track of samples from the field, to the laboratory and then to the database. The Chain of Custody (COC) forms have been revised to accommodate for the Water Information Network (WIN) database and are held in the RIB Branch in the DoE Hyatt Centre, East Perth office, they come with a booklet and guidelines to help guide users to fill in the forms. The COC's consist of three individual copies;

1. The White copy - Laboratory copy which accompanies the samples to the laboratory and remains at the laboratory.
2. The Pink copy - Copy that is sent to the laboratory with the samples but is returned to Head Office attached to the final chemistry hard copy report.
3. The Yellow copy - Copy that remains with ASB staff and is used for initial database entry.

The laboratory for analysis is Australian Government Analytical Laboratories (AGAL) unless arrangements have been made to have samples analysed at another laboratory. The COC form is partially filled in prior to field trips by sampling staff when sample the bottles are being labelled.

The following is pre-written onto the COC before sampling:
- Send samples to AGAL, 3 Clive Road, Cottesloe, WA.
- Payment code for this project is 1.AQ.27085.309 unless otherwise notified
- Sampling program code is PHC (Peel-Harvey Catchment)
- Sampling analysis plan circle YES
- Collection Agency is Aquatic Sciences Branch (ASB)

- Spatial pattern is *Fixed*
- Sampling frequency is Fortnightly or to be determined by PlaNet
- Sample number is the unique sample reference number corresponding to what is on the sample bottle. To save repetitive writing of this number, write the last three digits as you assign them to each sample.
- The matrix is filled in by a number code, which corresponds to either water (1) or sediment (3).
- The collection method for the surface is G for grab.
- The date is the date the samples are collected in dd/mm/yyyy format.
- The site reference number/code as the site code as detailed in Table 2 (eg PHS2, PHM1, PHH1).
- The site name is the full name of the site code (this is optional).
- The depth reference point is the point of reference where the depth reading is taken from. This is displayed on the COC booklet. WSL is written in this column to explain that it is from the water surface level.
- The depth for the G grab sample is zero (0) as it is a surface sample. Review with the Resource Information Branch on the protocol for autosamplers with regards to depth.
- Tick the relevant analysis that is required for the sample (eg TN&TP, FRP, NH3-N & NOx-N or DOC refer to Table 4)

Upon returning from the field the remaining information should be filled out. Write in the name of samplers (the name of the person/s collecting the samples) and the time (the time the samples are collected 24 hour clock). This information is generally scribed from the Field Observation Form (see next Section 10.3). The laboratories also require that the boxes in the top right corner at circled, this gives them information to how the samples have been handled.

Before sending the samples to the laboratory for analysis, at the bottom of the COC form write the name of the person relinquishing the samples and sign and date. When the samples are received at the laboratory the COC form must be signed, dated and account for how many samples are in the batch and their condition on arrival (circle YES or NO) by a laboratory employee.

## 10.3 Field Observation Forms

The field observation form (FOF) is used to record information during the sampling trip such as flow, stage height, physical measurements like temperature and conductivity and any other relevant comments. The field observation forms are pre printed and may be partially filled in before the field trip by DoE Staff.

Prior to the field trip the following information should be filled in:
- Region - as Aquatic Sciences Branch
- Project - as Catchment monitoring (PHC – with S (Serpentine), M (Murray) and H (Harvey) written to represent which sites)
- COC form number appropriate to the samples
- The site code as detailed in Table 2, only recording the site once
- When checking any instruments taken that have been calibrated with calibration solutions, scribe these readings onto the FOF form.

The remaining information is filled out in the field. It is important to remember when reading conductivity uncompensated (cond uncomp) that the units are recorded on the FOF.

## 10.4 Dispatch of water samples to Laboratory

Before delivering the samples to the laboratory all relevant paperwork must be filled out. All samples must be stored on ice bricks in a large esky and transported to the Australian Government Analytical Laboratories (AGAL) at 3 Clive Road, Cottesloe at the end of the day (if possible).

If due to circumstances that samples will not be delivered on the day of sampling, notify the laboratory and place all water samples in a fridge. Ensure that the Chain of Custody has the correct date of dispatch and are kept in a sealed plastic bag in the fridge with the samples. Refer to AGAL's Guidelines for Storage and Handling for accurate holding times of all analytes.

## *10.5 Quality assurance and control*

Quality assurance (QA) provides an indication of the certainty of your data. QA can be achieved by following certain quality control procedures during sample collection and handling. Historically, QA controls have relied on following the operating and maintenance procedures outlined in this guideline. However, QA also extends to assessing field work practices on data certainty. QA protocols for field work described below have been derived from AS/NZ 5667.1:1998. Data management information has been obtained from the document "COC form guidelines" which is produced by the Resource Information Branch.

The two main quality assurance controls that occur are:

- Field Blank - 1 sample quarterly
- Duplicate sample - 1 sample quarterly

An additional quality control sample can be carried out as part of a biannual audit to look at natural variation between time and place of taking a sample. This is the Replicate sample.

## *10.6 Blank, Duplicate and Replicate Samples*

A field blank is used to estimate contamination of a sample during the collection procedure or during laboratory analysis. When the field blanks are analysed they should read as analyte free (at the appropriate detection limit). A detection of the analytes may indicate a problem in sampling, handling, deionised water quality or laboratory analysis methods and further quality assurance investigations should occur.

A duplicate sample is obtained when a sample is taken from the same site, at the same time, using exactly the same methods. The sample is split into two samples and is analysed for the relevant variables. This will give a representation of sampling procedures and laboratory analysis methods.

A replicate sample is used to assess the homogeneity or natural variation of the environment and is a measure of the overall precision of the measurement at a sample site. Replicate samples are taken from the same sample site at the same time. Replicate samples provide a measure of the overall sampling precision affected by the environment, sample handling and laboratory.

Whether the sample is a blank, duplicate or replicate, it must be accounted for in the FOF and COC forms and accounted for when data is entered into the DoE WIN database. Refer to the Swan-Canning Cleanup Program Catchment guidelines (2003) for further detailed information and instructions.

# 11.0 DATA MANAGEMENT – DATA ANALYSIS – DATA MANAGEMENT - REPORTING AND COMMUNICATION PLANS

A more developed data analysis plan will need to be developed after initial PlaNet simulations and refurbishment of the primary and secondary LMU network is completed.

Data management will follow the established DoE requirements for data input into the Water Information database system (WIN). Responsibility for custodianship of the water quality data generated by this project and in the future should be shared between Mandurah staff and Head Office Aquatic Sciences staff.

Data analysis and reporting will need to be initiated as soon as PlaNet simulations are completed and as water quality data is collected to validate the simulations. There is also a need to review and report a synthesis of what the last several years of catchment nutrient concentration snapshots have revealed. PlaNet validation data, catchment snapshot data and historical data will need to be analysed as a matter of urgency because work for the decision support modelling that is part of another CCI project for this region will require this information as the model develops and is calibrated and validated.

Communicating results of analyses and liaising with the community and other major stakeholders as the project proceeds will also be necessary. This is because there is interest from the historical concern over nutrient enrichment and for comparing results against historical Ministerial Conditions and targets.

Furthermore, communicating monitoring results will help the community develop more meaningful long-term aspirational targets *sensu stricto* the current federal Natural Resource Management approach to improving catchment and estuarine water quality. A well developed communication plan should also entertain providing information and results through web page products such as report cards or environmental reporting and through a cross media approach that tries to reach all of the community.

## 12.0 GENERAL TIME LINES

| **YEAR ONE** | **ACTIVITY** |
|---|---|
| 1. Assess Primary LMUs | Repair and refurbish |
| 2. Initiate PlaNet simulations and data analysis | Training, analyses, minor reporting on results/conclusions |
| 3. Initiate sample collection to calibrate/validate simulations and fill information gaps | Collect samples, improve poor flow rating curves |
| 4. Continue to undertake catchment snapshots | Use information to target nutrient shedding catchments and land owners and help target location of secondary LMUs |
| **YEAR TWO** | |
| 1. Assess Secondary LMUs | Identify, refurbish, begin repair and establish new LMUs |
| 2. Initiate PlaNet simulations and data analysis | Training, analyses, minor reporting on results/conclusions |
| 3. Initiate sample collection to calibrate/validate simulations and fill information gaps | Collect samples, improve poor rating curves |
| 4. Continue catchment snapshot sampling | |
| 5. Final report | |
| 6. Outline future WQMP and community target setting strategy | |

## 13.0 FUTURE CONSIDERATIONS

The successful completion of this CCI project will leave a functioning load measuring network capable of accurately measuring nutrient loads leaving the coastal catchment. The network will compliment nutrient concentration sampling programs and provide the ability to test against nutrient targets. It will also provide a complementary tool to what is required in the Water Quality Improvement Plan being developed for the coastal catchment.

Some future considerations are:

- An adequate chemistry budget to measure loads for several years incorporating inter-annual variability.
- Analyses may indicate that the current chemistry/physical parameters that are measured will need to be changed or deleted.
- Field assistance and staffing for this program will need to be negotiated within DoE and other supporting government Local, State and Federal agencies.
- Maintenance of flow rating curves will require dedicated staff trained in hydrography and is not a trivial field program. It requires regular allocation of time to undertake this correctly.
- Analysis and reporting requirements will need to be adequately resourced.
- Review of Water Quality Monitoring Plan after two years, after PlaNet simulations and the network has become functional, will be critical and allow the WQMP to be more relevant to a wider water quality monitoring program.
- Review, assess and experiment with instantaneous flow and nutrient concentration measurement methods so that more time responsive water quality measurements are made. Related to this is the need to improve flow measurements in tidally affected areas, as in the ungauged portions of the coastal catchment which is a significant proportion of land that is not monitored yet may be producing problematical amounts of nutrients, ie consider evaluating better Doppler type flow meters.
- Ensure future monitoring compliments existing and future LWRDCC and other load based national initiatives.

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# 15.0 APPENDICES

## *15.1 Appendix One - Sampling registry*

| **Collection Agency – Contact Person** | **Sampling Locations** | **Parameters Analysed** | **Sampling Date** | **Collection Method** | **QA Statement (ie: NATA lab etc)** | **Where - How Data is Stored** |
|---|---|---|---|---|---|---|
| DoE Mandurah. Adrian Parker. | Various locations throughout catchment. Co-ordinates and mapping available via 'WIN' database. | Total P, Total N, Orthophosphorus, physicals (DO, pH, Turbidity, Temperature, EC), and phytoplankton | Ongoing – frequency dependent upon particular run. Typically fortnightly or monthly. | Grab and Integrated samples | NATA lab used. Formal Chain of Custody and Field Observation Forms. Regular calibration of sondes. | Data stored on DoE 'WIN' database |
| Dept Of Agric. Martin Clarke | Water & Rivers Bores<br>T450, Jarrah Rd, E392476, N6417780<br>1A, Greenacres Turf Farm, E395088,N6413788<br>5B, Greenacres, E395366,N6413412<br>T600, Yangedi Rd, E394368,N6407117<br>T570, Elliott Rd, E400326,N6410246<br>HS56, Curtis Rd, E390345, N6391439<br>HS48,Lake Mealup Rd, E382634, N6382955<br>HS38, Fishermans Rd, E390226, N6375721<br>HS31, E382802, N6371993<br>HS24, Landwehr Rd, E388969, N6361167<br>HS22, Bancell Rd, e397760, 6356295 | Heavy Metals, Total P, Total N, Physicals & Fluoride | Ongoing- monthly | Grab | Chemistry Centre | Dept of Agric Excel sheet, Waroona |
| Dept of Agric. Martin Clarke | Surface Points<br>Mealup Drain, PH3, E379957, N6382750<br>Mayfield Drain, PH4, E382543, N6369969<br>Meredith Drain, PH6, e384738, N6356897<br>Nambeelup Bk, PH16, E392863, N6402353<br>Gull Rd Drain, PH17, e389034, N6405482 | Heavy Metals, Total P, Total N, Physicals & Fluoride | Monthly when no/low flow, Fortnightly in wet season | Grab | Chemistry Centre | Dept of Agric Excel sheet, Waroona |
| Dept of Agric. Martin Clarke | Alkaloam Bores<br>RMB1, Johnston Rd, E384781, N6356830<br>RMB2, Johnston Rd, E384862, N6356795<br>RME1, Bageu Rd, MAeredith, E384328, N6351628<br>RME2, Bageu Rd, E384438, N6351668<br>RME3, Bageu Rd, E684552, N6351746<br>RML1, Selerian Rd, E387160, N6357375<br>RML2, Selerian Rd, E387205, N6357449<br>RML3, Selerian Rd, E387244, N6357516<br>RMK1, Lakes Rd, E394317, N6401965<br>RMK2, Lakes Rd, E394242, N6401729 | Heavy Metals, Total P, Total N, Physicals & Fluoride | Start & finish of season | Grab | Chemistry Centre | Dept of Agric Excel sheet, Waroona |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dept of Agric. Martin Clarke | Surface Points<br>Peel Inlet, PH1, E377324, N6388750<br>Harvey Est, PH2, E377687, N6382537<br>Harvey River, PH7, E398049, N6339608<br>Logue Bk Dam, PH8, E403961, N6347868<br>Drakesbrook Dam, PH9, E401692, N6363964<br>Waroona Dam, PH10, E402020, N6364997<br>Goegrup Lake, PH18, E386596, N6400920<br>Serpentine R, PH19, E383154, N6397313<br>Murray R, Ravenswood, PH20, E389954, N6393964<br>Murray R, Pinjarra, PH21, E394713, N9389459<br>Serpentine R, Serpentine, PH22, E405125, N6418886 | Heavy Metals, Total P, Total N, Physicals & Fluoride | Start & finish of season | Grab | Chemistry Centre | Dept of Agric Excel sheet, Waroona |
| City of Mandurah | Peel – Harvey Estuary Sites – locations soon to be available on Intramaps ie GIS. Now in hard copy | Thermo coliforms / Faecal strep's | Ongoing – monthly | Grab samples | NATA lab used – Pathcentre | Data stored in Environmental waters database. Currently under review |
| City of Mandurah | Mandurah canals – Pt Mandurah, Waterside, Ocean Marina, Eastport, Northport, Mariners Cove | Nitrate, Nitrite, Reactive Phos Turbidity, DO, Temp, Conductivity, Thermo coliforms / Faecal strep's<br>*Eastport, Northport, Mariners Cove – only Thermo coliforms / Faecal strep's* | Ongoing – monthly | Grab samples | NATA lab used – Pathcentre and ARL | Data stored in Environmental waters database. Currently under review |
| City of Mandurah | Ornamental Lakes ** Proposed only, not final as yet ** | Nitrate, Nitrite, Reactive Phos Turbidity, DO, Temp, Conductivity, Thermo coliforms / Faecal strep's Sediment samples for heavy metals | TBA | Grab samples | NATA lab used – Pathcentre | N/A |
| City of Mandurah | Edible Marine Life Survey **currently under review…may be modified** | Mussel flesh – heavy metals cadmium, lead, mercury. Thermo coliforms / Faecal strep's, salmonella, vibrio spp. | Monthly | Grab samples | NATA lab used – Pathcentre and ARL | Word Document – tables and hard copy |
| Jan Johnston<br>95255157 | Jarrahdale PS | EC<br>pH<br>Temperature | Monthly | Grab | Ribbons of Blue<br>Calibration of equipment. | Ribbons of Blue database |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Turbidity | | | Equipment checked annually<br>Training provided.<br>Follow up assistance by RoB coordinator | (ROB coordinator checked) |
| Michelle Murray<br>Michelle.Murray@det.wa.edu.au<br>95352257 | Serpentine PS | EC<br>pH<br>Temperature<br>Turbidity | Weekly | Grab | Ribbons of Blue<br>Calibration of equipment.<br>Equipment checked annually.<br>Training provided.<br>Follow up assistance by RoB coordinator | Students (Global School Project).<br>Ribbons of Blue database (ROB coordinator checked) |
| Charlie Ballard<br>Charles.ballard@det.wa.edu.au<br>94192355 | Calista PS | EC<br>pH<br>Temperature<br>Turbidity<br>PO4<br>NO3-N (LaMotte kit) | Seasonal | Grab | Ribbons of Blue<br>Calibration of equipment.<br>Equipment checked annually.<br>Training provided.<br>Follow up assistance by RoB coordinator<br>Nutrient sampling done by RoB coordinator | Ribbons of Blue database (ROB coordinator checked) |
| Merrilyn Jones<br>Merrilyn.jones@det.wa.gov.au<br>95301202 | Nth Dandalup PS | EC<br>pH<br>Temperature<br>Turbidity | Weekly | Grab | Ribbons of Blue<br>Calibration of equipment.<br>Equipment checked annually.<br>Training provided.<br>Follow up assistance by RoB coordinator | Students (Global School Project).<br>Ribbons of Blue database (ROB coordinator checked) |
| Max Williams<br>Max.williams@det.wa.edu.au<br>9581 0900 | Coodanup High | EC<br>pH<br>Temperature<br>Turbidity<br>DO %<br>Faecals<br>Flow<br>PO4<br>NO3-N (PalinTest kit) | Monthly from 1994 to 1998 | Integrated | Calibration of equipment.<br>Equipment checked annually.<br>Training provided.<br>Follow up assistance by RoB coordinator | School and RoB database |
| Jeremy Coates<br>95311066 | Pinjarra SHS | EC<br>pH<br>Temperature<br>Turbidity<br>PO4<br>NO3-N (LaMotte kit) | Seasonal | Grab | Calibration of equipment.<br>Equipment checked annually.<br>Training provided.<br>Follow up assistance by RoB coordinator | School and RoB database |
| Centre for fish and fisheries Research (CFFR) Murdoch for HRRT. | Various locations. Water and Rivers gauging station (GS location 613007 Bancell Brook); Bancell Brook at SW Hwy crossing; Cnr of | Numerical abundance of fish and decapod fauna; temperature; conductivity | Nov 11th 2002 & May 2003 (Further monitoring subject to funding) | Back-pack electrofisher (Smith-Root 12-A) supplemented with a 5m seine | | Report to the HRRT due in mid November. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Bancell and Brockman Rds; confluence of Bancell and Logue Brook. | | | net. 100 metres of stream sampled at each site. | | |
| Peel-Harvey Catchment Council/Serpentine Jarrahdale Landcare centre<br>Alex Hams | Dirk Brook Catchment – 20 sites | Total P, Total N, Orthophosphorus, physicals (DO, pH, Temperature, EC, Flow) | Ongoing during winter months Typically weekly, Following rainfall events | Grab samples | NATA lab used. Standard water monitoring methodology. | Data stored on computer at Landcare centre. Also in hard copy. |
| Alcoa World Alumina – Gordon Baird | Refer attached plan and excel sheet. | pH Electrical Conductivity Alkalinity Sodium Chloride Potassium Calcium Magnesium Bicarbonate Carbonate Chloride Fluoride Nitrate Nitrite Filterable Reactive Phosphorous (FRP) Silica Sulfate Heavy metals TDS Dissolved Organic Content Ammonia Total Kjeldahl Nitrogen (TKN) | Either weekly, monthly or bi-annually. | Grab and continuous flow. | NATA lab used. Internal SAP used. | Stored on Alcoa database and reported to DoE to fulfil various licence conditions. |
| Green Skills Inc. Donna Sampey | 13 sites on the Peel and Birrega Main Drains and Serpentine River, within the boundaries of Rockingham and Kwinana (see table below). | Temperature, pH, Conductivity, NOx, FRP, Turbidity | Monthly between September 2002 & September 2003 | Grab and Integrated samples | Field Observation forms. Regular calibration of equipment. | Final Report (in preparation). Database at Green Skills. Data will be provided to Peel DoE |
| Shire of Murray. Darryl Eastwell | Murray River, Corio Rd WTS, Old Dwellingup tip site, Canals in response to pollution incidents. | OC's OP's, metals, BTEX, bacteria | 6 monthly for tip sites, monthly for bacteria. | Grab | | Data presented in annual compliance report to DoE. Spreadsheet of bacto data on Shire server. |

## 15.2 Appendix Two – Sub-catchments of the Peel-Harvey Catchment

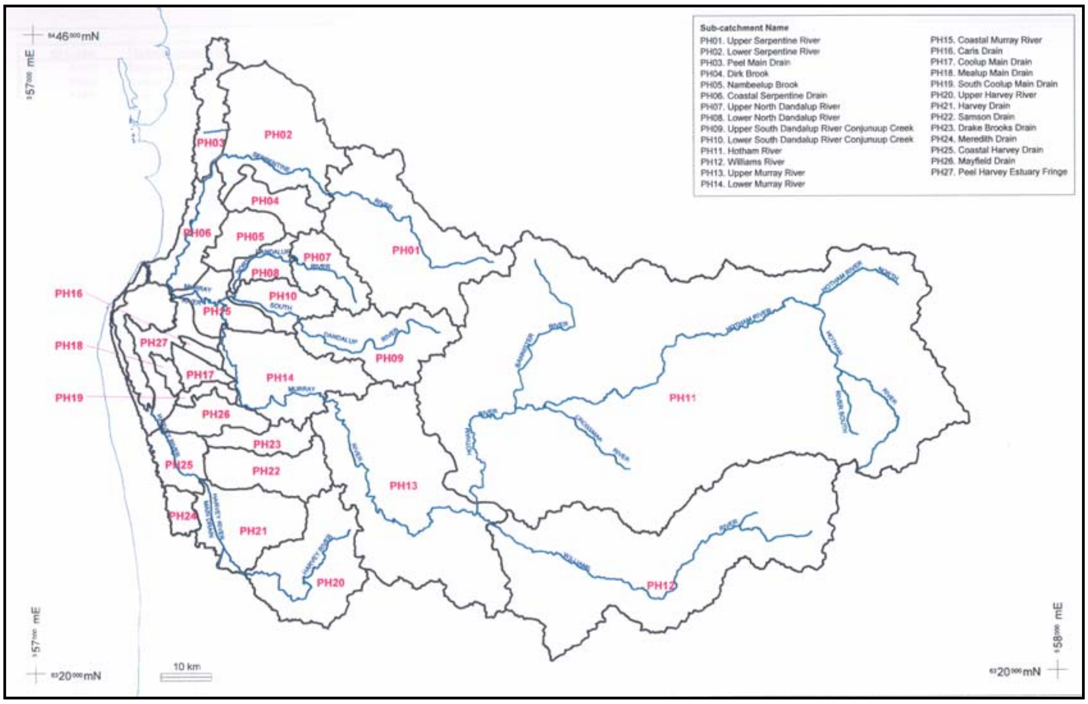

**Figure 7.** Location of system and coastal and inland large sub-catchments (DA Lord Associates and JDA Consultant Hydrologists, 2001).