Sunshine Coast Waterways Authority Bill 2026

Submission No: 031
Submission By: Pumicestone Passage Catchment Management Body Inc

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15 March 2026

The Chair
State Development, Infrastructure and Works Committee
Parliament House, George Street, Brisbane

Dear Mr McDonald,

SUBMISSION
SUNSHINE COAST WATERWAYS AUTHORITY BILL 2026

Introduction
The Pumicestone Passage Catchment Management Body (PPCMB) supports the establishment of a dedicated Sunshine Coast Waterways Authority (SWCA) to address the longstanding fragmentation in waterways management as it applies to the Pumicestone Passage.

We support the authority in its goal to achieve sustainable use, management and development of the waterways of the Sunshine Coast, with specific consideration given to Pumicestone Passage.

Background
For more than half a century, governments failed to address increasing concerns over erosion at the northern tip of Bribie Island and the instability of the Caloundra Bar. Although the extensive history of community advocacy and calls for active management led to such initiatives as the 1993 *Draft Integrated Management Strategy for Pumicestone Passage* (IMS - see attachment), there was little action.

The ensuing breakthroughs beginning in January 2022 caused extensive damage to the Caloundra foreshore, council infrastructure, marine infrastructure, recreational facilities, parkland, wildlife habitats and wetlands – all could have been avoided with active management of the area.

Only last year, Caloundra suburbs narrowly avoided devastation from Cyclone Alfred but still suffered very significant impact.

In response, the Crisafulli government commissioned the *Bribie Island Erosion and Breakthrough Review* which led to a program of short-term Emergency Works (now almost complete) and Recommendations for a long-term solution which have been supported by the government.
https://www.statedevelopment.qld.gov.au/infrastructure/projects-and-programs/bribie-island-erosion-and-breakthrough-review

Key Considerations for the SCWA

1) Diversity

The waterways listed in the SCWA Bill are vast, diverse and numerous (16), belonging to four main waterways:

- Noosa River
- Maroochy River
- Mooloola River
- Pumicestone Passage

While Noosa, Maroochy and Mooloola involve river systems and lakes, Pumicestone Passage – *being a 35 km long double-ended estuary bordered on one side by the 4th largest sand island in the world* – is quite rare with distinct management issues.

2) Unique Characteristics of Pumicestone Passage

a) Barrier Island: Caloundra was developed with the assurance of its barrier island, Bribie. The proposed long-term rectification works seek to address the effects of long-term neglect.

b) Broad catchment: With Deception Bay to the south, Pacific Ocean to the north, and freshwater inflow from major creeks and tributaries, the influences on water quality and ecology are complex

c) Land use and jurisdictions: Farming, urban, national parks, Ramsar wetlands, Inter Urban Break, Sunshine Coast Council, City of Moreton Bay, Qld Parks & Wildlife, Kabi Kabi Peoples Aboriginal Corporation.

d) Environmental significance

e) Economic significance

f) Port of Brisbane channel enhancement project

3) Organisational Arrangements

a) **Board Membership**

i) The effectiveness of the SCWA Board will be determined by the skill set and balance of expertise of its members. It will be critical that the profile of the board aligns with the environmental and organisational remit of the SCWA.

ii) Consideration should be afforded to the appointment of ex-officio members e.g. the Mayor or delegated representative of the Sunshine Coast Region.

iii) We suggest the CEO should be appointed by the Board, subject to ministerial approval. As the Bill is currently drafted there is no role for the Board in the appointment of the CEO.

b) **Responsiveness**
The SCWA will require mechanisms which enable it to respond effectively to the emerging needs of the diverse environment which it will serve. There is opportunity for:

i) Management planning tailored to the discreet needs of individual waterways while generating economies of scale offered by the scope of the authority, e.g. monitoring and modelling programs for water quality, ecology and morphology.

ii) Agile consultative processes that provide reliable, evidence-based information to management planning e.g. community reference groups - flexible, purposeful committee structures that draw well-qualified representation from across the communities of the Sunshine Coast waterways e.g. long-established community interest groups such as PPCMB and Caloundra Residents Association (CRA).

c) Transparency and Accountability
In order to firmly establish public confidence and performance-based accountability for the Sunshine Coast Waterways Authority as it assumes its role, a range of measures should be integrated within its operation:

i) Deliverables clearly articulated within the strategy

ii) Regular public reporting as part of a comprehensive community engagement strategy

iii) Operational congruence with statewide and council planning requirements

iv) Independent review process established.

4) Specific Recommendations which address the Unique Characteristics of Pumicestone Passage

a) That the SCWA strategy and works programs are informed by prior learning i.e. the *Bribie Island Erosion and Breakthrough Review Report*.

b) That the SCWA strategy includes specific environmental performance targets for Pumicestone Passage and Bribie Island.

c) That the SCWA strategy addresses the Port of Brisbane channel enhancement project in relation to the support of the restoration of the Bribie barrier island.

5) Conclusion

The economic, environmental and social wellbeing of the Pumicestone Passage and the Caloundra community demand that the momentum and gains achieved through the recent Emergency Rectification Works of north Bribie Island are converted into a long-term solution. This must be a key component of the strategy and management program of the SCWA.

The PPCMB strongly believes that this should be the priority of the newly established SCWA, through the implementation of the recommendations of the *Bribie Island Erosion and Breakthrough Review*. The recommendations:

a) to restore the barrier function of Bribie Island, and
b) to stabilise the bar in its original position

have been endorsed by government and received strong community support.

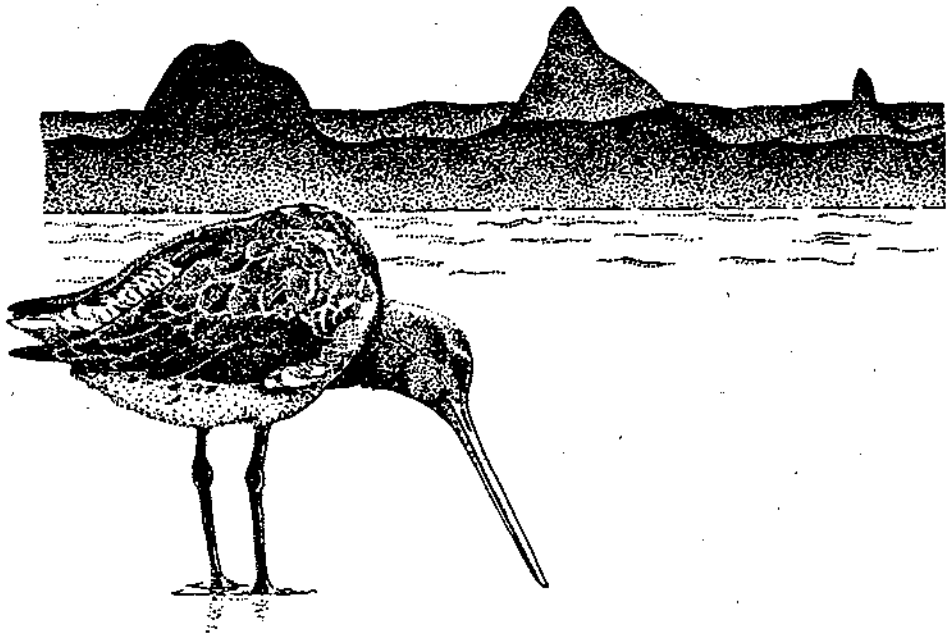
The recommended engineering solutions from the review offer the lowest-risk pathway to securing resilience, sustainability of lifestyle for community, and health of the waterway. The proposed solution restores tidal levels, salinity and passage dynamics to the known conditions around which Caloundra was originally planned and built. Concurrently, it supports and protects the ecological processes that underpin the unique amenity of Pumicestone Passage.

These works must be prioritised, funded and actioned by ongoing, effective and active management of the Passage. The result of any delay or inaction will see costs grow, and would knowingly place homes, the local economy and the environmental future of the community at increased, significant risk.

Yours sincerely,

Graeme Smith
President
Pumicestone Passage Catchment Management Body Inc.

Pumicestone Passage, its catchment and Bribie Island



Draft Integrated Management Strategy — Main report

November 1993

Queensland
Department of
Environment and Heritage

WILLING & PARTNERS PTY LTD

In association with

Neville Jones & Associates Pty Ltd

Ison Environmental Planners

Ken Todd Town Planning Pty Ltd

ERSIS Australia Pty Ltd

DISCLAIMER

The sole purpose of the services performed by Willing and Partners and its subconsultants and of this report is to propose and evaluate an Integrated Management Strategy (IMS) for Pumicestone Passage, its Catchment and Bribie Island in accordance with the scope of services set out in the contract between Willing and Partners Pty Ltd ("Willing and Partners") and the Queensland Department of Environment and Heritage (DEH) ("the Client"). That scope of services was defined by the requests of the Client, the time and budgetary constraints imposed by the Client, and the availability of access to Pumicestone Passage, its tributaries and the catchment.

Willing and Partners derived the data in this report primarily from visual inspections of the catchment and its waterways, data and information provided by the Client and other Government Departments and Caloundra City Council and Caboolture Shire Council. The passage of time, manifestation of latent conditions or occurrence of future events may require further exploration of the catchment, analysis of the data and re-evaluation of the findings, observations and conclusions expressed in the report.

In preparing this report, Willing and Partners has relied upon and presumed accurate certain information (or absence thereof) about historical and existing landuses, water quality data collected in Pumicestone Passage and its tributaries, data and information provided by the various Component Studies, digital data and environmental, conservation and planning guidelines provided by governmental officials and authorities, the Client and others identified herein. Except as otherwise stated in the report, Willing and Partners and its subconsultants have not attempted to verify the accuracy or completeness of any such information.

No warranty or guarantee, whether express or implied, is made with respect to the data reported or findings, observations and conclusions expressed in this report. Further, such data, findings, observations and conclusions are based solely upon existing landuses supplied in digital form, available information on best management practices and information contained in the Component Study reports and about proposed Strategic Plans in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Willing and Partners and the Client. Willing and Partners accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

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Glossary

Abiotic	The non-living components of ecosystems.
Aerobic sediments	Sediments which are well oxygenated and high in redox potential.
Allochthonous	Material that is derived externally.
Anaerobic sediments	Sediments that are devoid of oxygen and low in redox potential.
Autochthonous	Material that is produced within the ecosystem.
Autotroph	Bacteria and plants which are able to utilise inorganic chemicals for growth purposes.
Benthic	Organisms living in or on the sediments.
Benthos	The sum total of organisms living in or on the sediments.
Best Management Practice (BMP)	The best available, economically viable, management practice which minimises potentially adverse impacts of an activity.
Bio-availability	The fraction of the total chemical that can be taken up by organisms.
Biomass	The weight of living plants or animal population.
Biotic	The living component of the ecosystem.
Chelates	A complex molecule in which a central metal ion is attached to two or more non-metal atoms or group of atoms in the same molecule (called ligands).
Colloid	Fine particles, having a high surface area relative to mass, such that they form a stable suspension in water.
Crustacea	Class of jointed-legged animals (arthropods) which breath by means of gills and have two pairs of antennas. The Class includes crayfish, lobsters, shrimps, crabs, water fleas and barnacles.
Denitrification	The bacteriologically mediated process of release of nitrogen as gas.
Detritus	Unconsolidated sediments composed of both inorganic and dead and decaying organic material.
DO	The concentration of dissolved oxygen present in water.

Glossary

Ecologically Sustainable Development (ESD)	Development which improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.
Epilimnion	The uppermost layer of water bodies, characterised by well mixed and uniform physical and chemical properties.
Epiphytes	A plant that grows on the outside of another plant, using it as a support but not as a food source.
Euphotic zone	The uppermost layer of water in which light is available for photosynthesis.
Eutrophication	Enrichment of waters with nutrients, primarily phosphorus, causing abundant aquatic plant growth.
Halophytic	Plants and animals tolerant of high salinity environments.
Heterotroph	Bacteria, plants and animals which are dependant on preformed organic matter for growth.
Labile carbon	Carbon in a form (generally small molecular size) available for rapid take up by bacteria.
Lentic	Water bodies characterised by significant hydraulic retention (weeks to years), and low velocities and mixing regimes. Lentic waters are commonly referred to as standing waters, and include lakes and ponds. The morphology and ecology of estuaries are predominately those of limnetic waters.
Limnetic	The open water region of a lake.
Littoral zone	The interface zone between the land and the water body.
Lotic	A flowing water body such as a river.
Macrophytes	A large vascular aquatic plant, which can be emergent, submerged or floating.
Mangroves	The halophytic trees, shrubs and creepers found along the intertidal zone.
Molluscs	Animals of the mollusca phylum, including snails, cuttlefish, oysters, mussels and limpets.
Nitrogen fixing	The biological fixing of nitrogen from the atmosphere.

Glossary

Parameters: A measurable physical, chemical or biological characteristic or feature.

Physical:
Suspended solids (SS) - A measure of the fine suspended material which gives water a turbid appearance.

Secchi Disc - A measure of the depth of light extinction.

Chemical:
pH - A measure of the number of hydrogen ions in solution and is an important determinant of acidity or alkalinity.

TDS (Total Dissolved Salts) is a measure of the salinity of water, usually expressed in milligrams per litre

Phosphorous - one of several essential plant and animal nutrients, and is measured in a number of forms including:

Total phosphorus (TP) - a measure of both the dissolved and particulate (biotic & abiotic) forms of phosphorus

Filterable reactive phosphorus (FRP) and Ortho-phosphorus - a measures of dissolved or biologically available forms of phosphorus.

Nitrogen - one of several essential plant and animal nutrients, which is measured in a number of forms, including:

Total nitrogen (TN) - a measure of both inorganic and organic forms of nitrogen

Nitrate N - a measure of inorganic oxidised nitrogen

Ammonia N - a measure of inorganic reduced form of nitrogen

Keldahl nitrogen - a measure of organic nitrogen plus ammonical forms.

Oxygen - an essential element in the respiration of plants and animals, and an important determinant of reduction and oxidation processes. Related measures include:

Dissolved oxygen (DO) - a measure of the level of oxygen gas in solution.

Glossary

	Biological oxygen demand (BOD) - the 5 day oxygen demand associated with the decomposition of organic material ie. a measure of the demand on the oxygen gas in solution. *Biological:* Chlorophyll 'a' is used as a measure of the algal biomass. *Bacteriological:* E.coli (Escherichia coli) is used as an indicator of potential faecal pollution of waters.
Pelagic ratio	The ratio of volume to surface area of a water body.
Pesticides	A substance or mixture of substances used to kill unwanted species of plants or animals.
Photosynthesis	The conversion of carbon dioxide to carbohydrates by autotrophs (such as algae) in the presence of chlorophil using light.
Phytoplankton	The microscopic plants floating in water bodies.
Productivity	The production of organic matter from inorganic material.
Polycheates	Animals of the Polycheate phylum, including worms.
Refractory carbon	Carbon in a form (usually the larger molecular size) which is resistant to microbial decomposition.
Respiration	The process in which organic carbon compounds are oxidised to carbon dioxide and water, usually expressed in mg/L.
Riparian zone	The zone of aquatic and terrestrial plants associated with river corridors.
Saltmarsh	The halophytic grasses, sedges, rushes and succulents found along the intertidal zone.
Seagrass	Rooted marine angiosperms (flowering plants) which occur in sheltered coastal marine waters in the tropical and temperate climatic zones.
Toxicity	The potential or capacity of a material to cause adverse effects in a living organism.
Trophic level	The classification of waters according to their productivity - oligotrophic (low), mesotrophic (moderate) and eutrophic (high).
Zooplankton	The microscopic animals floating in the water body.

Acknowledgements

The Integrated Management Strategy for Pumicestone Passage, its Catchment and Bribie Island was prepared by a study team lead by Willing & Partners Pty Ltd on behalf of the Department of Environment and Heritage. The Strategy was prepared under the guidance of a Steering Committee comprising representatives from Queensland Government Departments and Local Government as follows:

- Department of Environment and Heritage
- Department of Housing, Local Government and Planning
- Department of Transport
- Department of Lands
- Department of Primary Industries
- Department of Tourism, Sport and Racing
- Department of the Premier, Economics and Trade Development

- Caloundra City Council
- Caboolture Shire Council

The assistance of all members of the Steering Committee and in particular officers of the Department of Environment and Heritage including Dr Ian Wilson, Ms Robyn Hesse, Mr John Bennett and Ms Vanessa Swinson is gratefully acknowledged.

The permission of a number of Queensland Government Departments to use a range of material is gratefully acknowledged as follows:

- Department of Lands (Digital contours and digital cadastral database)
- Department of Local Government, Housing and Planning (Broadhectare study)
- Department of Primary Industries (Fisheries) (Seagrass mapping)
- Department of Primary Industries (Forestry) (Remnant vegetation)
- Department of Primary Industries (Water Resources) (Rainfall data)

To support the preparation of the strategy, a series of component studies were commissioned. The permission of the following Departments to draw on the findings of the component studies is gratefully acknowledged:

- Department of Primary Industries:
  - groundwater resources;
  - agricultural chemical (fertiliser and pesticide) usage;
  - land resources and soil erosion; and
  - aquaculture.

- Department of Environment and Heritage:
  - water quality in Pumicestone Passage and its tributaries;
  - coastal processes; and
  - management planning for existing and proposed conservation reserves on and in the vicinity of Bribie Island and Pumicestone Passage.

Executive Summary

Since 1982 when strategies were prepared to protect water quality and ecological values of Pumicestone Passage, its catchment and Bribie Island, changes in landuse, land tenure and population have cast doubt on future reliance on the existing strategies. The Integrated Management Study (IMS) was commissioned to produce an ecologically sustainable strategy for landuse planning, environmental and resource management for Pumicestone Passage, its catchment and Bribie Island.

Pumicestone Passage, its Catchment and Bribie Island Values and Uses

The environmental values of Pumicestone Passage, its catchment and Bribie Island and their significance in relation to other estuaries were previously identified in the 1982 study. The current review accepted these environmental values and investigated their current status and condition and the extent to which these values were still adequately protected. It also identified changes which had occurred since 1982.

The 1982 study provided a qualitative description of the dominant geomorphological and ecological processes which determine community composition and structure. This was used as the reference point for evaluating the impacts of landuse change and for determining appropriate management practices for ecological sustainability.

The key environmental values of Pumicestone Passage and the estuarine reaches of the creeks discharging into the Passage identified in 1982 include:

- ecosystem protection including the protection of waters used for shellfish and fish production and for wildlife;
- conservation including amenity and aesthetics;
- recreation and tourism;
- commercial activities including fishing; and
- educational/scientific functions.

All these environmental values have implications for water quality within the Passage and the tributary creeks and were considered in the formulation of water quality objectives for the study area.

The Australian Water Quality Guidelines, released by the Australian and New Zealand Environment and Conservation Council (ANZECC) and the Australian Water Resources Council (AWRC) in November 1992, provide water quality guidelines for the sustainable management of water resources for a range of environmental values including the values identified for Pumicestone Passage and its environs. The Intergovernmental Agreement on the Environment requires that each State and Territory incorporate national guidelines into local administration of the environment. It is therefore appropriate that the Australian Water Quality Guidelines be adopted as the water quality guidelines for Pumicestone Passage, its catchment and Bribie Island.

Water Quality and Ecological Issues

As part of both the 1982 study and the current review, baseline monitoring programs were carried out between February 1978 and April 1980 and August 1991 to July 1992.

The changes in water quality between 1978-1980 and 1991-1992 and their implications included:

Nutrient and organic pollution:

- increased algal biomass levels in the tributaries and estuary have resulted from a significant increase in nutrient availability.
- increased nutrient availability reflects the growth of horticulture, aquaculture, and residential (rural & urban) landuses in the catchment;
- extremes in algal biomass levels are evident in the lower reaches of the tributaries. These give rise to odour problems and the depression of oxygen to levels which are lethal for biota;
- there is a substantial increase in algal biomass levels throughout the Passage. This may also give rise to potential odour problems and the depression of oxygen to levels which are lethal for biota;
- on the basis of these trends, there is a likelihood that the structure of plant communities will change due to reductions in the euphotic depth (leading to an increase in inter-tidal seagrass species and mangroves and a decrease in sub-tidal seagrass species); and
- increases in nutrient levels leading to increased algal and epiphytic growth and a decline in seagrass communities.

Sediment pollution:

- the overall level of suspended solids in the tributaries and Passage in the period 1991-1992 was lower than the levels in the period 1978-1980 reflecting a substantial decline in the impact of clearing of the catchment for the establishment of pine plantations in the early to late 1970s.

Natural organics:

- although the tributary creeks generally exhibit high levels of natural organics in their waters some tributaries have experienced an overall reduction. The greatest overall reduction has been in Lamerough Creek and the upper reaches of Coochin Creek. A reduction in humic content of drainage water as a result of the destruction of wetlands is likely to increase the availability of phosphorus and carbon thereby increasing algal biomass levels in the estuary.

The most critical water quality objectives are related to the protection of the aquatic ecosystems.

The changes which have occured in water quality and plant composition and structure indicate that current landuses and management practices are already significantly impacting on the estuary to levels in excess of the recommended limits in the Australian Water Quality Guidelines. The Passage has a substantial capacity to buffer the impact of pollutants through the capacity of the sediments, mangrove and saltmarsh areas to absorb pollutants and through natural patterns of alkalinity.

That such a change in estuarine water quality is observable in the period 1978-1980 to 1991 suggests that changes in pollutant exports associated with changes in landuse and management practices are already well in excess of sustainable levels.

Sustainable Loading Criteria

The major water quality problems identified in the water quality analysis were nutrient and organic pollution and toxic pollution by ammonia, elevated turbidity and oxygen demanding substances. However the latter three are largely secondary effects of excessive algal growth which was observed in the northern reaches of the Passage.

The determination of sustainable loads was based on the following:

- sustainable phosphorus loading levels, based on limiting algal biomass to sustainable levels;
- sustainable BOD loading levels based on limiting biologically available phosphorus to sustainable loading levels;
- sustainable algal biomass levels which are consistent with limiting pH change, DO and ammonia levels;
- sustainable nitrogen loading levels based on maintaining an N/P ratio at levels which limits the incidence of blue green algal blooms (N/P ratio = 16),
- sustainable pesticide loading based on the total exclusion of organochlorines and within the Australian Water Quality Guidelines for organophosphates.

Integrated Management Strategy

Drawing on the environmental values and the analysis of ecologically sustainable loadings, six alternative management strategies were formulated. Each of these included land use controls and management practices which were designed to contain cumulative pollutant exports within the sustainable levels.

The overall objective of the IMS is to secure the sustainable use of resources of Pumicestone Passage and its tributaries, while maintaining its environmental values. A comparison of the effectiveness and economic viability of the six strategies indicated that the desired objectives would be most efficiently achieved through the application of a range of techniques designed to reduce the pollutant exports from all land uses.

The IMS proposes simultaneous action in four areas:

- Planning Instruments and Policies
- Community Awareness
- Best Management Practices
- Further Studies

Planning Instruments and Policies

The mechanisms for implementing the IMS include:

(i) control of landuse activities and their location,
(ii) designate sensitive areas as conservation zones,
(iii) adoption of best management practices which limit the generation and export of pollutants to sustainable levels for the land and receiving waters,
(iv) provision of wastewater treatment and collection systems,
(v) encouraging industry self regulation and monitoring, and
(vi) community involvement.

The instruments available for implementing the preferred management strategy include legislative/administrative instruments, community stewardship and a combination of both. The principal instrument used for landuse control is the Planning Scheme for a local government area prepared under the Local Government (Planning and Environment) Act.

For the implementation of the IMS to succeed it will be necessary within both local government areas for the IMS to guide the strategic plans and development control plans. This may require planning schemes to incorporate additional zones eg. conservation zone, environment protection zone. Likewise, subdivision and building controls (eg. erosion and sediment controls) will need to be consistent with the IMS.

Of equal importance will be the development of a consistent approach to planning schemes and bylaws by both Caloundra City and Caboolture Shire Councils.

Future legislation, including proposed Environmental Protection Legislation and the new Local Government Act is expected to strengthen the legislative framework.

A system of industry self regulation and monitoring should be applied and the situation audited to evaluate the effectiveness and modify as required the adopted best management practices for land uses which are known to generate significant pollutant loadings.

Community Awareness

Two on-going State Government initiatives (the Integrated Catchment Management Program and Landcare Program) have sought, through the sponsorship of State Government and the involvement of local government, Industry groups, community groups and individuals to engender a sense of ownership and stewardship of local areas.

Typically these programs are managed by local groups who have a commitment to resolve issues such as land degradation, pesticide and fertiliser usage and stream bank erosion. The programs are providing benefits such as better farm management practices and better control of runoff beginning to emerge. Many of the solutions to problems have been generated by those involved in the groups. Through these groups, the many issues of concern related to runoff management, soil and water conservation and land degradation have achieved a much higher profile in the community with a resultant increase in concern amongst industry, community groups and individuals and a greater commitment to reaching solutions through consensus.

Recommended Best Management Practices

The review concluded that the objective of the IMS would be best achieved by implementing BMPs for all land uses. The recommended BMPs for each land use, which were drawn from the range of available BMPs, are summarised as follows.

Conservation Zones

An integrated suite of conservation zone management measures, including:

- clear designation of conservation zones associated with the protection of wetlands, buffer zones and riparian zones;
- identification of significant and sensitive habitats and locations for designation as conservation zones;
- provision of buffer zones around wetlands to manage potential conflicts with adjacent landuses
- development of interpretative material on the values of native vegetation, wetlands and riparian communities.

Urban

An integrated suite of stormwater and wastewater management measures, including:

(i) Urban development needs to be properly managed:

Implementation:

- strategic, development control and zoning plans;
- declaration of conservation and riverine zones;
- landscape protection plans.

(ii) Drainage management:

- incorporation of swales and buffer (vegetated interception) zones to intercept runoff and associated suspended materials;
- retention/establishment of riparian zones along stream corridors and estuary foreshores, as buffer zones; and the
- interception of stormwater runoff, and routing through sediment traps and trashracks, followed by storage in pollution control ponds or wetlands, prior to discharge to the Passage or its tributaries.

Implementation:

- application of development control and zoning plans;
- application of sub-division and building controls;
- environment protection policies and management plans;
- local government provision of urban stormwater pollution control infrastructure.

(iii) Wastewater management:

- connection of all properties to sewerage systems; and
- provision of a biological and chemical (where necessary) treatment facility, followed by land filtration or wetland treatment where appropriate to achieve an average effluent quality for total phosphorus not exceeding 0.5mg/L.

Implementation:
- environment protection policies, licencing & management plans;
- developer provision of sewerage systems - operation by local government.

(iv) Mosquito hazard management, including:
- identification of clearance zones around designated freshwater wetlands in order to exclude human habitation and other potentially conflicting uses;
- minimise sedimentation of tributaries in order to limit the potential for isolating pools of water from predators;
- design of edges to ponds and channels to minimise the potential for pools of water to be isolated from predators;
- construction of runnels to reduce the potential for pools of water to be isolated from predators;
- identification of pesticides which may be used safely with minimum risk to the ecology of the Passage and the catchment;
- request the Tropical Mosquito Research Centre and DPI to develop guidelines for the management of mosquitos.

Rural Residential

An integrated suite of measures to manage runoff and wastewater, including:

(i) Rural residential development to be properly managed:

- limit development to locations where the terrain, soils, block size and dwelling numbers are capable of containing all wastewater generated on the lot without leakage into the groundwaters.

Implementation:
- strategic, development control and zoning plans;
- declaration of conservation and riverine zones;
- landscape protection plans.

(ii) Drainage management:
- exclusion of stock from drainage lines and associated floodways;
- exclusion of development and stock from floodplains and riparian vegetation;
- establishment of swales and soakage pits in suitable soils and terrain;
- use of grassed/landscaped floodways;
- maintenance of buffer zones on the lower side of blocks and the exclusion of rural residential development from riverine zones;
- use of small water pollution control ponds.

Implementation:
- strategic, development control and zoning plans;
- application of sub-division & buliding controls;
- environment protection policies & management plans.

(iii) Wastewater management:
- adoption of composting toilets for sewage;
- recycling of treated wastewater;
- connection of all domestic wastewater (excluding septic tanks) to a common effluent system; and
- biological nutrient removal treatment of effluent or wastewater wetland treatment.

Implementation:
- environment protection policies, licencing & management plans;
- developer provision of common effluent systems - operation by local government.

(iv) Mosquito hazard management, including:
- identification of clearance zones around designated freshwater wetlands in order to exclude human habitation and other potentially conflicting uses;
- minimise sedimentation of tributaries in order to limit the potential for isolating pools of water from predators;
- design of edges to ponds and channels to minimise the potential for pools of water to be isolated from predators;
- construction of runnels to reduce the potential for pools of water to be isolated from predators;
- identification of pesticides which may be used safely with minimum risk to the ecology of the Passage and the catchment;
- request the Tropical Mosquito Research Centre and DPI to develop guidelines for the management of mosquitos.

Transport

(i) Transport landuse to be properly managed:

Implementation:
- strategic, development control and zoning plans;
- declaration of conservation and riverine zones;
- landscape protection plans.

(ii) Drainage management:
- minimise affected areas by fencing to prevent disturbance and drainage management
- diversion of drainage around works areas
- stabilisation of affected drainage lines through transport corridor
- save topsoil for subsequent rehabilitation of the site
- use of buffer zones and silt fences and sediment ponds

Implementation:
- application of development control & zoning plans;
- environment protection policies & management plans;

Extractive Industries

A suite of measures to manage runoff and dredging:

i) Extractive industry to be properly managed:
- based on land capability assessment;
- exclusion from sensitive sites such as erodible banks.

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- minimise affected areas by fencing to prevent disturbance and drainage management;
- diversion of drainage around area of operation;
- contain area of operation and collect/treat runoff prior to its discharge downstream;
- avoidance of exposure of acid sulphate soils;
- management of stockpile areas and access routes to prevent land degradation;
- location of stockpile areas within areas serviced by sediment ponds/runoff treatment systems;
- progressive rehabilitation as extraction proceeds;
- rehabilitation of site consistent with adjacent habitats and ecology.

Implementation:
- environment protection policies and management plans;
- application of development control and zoning plans.

(ii) Dredging management:
- exclusion of dredging operations from sensitive habitats;
- protection of the stability of channels and waterways;
- designation of sediment basins for the interception and dredging of material to maintain/rehabilitate habitats downstream of tributaries subject to high sediment loads.

Pasture (Grazing):

A suite of measures to manage runoff:

(i) Grazing to be properly managed:
- based on land capability assessment;

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- exclusion of stock from riverine corridors and margins;
- location of intensive stock holding areas away from major drainage lines;
- provision of vegetated buffer zones around the periphery of holdings.

Implementation:
- education and economic incentives;
- landcare programs;
- environment protection policies and management plans;
- application of development control and zoning plans.

(iii) Wastewater management:
- use of ponds and wetlands to treat wastewater from stock.

Implementation:
- environment protection policies and management plans.

Forestry (Pine Plantations):

A suite of measures to manage runoff:

(i) Forestry to be properly managed:
- based on land capability assessment;

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- improve design of roads and drainage to minimise soil erosion;
- limit size of clearing coupes, with staged clearing operation;
- exclusion of felling along stream and drainage lines and associated buffer corridors;
- rehabilitation of eroded/degraded areas;
- application of any pesticides/herbicides in locations, times and by methods to prevent/minimise any water-borne or wind-borne transport of these substances to receiving waters.

Implementation:
- environment protection policies and management plans;
- application of development control and zoning plans.

Horticulture

A suite of measures to manage tillage, fertiliser and pesticide use and runoff:

(i) Horticulture to be properly managed:
- based on land capability assessment;

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- direct drill based planting and/or contour-based tillage; and
- testing to assess optimum levels of fertiliser application;
- exclusion of horticulture from riverine zones or groundwater recharge zones;

- provision of vegetated buffer zones surrounding cultivated areas; and
- incorporation of swales to intercept runoff and re-use on the block, or route it through sediment ponds and wetlands prior to discharge from site.

Implementation:
- education and economic incentives;
- landcare programs;
- environment protection policies and management plans;
- application of development control and zoning plans.

Aquaculture

A suite of measures to manage discharges:

(i) Aquaculture to be properly managed:
- based on receiving water sustainability assessment;

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Discharge management:
- exclusion of discharges from tributaries susceptible to adverse impacts due to poor flushing or propensity for bar formation to isolate the waterway or other loadings on the tributary;
- exclusion of facilities from areas of permeable soils susceptable to water table impacts and groundwater pollution;
- exclusion of facilities from shoreline zones, riparian zones and floodplains;
- avoidance of exposure of acid sulphate soils during pond or channel construction;
- adoption of current discharge levels for BOD and TP as an interim ceiling of sustainable loadings;
- the Aquaculture Research Station be requested to undertake the development of guidelines for best management practices which are appropriate for the Passage and its tributaries;
- the intensive monitoring identified in Section 5.5.4 incorporate analysis of aquaculture discharges as part of a future review of the appropriateness of the interim discharge ceiling.

Recreation Boating

A suite of measures to manage wastewater discharges from vessels using the Passage or its tributaries:

(i) All vessels that have:
- sleeping accommodation and are greater than 6 m in length; or
- a galley; or
- a toilet;

are required to store waste in collection tanks or potable toilet with a pump-out facility for disposal at designated pump-out stations;
- provision of pump-out stations to receive wastewater discharges from vessels using the Passage or its tributaries.

Recreational and Commercial Fishing

An integrated suite of management measures including:

- maintaining commercial and recreation catches within sustainable levels;
- driving vessels in shallow waters so as not to disturb the habitat;
- ensure fishing gear is kept under close observation and retrieved when fishing is complete; and
- quick release of undersized catches if inadvertently caught.

Further Studies

The Review identified two major areas requiring further studies: the need for on-going water quality and ecological monitoring of waters of the Passage and its tributaries and the need to further develop best management practices which are appropriate for the local region. The recommended further studies are as follows:

Water quality and ecological monitoring

(i) selection of indicators of the health of the ecosystem. There is a need to:
- classify significant ecosystems/habitats and to define key indicators of their composition and structure;
- monitor indicators of key physico-chemical processes impacting on the ecosystems.

(ii) establishment of long term base-line water quality monitoring stations at:
- Bribie Island Bridge, to monitor long term changes in the quality of inflows from Deception Bay, the southern estuary, the Skids and the northern estuary.

(iii) periodically monitor storm events to:
- collect event water quality data to assess changes in pollutant exports from the catchment;
- review the calibration of the catchment based water quality model.

The monitoring should focus on representative stable catchments and catchments undergoing major landuse change.

(iv) utilisation of models in conjunction with monitoring to:
- evaluate changes in water quality across the catchment and within the estuaries;
- develop detailed local management plans and controls.

Best management practices

There is a need to:

- periodically monitor water quality to review the appropriate level of BMPs to be implemented;
- review BMPs in terms of their requirements and appropriateness for Pumicestone Passage and its catchment; and
- development of BMPs for aquaculture and mosquito management which are appropriate to the local region.

1. Introduction

1.1 Background

The purpose of an Integrated Management Strategy (IMS) is to integrate the management of land, water and related biological resources to achieve the sustainable and balanced use of these resources. It aims to foster joint action by all interested persons and groups, including those involved in primary production, environmental protection, land use planning, river engineering and natural resources management.

The continuing degradation of and increasing demands on land and water resources could reduce the ability of these resources to meet the community needs. Increasingly problems such as soil erosion, salinity, siltation of creeks and rivers, flooding, drainage, polluted water supplies, degraded water quality and damage to land and water based ecosystems are being encountered.

An IMS can provide a means of resolving these and other catchment problems.

1.2 Need for a Strategy

A Government policy to protect the environmental values of Pumicestone Passage and its environs and catchment has been in place since 1982. This policy was based on the recommendations of a 1982 study which identified specific catchment values and environment protection measures (QGIDC, 1982). The extent of the catchment is indicated in Figure 1.1.

The study found that Pumicestone Passage and its environs were important for conservation purposes, for fisheries and for recreation. The study also found the water quality in Pumicestone Passage was high but was dependent on two factors:

- the quality of water flowing from the catchment into Pumicestone Passage, and
- the pattern of water movement within the Passage itself.

Protection measures which were identified included:

- reservation and management of the Passage itself,
- acquisition, reservation and management of significant areas within the catchment and on Bribie Island for conservation and recreation purposes,
- prescription of an upper catchment population limit of 50 000 to 75 000,
- retention of extensive State Forests and private forests for productive forestry, and
- inclusion of consistent conservation policies in the respective strategic plans of Caloundra City Council and Caboolture Shire Council.

Since 1982 and the formulation of the strategies to protect the Passage, a number of changes in landuse and land tenure have occurred. These changes cast doubt on the reliance of the 1982 strategies to be effective in the future.

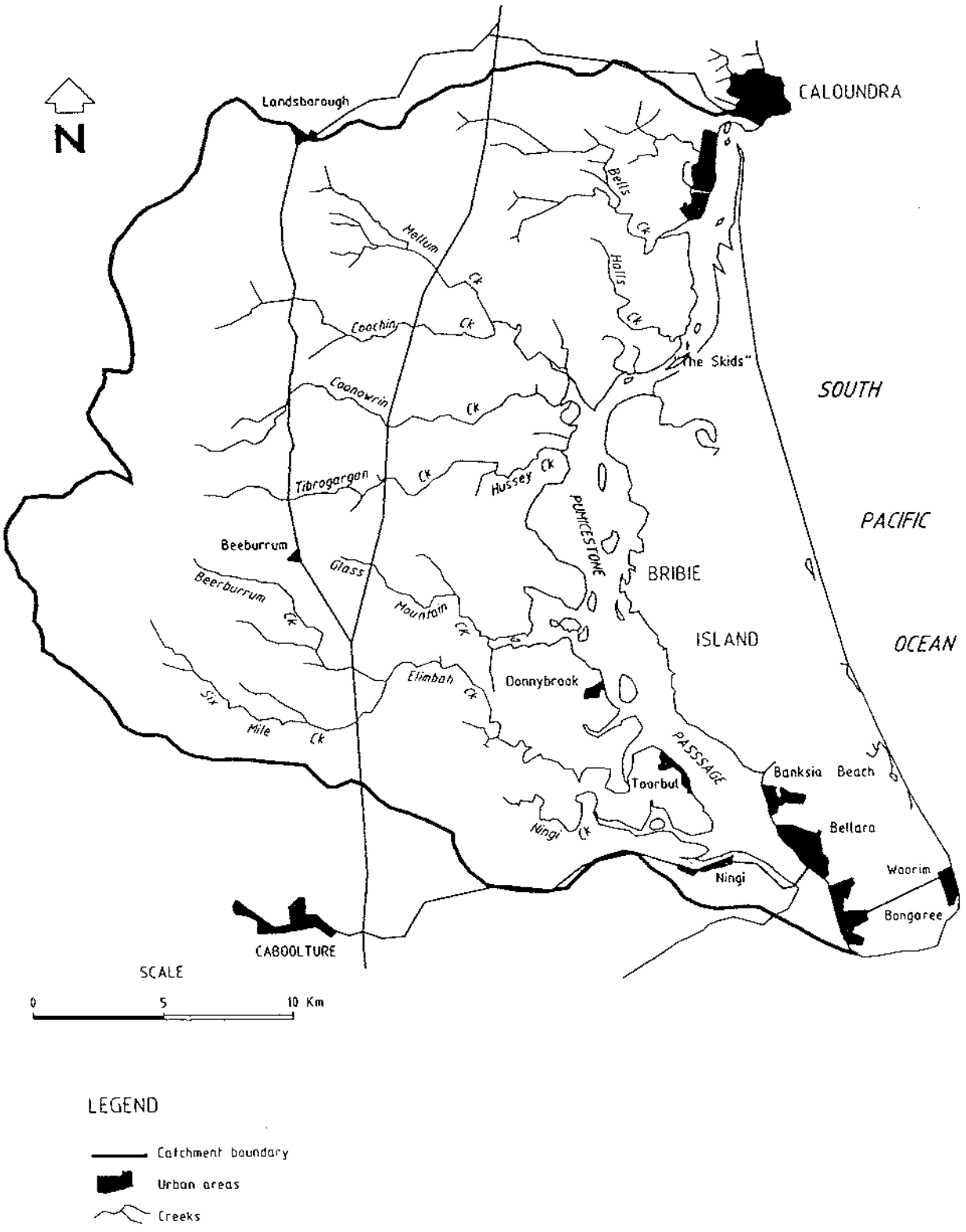


Figure 1.1 Pumicestone Passage, its Catchment and Bribie Island

Increases in water-borne pollutants and the reduction in water quality have been observed along with increases in intensive agricultural activity and expansion of agriculture and urban areas. The change in ownership of the private forests meant that there is no surety that the forests will be retained. Changes of landuse in these areas have the potential to impact on runoff water quality and ultimately the water quality of the Passage itself. Development approvals, which provide for a population within the catchment in excess of the proposed population limit of 75 000 recommended by the 1982 study have already been given. Investigations for new transport corridors are being conducted.

The planned changes in landuse have the potential to increase the export of nutrients and silt from the catchment to the tributary creeks and Pumicestone Passage. Increased pollutant loads have the potential to further degrade the environmental value of the Passage and its ecosystems unless appropriate resource management strategies are implemented.

The IMS study was commissioned to produce an ecologically sustainable strategy for landuse planning and resource management for Pumicestone Passage, its catchment and Bribie Island.

1.3 The Management Philosophy

Different ecosystems have different attributes and values and so have different conservation needs. Multiple use of a catchment and its waters means that conservation aims may include the protection of aesthetic, recreational, educational, ecological, biological, scientific, heritage and physical values.

The philosophy behind the IMS is the concept of "ecologically sustainable development". Three core objectives identified in the Draft National Strategy for Ecologically Sustainable Development, 1992 include the :

The philosophy behind the IMS is the concept of "ecologically sustainable development"

- enhancement of individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations;
- provision for equity within and between generations; and
- protection of biological diversity and the maintenance of ecological processes and systems.

Management of the catchment should also be consistent with the broad objectives of the "Towards a Queensland Conservation Strategy" (DEH, 1991) which are:

- to maintain essential ecological processes and life support systems;
- to preserve genetic and species diversity;
- to ensure the sustainable usage of species and ecosystems; and
- to maintain and enhance natural environmental qualities to provide for society's non-material needs.

The aim of the study is to produce an ecologically sustainable strategy for landuse planning and resource management. It also aims to ensure that the conservation values and the productivity of the land and water natural resources of Bribie Island, Pumicestone Passage and its catchment are maintained.

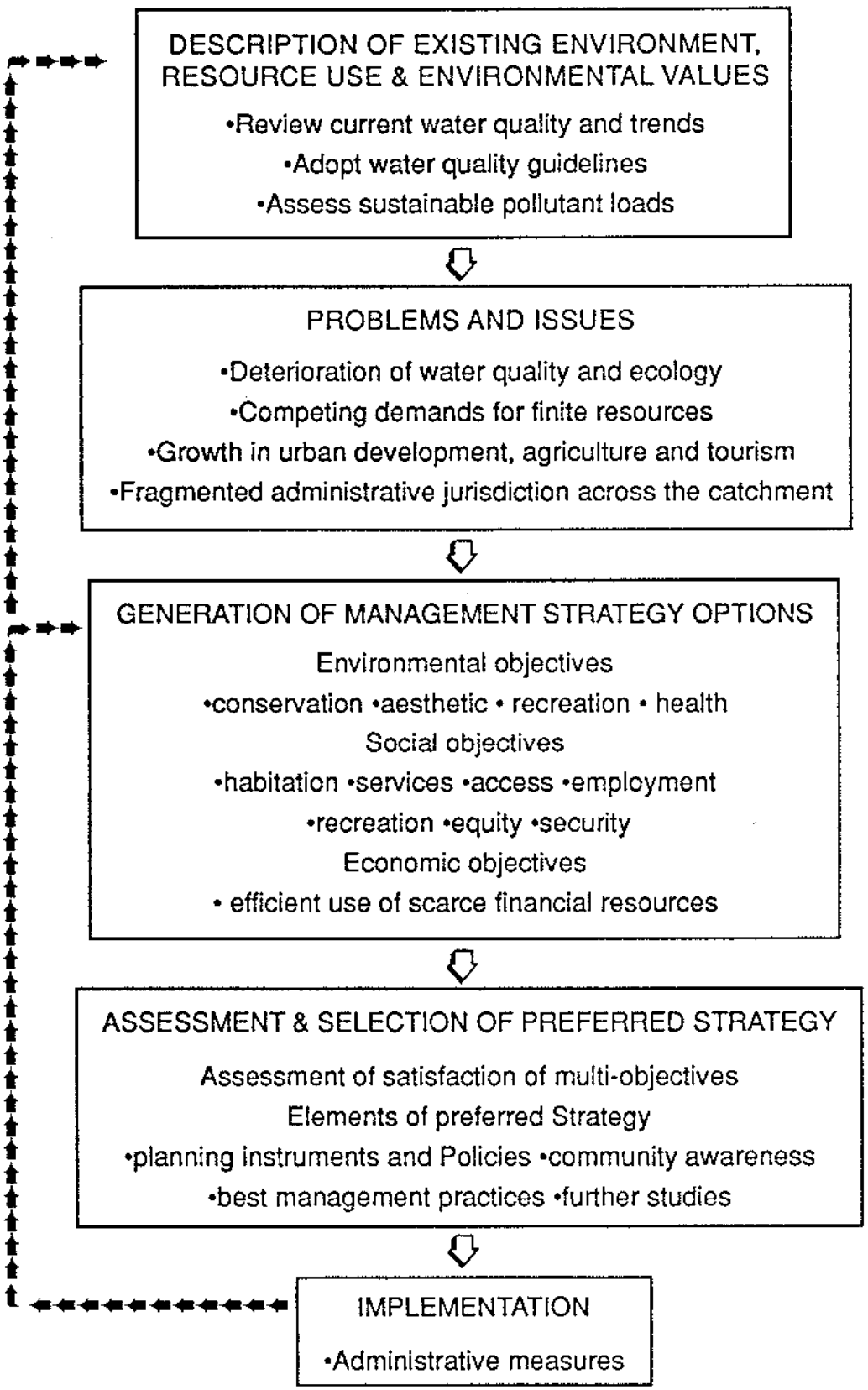


Figure 1.2 Development of a Water Quality based Integrated Management Strategy

1.4 The Study Structure

An outline of the process followed in developing the Integrated Management Strategy is given in Figure 1.2. Water quality considerations formed the primary focus of the IMS. Accordingly, the following report has been structured around the various activities and tasks identified in Figure 1.2 as follows:

Chapter 2 Reviews the ecological and environmental values of Pumicestone Passage to assess their significance in relation to other estuaries and the significant flora and fauna of the estuary. It also provides a qualitative description of the dominant geomorphological and ecological processes which determine community composition and structure as the basis for evaluating the impacts of landuse change and management practices for ecological sustainability. Water quality guidelines are also identified.

Chapter 3 Reviews the ecological and environmental values of the Pumicestone Passage catchment to assess their significance. The dominant geomorphological and ecological processes which determine community composition and structure are also described and form the basis for evaluating the impacts of landuse change and management practices for ecological sustainability.

Chapter 4 Reviews the water quality in Pumicestone Passage and its tributary creeks in 1978-1980 and 1991-1992 and considers current and projected water quality in terms of the water quality objectives for the tributaries and the Passage to allow the identification of current water quality and ecological problems and issues. The water quality objectives are also translated into sustainable loading criteria against which landuses and management practice options can be evaluated.

Chapter 5 Draws on the environmental values of Pumicestone Passage, its catchment and Bribie Island , the analysis of ecologically sustainable loadings and a range of management strategies. These strategies encompass landuse controls and management practices which are evaluated to establish if a strategy is able to contain cumulative pollutant exports within sustainable levels. A management strategy is also recommended.

1.5 Supporting Reports and Investigations

1.5.1 Departmental Reports and Data

A number of Queensland Government Departments provided a range of material during the course of the study, as follows:

- Department of Lands (Digital contours and digital cadastral database)
- Department of Local Government, Housing and Planning (Broadhectare study)
- Department of Primary Industries (Fisheries) (Seagrass mapping)
- Department of Primary Industries (Forestry) (Remnant vegetation)
- Department of Primary Industries (Water Resources) (Rainfall data)

To support the preparation of the strategy, a series of component studies was also commissioned as follows:

(i) Department of Primary Industries:

- groundwater resources

  a groundwater resources study was conducted with the aim of developing criteria appropriate to environmental protection of groundwater resources. The anticipated outcomes included: (i) improved definition of the groundwater resources, their catchment and safe yields, (ii) an assessment of recharge capabilities, and (iii) definition of water quality criteria appropriate to each groundwater catchment. The study highlighted widespread nitrate pollution of groundwater associated with recharge from areas of horticultural and urban landuse. Fertilisers and effluents from septic tanks have polluted the groundwater in many instances to the point where the groundwater does not meet health standards for safe potable water.

- agricultural chemical (fertiliser and pesticide) usage

  A study of pesticide use within the catchment was conducted to document the use of pesticides and review their likely environmental fate. The study noted that a significant increase in primary industry activities utilising pesticides had occurred since the previous 1982 study. The more persistent organochlorines have been progressively withdrawn from use since 1977, with a total ban on their use for bananas and sugar cane being implemented in the late 1980s. Despite these bans, residues of persistent organochlorines are still occurring in soils. The use of other persistent pesticides (EDB and lindane) continues.

  At the same time, the primary pesticide used for mosquito control (Temphos) is applied directly to water surfaces, is rapidly absorbed by plant tissue and bottom sediments where it is resistant to degradation.

- land resources and soil erosion

  Landuse information for the years 1974 and 1991 were collated by the Department of Primary Industries in 1992 and was provided in both a report entitled "Pumicestone Passage Catchment Area Comparative Landuse Study: 1974 - 1991" and in a digital format. Data collected included:

  - landuse within the study area for 1974 and 1991;
  - land tenure; and
  - remnant vegetation.

  A survey of soil erosion rates on horticultural farms within the catchment was also conducted. The survey concluded that the majority of soil erosion on horticultural farms in the catchment occurs on pineapple cropping land predominantly on shallower slopes.

- aquaculture:

  A report on the aquaculture component outlined the types and quantities of nutrients discharged from aquaculture facilities. The report found that effluent from aquaculture facilities was highly variable both in quantity and quality.

(ii) Department of Environment and Heritage:

- water quality in Pumicestone Passage and its tributaries:

  a major assessment of the landuse and water quality of Pumicestone Passage and environs was undertaken over the period 1978 to 1981 to investigate potential urban development within the Pumicestone Passage catchment. The final report which was entitled "Pumicestone Passage Water Quality and Landuse Study" (QGIDC, 1982).

  Surface water quality monitoring was undertaken over the period August 1991 to July 1992. The results from field and laboratory testing were used extensively in the course of the study for comparative purposes as well as the development of the computer based water quality model.

- coastal processes:

  the review of coastal processes was conducted in two parts. The first part involved an assessment of existing data to gain a qualitative impression of the coastal processes and possible future movements of northern Bribie Island and the extent, if any, of sedimentation in the central part of the Passage. The second part was a quantitative assessment of a number of factors highlighted during the first part of the study.

- management planning for existing and proposed conservation reserves on and in the vicinity of Bribie Island and Pumicestone Passage:

  as part of its program of preparing management plans addressing conservation and appropriate use of the national, environmental and marine parks it manages, DEH in conjunction with other interest Departments and Caloundra and Caboolture Councils prepared a report on the management framework, constraints and issues for the national, environmental and marine parks of Bribie Island and Pumicestone Passage.

1.5.2 Other Reports and Data

Strategic Plans from the Caloundra City Council (1992) and Caboolture Shire Council (1988) present the current planning policies of both Councils. These Strategic Plans, which are draft documents and are under review, were provided in a digital format.

Two reports, prepared by WBM Oceanics on behalf of Queensland Commodity Exports Pty Ltd present water quality monitoring data for Pumicestone Passage before and after the logging of pine forests within the catchment. Monitoring was undertaken from June 1991 to February 1992.

A report on the current state of archaeological knowledge of Pumicestone Passage , its catchment and Bribie Island was also prepared as part of the study by the Department of Anthropology and Sociology, University of Queensland. The scope of the study included:

- an assessment of the known and predicted distribution of archaeological sites within the study area,
- the design of a future survey strategy for the study area,
- specification of appropriate survey and sampling methods,
- identification of relevant local Aboriginal communities and the preparation of a statement as to key Aboriginal heritage issues.

2. Pumicestone Passage Values and Uses

A review of the environmental values of Pumicestone Passage was undertaken to re-assess their significance in relation to other estuaries and the significant flora and fauna of the estuary. It also provides a qualitative description of the dominant geomorphological and ecological processes which determine community composition and structure in these waterways as the basis for evaluating the impacts of landuse change and management practices for ecological sustainability. In particular, this review draws on the 1982 study (QGIDC, 1982).

The section describes the dominant geomorphological and ecological processes within Pumicestone Passage

2.1 Description of Estuary

2.1.1 Physical description

Estuary location and climate
Pumicestone Passage is located on the eastern coast of Australia just north of Brisbane, between 26° 48' 30" South and 27° 06' 00" South latitude, and 153° 02' East and 153° 10' East longitude.

It is located in a sub-tropical area and experiences a wet summer and a dry winter. The maximum and minimum annual average temperature range from 25.4 °C to 15.8 °C. The mild climate of the study area is governed by its sub-tropical location and associated weather patterns.

Geology
Bribie Island is a barrier island and comprises a strandplain of prograded beachridges of both Holocene and Pleistocene age (DEH, 1992a; Heckel and Day, 1976). The geological history of the bay has been dominated by sea level change (DEH, 1992a, Maxwell, 1970). Sea-level oscillations have produced a succession of differing sedimentary environments which have controlled sediment deposition.

Pumicestone Passage occupies an area of predominantly Quaternary marine and fluvial deposits, with the bed of the estuary intersecting Jurassic sedimentary rock.

The geology of Pumicestone Passage is significant for several reasons because it:

- provides a medium for the growth of marine organisms;
- aids in the transportation of sand; and
- influences, and is a reflection of, past and present coastal processes.

A significant proportion of Pumicestone Passage is less than two metres deep due to extensive intertidal deposits. Navigation is restricted to shallow draft vessels.

Estuary classification
Pumicestone Passage is a coastal plain or passage-type estuary which has been formed by Bribie Island to the east and the salt flats and wallum plains of Caboolture and Caloundra Shires to the west. The longitudinal axis of the Passage extends broadly north-south for approximately 45 km.

Pumicestone Passage is also one of only four major passage-type estuaries on the Queensland coast

Bribie Island and Pumicestone Passage form the northern most section of Moreton Bay, being one of only two large estuarine bays in Australia. The Passage is also one of only four major passage-type estuaries on the Queensland coast. Pumicestone Passage and southern Moreton Bay are the only such landscapes located near a large population centre (DEH, 1992a, QGIDC, 1982).

Major Physical Components

Pumicestone Passage is a passage-type estuary with a net tidally-induced exchange of around 1.7 million cubic metres of sea water occurring in a northerly direction on average each day. The southern inlet/outlet to the Passage is predominantly a channel with relatively steep sides and deep waters with a bed of coarse sediment which experiences rapid currents. A narrow and shallow channel ("the Skids") occurs in the region of the "null point" between the southern and northern estuaries. Tidal exchanges at the northern (Caloundra) outlet of the Passage are curtailed by a significant ocean sand bar located at the mouth of the estuary.

North and south of "the Skids" the Passage is wide and shallow, with predominantly fine silt and clay sediments and extensive intertidal zones. The Passage is less than 2 metres deep, at mean sea level, over 80% of its area.

A number of tributary streams with substantial estuaries discharge into the Passage. During the dry season, sediment builds up typically at the mouths of the streams. Flows in the tributaries during the wet season or during major floods are typically sufficient to scour out these deposits.

The physical behaviour of the Passage is influenced by any change to the geometry of the water body, for example as a result of dredging, of increasing the tidal compartment (i.e. the volume of water between high and low tide level) or the construction of any tidal barrier structures. The changes which could have a significant effect on the dispersion and assimilation of pollutants within the Passage are further constriction of the already narrow channels around "the Skids" due to continuing siltation, and increasing the tidal compartment north of "the Skids" by the development of canal estates (QGIDC, 1982).

In hydraulic terms, the estuary can be considered to be comprised of a series of irregular basins ranging in surface area from 470 Ha to 1380 Ha. For the comparative analysis of water quality data and water quality modelling the Passage was divided into five basins. The hydraulic properties of these five basins are given in Table 2.1.

Table 2.1 Hydraulic Properties of Pumicestone Passage

Basin	Basin Name	Surface Area (ha)	Volume (ML)	Average Depth (m)
Bongaree - Toorbul	PPASS1	1060	36400	3.44
Toorbul - Mission Point	PPASS2	1370	19700	1.44
Mission Point - Hussey Ck	PPASS3	1380	13800	1.00
Hussey Ck - Halls Ck	PPASS4	470	3900	0.84
Halls Ck - Caloundra Bar	PPASS5	740	8350	1.13

2.1.2 Geomorphology

The geomorphology of Pumicestone Passage is not only relevant for understanding present-day landscapes, but is also necessary for understanding the region's ecology.

As noted above, the Passage was created as a result of the formation of a barrier (Bribie Island). The evolutionary pattern of such systems is characterised by landward movement of the barrier island, as a result of coastal erosion on the ocean side and sedimentation within the estuary.

The propensity for formation of sand bars at the mouths to the estuary is a function of the width and depth of the mouth, the tidal and freshwater discharge velocities and the ocean swell in the proximity of the mouth. The southern mouth is free of sand bar formation, due to its width and depth, the extensive tidal currents through the mouth and the shelter from ocean swells afforded by Deception Bay.

The northern (Caloundra) mouth is more susceptible to the formation of a sand bar as a result of a reduced tidal discharge, its shallow mouth and its direct exposure to the ocean swell.

The salinity regimes observed through the Passage, ranging from euhaline (30 - 40%), at the mouths to mesohaline (5 - 18%) at the null point.

A hydrodynamic model has confirmed that a tidally-induced net flow occurs in Pumicestone Passage. Although the net flow would vary from day to day, its average magnitude and direction can be expected to be 1.825 million cubic metres per *tidal* day in the northerly direction (QDIDC, 1982).

The presence of net tidally-induced circulation in the Passage is of great significance for water quality and is a major factor distinguishing it from normal estuaries with only a single opening to the sea. In addition to mechanisms of fresh water inflow and tidal dispersion common to all Queensland estuaries, it provides an additional means of flushing pollutants from the system to the sea (Wallace, 1982). Its mean magnitude is dominant by comparison with fresh water inflow.

Sediments
Sediments, together with detrital material, are the major determinants of ecology and productivity of estuaries for the following reasons:

(i) sediment provides the habitat for benthic organisms such as burrowing polychaetes and crustaceans;
(ii) suspended material modifies the light regimes and productivity of estuaries;
(iii) particle size and associated adsorbed ions have a considerable bearing on dominant plant species; and
(iv) loading rates and the bond strength of ions are principle determinants of the availability of nutrients to interstitial and overlying waters.

Sediment loading on the Passage is a function of tidal inflows (ocean sources) and tributary discharges.

As ocean sources comprise only medium to coarse sand fractions, the bulk of the fine sediment through the Passage is derived from tributary discharges. There is little evidence of lateral or shoreline erosion through the Passage.

The level of sediment loading and particle size and composition varies through the Passage. The inlet/outlet channels adjacent to the mouths of the estuary are characterised by fine to coarse sand which provide a limited substrate for benthic organisms compared to the finer silts and clays further up the estuary.

Finer silts and clays in the central region of the Passage provide a rich substrate for benthic organisms and rooted plants and act as both a significant source and sink for adsorbed ions thereby dampening variations in water quality. The silts and clays are subject to re-suspension and redistribution by currents, wind driven mixing and by flows within the intertidal zone. The consultation comments also indicate a significant movement of sediments throughout the Passage.

The patterns of sediment deposition and resuspension are further modified by vegetation through local reductions in flow velocities and the associated deposition of sediments and the trapping of sediment by roots. However, zones of high suspended solids adjacent to discharge zones suppress the growth of vegetation through the limitation of light.

Suspended solids and light regimes
Suspended solids discharged into the estuary comprise fine colloidal clays, complex chelates of iron and manganese and organic material from wetlands and forest areas.

Concentrations of suspended solids through the Passage are influenced by a number of factors. The coagulation of suspended solids and their associated deposition is significantly enhanced by the high electrolyte concentration of seawater in the estuary. However, the organic chelates may improve the stability of metal complexes to sustain their concentrations well above their solubility product value.

Patterns of suspended solids through the Passage include:

(i) zones of maximum turbidity adjacent to the tributary outlets due to the presence of abiotic and dead biotic material;
(ii) reducing concentrations of suspended solids due to sedimentation as a function of the distance from the zone of tributary discharge;
(iii) increasing biotic material associated with photosynthesis in areas of improved clarity and high nutrient loads; and
(iv) zones of re-suspension of abiotic and biotic material associated with tidal currents.

Nutrient loading regimes
The nutrient loading regimes are linked primarily to the transportation, deposition and resuspension of particulate material.

Sources of nutrient loading comprise marine (tidal) inflows, tributary discharges and point source discharges, including effluent from aquaculture farms. Increased concentrations of nutrients in Deception Bay associated with discharges from the Caboolture River and other sources represent a potential source of increased nutrient loading on the Passage.

One component of the nutrient loads discharged by the tributaries is generated from non-point (diffuse) sources. These sources include direct rainfall precipitation and stormwater drainage from both surface runoff and groundwater seepage. Stormwater drainage may contain pollutants from a range of diffuse sources including agriculture and horticulture, forestry and/or from urban areas. The sediments forming the bed and banks of the waterways are also non-point sources of pollutants.

The other component of the nutrient loads discharged by the tributaries is generated from point sources including wastewater treatment plants, gravel washing plants, aquaculture operations etc. Various extractive industries based within or adjacent to the waterways including sand extraction and dredging are also potential point sources of pollution.

Zonation - terrestrial forest/heath, freshwater marshes, intertidal, subtidal zones
The upper slope, lower (wetland) slope, tidal zone and sub-tidal basin terrain units determine the characteristics of ecological succession at the estuary margins and govern the interactions between zones.

The freshwater wetlands modify catchment drainage patterns and water quality through the recharge of aquifers, temporary storage of floodwaters, trapping of nutrients and the export of significant levels of organic chelates which subsequently modify the availability of nutrients in the estuary.

The intertidal zones and salt marshes impact on water quality through the deposition of fine sediment and nutrients by the rising tide and the discharge of nutrients and detritus by ebb tide flow. These zones represent an important source and sink for nutrients which shape the sub-tidal ecology of the estuary. Material deposited in the intertidal zone is also highly erodible if the equilibrium of these zones is disrupted by clearing or filling.

2.1.3 Ecology

The low topographical relief of the Passage is typical of a barrier island estuary with a high pelagic ratio and productivity. It is characterised by extensive mud flats/intertidal zones and associated salt marshes and mangrove areas as indicated in Figure 2.1.

Tidal saltmarshes
The saltmarsh community consists of predominantly *Salicornia quinqueflora* and *Triglochin striata* in open to sparse herblands and large areas of bare mud (refer Figure 2.1). *Sporobulos virginicus* closed grasslands occur often in pure dense swards (DEH, 1992a; McDonald and Elsol, 1979). The saltmarshes are important buffer areas in the event of rising sea levels. The saltmarsh and claypans also provide areas for the potential expansion of mangroves.

Mangrove areas
The Pumicestone Passage mangrove community includes all seven species of mangroves which occur in Moreton Bay (*Avicennia marina var. australasica, Aegiceras corniculatum, Ceriops tagal var. australis, Rhizophora stylosa, Bruguiera gymnorhiza, Excoecaria agallocha, Lumnitzera racemosa*) (DEH, 1992a; Hyland et al., 1989). The most common mangrove is *Avicennia marina. Lumnitzera racemosa*, the rarest of all the mangrove species in Moreton Bay, occurs as isolated plants or small groups in Pumicestone Passage.

A tall shrubland of river mangrove *Aegiceras corniculatum* occurs adjacent to Hussey Creek and there are extensive tracts of grey mangrove scrub *Avicennia marina* surrounding Thooloora Island and nearby on the Bribie Island shore. The spotted mangrove-shrubland *Rhizophora stylosa* occurs as a relatively narrow strip of vegetation in several areas (Figure 2.1).

The most significant area of mangroves is the forest of orange mangrove *Bruguiera gymnorhiza* on the mainland shore opposite Long Island (DEH, 1992a; Olson, 1979). This stand is particularly valuable because it is an almost pure stand of mature trees.

Where a continuous intertidal gradient exists without extensive landward freshwater flow the various plant communities form a continuous sequence. Single-stemmed trees of 8 to 10 m give way to lower trees which become tall multiple-stemmed shrubs. Closed communities of low shrubs eventually become open and sparse communities with an understorey of halophytic herbs and grasses.

Seagrass beds
The Pumicestone Passage wetlands include four of the six species of seagrass found in Moreton Bay, (*Zostera capricorni, Halophila ovalis, H. spinulosa* and *H. decipiens*)

A survey of the seagrasses of Moreton Bay (from the Broadwater to Toorbul Point) identified seagrass meadows and areas of habitat supporting sparse and patchy seagrass cover within the Passage. (Crimp 1992; Hyland et al., 1989) (Figure 2.1).

Prawn trawling is the most important commercial fishery in Moreton Bay and three of the principal target species (*Penaeus esculentus, Metapenaecus endeavouri* and *M. bennettae*) are dependent on, or utilize seagrasses for juvenile habitat (Crimp, 1992; Young, 1978). Furthermore, some seagrass meadows support greater numbers of juvenile prawns compared to others (Poiners, et al., 1987), and in Moreton Bay, seagrass meadows dominated by *Zostera capricorni* are the most important to the commercial prawn trawl fishery (Crimp, 1992; Young, 1978).

Fauna

The fundamental determinants of the size of any level of aquatic life in a waterway are the status and extent of the supporting habitat and environment. Within the Passage, productivity of the aquatic fauna is influenced by a number of factors including the relative size, area and location of mangrove forests, seagrass meadows, sand and mud banks, bars, beaches and nutrient input from the tributary creeks.

Fish

The tidal wetlands act as nursery areas for many fish and crustacean species of recreational and commercial importance, particularly yellowfin bream (*Acanthopagrus australis*), mullet (*Mugil cephalus*), whiting (*Sillago ciliata, S. analis* and *S. maculata*), luderick (*Girella tricuspidata*), flathead (*Platycephalus fuscus*), garfish (*Hemiramphis spp.*) sand crabs (*Portunus pelagicus*), mud crabs (*Scylla serrata*) and several species of prawns (Tiger prawn (*Plebejus esculentus*), Bay prawn (*Metapenaeus bennettae*) Endeavour prawn (*Metapenaeus endeavouri*) and Hard-back prawns (*Trachypenaeus fulvus*)) (Department of Environment and Conservation, 1989).

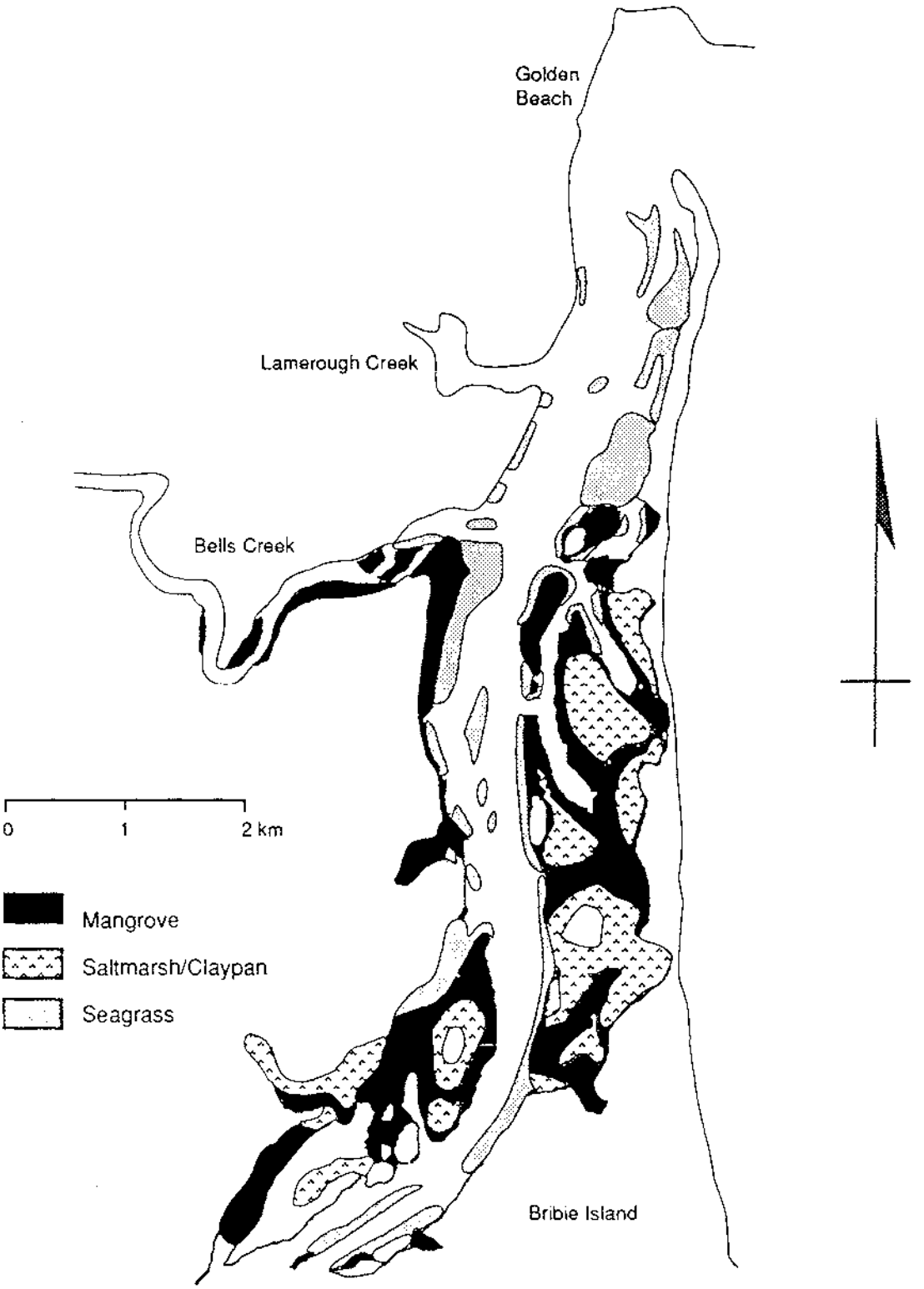


Figure 2.1a Mangroves, Seagrasses, Saltmarshes and Claypans of Northern Pumicestone Passage (after DEH, 1992a)

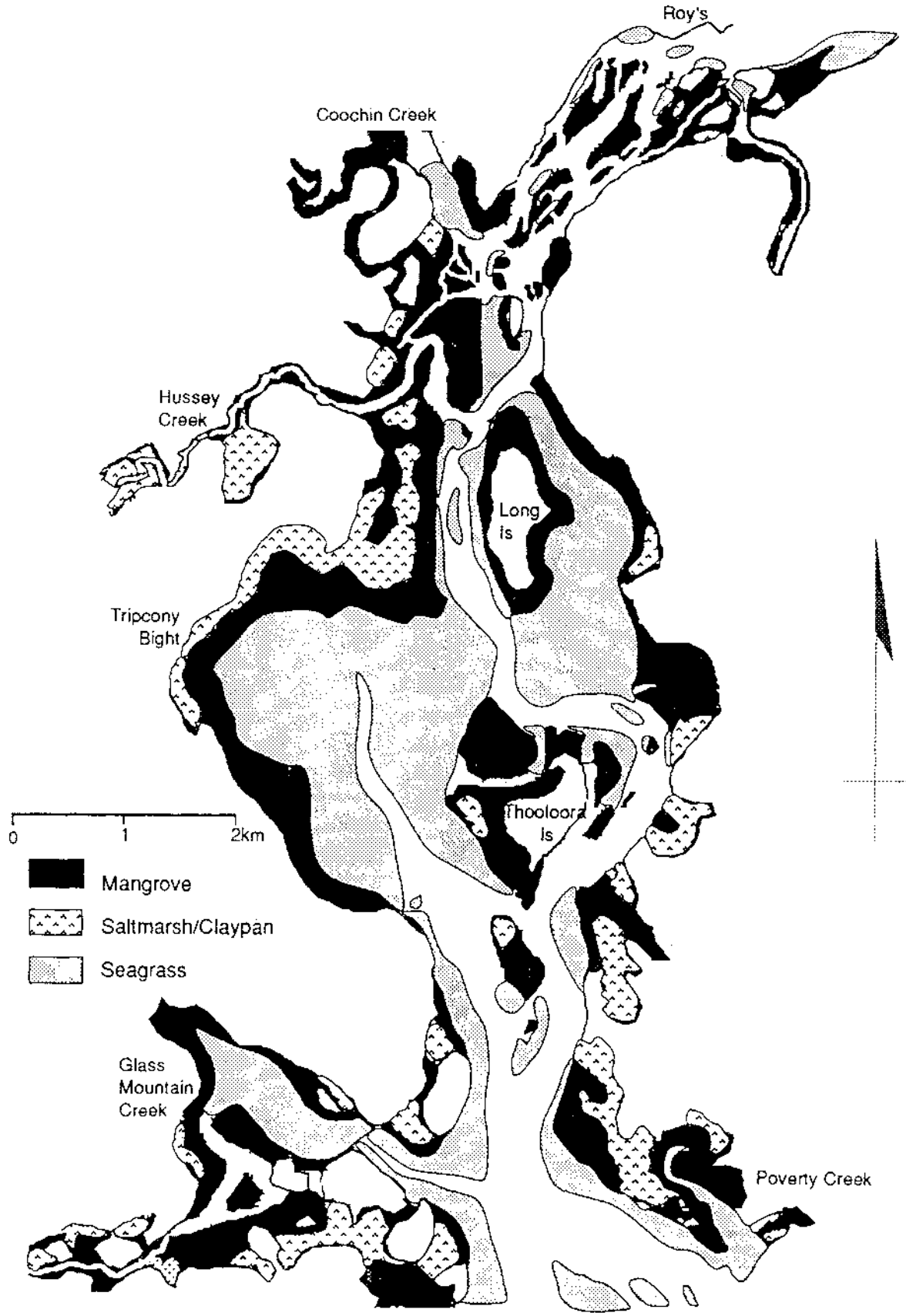


Figure 2.1b Mangroves, Seagrasses, Saltmarshes and Claypans of Central Pumicestone Passage (after DEH, 1992a)

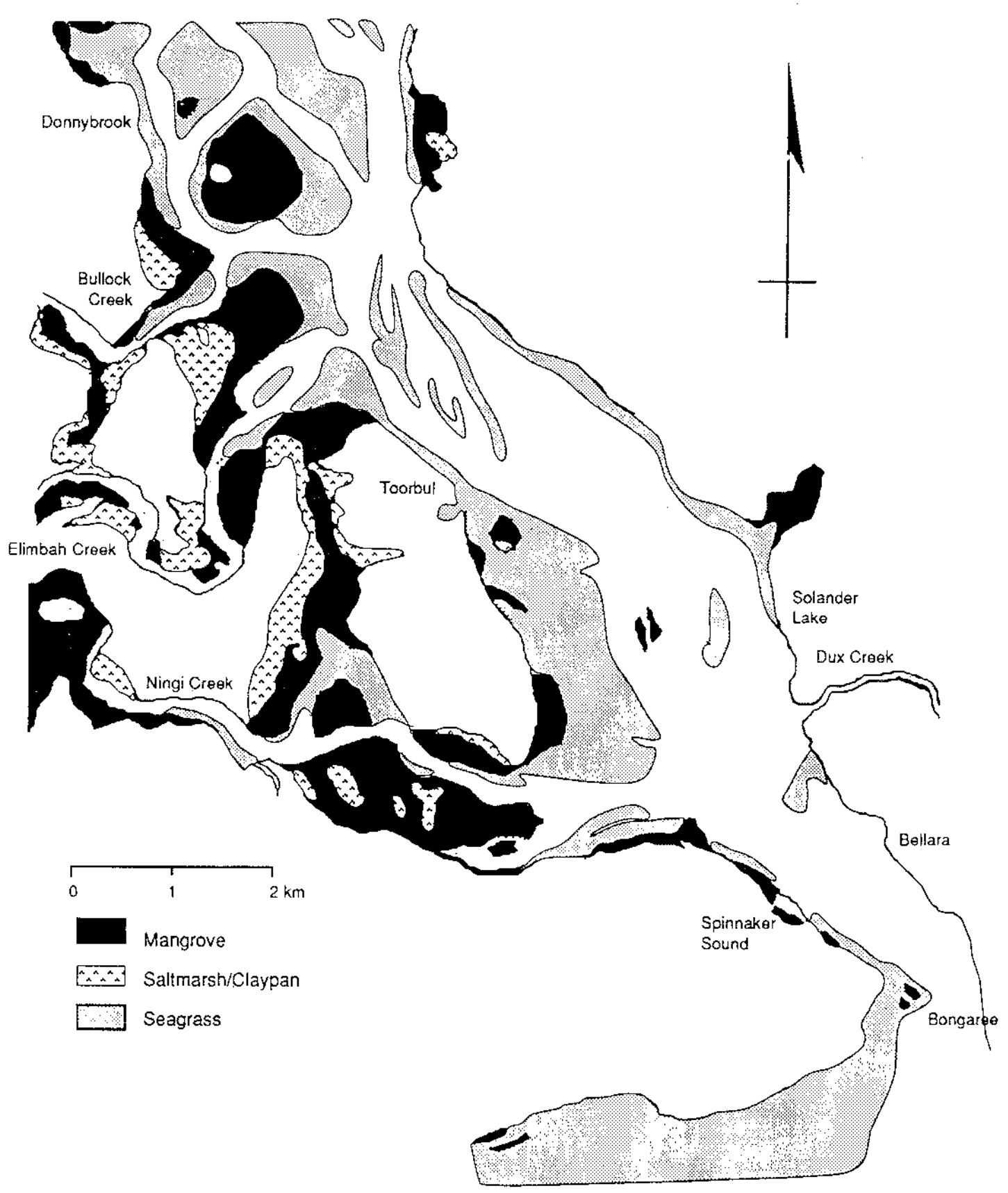


Figure 2.1c Mangroves, Seagrasses, Saltmarshes and Claypans of Southern Pumicestone Passage (after DEH, 1992a)

The northern section of the Passage between Bells Creek and the Caloundra Bar is one of the principal areas in south-east Queensland for the spawning run of yellowfin bream during the winter months. Other important species, including summer whiting, flathead and luderick also spawn in the area around the Caloundra surf bar (Department of Environment and Conservation, 1989).

Tagging studies carried out by DPI (Fisheries) have shown also that the bream stocks of Pumicestone Passage are crucial to the entire south-east Queensland bream fishery (DEH, 1992a; Pollock, 1984).

Dugong

Moreton Bay supports a permanent population of over 500 dugong (*Dugong dugon*). Despite their large size (3 m long and over 400 kg in weight) the dugongs tend to avoid areas of high human use and are difficult to observe under most conditions. Dugongs are of particular biological and conservation significance. They are the only herbivorous mammals that are strictly marine (Nishiwaki and Marsh, 1985), and they are considered to be vulnerable to extinction (Crimp, 1992, Thornback and Jenkins, 1982).

The Moreton Bay dugong population is unusual, and perhaps unique, for two reasons. First, it is the only large dugong population known to survive in such close proximity to a major city. Second, Moreton Bay dugongs tend to occur in relatively large herds of 50 to 250. These apparently unique biological characteristics, combined with the dugong's role in the cultural history of the region and its international status as a vulnerable species, put special responsibilities on management authorities to ensure the conservation of the Moreton Bay dugong population.

The distribution of dugongs within Pumicestone Passage is partially governed by the distribution of suitable areas of seagrass - their principal food. Sightings of dugong are common within the significant seagrass meadows. Herds of approximately a dozen dugong have been sighted in the central sections of the Passage.

Turtles

The green turtle (*Chelonia mydas*) is the most common species sighted. It is herbivorous, feeding on algae. Other species include the loggerhead (*Caretta caretta*) which is also regularly sighted in the Passage.

Dolphins

The bottlenose dolphin (*Tursiops truncata*) and the Indo-Pacific hump-backed dolphin (*Susa chinensis*) are seen regularly in the Passage.

Plankton

The plankton community varies significantly between the southern and northern estuaries of Pumicestone Passage. The plankton community which populates the southern estuary is typical of marine system comprising zooplankton and fish spawn whereas in the vicinity of Coochin Creek shrimp and crustacean forms of plankton are dominant.

Polychaetes

Polychaetes include swimming, crawling, burrowing and tube dwelling worms. Recreational and commercial activities have the potential to affect polychaete populations within Pumicestone Passage. Limited data are available on the severity of previous polychaete extractions by either recreational fishermen or commercial wormers.

Crustacea and molluscs

Pumicestone Passage supports a reasonable diversity of crustaceans, sand crabs (*Portunus pelagicus*), mud crabs (*Scylla serrata*) and several species of prawns (tiger prawn (*Plebejus esculentus*), bay prawn (*Metapenaeus bennettae*) endeavour prawn (*Metapenaeus endeavouril*) and hard-back prawns (*Trachypenaeus fulvus*)). In 1976 seasonal closure of commercial extraction was extended to year round closure.

The Passage also supports a range of shell fish including mussels, mud welks, oysters, crabs, mangrove snails and worms.

Avifauna
Quantitative information regarding terrestrial fauna is limited. Water birds common in the Passage and also at Buckley's Hole include the White-faced heron (*Ardea novaehollandiae*), striated heron (*Butorides striatus*), pacific black duck (*Anas superciliosa*), grey teal (*A. gibberifrons*), chestnut teal (*A. castanea*), black swan (*Cygnus atratus*), sacred ibis (*Threskiornis aethiopica*), straw-necked ibis (*T. spinicollis*), royal spoonbills (*Platalea regia*), great egret (*Egretta alba*), little egret (*E. garzetta*), eastern reef egret (*E. sacra*), and the Australian pelican (*Pelecanus conspicillatus*).

Seabirds common in the Passage include little terns (*Sterna albifrons*), crested terns (*S. bergii*) and common terns (*S. hirundo*) which use the Golden Beach roost. Flocks of 1000 little terns have been counted at the Golden Beach roost site and large flocks of several hundred regularly forage in Tripcony Bight (Driscoll, 1991). Darters (*Anhinga melanogaster*) and little pied cormorants (*Phalacrocorax melanoleucos*) are also common in the Passage and little black cormorants (*P. sulcirostris*) are common in winter, particularly at Buckley's Hole (DEH, 1992a; Driscoll, 1991).

Within the mangrove communities, kingfishers, warblers, whistlers and honeyeaters are common. Honeyeaters are also common in the Melaleuca forests and woodlands.

Several species of raptors, wedge-tailed eagle (*Aquila audax*), white-bellied sea eagle (*Haliaeetus leucogaster*), osprey (*Pandion haliaetus*), Nankeen kestrel (*Falco cenchroides*), whistling kite (*Haliastursphenurus*) and Brahminy kite (*H. indus*) are commonly seen in the foreshore habitats (and also within the pine plantations). Ospreys and Brahminy kites and collared sparrowhawks (*Accipiter cirrocephalus*) have been recorded nesting behind the mangroves along Pumicestone Passage. White-bellied sea eagles have been recorded nesting on Cowie Bank - a site which was abandoned in favour of Goat Island when adjacent forest was cleared for pine plantations (DEH, 1992a; Czechura, 1984). Peregrine falcons (*Falco peregrinus*) have been also observed hunting cormorants in Pumicestone Passage (DEH, 1992a; Czechura, 1984).

The wetlands provide habitat not only for resident and migratory avifauna but are important to other mainland avifauna during periods of environmental stress such as droughts in hinterland areas. *M. quinquenervia* trees flower prolifically in autumn and winter which is a time of high stress for many fauna. There is evidence to suggest that melaleuca nectar is an important food source for many birds and mammals at this time of year (DEH, 1992a; Hall, 1991).

Nectar and pollen produced by *Eucalyptus intermedia* and other bloodwoods in summer as well as that produced by melaleuca in late winter are a principal component of the diet of four species of flying fox found in south-east Queensland, namely the little red flying fox (*Pteropus scapulatus*), the grey-headed flying fox (*P. poliocephalus*), the black flying fox (*P. alecto*), and the Queensland blossom bat (*Syconycteris australis*) (DEH, 1992a; Hall, 1991).

Flying fox populations have been declining since the 1930s with more dramatic declines in the last 10-15 years, particularly the last two years. This has been attributed to the large-scale clearing of melaleuca wetlands and other habitat (DEH, 1992a; Hall, 1991).

Surveys undertaken in December 1989 (DEH, 1992a; Thompson, 1990) and November 1990 (DEH, 1992a; Driscoll, 1990) estimated between 10 000 and 15 000 waders use Pumicestone Passage in summer, indicating that it is a wader refuge of national significance, and of international significance for some species. Pumicestone Passage has approximately 20 percent of the waders in Moreton Bay in the summer, making it a significant component of the estuarine complex of Moreton Bay which is now recognised as one of Australia's most important wader refuges.

Trophic structure and productivity

The trophic structure within Pumicestone Passage depends primarily on the balance between production and loss. The loss of phytoplankton is mainly due to sinking below the photic zone or grazing by animals. Usually an inverse ratio exists between the numbers of phytoplankton and zooplankton with zooplankton peaks following the peaks of phytoplankton. Grazing promotes a rapid return of nutrients to water. There is some evidence that in areas where phytoplankton may be consumed as fast as it is produced, often it appears as if there is insufficient phytoplankton there to sustain the herbivores. It is possible that many herbivore forms can be carnivorous now and then. This indicates that detritus is an extremely important component of most herbivores diet (Holmes, 1989).

2.2 Environmental Values

This section reviews the environmental values of Pumicestone Passage

The key environmental values of Pumicestone Passage and the estuarine reaches of the creeks discharging into the Passage have implications for water quality. These values have been considered in the formulation of water quality guidelines for Pumicestone Passage and its tributary creeks.

2.2.1 Ecosystem protection

The health of the biological community is the determinant of the health of aquatic systems. Biological evaluation and monitoring of ecosystems is a necessary part of ensuring ecosystem protection.

Although individual biological species or the biological community as a whole may tolerate stressors such as toxicants and salinity, the assimilation of materials such as phosphorus, nitrogen and organic matter by individual organisms can lead biological communities to change in response to these materials. The ability to perceive these changes is limited by the precision of assessment methods and the understanding of the systems (ANZECC, 1992).

To be consistent with the philosophy of sustainable development (Commonwealth of Australia, 1990), water quality objectives for the protection of aquatic ecosystems require a non-degradation policy where the purpose of management is to ensure the maintenance and improvement of such ecosystems (ANZECC, 1992).

The establishment of physico-chemical water quality guidelines which respond to local conditions is necessary for ecosystem protection, to determine discharge controls and to identify problem contaminants in water.

The development of biological indicators applicable to the protection of aquatic ecosystems is in its infancy throughout the world. Owing to a general lack of detailed study of the biology and ecology of aquatic ecosystems in Australia, it is difficult to specify what biological indicators might be appropriate (ANZECC, 1992).

2.2.2 Conservation

The wetlands of Pumicestone Passage and Bribie Island have a high species diversity and contain species and communities which are rare or threatened.

The wetlands of Pumicestone Passage and Bribie Island have a high species diversity and contain species and communities which are rare or threatened.

Flora

This review has confirmed that the Pumicestone Passage wetlands include four of the six species of seagrass found in Moreton Bay, (*Zostera capricorni, Halophila ovalis, H. spinulosa*, and *H. decipiens*), and all seven species of mangroves which occur in Moreton Bay (*Avicennia marina var. australasica, Aegiceras corniculatum, Ceriops tagal var. australis, Rhizophora stylosa, Bruguiera gymnorhiza, Excoecaria agallocha* and *Lumnitzera racemosa*) (Hyland *et al.*, 1989).

The mangroves of Pumicestone Passage, which were previously described by Olson (1979) have been verified. The most significant area of mangroves is the forest of orange mangrove *Bruguiera gymnorhiza* on the mainland shore opposite Long Island (Olson, 1979). This stand is particularly valuable because it is an almost pure stand of mature trees. The only other sizeable community of this species in Moreton Bay is on the northern tip of Russell Island.

Fauna

A number of studies (Pumicestone Passage Water Quality and Land Use Study, 1982, Moreton Region Non-Urban Land Suitability Study, 1974 and the Moreton Region Growth Strategy Investigations, 1976) have rated Bribie Island and Pumicestone Passage as a high value fauna habitat.

Known marine fauna in the Passage include numerous species of fish and invertebrates, many of commercial and recreational importance.

Waterbirds and seabirds are common in the Passage with many terrestrial species also inhabiting the mangroves and salt marshes.

The Pumicestone Passage tidal wetlands are of national and international significance as a feeding and roosting site of migratory and wading birds and have been nominated under the Convention of Wetlands of International Importance as Waterfowl Habitat (Ramsar Convention). In a regional context, Pumicestone Passage has approximately 20% of the waders in Moreton Bay during the summer, making it a significant component of the estuarine complex of Moreton Bay which is now recognised as one of Australia's most important wader refuges. Thirty-two bird species which use Pumicestone Passage and Bribie Island as a staging area during migration are listed in the schedule attached to the Japan-Australia Agreement for the Protection of Migratory Birds and Birds in Danger of Extinction and their Environment (JAMBA) and thirty-five are listed in the schedule attached to the China-Australia Migratory Birds Agreement (CAMBA) (DEH, 1992a). Major roosting, staging and feeding sites are given in DEH (1992a).

The tidal wetlands of Pumicestone Passage are highly productive areas with high fishery value providing important nursery areas for the juvenile stages of a range of estuarine species (providing both food and shelter).

The Pumicestone Passage tidal wetlands are of national and international significance as a feeding and roosting site of migratory and wading birds

Seagrasses are also important in supporting dugong and turtles and some water birds directly. Both seagrasses and mangroves provide habitat for many invertebrate species which, in turn, support large numbers of wading bird species.

The tidal wetlands have high value particularly as nursery areas for many fish and crustacea of commercial and recreational importance. Bream stocks of Pumicestone Passage are crucial to the entire south-east Queensland bream fishery (DEH, 1992a).

In addition, the mangroves and salt marsh/claypan systems of Pumicestone Passage are important buffer areas for erosion controlling acting as sediment traps, erosion inhibitors and providing potential areas for mangrove expansion.

Tidal wetlands

The estuary contains valuable tidal wetland communities comprising seagrasses, mudflats, mangroves and salt marshes, a large area of which have already been destroyed in southern Queensland.

In 1975, the tidal wetlands of Pumicestone Passage represented 14% of the mangrove vegetation and 20% of the salt marshes in southern Queensland from Noosa to the NSW border (Gutteridge Haskins & Davey, 1975).

Between the Caboolture River and Caloundra there are 1648 ha of seagrass, 2169 ha of mangroves and 1006 ha of salt marsh/claypan . These tidal wetlands are represent a shrinking resource as a result of wetland destruction for urban development, canal developments, marinas, airport redevelopment and harbour extensions. Between 1984 and 1987, 121 ha of mangroves, 50 ha of salt marsh/claypan and 19 ha of heathland were destroyed for developments at Dux Creek, Solander Shores, Spinnaker Sound, Bongaree and Lamerough Creek (Hyland and Butler, 1988), all within the study area.

Protection of food for wildlife
Many wildlife species are predators and therefore very vulnerable to substances which can bioaccumulate along the food chain. In those instances, environmental levels which are safe for fish and invertebrates do not necessarily convey safety to predators or even to scavengers that consume aquatic organisms. Stringent guidelines may therefore be required for the protection of wildlife from pollutants which are able to concentrate along the food chain.

Reserves and protection status
The Pumicestone Passage Marine Park was gazetted on 30 January 1986 (Figure 2.2). The gazettal established one General Use Zone which makes provision for:

(i) the conservation of, research in, and reasonable use and enjoyment by persons, of the area within the Zone;
(ii) the exercise by the appropriate statutory authorities of the powers conferred upon them in relation to the area within the Zone.

The Pumicestone National Park was gazetted on 18 August 1988. The cardinal principle of management of the national park is the permanent preservation of its natural condition.

The Bribie Island Environmental Park which is located on the ocean side of Bribie Island was gazetted on 2 November 1989.
The Buckley's Hole Environmental Park at the southern end of Bribie Island was gazetted on 30 November 1991 (Figure 2.2).

A substantial area including the central narrows of Pumicestone Passage is also declared as Pumicestone Passage Fish Habitat Reserve. Adjacent areas on the eastern side of Bribie Island are declared as the Bribie Island Wetland Reserve (Figure 2.3). These reserves generally extend to the high water mark within the estuary and the low water mark along the eastern and southern beaches of Bribie Island.

Dredging in the Tweed and Mooloola Rivers has been associated with collapses in their bream fisheries. It is considered that similar action in the Passage would yield the same result (DEH 1992).

2.2.3 Recreation and tourism

The estuary has a high recreational value providing for a wide variety of nature-based activities including fishing, swimming, boating, bird-watching and scenic viewing. The location relative to Brisbane and the Sunshine Coast makes it a valuable open space and recreational asset for the people of south-east Queensland (DEH,1992).

Fishing
The Passage is a popular recreational fishing area for visitors and local residents and is renowned for its excellent bream, whiting, flathead and mud crab fishing. Bream and whiting are the main target species of amateur anglers whose catch is reportedly significantly higher than the quantity caught by commercial fishers. Although recent data are not available, it is apparent that well in excess of 10 000 anglers visit the Passage during both the winter-time bream season and summer-time whiting season (QFMA, 1992).

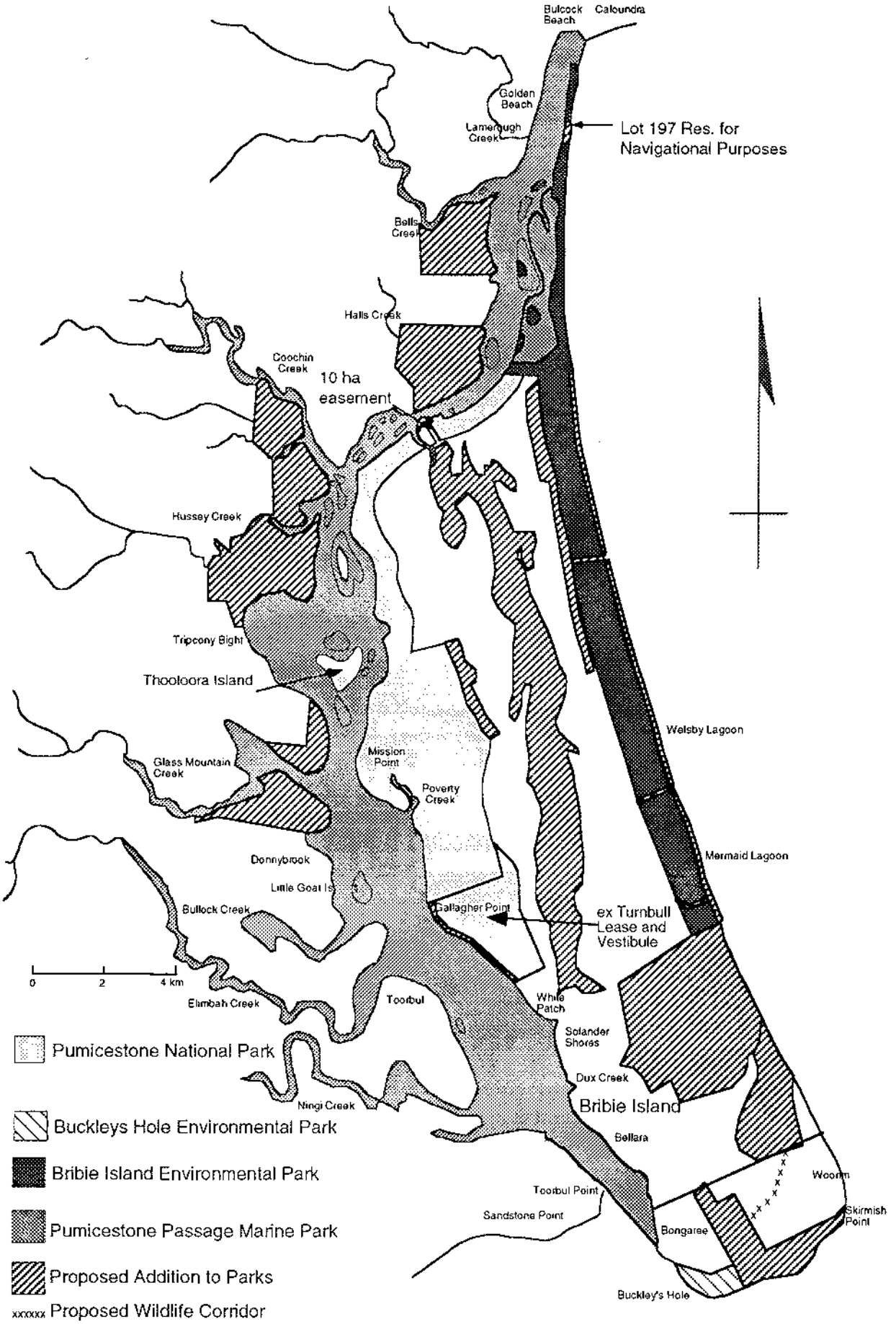


Figure 2.2 Pumicestone Passage and Bribie Island Park Boundaries and Proposed Additions to Parks (after DEH, 1993)

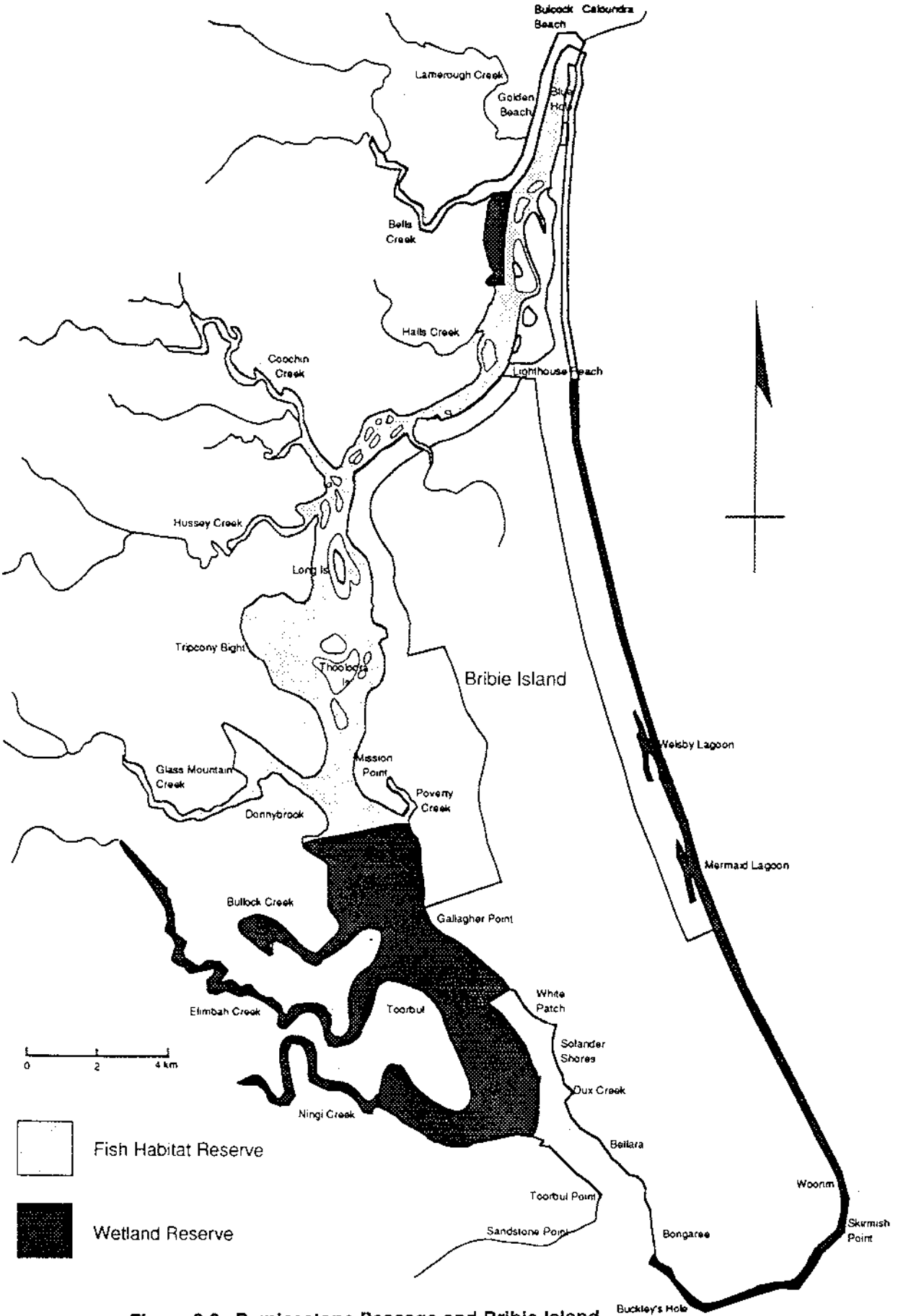


Figure 2.3 Pumicestone Passage and Bribie Island Fisheries Reserves (after DEH, 1992a)

Swimming and boating
The main locations for swimming are Bulcock Beach at Caloundra, Golden Beach, the western side of the Bribie Island spit (accessed by boat), Bongaree, and to a lesser extent the beaches north of Spinnaker Sound and north of Dux Creek. In these locations the beaches are sandy and sheltered. The water is usually quite clear. Toward the central reaches of the Passage the water and beaches are progressively muddier and, thus, less appealing to swimmers (DEH,1992).

The more open northern and southern ends of the Passage and their proximity to the major development nodes and boat ramps makes them important areas for boat-based activities. Sailing, water-skiing and other pleasure boating activities are very popular in these areas (DEH,1992).

For the purposes of water quality objectives, recreational activities such as swimming and boating are divided into three categories:

(i) Primary Contact: Activities in which the user comes into frequent contact with water, either as part of the activity or accidentally (e.g. swimming, sail-boarding);
(ii) Secondary Contact: Activities in which the user would generally have less frequent contact with water (e.g. boating, fishing);
(iii) Visual Uses.

Bird-watching and scenic viewing
Most bird-watching and scenic viewing would take place from Bribie Island and the mainland. The Passage and its wetlands contribute significantly to the bird habitat and natural amenity of the area enhancing the potential for these activities and their consequent attractiveness to visitors and residents.

2.2.4 Economic

Commercial fishing
The Passage is harvested by both recreational and commercial fishers. The commercial fishery in the Passage is based on fish (mullet, yellowfin bream, summer whiting and tailor), prawns and crabs and is limited to accommodate the interests of recreational fishing.

All commercial licences within the Passage are subject to a "sunset" clause ie. they cannot be sold or transferred and thus will terminate when the current operator retires from the industry. Since the limited licence scheme was introduced in 1981, the commercial catch has shown no consistent trend. Mullet, which is not a recognised angling fish, represents the majority of the catch (about 70%) (QMFA, 1992). The annual average total commercial catch over the period 1989-1991 was 153 tonnes.

Mariculture/aquaculture
Mariculture of oysters occurs mainly in Elimbah Creek. Three licensed aquaculture farms are located at Bullock, Elimbah and Ningi Creeks. Only the Ningi Creek farm was in operation during the period of water quality monitoring (August 1991 to July 1992). The commercial viability of these farms is unproven as the industry in this area is only in its infancy.

An indication of State Government support for the industry is manifested in the establishment of an Aquaculture Research Centre serving all of Queensland. The Centre undertakes research into all aspects of aquaculture, provides stock for various reservoirs and lakes throughout the State and trains fishers and aquaculture operators. It is located at Woorim on the eastern coast of Bribie Island outside the Pumicestone Passage catchment.

Extractive industries
Sources of well-graded construction sand have been identified in commercial quantities on the alluvial flats of several small mainland streams draining into Pumicestone Passage including Elimbah, Glass Mountain, Hussey, Coonowrin and Coochin Creeks. There are currently no extractive industry permits approved for the estuary although sand extraction is occurring off-stream adjacent to a number of the creeks which drain into the Passage.

2.2.5 Education and scientific investigation

Pumicestone Passage has a high educational value, particularly for birdlife and wetland studies and provides an important reference point for scientific study.

Education
Opportunities for formal and informal educational activities exist throughout the estuary. A wide range of natural community types is represented. Pumicestone Passage, because of the high quality of the habitat, the diversity of lifeforms and communities present and its ready access to major population centres is particularly well suited to wetland studies at primary, secondary and tertiary education levels. It is currently visited by many schools and tertiary institutions.

Scientific investigation
The Passage also has high scientific value particularly as a benchmark/reference site because it is one of only four major passage type estuaries in Queensland and is situated at the interface between the tropical and temperate boundaries of many marine species.

The tidal wetlands of the Passage are of national and international significance as a feeding and roosting site for migratory and wading birds as well as being important nursery areas for the juvenile stages of a range of estuarine species.

The seagrasses and mangroves are representative of those found in Moreton Bay with the mainland mangrove forest opposite Long Island and worthy of scientific study (DEH, 1992a).

2.3 Water Quality Guidelines

The key environmental values have major implications for water quality

The Australian and New Zealand Environment and Conservation Council (ANZECC) and the Australian Water Resources Council (AWRC) have developed a national water quality management strategy that seeks to manage the nation's water resources on a sustainable basis. The Australian Water Quality Guidelines which have been released by ANZECC provide numerical and narrative criteria to assist in managing water resources in a sustainable manner.

The approach adopted in preparing the Australian Water Quality Guidelines (ANZECC,1992) comprised :

(i) a review of the most recent overseas criteria documents, particularly those produced by the United States (USEPA 1986), Canada (CCREM 1991) and the World Health Organisation (WHO 1980,1984);

(ii) a broad review of the relevant Australian information (both published and unpublished) to supplement or modify overseas information where this was judged to be inappropriate;

(iii) a detailed public review of the draft.

Each waterbody may have a number of environmental values, including recreational use, potable water supply, ecosystem protection and irrigation, that need to be measured in order to test whether they are being protected. Water quality criteria or other indicators of the health of systems provide the means to make such measurement. Each environmental value is given a set of numerical or narrative criteria that must be met to ensure that the particular environmental value can be fully protected.

The approach adopted has limitations eg. the water quality indicators used are almost exclusively physico-chemical and not biological. It is assumed that protecting the aquatic environment by considering the quality of the water compartment will provide adequate protection of the whole ecosystem. Other factors, such as serious pollution of sediments, reduction in stream flow (from damming or building of barriers) or removal of habitat (de-snagging, draining wetlands), could equally cause significant deterioration in the ecosystem.

Five environmental values are considered in the national guidelines:

(i) ecosystem protection (both inland and marine), including protection of waters used for shellfish and fish production and by wildlife;
(ii) recreation and aesthetics;
(iii) raw water for drinking water supply;
(iv) agricultural water; and
(v) industrial water.

Sets of key indicators of water quality are nominated to provide a means of identifying and measuring change in each environmental value. The key indicators are still largely physico-chemical; for example pH, conductivity, nutrient concentrations and toxicant concentration.

The adoption of the Australian Water Quality Guidelines is appropriate for Pumicestone Passage and its tributaries and is likely to be in accord with the proposed Queensland Environment Protection Policy for Water.

The adoption of the Australian Water Quality Guidelines is appropriate for Pumicestone Passage and its tributaries

3. Catchment Values and Uses

A review of the environmental values of the Pumicestone Passage catchment was undertaken to re-assess their significance. It also provides a qualitative description of the dominant geomorphological and ecological processes which determine community composition and structure as the basis for evaluating the impacts of landuse change and management practices for ecological sustainability.

3.1 Description of Catchment

The section describes the dominant geomorphological and ecological processes within the Pumicestone Passage catchment

The catchment includes much of Bribie Island and the adjacent mainland areas extending from South Point at the southern mouth of Pumicestone Passage to the Caloundra Bar in the north and from the watershed of the D'Aguilar Range in west to the Passage itself.

3.1.1 Physical description

Climate

The mild climate of the catchment is largely governed by its subtropical location and associated weather patterns, and by physiographic features. The average annual rainfall varies between 1260 mm in the south of the catchment up to 1620 mm in the north-west of the catchment. There is a marked seasonal tendency with around 60 percent to 70 percent of the annual rain falling in the December to April period. A significant proportion of this rainfall is high intensity thunderstorm rain. The driest period is from August to September.

The variation in temperature and humidity is narrow which is typical of maritime localities however there is a pronounced coast-inland gradient in the temperature range. The hottest months are December and January, when daily mean maximum temperatures reach 28-29^{o}C. July is the coldest month with the daily minimum temperature averaging 11^{o}C at Caloundra. Frosts do not occur in localities exposed to the open sea but a few kilometres inland they can be expected between May and August.

Prevailing winds are predominantly from the south-east throughout the year. A proportion of afternoon northerlies to easterlies occurs from September through to March and some morning westerlies and southerlies between June and January. Stronger winds are almost always from the south-east, east or south; winds from the other directions are generally light breezes.

The catchment is at the southern limit of cyclone influences in Queensland. It is periodically affected by cyclones during the months from December to April.

Geology and terrain

The catchment consists mainly of sedimentary rocks ranging from conglomerates to fine-grained sandstones. The general strike of the rocks is in a north-westerly direction. On the north-west catchment boundary the Landsborough Sandstone forms undulating to steep hills with miscellaneous volcanic and metamorphic rocks forming similar topography along the south-west boundary. Lateritised Landsborough Sandstone forms undulating to steep low hills in the central part of the catchment.

A series of spectacular alkaline trachyte plugs form the Glass House Mountains.

Quaternary alluvium of gravel, sand, silt and clay forms level to gently undulating alluvial plains along all the major drainage lines. A thin strip (up to 5 km) of coastal lowlands fringes Pumicestone Passage on both the mainland and Bribie Island. The lowlands are formed on windblown sand deposits, tidal sand deposits as well as lagoonal and tidal mud and silt deposits. These deposits form rolling rises, gently undulating plains, and level plains with intermittent swamps. Most of the catchment area draining into the Passage is less than 20 m above mean sea level.

3.1.2 Geomorphology

Soils
Red and yellow podzolics have textured profiles with red and yellow clay often mottled subsoils and tend to have an acid reaction. They dominate the upper slopes and crests of the undulating to hilly land. Red and yellow earths also occur on these lands. They are uniform to gradational, deep, medium-textured, porous soils which have little or no structure and an acid soil reaction trend. Non-calcic brown soils have textured profiles with either mottled or whole coloured yellow or brown clay subsoils. They are restricted to the moderate to steep slopes of the Landsborough Sandstone. Shallow, stony lithosols occur on the Glass House Mountains and along the western boundary of the catchment.

The alluvial floodplains contain alluvial soils, prairie soils and black earths with gleyed podzolic soils, humus podzols and peaty podzols in the poorly drained areas.

The estuarine delta contains gleyed podzolic soils, humic gleys, humus podzols and peaty podzols. Siliceous sands and earthy sands also occur on the coastal sand dunes and associated sand plains. Solonchaks occupy the marine muds in the tidal zone.

Surface hydrology
Catchment runoff is a function of climate, terrain, soils and vegetation. Vegetation has a major influence on runoff through its interception of a portion of rainfall and its maintenance of a high soil surface infiltration capacity. The evapo-transpiration of sub-surface water by vegetation also influences soil moisture conditions and controls groundwater levels.

The bulk of pollutants exported from the catchment is mobilised and transported during elevated runoff conditions in the 'wet' season. The transportation, deposition and resuspension of nutrients and organic materials is linked primarily to the wash-off and transportation of particulate material from catchment surfaces.

The bulk of pollutants exported from the catchment is mobilised and transported during elevated runoff conditions in the 'wet' season

Catchment runoff is also influenced by changes in landuse which increase impervious surfaces within a catchment which in turn change drainage patterns or changes in vegetation or soil moisture conditions.

The hydrological response of the catchment to spatial and temporal distributions of rainfall and to changes in landuse within the catchment is reported in detail in the component study report entitled "Environmental Objectives for Water Quality".

Groundwater hydrology
Groundwater is a source of water supply for domestic, irrigation and industrial purposes within the catchment. Yields from bores are in the range of 20 to 800 m^3/day with salinity levels between 100 to 5000 mg/L.

The analysis of mainland groundwater quality reported in the Groundwater Resource Study conducted by the Department of Primary Industries (Water Resources) in 1992 highlighted widespread nitrate pollution of groundwater associated with recharge from areas of horticultural and urban landuse. In many instances the groundwater does not meet health standards for safe potable water. This pollution of the groundwater was attributed to fertilisers and effluents from septic tanks.

In the case of Bribie Island, groundwater provides the town water supply to residents. The potential divertible long term yield of groundwater from Bribie Island is estimated to be 15000 to 25000 ML per annum. The groundwater beneath Bribie Island was found to have a low pH but is suitable for drinking.

Soil erosion
A survey of soil erosion rates on horticultural farms within the catchment conducted by the Department of Primary Industries in 1992 identified a series of factors which influence the rates of erosion. The primary factors are the slope of the land, its erosion rating and the type of crop grown in a horticultural area. The categories of crops included: pineapples, tree crops (macadamias, pecans, citrus, custard apples, lychees), vegetables and bananas. The variation in estimated soil loss as a function of erosion rating was similar for each of the three slope categories identified: 0-8 percent, 9-15 percent and >15 percent. In the case of a "slight" erosion rating, the annual soil loss was estimated to be 2-6 tonnes/ ha, for a 'moderate' erosion rating it was 11-16 tonnes/ha and for a 'severe' erosion rating it was 20-32 tonnes/ha.

3.1.3 Ecology

Flora
Much of the catchment is forested land. This comprises native and littoral vegetation and plantations of mainly exotic pine (*Pinus elliotti var. elliotti*) with some plantings of loblolly pine (*P. taeda*). Between 1974 and 1991 the percentage of the catchment area under plantation increased from 32 percent to 39 percent. It is anticipated that the privately owned established pine plantation will go out of production over the next 10-15 years.

Blackbutt and bloodwood open forest occur on the undulating to steep hills on the north-west boundary of the catchment. Spotted gum and ironbark open forest occupy similar terrain along the south-west boundary. The undulating to steep low hills in the central part of the catchment contain mainly blackbutt and bloodwood open forest. The Glass House Mountains have either sparse tussock grassland or red-gum open forest.

Melaleuca Forest
Bribie Island is low-lying with a maximum elevation of less than 10 m. Most of the island is wetland with low sand dune complexes towards the centre of and along the eastern beach. The coastal wetland areas of *Melaleuca quinquenervia* forests and heathlands between the NSW border and Noosa have been extensively drained and cleared for a range of urban and rural developments. This has included extensive areas within the study area. The remaining coastal freshwater wetlands are being increasingly fragmented. The areas remaining on the mainland and Bribie Island represent the largest remaining *Melaleuca quinquenervia* wetlands in southern Queensland. Valuable stands of *Livistona australis* palms are also contained within uncleared *Melaleuca quinquenervia* open-forest in the central part of Bribie island.

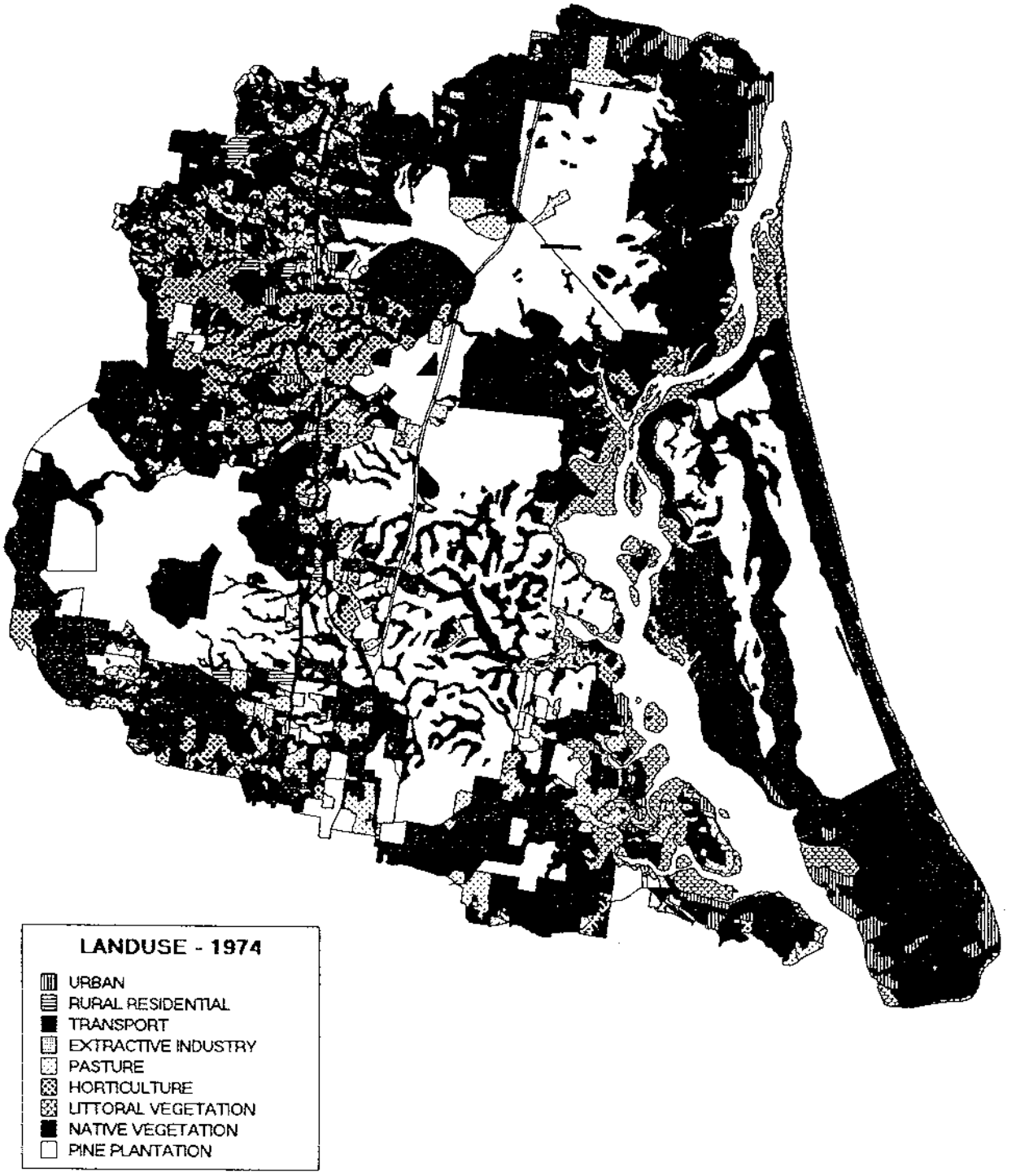


Figure 3.1 Catchment Landuse in 1974

Heathlands
Many of the heathland communities on Bribie Island or adjacent to the Passage are virtually the only examples of their type remaining and these vegetation units are now rare due to extensive clearing (DEH, 1992a).

The Banksia heathland area south of the pine forest on Bribie Island is the only significant remnant of the once extensive heath community. Most of this heathland was cleared and drained for pastoral uses and later pine plantations (DEH, 1992a). This heathland is of national significance as it and another at Lake Weyba are the only remaining examples of coastal heathlands which have developed on low sand plains. Banksia woodlands and heathlands, which are floristically diverse and have particular appeal as "wildflower" areas, are threatened elsewhere by development.

Fauna
Aquatic fauna is previously discussed in detail in Section 2.1.3. Quantitative information regarding terrestrial fauna is limited. However, avifauna is discussed in Section 2.1.3. A listing of native fauna recorded for Pumicestone Passage and Bribie Island, including mammals, amphibians, reptiles and birds, is presented in Appendix B of the report entitled "Management Planning for National, Environmental and Marine Parks of Bribie Island and Pumicestone Passage" (DEH, 1992a).

3.2 Catchment Landuse

3.2.1 Landuse patterns

Digital landuse data from the "Pumicestone Passage Catchment Area Comparative Landuse Study: 1974 - 1991" (DEH, 1992a) was used to determine the total area of each landuse within the catchment both in 1974 and 1991. Where possible, the classification of landuses followed the Draft National Landuse Code. For comparison purposes, a system of broad landuse categories was selected. These broad categories included:

- Urban;
- Rural residential;
- Transportation corridors and airfields;
- Extractive industries;
- Pasture;
- Horticulture;
- Littoral vegetation;
- Native vegetation; and
- Pine forest.

The landuse patterns in 1974 and 1991 are presented in Figures 3.1 and 3.2, respectively. The proportions of the catchment area devoted to each landuse in 1974 and 1991 are presented in Figure 3.3.

Urban
Urban areas include the towns of Landsborough, Beerwah, Glass House Mountains, Beerburrum and Elimbah along the old Bruce Highway and North Coast Railway. These towns are collectively known as the "Railway Towns" and provide a mix of residential, business and agricultural services, and commercial and small scale industrial uses.

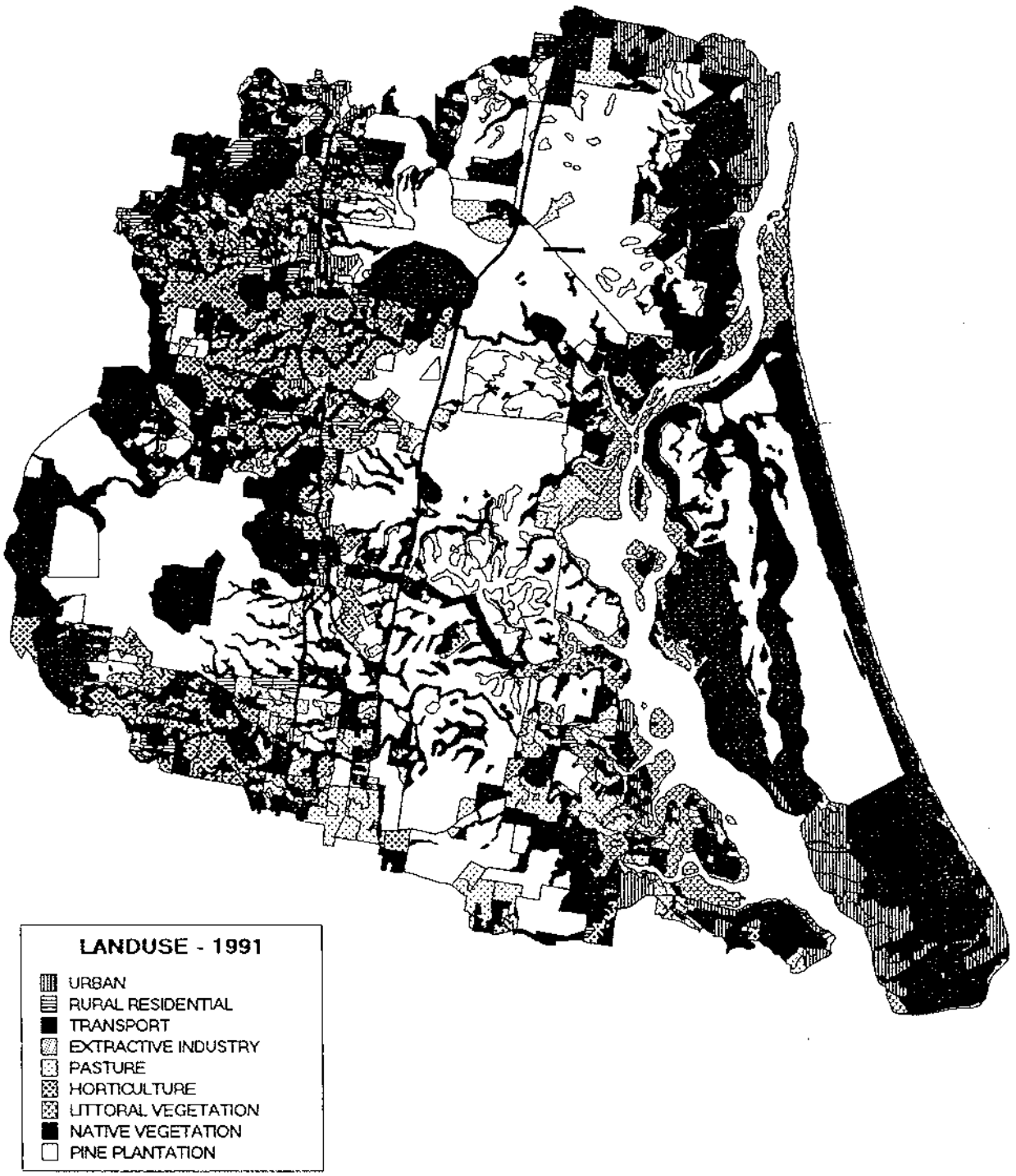


Figure 3.2 Catchment Landuse In 1991

The urban area located at Golden Beach, which is the southern extension of Caloundra, is within the northern limits of the catchment area. In the south of the catchment are the urban areas of Banksia Beach, Bellara, Bongaree, Woorim and White Patch on Bribie Island as well as Ningi, Toorbul, Toorbul Point, Donnybrook and Meldale on the mainland.

Rural residential
Developed rural residential areas are centred on the railway towns, west of Caloundra, west of Toorbul, close to Caboolture at the southern edge of the catchment, and along the D'Aguilar Range on the western edge of the catchment.

Transport
The catchment contains the major north-south link between Brisbane and the Sunshine Coast and beyond to North Queensland coastal areas. The study area is served by a major national highway, the North Coast Railway and a well established network of roads. It is anticipated that this transport function will be increasingly important as the populations in the coastal regions of Queensland continue to grow.

Major east west links include the Mooloolah-Caloundra Road near the northern boundary of the catchment, the Beerwah Road to Peachester, Landsborough Road to Maleny, and Bribie Island Road linking Caboolture to the Island. All roads access the Bruce Highway (Figure 1.1).

Extractive industries
There are currently no extractive industry permits approved for the estuary although sand extraction is occurring off-stream adjacent to a number of the creeks which drain into Pumicestone Passage.

Pasture
Grazing land is scattered through the middle and north of the catchment and in the southern area of the catchment to the north of Caboolture and west of Toorbul Point and comprises both native and improved pasture (Figure 3.2).

Horticulture
Horticultural activities within the catchment are concentrated in the Coochin Creek catchment south of Landsborough and along the southern boundary of the catchment in the vicinity of Mount Miketeebumulgrai and the Saddle Backs. Some isolated areas of horticultural activity are located near the Skids and to the south of Donnybrook.

Horticultural activities include cultivation of pineapples, tobacco, bananas, sugar cane, tree and vine crops, and shallow rooted crops. The majority of soil erosion on horticultural farms occurs on the pineapple cropping land predominantly on shallower slopes with smaller contributions from tree crops, predominantly macadamias and pecans.

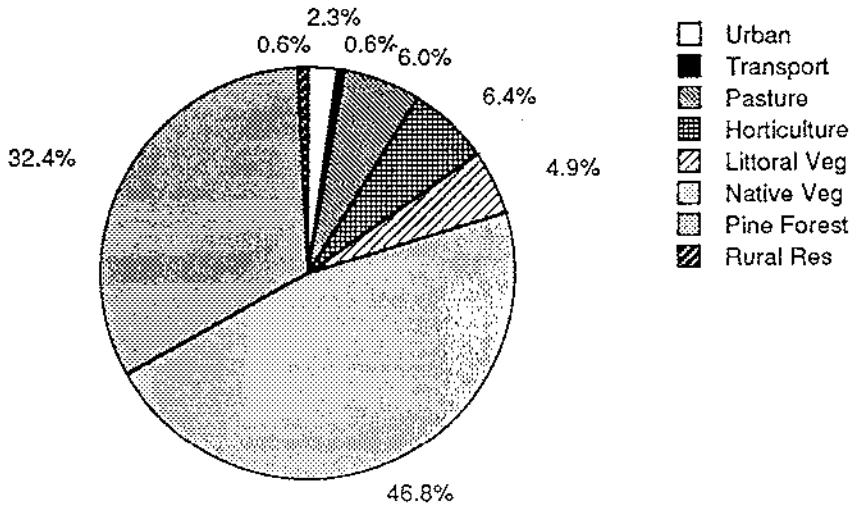
Native and littoral vegetation (open space)
In 1991, approximately 230 km^2 (38 percent) of the catchment area was open space under native or littoral vegetation. Of this area, 12 percent was classified as littoral vegetation. Native vegetation within the catchment includes casurina forest, melaleuca dominated forests and woodland, dry sclerophyll forest, sedgeland, heath and wallum communities.

Pine forests

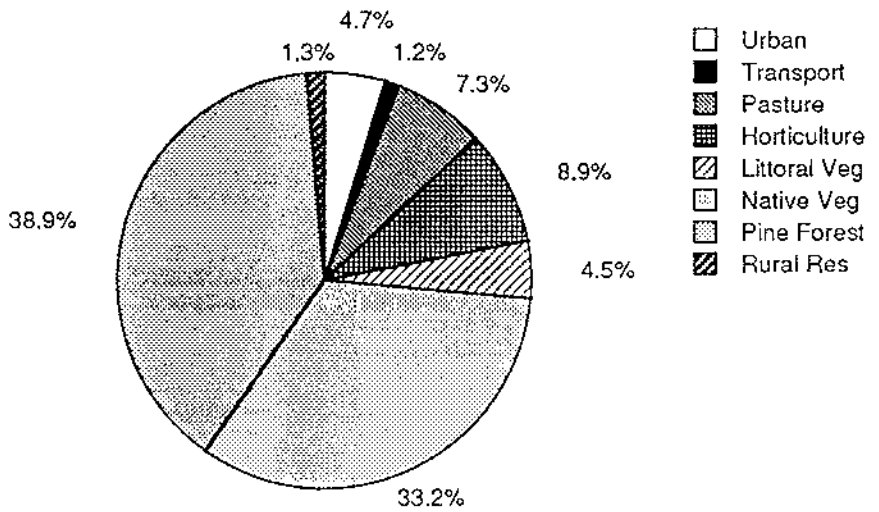
Forestry occupies extensive areas of the catchment area and in 1991 was the single most predominant landuse.

In particular, almost all the land adjacent to and east of the Bruce Highway, large areas of Bribie Island and an expansive area west of Beerburrum extending west to Woodford is used for forestry purposes. Approximately 35% of the area under pine forests is privately owned, the remainder is State Forest and Crown lease.

Since 1974 the single greatest change in landuse has been the reduction in the area of native vegetation by 130 km^2. The landuses which gained from this reduction are indicated in Figure 3.4.



1974 Landuse



1991 Landuse

Figure 3.3 Catchment Landuse by Category In 1974 and 1991

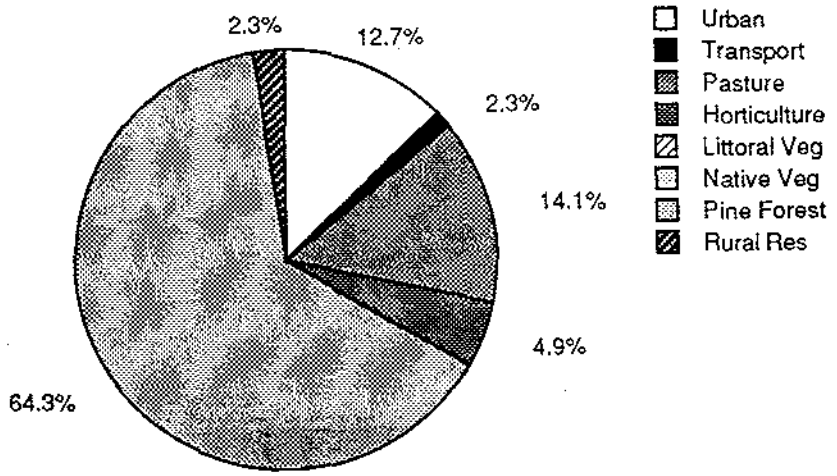


Figure 3.4 1991 Landuse of Former (1974) Native Vegetation

3.2.2 Strategic Plan landuse

Strategic Plans are intended to provide the future landuse patterns expressed in terms of dominant landuse designations. These designations include urban, rural residential and rural land, special purpose land such as State Forest, and open space areas. The proposed landuse patterns within the catchment under the current Strategic Plans of Caloundra City Council and Caboolture Shire Council are indicated on Figure 3.6. To facilitate the direct comparison of planned strategic landuses and current landuse patterns the landuse data was amended and transformed into the same landuse categories adopted for 1974 and 1991. The transformed proportions of each planned landuse is presented in Figure 3.5.

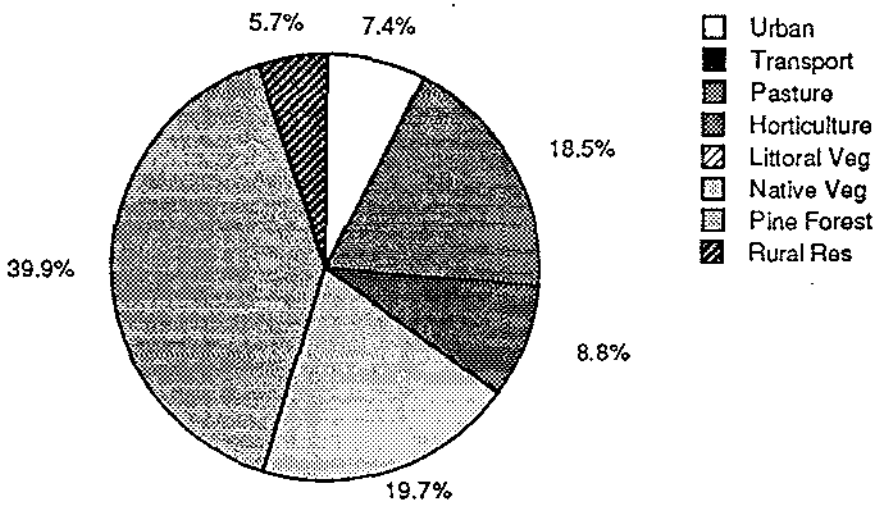


Figure 3.5 Catchment Landuse for Strategic Plans by Category

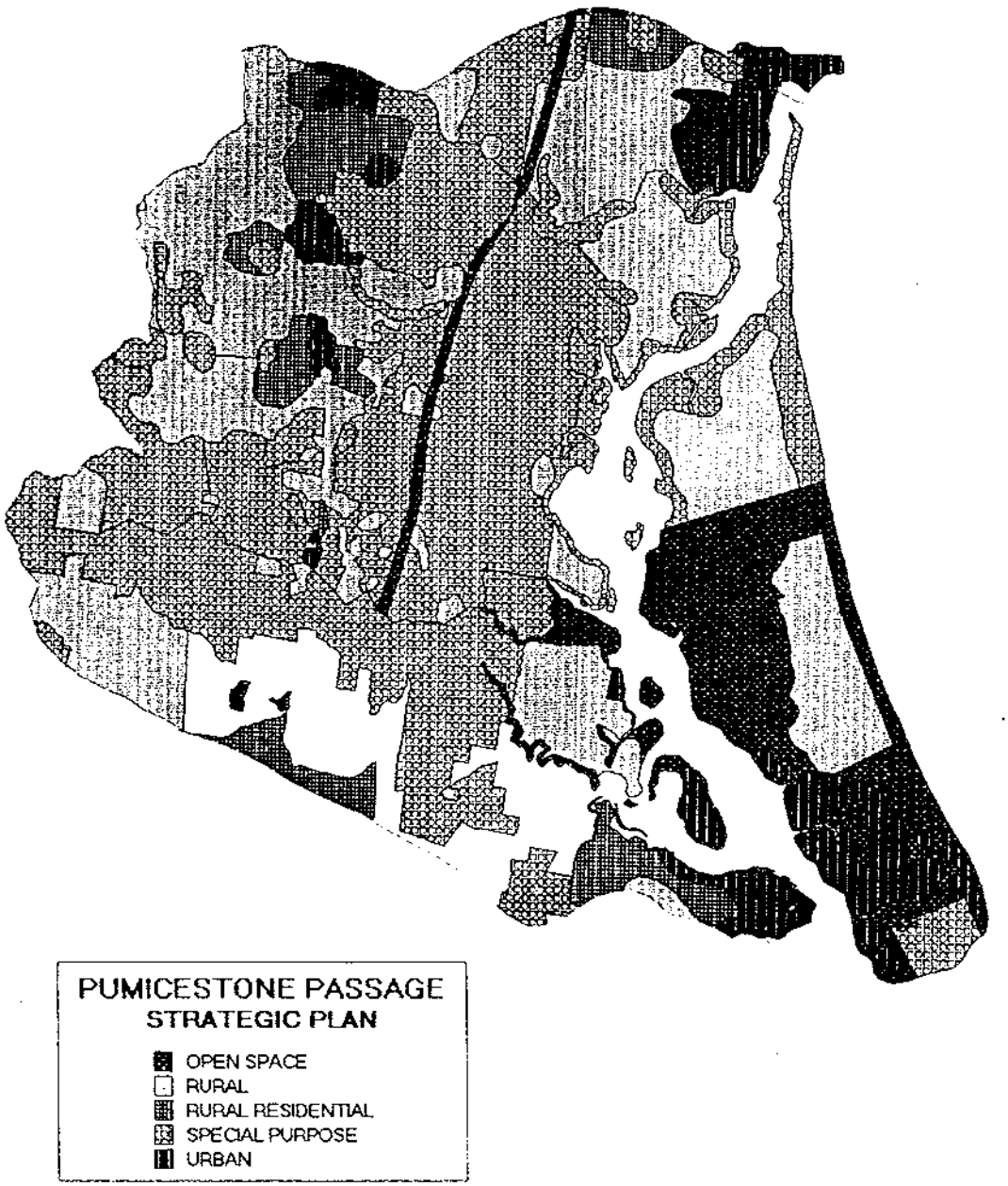


Figure 3.6 Catchment Landuse for Current Strategic Plans

3.2.3 Population growth and projections

Population growth 1986 to 1991

In 1986 the population within the catchment was approximately 19 300 persons. Since then it has increased at a rate of 8 percent a year to 28 300 in 1991. This growth rate is well above the Queensland average of 2.9 percent a year during the same period.

The major urban areas of growth in the catchment area are Bribie Island, Golden Beach south of Caloundra, the Landsborough area and the area north-east of Caboolture. Table 3.1 provides a summary of population growth for selected urban areas within the catchment.

Predictions of future growth for each Council area have been made by Caloundra City Council and Caboolture Shire Council.

Table 3.1 Population Growth at Selected Localities from 1986 - 1991

Locality	1986	1991	Growth p.a. (%)	Percentage of 1991 Popn (%)
Bellara Area - Bribie Island	5702	7891	6.7	27.8
Woorim Area - Bribie Island	1155	1419	4.2	5.0
Golden Beach - Sth Caloundra	4336	4878	2.4	17.2
Landsborough & district	1929	3278	11.2	11.6
Beerwah	694	1088	9.4	3.8
Glass House Mountains	328	414	4.8	1.5
Beerburrum	108	130	3.8	0.5
N.E. Caboolture	1270	3613	23.3	12.7

Source: Australian Bureau of Statistics Census of Population and Housing

Caloundra City Council

Within the draft Strategic Plan three possible growth scenarios for the City are considered for population to the year 2001. The low growth scenario, based upon the Applied Population Research Unit (APRU) study (high series), predicts a population of 72 284 persons, the medium growth scenario predicts 90 700 persons while a high growth scenario projects a population of 115 700 persons in the year 2001.

The draft planning study concludes that the likely growth rate will be 5.4 percent to the year 2001.

Caboolture Shire Council

Population projections for Caboolture Shire are also provided within their draft Strategic Plan. The analysis of population projections considers the APRU estimates and those produced by the Planning Collaborative in conjunction with the Council. The anticipated growth rate is around 6.0 percent to the year 2001.

SEQ 2001

Work by the Queensland and local governments in south-east Queensland is aimed at managing the projected growth in the foreseeable future. This growth, on current trends, anticipates an increase of 100 000 people between 1991 to 2001 (APRU).

The objective of the SEQ Regional Planning Advisory Group and the SEQ 2001 project is to develop strategies for state agencies, member Local Governments and the community and other interest groups which will ensure that the overall pattern of development in the region reflects community values for environmental management and social, economic and physical development. A series of policy papers is expected to be completed by June 1993 along with a framework for managing growth.

3.2.4 Urban growth

Caloundra City Council has identified major constraints to urban growth in the catchment as flooding areas along the Lamerough Creek, landslip areas in the ranges, protection and preservation of valuable horticultural land, beach protection and coastal management areas, environmentally sensitive areas, scenic areas, extractive resources and the provision of services.

Similarly, Caboolture has undertaken an analysis of land within two kilometres of existing urban centres to determine the suitability of the land for urban use. Assessment criteria adopted include consideration of physical constraints such as flooding and unstable soils, proximity to existing services to ensure a logical progression of the network and the area required to accommodate population growth for the next 10 years.

The Department of Housing, Local Government and Planning has also published a "Policy on Good Quality Agricultural Lands 1/92".

3.3 Environmental Values

This section reviews the environmental values of the Pumicestone Passage catchment

3.3.1 Cultural heritage

Aboriginal occupation of the region has been on-going for at least 22 000 years. However, due to post-Pleistocene sea level changes much of the archaeological record for this early time period has been inundated and/or lost. While there is a good record for at least the past 10 000 years in the hinterland, little material older than the past 3000 years exists for the coastal strip.

Bribie Island has high heritage values with many cultural heritage sites recorded. Cultural heritage sites include evidence of Aboriginal occupation, evidence of early European occupation such as the historic lighthouses, the old fish cannery site and the WWII gun emplacements near the eastern beach.

The Aboriginal archaeological sites are predominantly located on the Passage side of the island although the pine plantations, particularly in the north, contain a significant archaeological heritage resource. Almost 100 archaeological sites have been found. These sites are almost exclusively shell middens (food remains and other materials discarded from camp sites).

The sites represent a significant degree of variability in their cultural content and distribution. At present they are thought to represent different functions within the Aboriginal settlement - subsistence regime. One site represents a large base camp which may date back as far as 5000 years and certainly within the past 2500 years.

Bribie Island is first mentioned historically when in 1799 Mathew Flinders landed on the beach of what is now Bongaree, on the south-west coast. A "misunderstanding" between the landing party and the islanders caused a spear to be thrown and the area was named Skirmish Point. However subsequent meetings were of a much more friendly nature. John Oxley found three castaways living with the islanders in 1823. Oxley took two castaways, Pamphlett and Finnegan, away from the island but the third, Uniake, stayed behind to record Aboriginal life.

3.3.2 Conservation

As discussed in Section 2.2.2, the wetlands of Bribie Island and Pumicestone Passage have a high species diversity and contain species and communities which are rare or threatened. The flora and fauna are reviewed in Section 2.2.2. The high value placed on the flora and fauna habitat is evidenced by the protection status accorded to the various Parks and Reserves gazetted for Pumicestone Passage and Bribie Island.

3.3.3 Open Space Recreation

Recreational values
The recreational opportunity value of the catchment is increasing because the Sunshine Coast - Gold Coast corridor is Australia's fastest population growth area. The catchment is the only large area of natural open space on the near northern side of Brisbane. It is also of high value because of the diversity of recreational opportunities. Land based opportunities include picnicking, camping, four-wheel-drive activities, bird-watching and scenic viewing. The National and Environmental Parks also have bushwalking value and further potential for camping.

Tourism and recreational activities are undertaken in the catchment in three main localities:

(i) Glass House Mountains and the rural hinterland;
(ii) Pumicestone Passage; and
(iii) Bribie Island.

Glass House Mountains and rural hinterland
This area contains the most scenic landscapes of the catchment. The Glass House Mountains formation is a spectacular regional landmark which is clearly visible from several popular destinations within the catchment. The rural character, forests, and the Glass House Mountains and Wildhorse Mountain lookouts and information centres are the primary attraction for families and sightseers.

The townships which service the rural area include Elimbah, Beerburrum, Glass House Mountains, Beerwah and Landsborough. Access to the Glass House Mountains precinct is via the Bruce Highway along Glass House Mountain Road. Several scenic routes and the electrified rail link provide access to the lookouts, picnic grounds and townships.

Pumicestone Passage
The high recreational values of the Passage are discussed in Section 2.2.3.

Bribie Island
Bribie Island supports a range of recreational activities including camping, picnicking, nature appreciation, four-wheel driving, bushwalking, sightseeing, wildflower walks, archaeological tours, and educational and research activities. The potential for substantially increased open space usage is high.

Nature of facilities
The DPI Forest Service and the Queensland National Parks and Wildlife Service (Q.NPWS) provide picnic facilities and camping grounds on both the mainland and Bribie Island. Some picnic areas and associated lookouts are within the Glass House Mountains. Several walking tracks are provided to access Mount Beerwah and Mount Beerburrum in particular by the DPI Forest Service. The striking appearance and scenic lookouts to Pumicestone Passage and its hinterland have made the Glass House Mountains a very popular destination for sightseers, bushwalkers, picnickers and mountain climbers. Other picnic and barbecue facilities are provided by the Q.NPWS at Mission Point and Lighthouse Reach, Bribie Island. Other picnic grounds are located at Gallagher Point, Welsby and Mermaid Lagoons. The Lions Club has picnic grounds at Blue Hole on the western beach of the Bribie Island Spit (DEH, 1992a).

Camping is confined to Coochin Creek Park located on the western shores of the Pumicestone Passage. Permits are issued and access is from Roy's Road. The Mission Point camping grounds are a very popular holiday destination where a wide range of recreational activities are pursued.

Several small scale tourist attractions such as the Queensland Reptile and Fauna Park and the Tram Museum are also located in the catchment. Other sites such as the Abbey Museum, the Caboolture Historical Village, the Air Museum and the midden sites and World War II fortification bunkers on Bribie Island provide points of historic interest and culture for visitors.

Day Visits
Little information has been recorded on day trips. However it is considered that most visitors use the Pumicestone Passage area for day trip activities.

Accommodation
The study area has minimum accommodation facilities outside of the main population centres. Caravan parks are located at Landsborough, Toorbul and Woorim. No specific data is available for accommodation.

Parkland and open space
The principle of the Caboolture Shire Draft Strategic Plan is to link bushland with State Forest and privately owned plantations to the foreshore and estuarine areas by using creeks and rivers to form environmental corridors.

The Caloundra City Draft Strategic Plan principle is not as explicitly set out but it is assumed to concentrate upon the use of open space to connect the Glass House Mountains with surrounding State Forest.

3.3.4 Visual quality

Coastal landscapes are a visual resource encompassing all the visible landform, water form, vegetation and cultural components of the coast. Significant recreational landscapes along the coast include ocean beaches, calm water beaches, low coastal dunes, estuarine areas, tall eucalypt forests, heathland and freshwater swamps.

Further inland the Glass House Mountains provide an attractive backdrop for recreational pursuits.

The viewshed for the catchment area encompasses the hinterland mountains, coastal lowlands and Bribie Island. The viewshed of the Passage itself comprises areas adjacent to the Passage, the Glasshouse Mountains, hinterland ranges and the waterways.

Glass House Mountains
The Glass House Mountains are the single most important visual feature of the catchment area. These mountains provide a prominent and distinctive landscape feature offering a high level of visual interest when seen from many parts of the region. The extent and quality of these mountain views merit protection from degradation by inappropriate or insensitive landuses.

Hinterland ranges
The hinterland ranges are a very important component of distant skyline views. Closer views disclose that these areas offer a wide variety of landscape elements including natural vegetation, rural areas and townships offering a variety of activities, textures, colours and forms. To maintain the tourist appeal of the hinterland areas, the existing visual character should be protected.

Farmlands
Farmland areas are characterised by undulating and steeply sloping lands of the hinterland. These areas provide a high level of visual interest offering a variety of forms, colours, textures and activities with a blend of 'natural' landscape and built structures. These areas are viewed from mountains and hinterland areas especially along scenic drive roads which are of particular importance for tourism.

Forestry areas
Forestry areas are a very distinctive element of the landscape of the catchment arising from the relatively hard edges to the sky and surrounding vegetation combined with a high degree of uniformity of colour and texture. While on the one hand this uniformity reduces the level of visual interest, it does provide a contrast in the overall texture of the landscape.

These areas are highly visible to the majority of visitors to and residents of the catchment as the Bruce Highway passes through the forest plantations.

Pumicestone Passage
The Passage can be viewed from the Glass House Mountains, Bribie Island Bridge, the Caloundra coastline, some distant roads, adjacent waterways and the Passage itself. Given the high numbers of people enjoying recreational activities in the Passage, the scenic beauty of the landscape is appreciated by many people.

Lowland wetlands

The major visual impact of the wetlands is from the waterways with slightly less appeal from landward views. These areas are largely protected by their location within park areas, although some areas are being degraded by four wheel drive vehicles.

Urban areas

The visual quality of the urban areas varies according to location and scale of development. Urban areas on the coast are less visually appealing than the smaller picturesque townships. The railway towns add to the scenic quality of the hinterland whereas Golden Beach does not provide a similar visual appeal.

4. Water Quality and Ecological Issues

The section identifies the trends in water quality and determines the implications for environmental values and ecologically sustainable development

Evaluation of the water quality in Pumicestone Passage and its tributary creeks in 1978-1980 and 1991-1992 disclosed significant trends in water quality. Consideration of current and projected water quality in terms of the water quality objectives for the tributaries and the Passage enabled the identification of current water quality and ecological problems and issues. Which in turn enabled the translation of water quality objectives into sustainable loading criteria against which landuses and management practice options can be evaluated.

4.1 Water Quality and Ecological Processes

4.1.1 Estuarine processes in the tributaries

The natural pattern of catchment runoff and constituents is a function of climate, terrain, soils and vegetation. The vegetation canopy intercepts a portion of the rainfall and maintains a high soil surface interception and infiltration capacity. Vegetation may also contribute to evapo-transpiration losses of rainfall and control groundwater levels.

The capacity of soil to store water is a function of soil porosity, depth, hydraulic conductivity, and the occurrence of impermeable clay layers or peat layers. The erodability of soils is a function of precipitation rates, vegetative cover, drainage area, slope, soil (aggregation) characteristics and landuse. Natural leaching of soil minerals occurs as a result of throughflow of rainfall into lower soil horizons and its ultimate drainage to surface waters.

The terrain, soils and vegetative cover which is influenced by landuse such as loss of vegetative cover and impervious surfaces have a substantial influence on these processes. Changes in landuse give rise to changes in drainage patterns; changes in vegetation and impervious areas which reduce soil moisture storage (exacerbation of peak runoff); the exposure of soils leading to erosion; and the destabilisation of the beds and banks of drainage channels. The application of fertilisers and chemicals to the soil may lead to nutrients and chemicals ultimately entering the water system.

The bulk of pollutants exported from catchments is mobilised and transported during rainfall events

The water quality review established that the bulk of pollutants exported from catchments is mobilised and transported during rainfall events. The transportation of pollutants occurs primarily as particulate material washed from catchment surfaces and the dissolution of soil and rock ions by rainwater infiltrating the soil and aquifers discharging to streams at low points in the basin. The limited groundwater quality monitoring data which was available indicated a potential for pollutants to be washed through to the groundwater and discharged ultimately to the surface waters.

Likewise changes in landuse may lead to the increased discharge of wastes. Wastewater discharges can introduce bacteria and organic matter, which impact on recreational use and edibility of crustacea, and nutrients which elevate phytoplankton production and potentially lead to the loss of habitats and changes in ecological community structure and composition (due to epiphytic growth), de-oxygenation of receiving waters and odours and scums.

The pollutant pathway may be modified in some cases by the presence of groundwater systems and associated recharge and discharge zones, with shifts in the temporal and locational patterns of exports to tributary streams and the Passage.

The loss of wetlands and saltmarsh/mangrove areas along the margins of the estuary due to drainage and/or filling of land would both deplete the nutrient interception capacity of these areas and the source of detritus available to the estuary. This would lead to an increase in phytoplankton growth and changes in plant communities and structure. Overall there would be a depletion of estuary production.

The implications of changes in catchment pollutant exports (associated with landuse change) for estuarine processes are summarised in Table 4.1.

Dredging of entrance and navigation channels may also impact on local vegetation and habitats and cause changes in salinity and light regimes within the tributaries.

The export constituents identified in Figure 4.2 represent the critical catchment exports that need to be analysed in terms of implications of landuse change in the catchment for water quality and ecology of the estuarine system.

The tributaries comprise two discrete systems, namely the freshwater dominant reaches at and above the reach of the high tide, and tidally affected reaches or estuaries.

The dominant system and associated processes are largely determined by flow regimes with:

(i) freshwater dominant regimes under elevated runoff conditions during storm events with their associated transportation, deposition and resuspension of suspended materials, including nutrients and organic materials; and

(ii) estuarine, or 'in-lake', dominated processes during the dry periods which are characterised by depressed DO levels, the release of nutrients from the sediments deposited during high flow conditions and subsequent algal growth.

The upper and intermediate zones of the estuaries are characterised by extreme biological activity, with rapid sedimentation of suspended solids during high flows in the highly saline estuarine waters. This is followed by decomposition under low flow conditions with an associated depression of DO levels leading to the release of nutrients from the sediments which promotes high algal growth. In the lower reaches of the estuaries this level of activity appears to be reduced by tidal mixing. Algal growth in these zones may be limited by short residence times and by elevated turbidity.

Superimposed on these processes are the point source discharges of organic wastewater. The high levels of nutrients and BOD in these discharges have the potential to substantially modify sediment nutrient release rates, thereby exacerbating algal growth rates and associated impacts on DO and pH levels.

The extreme variations in salinity levels and variable water levels in the estuaries limit the viability of large rooted aquatic plants. Instead planktonic algae and micro-organisms dominate the ecology of these zones.

Table 4.1 Implications of Landuse Change for Estuarine Processes

Pollutant	Implications for Estuarine Processes
Sediment	- a loss of estuary depth; - modification of light regimes which impacts on primary production and leads potentially to loss of seagrass; - changes in sediment buffering (adsorbed metals, pesticides and nutrients); - loss of habitats, changes in substrate (plant composition and structure) can also lead to changes in the species of birds utilising wetlands; and - creation of barriers to predation, with changes in population dynamics of such insects as mosquitos.
Organic compounds	- changes in humic and chelate composition of organic colloids leading to changes in the adsorption of metals and nutrients; and - changes in availability of carbon.
Fresh water	- changes in salinity regimes (plant composition and structure, ionic adsorption chemistry); - stratification (de-oxygenation); and - changes in suspended material composition (light regimes).
Nutrients	- elevated phytoplankton production; - changes in species composition; - growth of epiphytes causing potential loss of seagrass; - loss of habitats; - de-oxygenation due to increased algal biomass; and - increased odours and scums due to increased algal biomass.
Suspended solids	- changes in light regimes which impact on primary production; and - changes in ion adsorption (availability of nutrients).
Toxic compounds	- changes in structure and composition; and - health risk with crustacea including cultured prawns
Bacteria	- fecal pollution; and - health risks with molluscs.

4.1.2 Estuarine processes in Pumicestone Passage

Sediments are the major moderating factor determining nett water quality and ecological responses in estuaries

Sediments are the major moderating factor determining nett water quality and ecological responses to pollution discharges in estuaries. The sediments of the Passage have a significant yet finite capacity to buffer changes in water quality and moderate algal growth because sediments determine:

- the chemistry (in part) of interstitial and overlying waters;
- fluxes including the rates of adsorption and release of ions;

- the deposition and resuspension of material and transport of constituents; and
- the composition of dominant plant communities and structures.

High rates of sedimentation may also blanket seagrass or benthic algal communities to the point where they are no longer viable.

The inter-tidal zones including seagrass, mangroves and saltmarsh areas play an important role through the adsorption of organic and dissolved nutrients in the rising tide, and their transformation and partial return in a detritus form on the ebb tide, i.e. they act as a nett sink. The productivity of estuaries is therefore directly correlated to their tidal range and the reciprocal of their mean depth.

The tidal movement not only induces currents which circulate sediment and associated constituents but also maintains a mixed water column and salinity regimes necessary for the growth of halophytic plants. Tidal movement also contributes to inflow of marine constituents and the flushing of estuary constituents with the receding tidal flow.

Estuaries exhibit high rates of internal recycling of nutrients between plant photosynthesis, plant death and their sedimentation, decomposition and mineralisation leading to re-release of nutrients for plant uptake. The rate of release of nutrients is a function of the biologically available carbon necessary for bacterial reduction of iron, sulphur and other phosphorus bonding ions in the sediments. Although estuaries are highly productive systems, the organic matter comprises substantial proportions of cellulose, lignins and humus which are relatively resistant to breakdown. Hence carbon from organic material is less biologically available. Consequently, external (allochthonous) sources of biologically available carbon such as sewage, aquaculture or agricultural wastewater discharges can significantly impact on estuaries by stimulating the release of phosphorus from the sediments and promoting plant growth. Allochthonous sources may constitute up to 60 percent to 70 percent of the total biologically available carbon.

It is evident from the review that a significant increase in discharges of organic material to the Passage from allochthonous sources is generating a substantial increase in the available phosphorus and is promoting algal growth to the point that the Passage is under stress. There is a need to substantially reduce the loading of labile sources of organic material and to safeguard the intertidal saltmarshes and mangrove areas.

The humic substances discharged from wetland (organic colour) not only constitute refractory organic compounds which are resistant to chemical and biological uptake but also adsorb (chelate) metal ions thereby depleting their availability to sustain the growth of algae and bacteria.

The water clarity determines the availability of light for plant photosynthesis. The discharge or resuspension of fine particles (associated with high flows or tidal currents) limits light penetration which limits the rate of photosynthesis.

There are also two dominant food webs in estuaries, namely, the detritus-generated food web and the primary production generated food web. In the case of the detritus generated food web, dead organic matter derived principally from seagrass, saltmarsh, mangroves and benthic algae, provides a substrate for decomposition. The decomposers are consumed by microfauna which in turn provide a food source for higher carnivores.

In the case of the primary production generated food web, phytoplankton, vascular plants, and benthic algae synthesise the cellular material. Zooplankton graze on the phytoplankton and are, in turn, consumed by the carnivores including crustacea and fish. Consequently, the protection of the plant communities and structures is critical to the maintenance of the whole food chain and bio-diversity of the estuary.

These patterns of internal recycling of materials and associated community structures are modified by three external loading conditions:

(i) the daily nett northerly tidal flow through the Passage and associated loading of nutrients and other constituents from Deception Bay;
(ii) discharges of drainage waters from tributary streams along the Passage with their associated modification of levels of salinity, suspended solids, nutrients and organic materials; and
(iii) tidal exchange at the two seaward boundaries.

The algal biomass is high following major tributary discharges during the wet season in the March to May period. This increase reflects the substantial increase in biologically available carbon necessary to drive the bacterially mediated reduction processes which leads to the release of phosphorus.

Subsequently, the levels of available carbon decline over the dry season due to a number factors including the on-going loss of carbon dioxide (CO_2) to the atmosphere, its transformation into less available (refractory) forms and the take-up of carbon in the food chain and its storage in anaerobic sediments. The implications of this understanding of ecological processes include:

- the importance of limiting allochthonous sources of labile carbon; and
- the importance of maintaining wetlands, saltmarsh and mangrove areas as zones of transformation of carbon into detritus (refractory) forms.

During the 'dry season', the daily pattern of tidal ebb and flow, which is substantially greater than the nett northerly flow, leads to the substantial recycling of nutrients and carbon within the estuarine system.

4.2 Review of Water Quality Trends

The findings of previous water quality studies in 1978-1980 and the current review of1991-1992 data and the interpretation of the trends in the data reported in the Component Study on "Environmental Objectives for Water Quality" are summarised in this Section. The implications of these trends and the underlying processes evident in the data are discussed.

The 1991-1992 monitoring period was significantly different from the 1978-1980 period in terms of rainfall and associated quantity of runoff from the catchment. Annual rainfalls (averaged over the catchment) are compared in Figure 4.1. In comparing water quality between the two study periods it is important to account for this difference in rainfall and runoff.

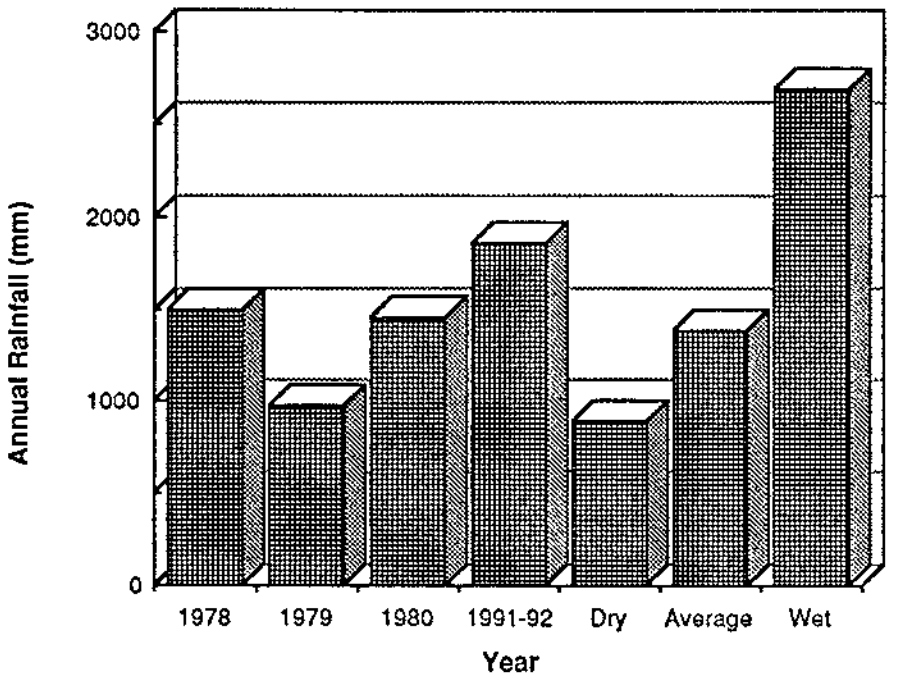


Figure 4.1 Catchment Averaged Annual Rainfall

4.2.1 Trends in observed water quality

The trends in water quality are considered in two parts. The water quality trends in the tributaries are considered first followed by a discussion of the trends in the Passage itself.

Tributaries

Changes in tributary water quality between the water quality monitoring periods 1978-1980 and 1991-1992 are consistent with changes in landuse across the catchment. The following changes were observed in the tributary creeks.

Nutrient and organic pollution:

- with the exception of Coochin Creek, there was a marginal reduction in total phosphorus levels (although a significant increase in loading associated with the substantially higher discharges in 1991-1992). A 15 percent increase in total phosphorus levels occurred in Coochin Creek. Increased runoff has two effects, namely the dilution of point source discharges and the increased export of pollutants from diffuse sources. This anomoly is explained by the high level of soil and associated nutrients washed-off from the catchment in the period 1978-1980 associated with the impact of land clearing for pine plantations, and the substantial decline in this source over the period 1980 to 1991-1992;
- levels of total nitrogen increased in the case of Bells and Coochin Creeks, but reduced in Lamerough and Elimbah Creeks. The increase in Bells Creek is consistent with the establishment of the sugar cane pilot plantation adjacent to the creek while the increase in Coochin Creek reflects the higher runoff flushing nutrients further through the estuary system;
- a significant increase in DO levels was apparent in Lamerough, Bells, Coochin, Elimbah and Ningi Creeks. This indicates a marked increase in algal productivity;
- significant increases in algal growth, which is reflected in extreme values of DO, occurred in Bells, Lamerough, Coochin, Bullock and Ningi Creeks;

- pH levels were generally similar to those of 1978-1980. However, under the substantially increased fresh water discharges associated with the higher rainfall in 1991-1992, a marked reduction in pH would normally have been expected. This anomoly is explained by the substantial increase in algal biomass evident in the 1991-1992 period as compared with the 1978-1980 period; and
- high *E.coli* levels were recorded on occasions in all monitored tributary creeks. The readings on 5-6 May 1992 on all creeks but Ningi Creek ranged from 180 to 800 CFU/100 mL. This was attributed to the higher tributary discharges in this period. The recorded levels were well in excess of AWQG recreation guideline value for primary contact of 150 CFU/100 mL;

Sediment pollution:

- notwithstanding the higher runoff for 1991-1992, suspended solids concentrations and turbidity were generally lower than for 1978-1980. However, Secchi disc depths were reduced by some 50 percent. This anomoly reflects the change in the dominant type of suspended solids, namely from abiotic material in the period 1978-1980, associated with the erosion from areas cleared for pine plantations, to biotic material in the period 1991-1992 associated with the substantial increase in algal biomass;

Toxic pollution:

- substantial increases in ammonia levels in Lamerough, Bells and Coochin Creeks were evident, reflecting increased levels of organic matter and algal biomass in the period 1991-1992 as compared to the period 1978-1980.

Natural organics:

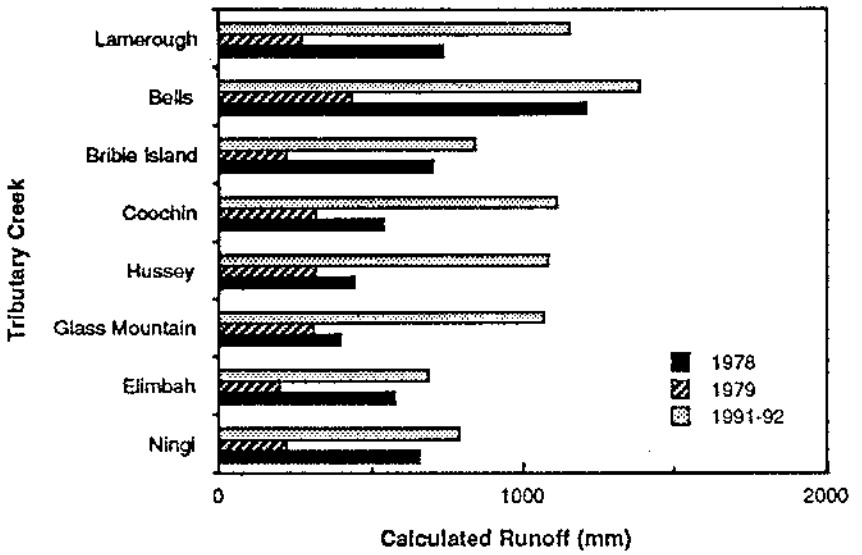
- a marked reduction (50 percent) in colour and suspended solids was identified in Lamerough Creek possibly reflecting the substantial drainage/removal of wetlands from the catchment.

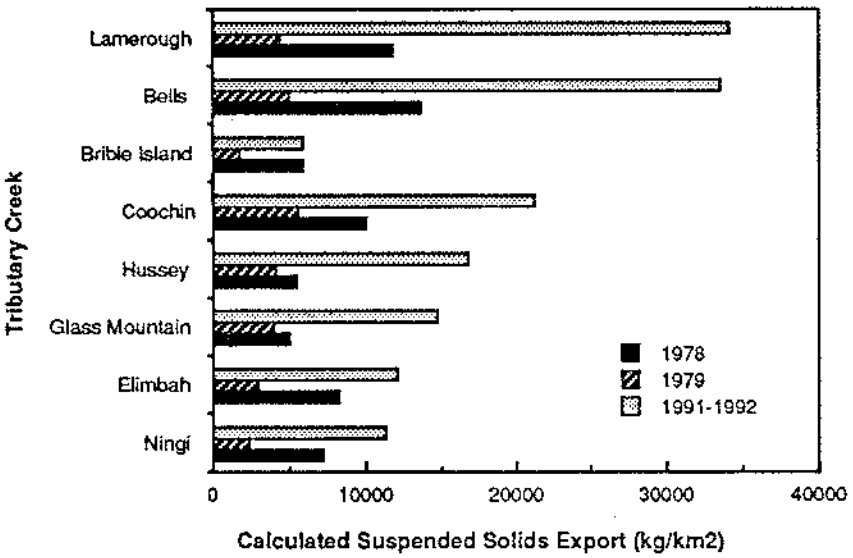
A comparison of the estimated annual pollutant export per unit area for each tributary over the two periods of monitoring is given in Figure 4.2.

The substantial increase in runoff associated with the higher rainfall in the 1991-1992 period lead to a substantial increase in exports across the tributary catchments in comparison with the 1978-1980 export levels. Changes in landuse explain 30-40 percent of increased exports in the case of Bells Creek, 20-25 percent of nutrients exports and 50 percent of suspended solids exports in the case of Elimbah Creek, and 10-15 percent in the case of Coochin and Glass Mountain Creeks.

High nutrient exports for Coochin, Elimbah and Bells Creeks (as compared to Glass Mountain Creek) reflect the extent of horticulture and agricultural industry in these catchments, while the high suspended solids exports in the case of Coochin and Bells Creeks reflect the high level of horticulture.

Chlorophyll 'a' concentrations provide one measure of the trophic state of a water body. High concentrations of chlorophyll 'a' (> 15 µg/L) typically indicate a water body which has become eutrophic. The estimated levels of chlorophyll 'a' are proportional to the biologically available phosphorus loading rates, and inversely proportional to inflow divided by the surface area of the water body and its average depth.





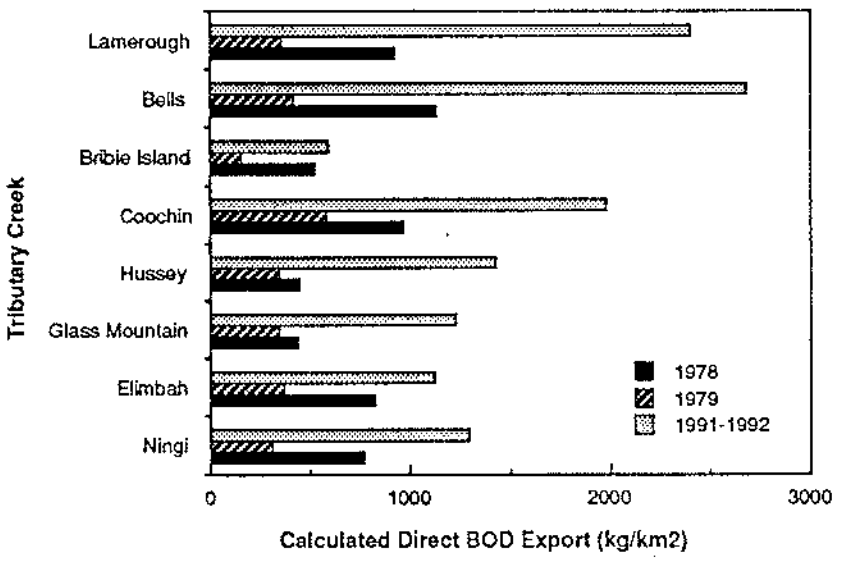
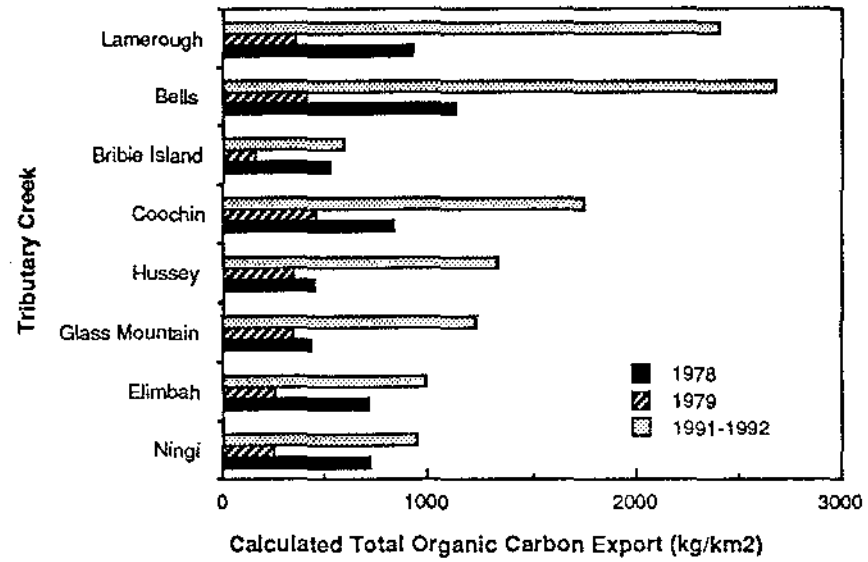
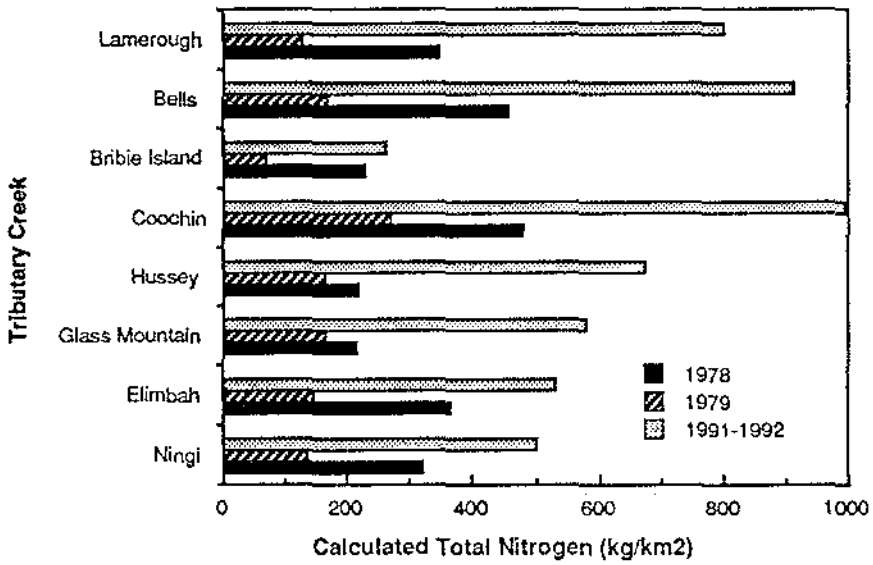


Figure 4.2 a Summary of Tributary Creek Exports





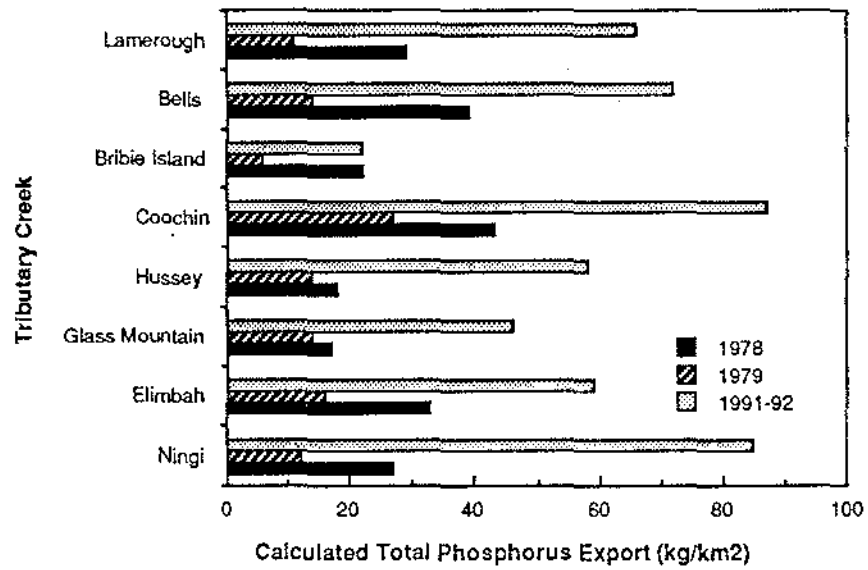


Figure 4.2 b Summary of Tributary Creek Exports

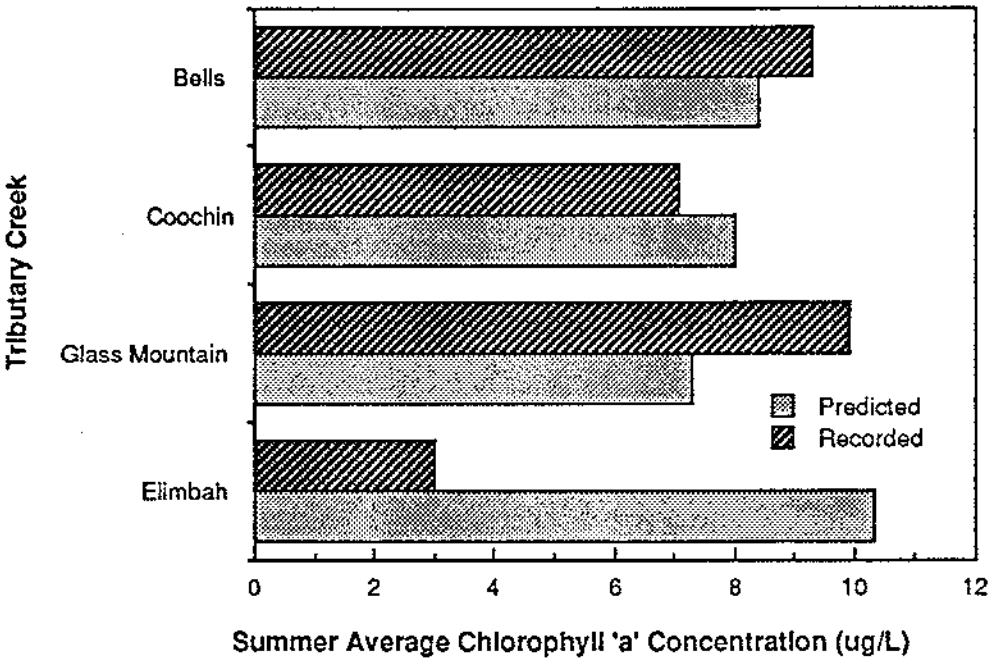


Figure 4.3 Predicted versus Recorded Summer Average Chlorophyll 'a' Concentrations for 1991-1992

Based on the estimated pollutant export levels (refer Figure 4.2) summer average chlorophyll 'a' values were determined and are compared with recorded data in Figure 4.3. The estimated levels of annual average chlorophyll 'a' for Elimbah and Coochin Creeks exceeded the limit of guideline values. However, the monitored levels were well below the levels estimated by the water quality model in these two creeks. This may be explained by high levels of pesticides that have accumulated in the sediments or possible high H_2S levels which could suppress biological activity in these waters.

The apparent anomaly of reduced total phosphorus levels with increased algal biomass is due to high levels of abiotic suspended solids dominating tributaries in 1978-1980 with phosphorus adsorbed onto suspended material, and the lack of biologically available carbon (relative to 1991-1992 levels) necessary to release phosphorus for algal uptake.

The higher algal biomass levels in the 1991-1992 period resulted from increased levels of biologically available phosphorus which in turn were consistent with increased loads of biologically available carbon probably as a result of increased agricultural productivity in the period 1991-1992.

While monitoring of pesticides in the sediments was not undertaken as part of the 1991-1992 monitoring program, a study of a range of pesticides was undertaken by the Department of Primary Industries in 1992 (Simpson et al., 1992). The study noted that a significant increase in the use of utilising pesticides by primary industries had occured since the previous 1982 study.

The more persistent organochlorines have been progressively withdrawn from use since 1977 with a total ban on their use for bananas and sugar cane since the late 1980s. Despite these bans, residues of persistent organochlorines are still occurring in soils. The use of other persistent pesticides (EDB and lindane) continues.

At the same time, the primary pesticide used for mosquito control (Temphos) is applied directly to water surfaces and is rapidly absorbed by plant tissue and bottom sediments where it is resistant to degradation.

Pumicestone Passage

A series of changes in the quality of the waters of Pumicestone Passage was also identified as follows:

Nutrient and organic pollution:

- there was a marginal (5-30 percent) decrease in total phosphorus through the Passage;
- a significant (40-75 percent) decrease in total nitrogen and organic nitrogen (50 percent) was recorded throughout the Passage; an increase in ammonia at a number of stations and a significant increase (100 percent) in inorganic N at all stations was recorded;
- generally there was an increase in N/P ratios to more constant values (9-12) throughout the Passage;
- a significant elevation in algal biomass levels was noted throughout the Passage with recorded chlorophyll 'a' levels being well in excess of the AWQG guideline values,
- a significant increase (30 percent) in DO to supersaturation levels was noted during the day. Likewise, it is almost certain that DO levels would be depressed to values below the AWQG 80 percent saturation minimum guideline value during the evening; and
- the significant increase in average pH levels (0.5 units) was well in excess of the AWQG 0.2 unit maximum guideline. Marine waters are strongly buffered so that a small pH change indicates a major change in the ecosystem.

The toxicity of pollutants such as ammoni is significantly increased with increases in pH. Increased pH impacts directly on marine plankton and benthic invertebrates and also affects sediment redox potential, increasing the release of nutrients from the sediments.

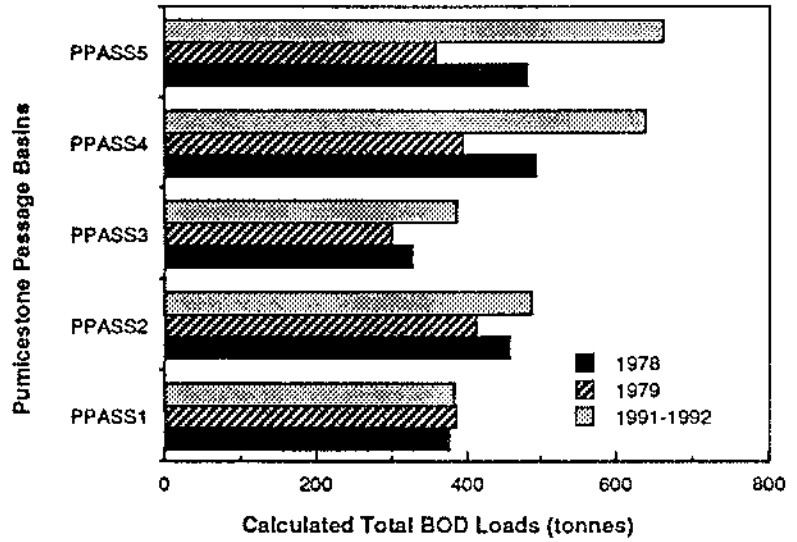
Sediment pollution:

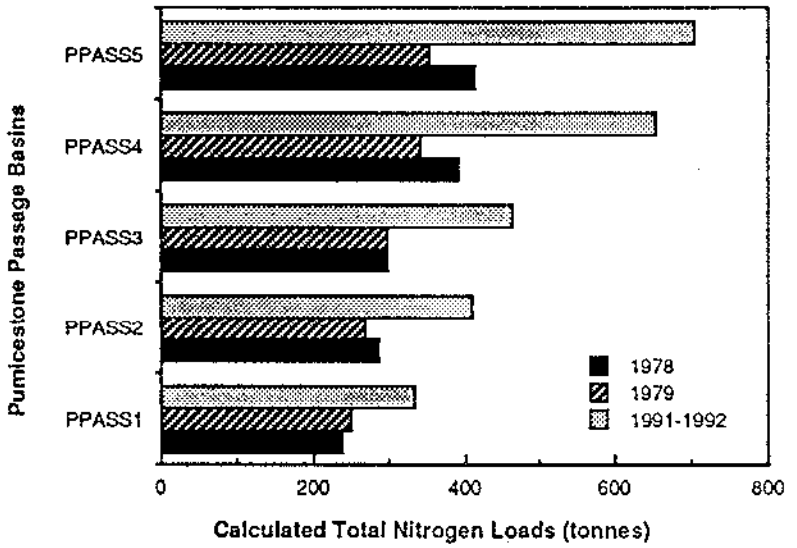
- a significant (40 -50 percent) reduction in suspended solids was identified;
- a significant (60 percent) reduction in the average Secchi disc depth was well in excess of the maximum permissible guideline reduction of 10 percent while an increase in turbidity was identified. This apparent anomoly between reduced suspended solids and increased turbidity/ reduced Secchi disc depth is explained by the change in the dominant form of suspended solids, from abiotic in the 1978-1980 period to biotic (algae) in the 1991-1992 period.

Toxic pollution:

- a significant increase in ammonia levels was identified in the middle to northern end of the Passage.

A comparison of the estimated annual pollutant loadings on the Passage for the two periods estimated using the water quality model is given in Figure 4.4. The basis of these estimates is described in the Component Study report on "Environmental Objectives for Water Quality".





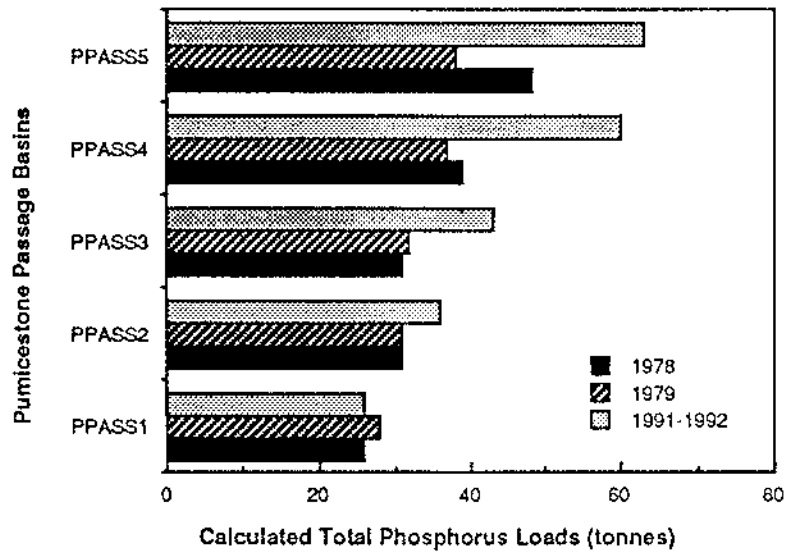


Figure 4.4 Various Pollutant Loads on Pumicestone Passage

The substantial increase in runoff associated with the higher rainfall in the 1991-1992 period lead to a substantial increase in exports across the catchment in comparison with the 1978-1980 export levels. Changes in landuse explain some 5-10 percent of the increase in nutrient loads and some 10-20 percent of the increase in suspended solids in the Passage.

Based on the estimated pollutant export levels (refer Figure 4.4), summer average chlorophyll 'a' values were determined and are compared with recorded data in Figure 4.5. The estimated levels of average annual chlorophyll 'a' for the northern arm of the Passage are at the upper limit of the indicative range of 1-10 µg/L which the AWQG notes are levels at which problems have been known to occur. Statistically extreme values based on the average concentrations would be expected to be some two to three times greater than the guideline limit. The AWQG include provision for the development of local guidelines and this issue is addressed in Section 4.3.

As was found in the tributaries, the reduced total phosphorus - increased algal biomass anomaly was attributed to high levels of abiotic suspended solids occurring in the Passage in the 1978-1980 period which was possibly due to on-going land development and the establishment of pine plantations at that time.

Although surveys of plant biomass have not been undertaken, comments received on the Issues Paper suggested that there has been an increase in seagrass from 1978 to 1992. One comment suggested that annual die-back of seagrass in August-September was due to a brown slime growth on its surface.

This observation is consistent with increased availability of phosphorus in the water column, with associated increases in planktonic and epiphitic algal growth. The increased turbidity associated with planktonic algae and the surface coverage of epiphitic growth each diminish the light available for seagrass growth.

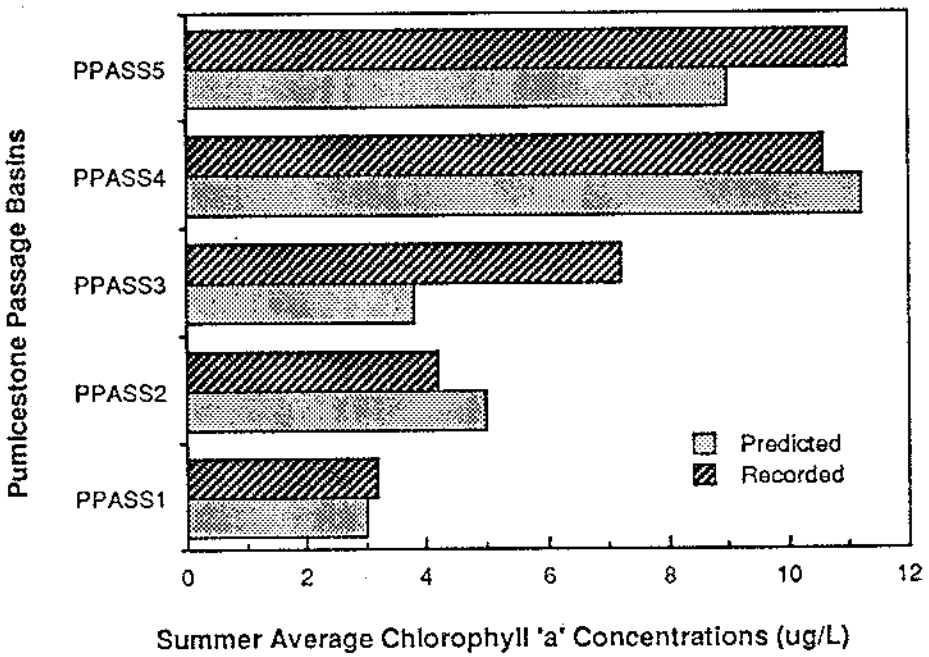


Figure 4.5 Predicted versus Recorded Summer Average Chlorophyll 'a' Concentrations for 1991-1992

While nitrogen is a primary nutrient necessary to sustain plant growth and is often cited as the limiting nutrient for estuaries, the typical ratio of total nitrogen to biologically available phosphorus of 16 to 30 for Pumicestone Passage suggests that nitrogen is not the critical nutrient in this case.

4.2.2 Implications of changes in water quality

The implications of the changes in water quality include:

Nutrient and organic pollution:

(i) an increase in algal biomass with extreme algal biomass levels evident in the lower reaches of the tributaries giving rise to odour problems and the depression of oxygen to levels which are lethal for biota; and

(ii) on the basis of these trends, it is likely that the structure of plant communities will change due to reductions in the euphotic depth (leading to an increase in inter-tidal seagrass species and mangroves and a decrease in sub-tidal seagrass species).

Sediment pollution:

(i) reductions in suspended solids in the tributaries and Passage coincided with reductions in the euphotic depth due to increased levels of biotic material. As noted previously, the reduction in euphotic depth reflects the shift in dominant suspended solids, from abiotic in 1978-1980 to biotic (algae) in 1991-1992.

Natural organics:

(i) although the tributary creeks generally exhibit high levels of natural organics in their waters, some tributaries have experienced an overall reduction. The greatest reduction has been in Lamerough Creek and the upper reaches of Coochin Creek. A reduction in humic content of drainage water as a result of the destruction of wetlands is likely to increase the availability of phosphorus and carbon, thereby increasing algal biomass levels in the estuary.

Chapter 2 discusses the environmental values of the Passage and its tributaries and recommended the adoption of the AWQG for Fresh and Marine Waters. The proposed Queensland Environment Protection Policy for Water is likely to be in accord with the AWQG. The most critical water quality objectives in the AWQG relate to the protection of aquatic ecosystems.

The most critical water quality objectives for Pumicestone Passage relate to the protection of aquatic ecosystems

The changes which have occurred in water quality and plant composition and structure indicate that current landuses and management practices are already significantly impacting on the estuary to levels in excess of the Guidelines. The Passage has a substantial capacity to buffer the impacts of pollutants in terms of the capacity of the sediments, mangrove and saltmarsh areas to absorb pollutants, and the natural patterns of alkalinity and re-oxygenation. That such a change in estuarine water quality has been observed suggests that changes in pollutant exports over the period 1978 to 1992 are already well in excess of sustainable levels.

Current landuses and management practices are already impacting on the estuary to levels in excess of the Australian Water Quality Guidelines

4.3 Critical Pollutants

The analysis of monitored data and water quality modelling results presented in Chapter 4 identified the water quality parameters which exceed the guideline values for the AWQG.

The pollution problems which were identified included:

Nutrient pollution:

- high levels of algal biomass reflecting increases in biologically available phosphorus;
- elevated pH associated with the high levels of algal photosynthesis ; and
- both elevated and depressed DO levels associated with algal respiration and decomposition.

Organic pollution:

- high BOD and *E.coli* loadings.

Sediment pollution:

- reduced euphotic depths which was attributed to increased levels of biotic (algae) material; and
- previous high levels of sediment (abiotic) loading impacted on the euphotic depth, and potentially impacted on the health of seagrass and mangrove areas.

Toxic pollution:

- elevated ammonia levels which reflect increased levels of organic matter and algal biomass; and
- accumulation of pesticides in the sediments inferred from lower than predicted chlorophyll 'a' levels in a number of tributary creeks.

Natural organics:

- a reduction in colour and natural organics due to the destruction of wetlands.

More than half of the pollutant loadings on the Passage are associated with the inflows from Deception Bay. Any changes in water quality in Deception Bay will impact directly on the future water quality and ecology of the Passage.

4.4 Sustainable Loading Criteria

Based on the review of water quality data and ecological processes, the water quality objectives were translated into criteria for sustainable loads for the critical pollutants. The sustainable loading criteria provide a basis for the evaluation of sustainable landuses and catchment management practices.

The major water quality problems identified in the water quality analysis were nutrient and organic pollution. The potential for toxic pollution by ammonia is a secondary effect of excessive algal growth. The determination of sustainable loads was based on:

- the limits on permissable change in pH where pH is primarily a function of algal photosynthesis. Hence compliance with the AWQG is determined in relation to sustainable phosphorus and BOD loadings (Figure 4.7);
- the permissable DO levels where DO levels are primarily a reflection of either supersaturation of oxygen by algae during periods of photosynthesis or depression of oxygen by algae during periods of respiration or due to decomposition following collapse of algal blooms (refer Figure 4.8). The collapse of a bloom may be triggered by sudden changes in temperature, salinity, or depletion of available phosphorus necessary to sustain growth;

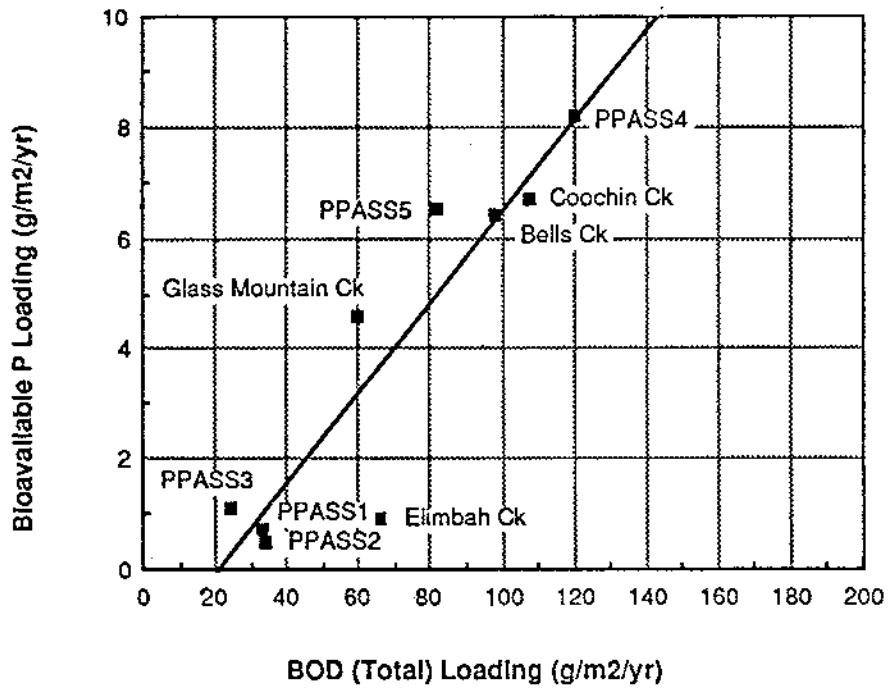


Figure 4.6 Biologically Available Phosphorus Loading Against BOD Loading

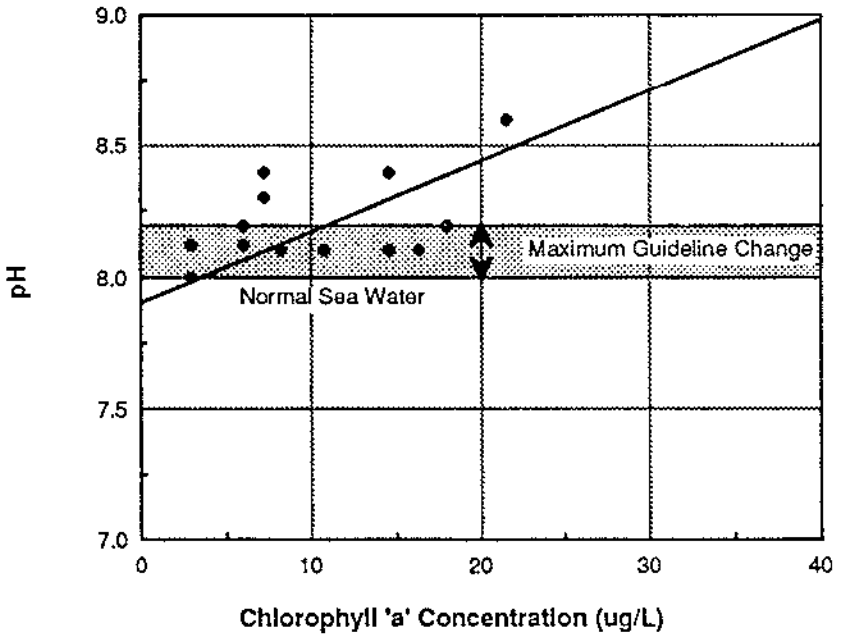


Figure 4.7 pH Against Chlorophyll 'a' Concentration

- the permissable ammonia level, which is a function of organic material and DO levels, both of which reflect the level of algal biomass (Figure 4.9). Compliance with the AWQG therefore relates primarily to sustainable phosphorus and BOD loadings;
- the limitation of algal biomass levels which is consistent with limiting pH change, DO and ammonia levels;
- the determination of sustainable phosphorus loading levels based on sustainable algal levels and BOD loading;

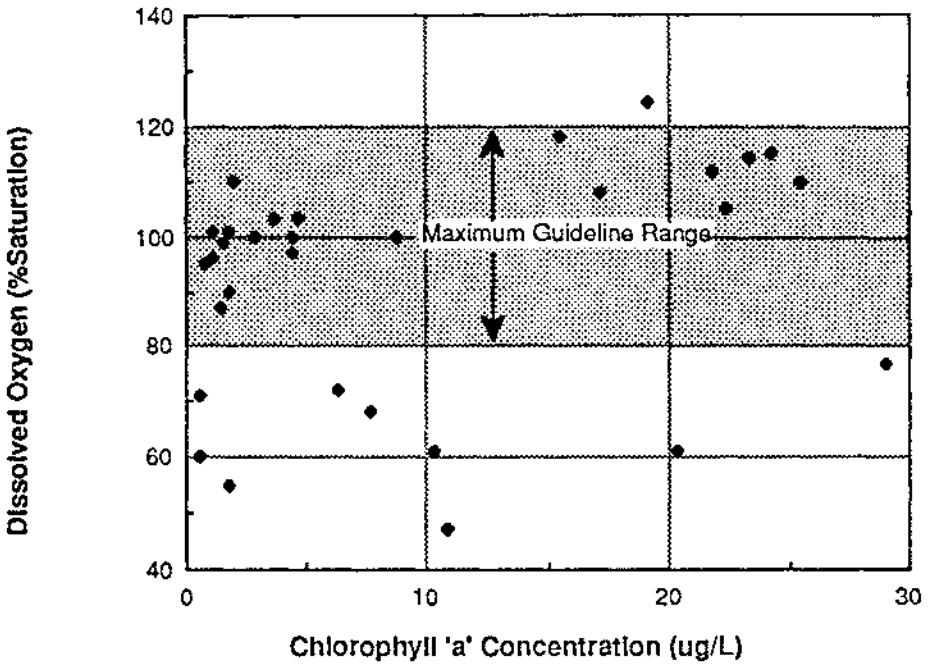


Figure 4.8 Dissolved Oxygen Against Chlorophyll 'a' Concentration

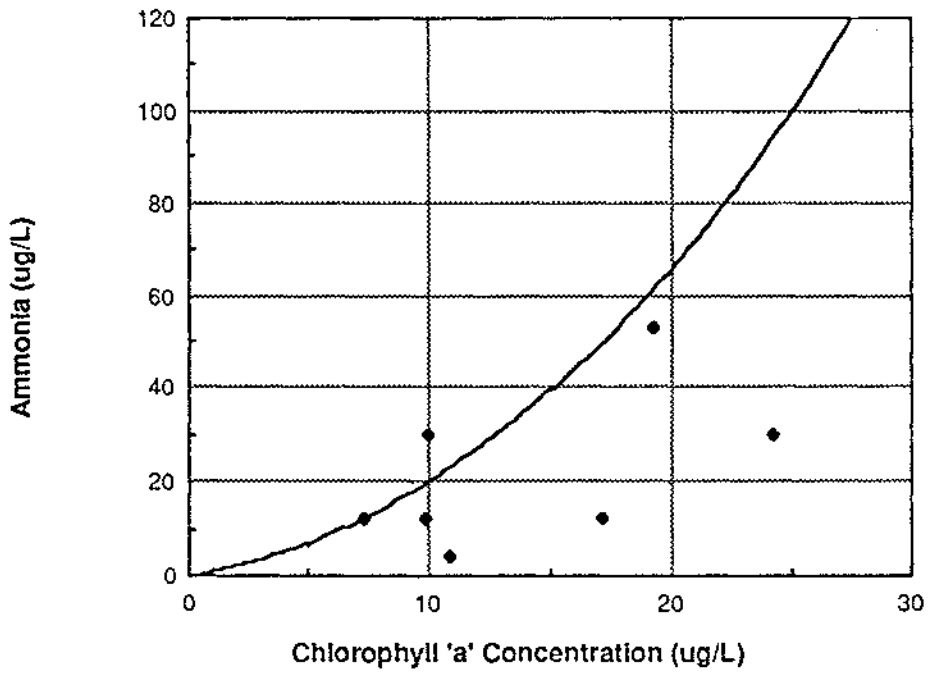


Figure 4.9 Ammonia Against Chlorophyll 'a' Concentration

- the determination of sustainable BOD loads which determine the biological availability of phosphorus (Figure 4.6);
- the determination of sustainable nitrogen loading levels based on a lower limit of 16 times the sustainable biologically available phosphorus loading necessary to maintain an TN/TP ratio which limits the incidence of blue-green algae and a limit equivalent of 600 µg/L in accordance with the AWQG. This limit is based on limiting the potential total algal biomass level to within AWQG values;

- the determination of sustainable pesticide loading was based on total exclusion of the application of organochlorines and limiting organophosphates to the recommended maximum concentrations identified in Table 2.10 of the Guidelines; and
- determination of suspended solids loading levels based on the Guideline requirement for levels not to exceed the seasonal averages by more than 10 percent. This loading translates to sustainable algal biomass levels (biotic forms of suspended solids) and the discharge of soil and related abiotic forms of suspended solids.

The AWQG identify a chlorophyll 'a' limit of 10 µg/L for estuaries and embayments. The correlation of monitored chlorophyll 'a' values with monitored pH and DO values given in Figures 4.7 and 4.8 supports the adoption of a 10 µg/L chlorophyll 'a' level as the appropriate guideline.

Statistical analysis of summer chlorophyll 'a' levels for each station in the Passage determined a standard deviation of 0.75 times the average. Based on this distribution, the likelihood of summer chlorophyll 'a' values exceeding guideline chlorophyll 'a' values of 10 mg/L or 15 mg/L was calculated. The results are presented in Table 4.2.

Table 4.2 Likelihood of Exceeding Summer Chlorophyll 'a' Guideline Value

Mean Summer Chlorophyll 'a' (µg/L)	Equivalent $P_{bioavail}$ (µg/L)	Probability Level Exceeds 10 µg/L	15 µg/L
4	14	3%	<1%
5	18	10%	<1%
6	22	25%	3%
7	26	29%	7%
8	30	37%	12%

For a chlorophyll 'a' criteria which limits the likelihood of exceeding 15 µg/L to less than or equal to 10 percent, a summer average chlorophyll 'a' value of 7 µg/L would be the sustainable limit and this was adopted for computing sustainable loads.

For each Passage basin, the hydraulic data and hydraulic loading were used to determine the sustainable loading of biologically available phosphorus using the Vollenweider model. The sustainable BOD loading was computed in turn using the correlation between biologically available phosphorus loading and BOD loading presented in Figure 4.4.

The minimum and maximum sustainable total nitrogen loading was determined using the previously identified criteria, namely:

(i) the minimum loading equals 16 times the sustainable biologically available phosphorus; and

(ii) the maximum permissable loading (g/m^2) equals 0.6 times the hydraulic loading (m^3/m^2).

The sustainable pesticide loading was determined using the previously identified criteria, namely the sustainable pesticides loading (g/m^2) equals 0.0001 times the hydraulic loading (m^3/m^2).

The sustainable loadings are summarised in Tables 4.3, 4.4 and 4.5. In some instances, sustainability is determined by the loading capacity of the local tributary estuary. In other cases, the sustainable loading is determined by the loading capacity further downstream in the Passage (refer Table 4.6). The variability of the sustainable loading on each tributary and Passage node is a reflection of varying hydraulic loading and retention time associated with different runoff conditions.

Table 4.3 Proposed Schedule of Annual Sustainable Biologically Available Phosphorus and BOD Loadings

Watercourse/ Passage Basin	Sustainable Biologically Available Phosphorus Loading (tonnes)			Sustainable BOD Loading (tonnes)		
Annual Rainfall	Dry	Average	Wet	Dry	Average	Wet
Elimbah Ck	0.77	1.41	4.98	45.80	62.98	137.40
Glass Mountain Ck	0.15	0.29	1.37	8.06	10.74	37.59
Coochin Ck	1.27	2.48	8.14	50.88	76.32	216.24
Bells Ck	0.68	1.43	3.33	27.00	40.50	90.00
PPASS1	19.29	17.70	6.78	689.00	363.00	424.00
PPASS2	18.90	18.08	11.51	753.50	685.00	548.00
PPASS3	18.90	18.49	15.45	690.00	690.00	621.00
PPASS4	19.32	20.12	24.02	564.00	587.50	680.00
PPASS5	21.09	23.09	30.12	592.00	666.00	703.00

Table 4.4 Proposed Schedule of Annual Sustainable TN Loadings

Watercourse/ Passage Basin	Sustainable TN Loading (tonnes) Minimum			Maximum		
Annual Rainfall	Dry	Average	Wet	Dry	Average	Wet
Elimbah Ck	12.59	22.90	80.15	15.11	28.85	107.86
Glass Mountain Ck	2.50	4.65	21.84	3.00	6.014	29.97
Coochin Ck	20.35	39.85	130.59	26.46	52.91	180.11
Bells Ck	10.80	22.95	53.10	13.77	29.97	72.09
PPASS1	307.40	286.20	106.00	356.16	324.36	108.12
PPASS2	301.40	287.70	178.10	369.90	353.46	213.72
PPASS3	303.60	303.60	248.40	380.88	372.60	306.36
PPASS4	310.20	324.30	385.40	414.54	434.28	518.88
PPASS5	340.40	370.00	488.40	439.56	483.96	639.36

Table 4.5 Proposed Schedule of Annual Pesticide Loadings

Watercourse/ Passage Basin	Sustainable Pesticide Loading (kg)		
Annual Rainfall	Dry	Average	Wet
Elimbah Ck	2.5	4.8	18.0
Glass Mountain Ck	0.5	1.0	5.0
Coochin Ck	4.4	8.8	30.0
Bells Ck	2.3	5.0	12.0
PPASS1	59.4	54.1	18.0
PPASS2	61.7	58.9	35.6
PPASS3	63.5	62.1	51.1
PPASS4	69.1	72.4	86.5
PPASS5	73.3	80.7	106.6

The sustainable loadings for biologically available phosphorus given in Table 4.3 give no clear indication of the Passage basin which is likely to limit the distribution of sustainable loadings throughout the catchment. The net sustainable bioavailable phosphorus per unit of catchment area given in Table 4.6 gives a better indication. The unit sustainable load is the sustainable load less the estimated bioavailable phosphorus discharging into the Passage from Deception Bay. It is evident that Hussey Ck - Halls Ck (PPASS4) is the critical reach in the Passage.

Table 4.6 Net Sustainable Export of Bioavailable Phosphorus (kg/ha of catchment area)

Watercourse/ Passage Basin	Cumulative Catchment Area (ha)	Net Sustainable Bioavailable Phosphorus (kg/ha)		
Annual Rainfall		Dry	Average	Wet
Elimbah Ck	133.92	5.7	10.5	37.2
Glass Mountain Ck	19.22	7.9	15.1	71.1
Coochin Ck	180.91	7.0	13.7	45.0
Bells Ck	41.36	16.5	34.6	80.5
PPASS1	68.02	214.9	191.6	31.0
PPASS2	226.07	57.8	54.2	25.1
PPASS3	336.98	35.3	34.1	25.1
PPASS4	580.66	7.1	8.7	15.2
PPASS5	662.81	10.7	13.7	24.3

4.5 Sustainable Catchment Loadings

The water quality investigations identified algal growth as the principal cause of changes in pH , elevation and depression of DO levels, increases in ammonia levels and reduction of the euphotic depth.

To protect the environmental values of Pumicestone Passage, its catchment and Bribie Island it will be necessary to:

- limit the discharge of nutrients;
- limit the discharge of organic wastes;
- control the use and discharge of pesticides; and
- limit sediment exports.

Sustainable loading levels for nutrients, BOD and pesticides were identified for the various Passage basins and a number of tributaries in Section 4.4. As indicated in Table 4.6, PPASS4 is the most critical basin in terms of sustainable loading. Consequently, it determines the sustainable export over much of the catchment and was used as the basis of the following analysis of sustainable loadings.

In the case of PPASS4, Table 4.7 provides a comparison of current and estimated future loading under the landuse pattern provided in the Strategic Plan outlined in Section 3.2.2 with sustainable loading levels.

Table 4.7 Comparison of Current and Future Annual Loading with Sustainable Loading for PPASS4

Pollutant	1991/1992 Loading	Strategic Plan Loading	Sustainable Loading
Total Phosphorus* (tonnes/yr)	60.2	61.4	33.6
BOD (tonnes/yr)	913.0	918.7	590.0
Total Nitrogen (tonnes/yr)	652.0	524.3	324 - 434
Suspended Solids (tonnes/yr)	13600.0	8900.0	

Notes: * Based on 60 percent biological availability of total phosphorus

As outlined in Section 4.1, in many cases transfers from the sediments to the water column determine the prevailing concentrations of pollutants or changes in water quality. These processes are controlled by the overall loading of pollutants on the sediments.

However, in the case of conservative elements including salinity, mass flows of the various inputs determine the prevailing estuary water quality.

The export of pollutants from the catchments, together with inflows from Deception Bay, determines overall loading on the estuaries. Ecologically sustainable landuses were determined in terms of sustainable loads on the estuary.

Sustainable loads were estimated in Chapter 4 in relation to nutrients, organic matter and toxicants, and suspended solids. In some cases, the most critical sustainable loading limit may relate to local impacts while in most cases the cumulative catchment loading in relation to a sensitive downstream node will determine the critical sustainable loading across the catchment.

As PPASS4 is the most critical downstream node, the sustainable estuary loads for a range of target chlorophyll 'a' objectives summarised in Tables 4.8 and 4.9 are based on the sustainable loads for PPASS4.

Table 4.8 Sustainable Loads of Critical Pollutants for PPASS 4

Target Chlorophyll 'a' (µg/L)	Equivalent $P_{bioavail}$ (µg/L)	Sustainable TP Loading* (tonne)			Sustainable BOD Loading (tonne)		
		Dry	Average	Wet	Dry	Average	Wet
5	18	22.3	23.3	27.7	420	450	480
6	22	27.3	28.3	33.8	470	490	590
7	26	32.2	33.7	40.0	564	590	680
8	30	37.2	38.9	46.2	635	658	752

Note: * Based on 60 percent biological availability of Total Phosphorus

Table 4.9 Sustainable Total Nitrogen Loads for PPASS4 (tonnes)

Target Chlorophyll 'a' (µg/L)	Equivalent $P_{bioavail}$ (µg/L)	Min Sustainable TN Loading			Max Sustainable TN Loading		
		Dry	Average	Wet	Dry	Average	Wet
5	18	214	224	266	415	434	519
6	22	260	279	325	415	434	519
7	26	309	323	385	415	434	519
8	30	360	370	440	415	434	519

5. Integrated Management Strategies

This section identifies management strategies to reduce cumulative pollutant loads to sustainable levels

Drawing on the environmental values of Pumicestone Passage, its catchment and Bribie Island and the analysis of ecologically sustainable loadings, a range of management strategies have been formulated to contain pollutant exports within the sustainable levels.

The management strategies have been assessed against a range of environmental, social and economic objectives to identify a preferred strategy.

The implementation details and administrative measures are outlined for the preferred strategy.

5.1 Summary of Environmental Values

A range of environmental values was identified for Pumicestone Passage, its catchment and Bribie Island in Chapters 2 and 3.

The major Passage values were identified as:

- its international, national and regional ecosystem significance in terms of its diversity of wildlife and habitats;
- its marine and wetland conservation values;
- its regional economic values;
- its recreation and tourism; and
- its educational and scientific interests.

The ecosystem protection, conservation and fishing values depend on the protection of the water quality and ecology of the Passage. Estuarine ecosystems depend on the protection of the patterns of tidal and freshwater flows, intertidal flows, and water quality to sustain their dynamic processes and productivity. The estuary sediments and extensive mangrove and saltmarsh areas are important elements of the ecosystem, and cushion changes in water quality.

The creation of fisheries reserves and marine parks provides a basis for the physical protection of habitats. However, the sustainability of the ecosystems of Pumicestone Passage and their biodiversity are dependant on the wider protection of water quality and flow regimes through catchment protection.

In the case of the fishery resource, its productivity is a function of the pelagic ratio (of surface area to volume), and the trophic regime which reflects the nutrient loading level and the sediment/suspended solids regime. A change in the trophic regime may lead to a substantial change in the structure and composition of the fishery.

The aesthetic values of the Passage, together with its recreation and tourism values, depend on the maintenance of water quality by avoiding bacteriological pollution, algal blooms and gross pollution.

The major catchment environmental values were identified as:

- its wetlands and heathlands
- its sites of cultural heritage
- its surface and groundwater supplies
- its recreation and tourism values
- its aesthetic and visual quality
- its regional economic significance, including agriculture, forestry and extractive industry

Melalueca wetlands and heathlands are located principally in the lower parts of the catchment and on Bribie Island. Some of these areas have been included in the National and Environmental Parks of Bribie Island and Pumicestone Passage. Corridors of natural vegetation have been retained along many of the tributaries draining the catchment. Tidal wetlands of the Passage are included within the marine parks and fisheries reserves.

Evidence of Aboriginal occupation of Bribie Island and the hinterland areas and features of early exploration represent the important cultural heritage of the area. The area also represents a cultural resource to Aboriginal people associated with the region.

Surface water provides an important source of water supply for irrigation and stock purposes, while groundwater is an important source of water supply for domestic, irrigation and industrial purposes. Groundwater ultimately discharges to the tributary creeks and to the Passage, impacting on overall water quality and ecology of the waterways. In the case of Bribie Island, groundwater provides the town water supply to settlements on the Island and is essential for the healthy function of the Island freshwater wetlands.

Recreation values focus on the Glass House Mountains, hinterland rural areas, Bribie Island, Pumicestone Passage and associated waterways.

The catchment also currently supports substantial primary industry including in terms of forestry, horticulture, fishing and grazing. Extractive industry is also significant.

5.2 Landuse and Development Trends - Problems and Issues

As outlined in Section 3.2, major landuses in the catchment in 1991 comprised pine forest (38.9 percent), open space (33.2 percent), horticulture (8.9 percent), grazing (7.3 percent) and urban (4.7 percent). Projections to the year 2001 contained in the local authority Strategy Plans indicate a further loss of open space to horticulture, grazing, and urban and rural residential land uses. These projections represent a doubling in the area of horticulture and urban land uses, and close to trebling in the area of rural residential land use. These forecasts have been made on the basis of minimal change in the area of pine forest across the catchment.

The population forecasts for the Caloundra and Caboolture draft Strategic Plans indicates continued strong growth (5.4-6.0 percent) across the catchment to the year 2001.

Pressure for expansion of urban and rural residential landuses, agricultural activities, and the potential for replacement of pine plantations with other rural or urban land uses following the harvesting of existing timber have significant implications for the water quality of tributaries and the Passage.

While addressing local public health and environmental quality issues, the provision of full sewerage for Landsborough and other towns may exacerbate nutrient export to the Passage, depending on the standards of treatment (secondary or tertiary) and the discharge policies adopted (discharge directly to tributaries, or a requirement for re-use).

Existing water quality problems identified in Chapter 4 include:

- increases in algal biomass to levels creating oxygen stress with potential impacts on aquatic animals;
- periods (associated with land clearing) of elevated sediment and suspended solids levels in discharges with an associated potential impact on the composition and structure of aquatic plants in the estuaries;
- reduction in levels of natural organics in tributaries and estuarine waters (as a result of the draining of wetlands) increasing the biological availability of phosphorus; and
- significant increases in the level of discharge of organic wastes to estuaries (horticulture, aquaculture and septic tank/sewage treatment plant effluents) promoting the release of nutrients from sediments and exacerbating algal growth.

Associated with these changes in nutrient regimes and algal biomass levels, there is a potential for substantial changes in the composition and structure of ecosystems, with losses of seagrass habitats, decline in the fishery, migration of shorebird populations and increasing incidence of algal blooms.

As noted in Section 4.5, the total exports of a number of constituents already exceeds the ecologically sustainable loading of tributaries and Passage estuaries. Continued growth without substantial change in land use management practices will lead to a decline in the ecological and environmental values of the Passage and its catchment.

The analysis of mainland groundwater quality reported in the Groundwater Resource Study conducted by DPI Water Resources (1992) highlighted the widespread nitrate pollution of groundwater associated with recharge from areas of horticultural and urban landuse. Fertilisers and effluents from septic tanks have polluted the groundwater in many instances to the point where the groundwater does not meet health standards for safe potable water. Investigation of the quality of the groundwater beneath Bribie Island found that, while it is low in pH, it is of a quality which is suitable for drinking.

Further clearing of native forest may lead to acidification of soils and groundwater. Likewise, clearing of pine plantations will mobilise iron and manganese, lead to acidification of groundwater and increase the export of sediment and suspended solids.

The review has highlighted the need to consider options for controlling on-going landuse and management to reduce current and future levels of pollutant exports to sustainable levels.

In response to the problems and issues outlined above, the following objectives have been identified as the basis for evaluating a range of management strategies:

- integrated management of land, water and related biological resources of the Passage and its catchment;
- protection of ecological and environmental values of the Passage and the catchment;
- social equity in terms of the distribution of opportunities and costs across the various community groups;
- economic efficiency and financial viability; and
- participation of all stakeholders in determining management strategies.

5.3 Generation of Management Strategies

This section adopts an Integrated Management Strategy approach to the protection and management of the resources and environmental values of the region and identifies a range of possible management strategies, in terms of:

- landuses and their locational criteria
- designation of conservation areas
- landuse management practices
- infrastructure provision

and evaluates each of the options in terms of:

- meeting the sustainable loading criteria identified in Chapter 4; and
- their social, economic and administrative implications.

Management strategies may comprise a number of techniques to secure the sustainable use of the resources of a catchment, including:

- exclude or constrain permissible landuses to levels and locations consistent with sustainable loading;
- designate significant or sensitive areas as conservation zones;
- require the application of land (best) management practices to limit exports for permissible landuses to levels consistent with sustainable loading; or
- a mix of all of the above.

The range of land uses, available management practices, and indicative export rates are summarised at Table A.1. This table provides the basis for the development of the management options outlined below.

The generation of management strategy options was guided by the following principles:

- the long-term sustainability of the resources of the catchment and the Passage;
- the identification of possible future population and settlement scenarios based on the current Strategic Plans for Caloundra City and Caboolture Shire Councils; and
- the equitable allocation of sustainable loads across landuses, as follows:
  - the application of economically achievable best management practices (BMPs) across all landuses;

- the application of the "polluter pays" principle, with a higher level of containment required for higher polluting landuses than for the lower polluting landuses; and
- the limitation of highly polluting landuses, on the basis of general interest or opportunity costs and other uses foregone.

Six management strategies were developed and are described in Table 5.1.

Table 5.1 Summary of Alternative Management Strategies

Management Strategy No.	Description
1	Current land management practices plus provision of secondary treatment of sewage for all urban areas
2	Adoption of first level BMPs for all landuses (refer Appendix A.4)
3	Adoption of second level BMPs for all landuses (refer Appendix A.4)
4	Adoption of second level BMPs for the three landuses with highest pollutant exports
5	Adoption of second level BMPs for the five landuses with highest pollutant exports
6	Adoption of second level BMPs and the exclusion of aquaculture and a 50 percent real reduction of horticultural landuse

Note: First level BMPs provide a first level of treatment beyond conventional practice i.e. primary treatment
Second level BMPs provide an extra level of treatment beyond the first level i.e. secondary treatment

5.4 Assessment of Management Strategies

In undertaking an assessment of the management strategies, the five objectives identified in Section 5.2 formed the basis of the assessment of the performance of the management strategies.

The integrated landuse exports-receiving water response model which was applied as the basis of this analysis ensured that the first objective of 'integrated management of resources' was applied to all strategies.

The second objective to 'protect ecological and environmental values' may be assessed in terms of the level of exports for each management strategy, related to the ecologically sustainable loadings determined in Chapter 4.

The equitable distribution of opportunities and costs across stakeholders, which was the third objective, may be assessed in terms of the costs borne by each group and the opportunity to secure the desired uses across each group.

The fourth objective of economic efficiency may be assessed in terms of the comparative costs incurred in securing reductions in exports of pollutants across the various options, using the no-action option as the basis of comparison. Financial viability is a function of mechanisms for securing funding of the protection measures and for recovering the investment in the protection measures.

The consultation process embraced in the study through input following publication of an Issues Paper and consultation with a wide range of authorities on the findings and recommendations of report, provides the basis of the fifth objective to achieve a 'collaborative approach across the community to determine the appropriate management strategy'.

An analysis of the management strategy options for the catchment draining to the PPASS4 basin is summarised in Appendix A.6. A comparison of the annual export estimates for each management strategy with the sustainable values under an "average" rainfall year (refer Table 5.2) indicates that, for catchment landuse patterns based on the current Strategic Plans, either the extensive application of best management practices (BMPs) across all land uses (as in Management Strategy 3), or some curtailment of the most highly polluting landuse activities (as in Management Strategy 6) will need to be implemented to reduce pollutant exports to sustainable levels. An assessment of the performance of the management strategies against the criteria outlined above is provided at Tables 5.2, 5.3 and 5.4.

The analysis presented in Appendix A.6 indicates the importance of full provision of sewerage to urban areas discharging septic tank effluents to the Passage or its tributaries. The analysis also indicated that the inflows from Deception Bay into the Passage represent some 50 percent to 67 percent of the total sustainable loading of pollutants on the Passage. Any changes in water quality in Deception Bay as a result of a growth in urban and industrial discharges to Deception Bay will directly impact on the future water quality and ecology of the Passage. Wastewater treatment management practices should therefore also be applied to catchment areas draining to Deception Bay.

The economic assessment of the six management strategies was undertaken on the basis of full provision of sewerage services to all urban areas. This was common to all management strategies. The estimated costs for each BMP are summarised in Appendix A. The net present values summarised in Appendix A.6 include capital and recurrent costs (for a period of 20 years, discounted at an interest rate of 10 percent to present value).

Table 5.2 Assessment of Management Strategies Against Sustainable Loadings

Management Strategy No.	Pollutant loading / sustainable loading (%) TP	BOD	TN
1	+83%	+56%	+22%
2	+61%	+11%	-5%
3	+18%	-1%	-12%
4	+16%	+15%	-12%
5	+12%	+10%	-12%
6	+3%	-4%	-15%

Table 5.3 Assessment of Management Strategies Against Social Equity Objectives

Strategy No.		Urban	Rural	Recreation	Development	Forestry	Aquaculture	Horticulture	Pasture
1	Cost ($m)	0	0		0	0	0	0	0
	Availability	F	F	C		F	F	F	F
2	Cost ($m)	+6	+10		SC	+5	+.02	+0.7	+1.2
	Availability	F	F	C		F	F	F	F
3	Cost ($m)	+10	+10		SC	+5	+.02	+0.9	+1.2
	Availability	F	F	M I		F	F	F	F
4	Cost ($m)	+10	0		SC	0	0	+0.9	0
	Availability	F	F	M I		F	F	F	F
5	Cost ($m)	+10	+10		SC	0	+.02	+0.9	0
	Availability	F	F	M I		F	F	F	F
6	Cost ($m)	+10	+10		SC	+5	-	+0.4	+1.2
	Availability	F	F	M I		F	50% Red	F	F

Notes: C - Closed to use (not available) SC - Significant Cost
F - Fully available M I - Minimal Impact

Table 5.4 Assessment of Management Strategies Against Economic Objectives

Management Strategy No.	Additional Cost	Financial Viability
1	+$0m	Urban costs incorporated into development - recovered in sale of land
2	+$22m	Rural costs met by land owner contributions - operation costs recovered in rates
3	+$27m	Aquaculture costs met by operators
4	+$12m	Horticulture costs met by farmers
5	+$21m	Pasture costs met by farmers
6	+$26m	Forestry opportunity costs carried by Government

The economic analysis indicated that Management Strategy No 6 is marginally cheaper than Strategy No 3. However, the major social and economic impacts of substantially reducing the extent of horticulture within the catchment outweigh the slight cost difference to the extent that Strategy No 3 is considered to be the best management strategy.

In addition to the issues of landuse and management practices which have been addressed in the above analysis, there are a number of landuse locational criteria and policies for the protection of wetlands and native vegetation that will also need to be integrated into the management strategy.

5.5 Recommended Integrated Management Strategy

The overall objective of the IMS is to secure the sustainable use of resources of Pumicestone Passage and its tributaries, while maintaining its environmental values. A comparison of the effectiveness and economic viability of the six strategies indicated that the desired objectives would be most efficiently achieved through the application of a range of techniques designed to reduce the pollutant exports from all land uses.

A management strategy which applies second level best management practices to all catchment landuses is recommended

The IMS proposes simultaneous action in four areas:

- planning instruments and policies
- community awareness
- best management practices
- further studies

5.5.1 Planning Instruments and policies

The mechanisms for implementing the preferred management strategy include:

(i) control of landuse activities and their location;
(ii) designate sensitive areas as conservation zones;
(iii) adoption of best management practices which limit the generation and export of pollutants to sustainable levels for the land and receiving waters;
(iv) provision of wastewater treatment and collection systems;
(v) encouraging industry self regulation and monitoring; and
(vi) community involvement.

The instruments available for implementing the preferred management strategy include legislative/administrative instruments, community stewardship and a combination of both. The principle instrument used for landuse control is the Planning Scheme for a local government area prepared under the Local Government (Planning and Environment) Act. The Planning Scheme is composed of four principal parts:

1. provisions for the regulation, implementation and administration of the Scheme
2. zoning and regulatory maps
3. strategic plan
4. development control plans

Supporting documentation for a planning scheme may include planning studies and planning policies. The IMS report could be used as a supporting document.

The provisions for the regulation, implementation and administration of the scheme provide for the designation and statement of intent for each zone, requirements for the use of land and buildings, erection of buildings and subdivision of land.

The zoning and regulatory maps depict, on a cadastral base, the zones into which a scheme area is divided or areas which are subject to particular planning controls.

The strategic plan includes a map showing the preferred dominant land uses for an area, a statement of objectives in respect of each of the preferred dominant land uses and criteria for the achievement of these objectives and the implementation of the plan.

A development control plan (DCP) includes maps which indicate the intentions for future development of the area designated on the maps to a greater level of detail than for the Strategic Plan and include statements of the intent of the DCP and criteria for its implementation.

For the implementation of the IMS to succeed it will be necessary within both local government areas for the IMS to guide the strategic plans and development control plans. This may require planning schemes to incorporate additional zones eg. conservation zone, environment protection zone.

Likewise, subdivision and building controls (eg. erosion and sediment controls) will need to be consistent with the IMS. Of equal importance will be the development of a consistent approach to planning schemes and bylaws by both Caloundra City and Caboolture Shire Councils.

Various Acts of Parliament also provide for the regulation and administration of activities which might influence the outcome of the IMS. These Acts relate to water resources, water supply and sewerage, resource industries, pesticide usage, conservation and heritage. Future legislation, including the proposed Environmental Protection Legislation and the new Local Government Act is expected to strengthen the legislative framework.

5.5.2Community awareness

Two on-going State Government initiatives (the Integrated Catchment Management Program and Landcare Program) have sought, through the sponsorship of State Government and the involvement of local government, industry groups, community groups and individuals, to engender a sense of ownership and stewardship of local areas.

Typically these programs are managed by local groups which have a commitment to resolve issues such as land degradation, pesticide and fertiliser usage and stream bank erosion. The programs are providing benefits such as better farm management practices and better control of runoff. Many of the solutions to problems have been generated by those involved in the groups. Through these groups, the many issues of concern related to runoff management, soil and water conservation, and land degradation have achieved a much higher profile in the community with a resultant increase in concern amongst industry, community groups and individuals and a greater commitment to reaching solutions through consensus.

5.5.3 Recommended Best Management Practices

Best management practices can substantially reduce the levels of pollutant export from a catchment

The review concluded that the objective of the IMS would be best achieved by implementing BMPs for all land uses. The recommended BMPs for each land use, which were drawn from the range of available BMPs (refer Appendix A), are summarised as follows.

Conservation Zones

An integrated suite of conservation zone management measures, including:

- clear designation of conservation zones associated with the protection of wetlands, buffer zones and riparian zones;
- identification of significant and sensitive habitats and locations for designation as conservation zones;
- provision of buffer zones around wetlands to manage potential conflicts with adjacent landuses; and
- development of interpretative material on the values of native vegetation, wetlands and riparian communities.

Urban

An integrated suite of stormwater and wastewater management measures, including:

(i) Urban development to be properly managed:

Implementation:

- strategic, development control and zoning plans;
- declaration of conservation and riverine zones; and
- landscape protection plans.

(ii) Drainage management:

- incorporation of swales and buffer (vegetated interception) zones to intercept runoff and associated suspended materials;
- retention/establishment of riparian zones along stream corridors and estuary foreshores, as buffer zones; and
- interception of stormwater runoff, and routing through sediment traps and trashracks, followed by storage in pollution control ponds or wetlands, prior to discharge to the Passage or its tributaries.

Implementation:

- application of development control and zoning plans;
- application of sub-division and building controls;
- environmental protection policies and management plans;
- local government provision of urban stormwater pollution control infrastructure.

(iii) Wastewater management:

- connection of all properties to sewerage systems; and
- provision of a biological and chemical (where necessary) treatment facility, followed by land filtration or wetland treatment where appropriate to achieve an average effluent quality for total phosphorus not exceeding 0.5 mg/L.

Implementation:
- environmental protection policies, licencing and management plans; and
- developer provision of sewerage systems - operation by local government.

(iv) Mosquito hazard management, including:
- identification of clearance zones around designated freshwater wetlands in order to exclude human habitation and other potentially conflicting uses;
- minimise sedimentation of tributaries in order to limit the potential for isolating pools of water from predators;
- design of edges to ponds and channels to minimise the potential for pools of water to be isolated from predators;
- construction of runnels to reduce the potential for pools of water to be isolated from predators;
- identification of pesticides which may be used safely with minimum risk to the ecology of the Passage and the catchment; and
- request the Tropical Mosquito Research Centre and DPI to develop guidelines for the management of mosquitos.

Rural residential

An integrated suite of measures to manage runoff and wastewater, including:

(i) Rural residential development to be properly managed:

- limit development to locations where the terrain, soils, block size and dwelling numbers are capable of containing all wastewater generated on the lot without leakage into the groundwaters.

Implementation:
- strategic, development control and zoning plans;
- declaration of conservation and riverine zones; and
- landscape protection plans.

(ii) Drainage management:
- exclusion of stock from drainage lines and associated floodways;
- exclusion of development and stock from floodplains and riparian vegetation;
- establishment of swales and soakage pits in suitable soils and terrain;
- use of grassed/landscaped floodways;
- maintenance of buffer zones on the lower side of blocks and the exclusion of rural residential development from riverine zones; and
- use of small water pollution control ponds.

Implementation:
- strategic, development control and zoning plans;
- application of sub-division and buliding controls; and
- environmental protection policies and management plans.

(iii) Wastewater management:
- adoption of composting toilets for sewage;
- recycling of treated wastewater;
- connection of all domestic wastewater (excluding septic tanks) to a common effluent system; and
- biological nutrient removal treatment of effluent or wastewater wetland treatment.

Implementation:
- environmental protection policies, licencing and management plans; and
- developer provision of common effluent systems - operation by local government.

(iv) Mosquito hazard management, including:
- identification of clearance zones around designated freshwater wetlands in order to exclude human habitation and other potentially conflicting uses;
- minimise sedimentation of tributaries in order to limit the potential for isolating pools of water from predators;
- design of edges to ponds and channels to minimise the potential for pools of water to be isolated from predators;
- construction of runnels to reduce the potential for pools of water to be isolated from predators;
- identification of pesticides which may be used safely with minimum risk to the ecology of the Passage and the catchment; and
- request the Tropical Mosquito Research Centre and DPI to develop guidelines for the management of mosquitos.

Transport

(i) Transport landuse to be properly managed:

Implementation:
- strategic, development control and zoning plans;
- declaration of conservation and riverine zones; and
- landscape protection plans.

(ii) Drainage management:
- minimise affected areas by fencing to prevent disturbance and drainage management;
- diversion of drainage around works areas;
- stabilisation of affected drainage lines through transport corridor;
- save topsoil for subsequent rehabilitation of the site; and
- use of buffer zones, silt fences and sediment ponds.

Implementation:
- application of development control and zoning plans;
- environment protection policies and management plans;

Extractive industries

A suite of measures to manage runoff and dredging:

i) Extractive industry .to be properly managed:
- based on land capability assessment; and
- exclusion from sensitive sites such as erodible banks.

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- minimise affected areas by fencing to prevent disturbance and drainage management;
- diversion of drainage around area of operation;
- contain area of operation and collect/treat runoff prior to its discharge downstream;
- avoidance of exposure of acid sulphate soils;
- management of stockpile areas and access routes to prevent land degradation;
- location of stockpile areas within areas serviced by sediment ponds/runoff treatment systems;
- progressive rehabilitation as extraction proceeds; and
- rehabilitation of site consistent with adjacent habitats and ecology.

Implementation:
- environmental protection policies and management plans; and
- application of development control and zoning plans.

(ii) Dredging management:
- exclusion of dredging operations from sensitive habitats;
- protection of the stability of channels and waterways; and
- designation of sediment basins for the interception and dredging of material to maintain/rehabilitate habitats downstream of tributaries subject to high sediment loads.

Pasture:

A suite of measures to manage runoff:

(i) Grazing to be properly managed:
- based on land capability assessment.

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- exclusion of stock from riverine corridors and margins;
- location of intensive stock holding areas away from major drainage lines; and
- provision of vegetated buffer zones around the periphery of holdings.

Implementation:
- education and economic incentives;
- landcare programs;
- environmental protection policies and management plans; and
- application of development control and zoning plans.

(iii) Wastewater management:
- use of ponds and wetlands to treat wastewater from stock.

Implementation:
- environmental protection policies and management plans.

Forestry

A suite of measures to manage runoff:

(i) Forestry to be properly managed:
- based on land capability assessment.

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- improve design of roads and drainage to minimise soil erosion;
- limit size of clearing coupes, with staged clearing operation;
- exclusion of felling along stream and drainage lines and associated buffer corridors;
- rehabilitation of eroded/degraded areas; and
- application of any pesticides/herbicides in locations, times and by methods to prevent/minimise any water-borne or wind-borne transport of these substances to receiving waters.

Implementation:
- environmental protection policies and management plans;
- application of development control and zoning plans.

Horticulture

A suite of measures to manage tillage, fertiliser and pesticide use and runoff:

(i) Horticulture to be properly managed:
- based on land capability assessment.

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Drainage management:
- direct drill based planting and/or contour-based tillage;
- testing to assess optimum levels of fertiliser application;
- exclusion of horticulture from riverine zones or groundwater recharge zones;

- provision of vegetated buffer zones surrounding cultivated areas; and
- incorporation of swales to intercept runoff and re-use on the block, or route it through sediment ponds and wetlands prior to discharge from site.

Implementation:
- education and economic incentives;
- landcare programs;
- environmental protection policies and management plans; and
- application of development control and zoning plans.

Aquaculture

A suite of measures to manage discharges:

(i) Aquaculture to be properly managed:
- based on receiving water sustainability assessment.

Implementation:
- provision of resource data by Department of Primary Industries.

(ii) Discharge management:
- exclusion of discharges from tributaries susceptible to adverse impacts due to poor flushing or propensity for bar formation to isolate the waterway or other loadings on the tributary;
- exclusion of facilities from areas of permeable soils susceptable to water table impacts and groundwater pollution;
- exclusion of facilities from shoreline zones, riparian zones and floodplains;
- avoidance of exposure of acid sulphate soils during pond or channel construction;
- adoption of current discharge levels for BOD and TP as an interim ceiling of sustainable loadings;
- the Aquaculture Research Station be requested to undertake the development of guidelines for best management practices which are appropriate for the Passage and its tributaries; and
- the intensive monitoring identified in Section 5.5.4 incorporate analysis of aquaculture discharges as part of a future review of the appropriateness of the interim discharge ceiling.

Recreation Boating

A suite of measures to manage wastewater discharges from vessels using the Passage or its tributaries:

(i) All vessels that have:
- sleeping accommodation and are longer than 6 m; or
- a galley; or
- a toilet;

are required to store waste in collection tanks or portable toilet with a pump-out facility for disposal at designated pump-out stations;
- provision of pump-out stations to receive wastewater discharges from vessels using the Passage or its tributaries.

Recreational and Commercial Fishing

An integrated suite of of management measures including:

• maintaining commercial and recreation catches within sustainable levels;

• driving vessels in shallow waters so as not to disturb the habitat;

• ensure fishing gear is kept under close observation and retrieved when fishing is complete; and

• quick release of undersized catch if inadvertently caught.

5.5.4 Further Studies

The Review identified two major areas requiring further studies: the need for on-going water quality and ecological monitoring of waters of the Passage and its tributaries and the need to further develop best management practices which are appropriate for the local region. The recommended further studies are as follows:

Water quality and ecological monitoring

(i) selection of indicators of the health of the ecosystem. There is a need to:
- classify significant ecosystems/habitats and to define key indicators of their composition and structure; and
- monitor indicators of key physico-chemical processes impacting on the ecosystems.

(ii) establish long term base-line water quality monitoring stations at:
- Bribie Island Bridge, to monitor long term changes in the quality of inflows from Deception Bay, the southern estuary, the Skids and the northern estuary.

(iii) periodically monitor storm events to:
- collect event water quality data to assess changes in pollutant exports from the catchment; and
- review the calibration of numerical models.

The monitoring should focus on representative stable catchments and catchments undergoing major landuse change.

(iv) utilisation of models in conjunction with monitoring to:
- evaluate changes in water quality across the catchment and within the estuaries; and
- detailed development of local management plans and controls.

Best management practices

There is a need to:
- periodically monitor water quality to review the appropriate level of BMPs to be implemented;
- review BMPs in terms of their requirements and appropriateness for Pumicestone Passage and its catchment; and
- develop BMPs for aquaculture and mosquito management which are appropriate to the local region.

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Appendix A Best Management Practices

A.1 Surface Runoff

A.1.1 Non-Point source pollution of stormwater

A wide variety of materials can be brought into drainage systems by rainfall and runoff, even when point sources are excluded. Typical non-point source "pollutants" may include (Goyen and McLaughlin, 1978): sediment, suspended solids, litter, floatable plant debris, e.g. leaves, oil and grease, nutrients: phosphorus and nitrogen compounds, toxic materials: heavy metals, pesticides, insecticides, herbicides, bacteria, viruses and other organisms, oxygen demanding substances and aquatic weeds.

In rural areas, pollutants typically comprise products of river bank and catchment erosion, nutrients and sediments from farmland and decaying vegetative matter originating from forest plantations and natural bushland.

In urban areas, pollutants typically include nutrients and vegetative litter from domestic and public gardens, petrochemical contaminants from the road system, paper, plastics and other solids discarded in streets, sediment from construction sites and disturbed areas and airborne pollutants washed into drainage systems during rainfall events.
The relative importance of the different pollutants varies according to the predominance of different sources in the catchment, the nature of the receiving waters and their water quality objectives (such as protection of desirable uses).

Particular pollutant source areas (Willing & Partners 1989) are summarised below.

Rural Areas
The process of grazing may reduce vegetative cover and may increase the potential for soil erosion from runoff as well as contributing to mechanical erosion from general stock movement. Areas that are cultivated may release chemicals used to aid plant growth, insecticides applied to fruits and vegetables to control insects and nutrients from decomposing plant matter. Plant litter produced by harvesting may be transported by surface runoff.

The Groundwater Resource Study (DPI, 1992) highlighted excessive concentrations of oxides of nitrogen in some areas. In particular; concentrations of nitrogen greater than recommended limits for drinking and irrigation were identified in the Elimbah Creek / Ningi Creek, Glass Mountain Creek / Bullock Creek and Coochin Creek groundwater catchments. These higher concentrations are most likely due to the excessive use of fertilisers, intensive animal operations and/or domestic septic tanks.

Stream bank and catchment erosion
Erosion is an on-going process, observed throughout the natural landscape. Urban and rural development accelerates erosion processes in soils and exposes areas which were relatively stable through the removal of protection by vegetative cover.

Greater velocities and volumes of flow will increase rates of erosion compared to the rates typical of the natural landscape. Structures constructed on the stream bank or in the river bed disrupt flow and may cause localised scour.

As a result of greater levels of erosion, sediment loads deposited at other locations or carried by streams will increase. If carried by a river, the sediment will ultimately be deposited in a waterhole, lake or estuary.

Residential areas
A significant proportion of the pollutants in urban areas is generated by the activities of residents. Such activities include (SPCC, 1986):

- dumping of garden litter and lawn clippings on public reserves or in street gutters;
- washing and maintaining of motor vehicles at the kerbside where wastes (detergents, oils etc) can run away in the drainage system;
- soiling of streets and footpaths by domestic pets; and
- inexpert and inappropriate fertilising and top dressing of lawns and gardens.

Individual instances of such activities are reasonably insignificant but the cumulative impact on receiving waters can be considerable.

Commercial and Industrial areas
General street garbage is more evident in non-residential areas due in part to greater concentrations of people and much more activity on the streets. The problem is exacerbated visually by discarded bulk waste such as product wrappings and containers (ACT Planning Authority, 1992b).

Floor washdown and trade wastes are often inadequately disposed of and can ultimately discharge to surface drains.

Road Runoff
Pavement surface contaminants are comprised mainly of particulate matter but also include non-particulate soluble and suspendable matter, all of which may be washed off the pavement surface by stormwater runoff.

On freeways and major arterial roads, traffic generated contaminants would constitute the major source of stormwater pollutant loads. These contaminants also differ from those generated by urban areas overall. In urban streets, however, a large portion of the contaminants comes from surrounding areas. This includes plant and other organic matter, nutrients (such as phosphorus and nitrogen) and litter.

Motor vehicles contribute a broad range of pavement surface contaminants including leakage of fuel, lubricants, hydraulic fluids and coolants; fine particles worn from tyres, clutches and brake linings; particulate exhaust emissions; dirt, rust and decomposing coatings which drop off undercarriages; vehicle components broken by vibration or impact and also litter discarded by vehicle occupants.

Heavy metals deposited on road surfaces include lead, zinc, cadmium and copper, all of which have adverse effects on biota. Lead is closely associated with dust and dirt because much of the lead which is deposited is absorbed on to dust and dirt particles. The loadings of these pollutants on a freeway are a function of the traffic load and its characteristics, rainfall magnitude and frequency, and cleaning practices (Horner and Mar, 1983).

The road surface itself is a source of pollutants. Asphalt surfaces have been found to have pollutant loadings 80% higher than concrete surfaces and US data (DMR, 1981) suggests that degrading asphalt particles are a major component of the increased pollutant loads.

A.1.2 Areas of changing land use

Changes in land use may lead to significant changes in the pattern of runoff and the export of constituents from a catchment. In particular, the change from rural to urban land use leads to significant increases in the export of non-point source pollutants. Changes in constituent processes as a result of land use change and their implications for pollutant loadings/impacts may include:

- significant increase in direct washoff to drains due to an increase in the area of impervious surfaces;
- changes in rainfall infiltration rates as a result of the sealing of surfaces, removal of topsoil and loss or alteration of vegetative cover;
- exacerbation of soil erosion as a result of modified drainage, increased peak discharges, losses in vegetative cover, changes in groundwater regimes, exposure of subsoils in construction or tillage and/or development on steep terrain or erosion hazard areas;
- physical disturbance of benthic and riparian habitats by sedimentation and streambank erosion;
- a more shifting, unstable and coarsely textured streambed;
- accumulation of imported materials (fertilisers, pesticides etc) on surfaces and in the groundwater;
- increased spillage and overflows in urban areas including the spillage of chemicals, oil, trash and debris, sewage and industrial wastes;
- reduced retardation of flow and interception of pollutants as a result of the loss of natural and constructed depressions and basins;
- reduced sediment interception as a result of increased discharge velocities and replacement of natural, vegetated drainage systems with engineered drainage systems e.g. natural creeks replaced by concrete-lined channels;
- enhanced remobilisation of material due to 'sharper' stormwater runoff peaks and the lining of drainage channels;
- changes in the diversity and abundance of aquatic organisms;
- wider and shallower stream channels with fewer pools which support fish;
- greater extremes in water temperature.

A.1.3 Selection of Best Management Practices

The adoption of prescribed management techniques to be applied across land uses as the basis for limiting or reducing exports of critical constituents to levels consistant with sustainable loading of downstream waters, is the most common approach to addressing non-point sources of pollution. The approach offers a number of advantages in that it:

- is simple to administer
- minimises uncertainty in relation to investment
- is effective, economic and equitable attainment of goal.

The Report identifies a range of techniques which may be applied in limiting or reducing the export of pollutants.

The selected management approach will involve the application of a range of techniques which collectively secure the desired reduction in exports, respond to a range of other objectives including economics, and adapt to local constraints and opportunities.

The selection of techniques needs to canvas a range of possible strategies:

- at-source minimisation through limitation of constituent mobilisation and runoff depth (land developer, owner)
- interception of entrained materials and retardation of flow (drainage authority)
- management of receiving water and uses (planning and management authorities).

Steps in the design of a management strategy include the:

(i) establishment of the sustainable catchment loading for a range of critical constituents in relation to ecological sustainability of downstream waters;
(ii) analysis of existing and proposed land uses across the catchment, and levels of exports of critical constituents;
(iii) determination of export reduction targets for critical constituents necessary to secure sustainability;
(iv) for critical constituents and levels of reduction requirements, identify the range of possible management techniques;
(v) check viability of techniques in relation to terrain, soils, climatic and land use constraints; and
(vi) identify pre-treatment requirements necessary for each technique to protect its hydraulic, chemical and ecological efficacy.

A.1.4 Outline of Best Management Practices

A wide range of best management practices (BMPs) are available. BMPs which could be applied in the Pumicestone Passage catchment are outlined below.

Land Use Practices

Land capability assessment
Excludes development in inappropriate areas and identifies techniques required to manage hazards as a condition of development.

Cultivation/Tillage
Adoption of direct drilling of seed and fertiliser instead of broad cultivation to substantially reduce erosion of exposed soils. Best management practice includes the timing and design (contour banking) of cultivation to minimise soil loss.

Fertiliser
Selection of type (rate of release) and application rate (soil testing) to optimise production.

Local Drainage Management
Establishment of drains to intercept runoff above works or a cultivation area and to transfer runoff either through or around a site in an existing or stabilised drain.

Sediment Traps
The traps intercept sediment washed into drains particularly after storms. Chemical dosing may also be used to treat runoff before it is discharged downstream.

Silt Fences
Use of hay bales or geotextile fabric to form a fence which reduces the velocity of overland runoff and traps sediment near its source.

Grassed Swales
Shallow depressions to intercept and temporarily retain runoff to enhance soakage and trap suspended materials transported by local runoff.

Buffer Zones
A vegetated area designed to intercept suspended material in runoff from adjacent land. Stock should be excluded from buffer zones to encourage robust vegetative growth. Such buffer zones should be in addition to conservation and riparian zones set aside for the protection of environmental values.

Revegetation
Stabilisation of exposed soil surfaces by grass or other vegetative cover. Mulching assists in the establishment and early growth of plants as well as providing temporary stabilisation of the new vegetation.

Drainage Management (Structural controls)

Soakage pits/recharge basins
The interception of runoff in local pits, trenches and basins allows groundwater soakage and recharge which reduces the rate and volume of runoff

Retarding Basins
The temporary storage of runoff in retarding basins during storm events reduces the peak flow downstream of a basin. These basins may also partially trap sediment transported during floods.

Grassed and Landscaped Floodways
Natural waterways and grassed and landscaped floodways have a substantial capacity to intercept suspended material during periods of high flow as well as providing a range of other economic, aesthetic and recreational benefits.

Gross Pollutant Traps
A sediment trap combined with a rubbish rack to intercept coarser sediment, rubbish, debris and other floating material transported by runoff. A gross pollutant trap (GPT) is designed to be cleaned periodically to maintain its trapping efficiency. Major and/or minor GPTs are typically located in trunk floodways or at stormwater outfalls.

Water Pollution Control Ponds (WPCPs)
Shallow ponds are used to intercept pollutants through a range of physical (filtration, sedimentation) and biologica processes (adsorption on to fine sediment particles, biological uptake). The growth of rooted plants within a pond enhances their appearance and trapping efficiency.

Ponds may also reduce peak flood levels downstream through retardation of floods. Water pollution control ponds are typically protected from the inflow of coarse sediment by the presence of upstream GPTs.

Wetlands
Wetlands are shallow water bodies which intercept pollutants through a range of physical (filtration) and biological processes (adsorption on to fine sediments, biological uptake) with the pollutants ultimately being incorporated into the bottom sediments. Wetlands may also provide a range of other conservation and education values. Wetlands constructed for pollution control should be in addition to natural wetlands which are likely to lie within proposed conservation and riverine zones to protect both environmental values and wetland vegetation which has evolved under low phosphorus conditions.

Guidance on the design and effectiveness of these practices are provided in ACT Planning Authority (1992a and 1992b), SPCC (1989), NCDC (1988), AMCORD (1990), QUDM (1992). Management systems incorporating gross pollutant traps, wetlands, water pollution control ponds and lakes have been shown to be extremely successful in reducing pollutant levels to those of the pre-existing "undeveloped" catchment with appropriate construction stage controls and adequate maintenance (NCDC, 1989).

A.2 Wastewater

A.2.1 Domestic sewage

Current practice in *rural residential* areas within the catchment allows the use of septic tanks and absorption trenches or commercially available on-site treatment systems. Many other techniques are available and are under consideration by the local authorities. Appropriate soil testing and assessment of potential groundwater impact will be appropriate in the selection of the treatment/disposal technique. Considering difficulties in other areas (Caloundra City Council,1991), such investigation is justified.

Sewage treatment in the *small townships which are not sewered* is achieved by septic tank and absorption trenches and holding tanks. One town in particular (Landsborough) has reported a higher than normal level of infectious disease of an enteric nature (Caloundra City Council, 1991). Bacteriological sampling of numerous watercourses in the Landsborough township was carried out for approximately 12 months with two sample locations consistently recording E.coli counts in excess of 8000 CFU/100 mL. This has been attributed to poor drainage systems. These watercourses eventually discharge into Mellum Creek.

Caloundra City Council is currently developing a policy and guidelines for wastewater disposal in non-sewered areas. Considering the problems highlighted by the Groundwater Resource Study (DPI, 1992) and the extensive aquifer throughout the catchment, such a policy and guidelines are considered essential for the protection of the groundwater resources with a particular emphasis on nitrogen problems.

As a consequence of these health problems, Caloundra City Council has resolved to sewer Landsborough although the method of treatment has not been determined. It is likely that tertiary treatment to remove nutrients will be favoured.

Allowance has been made in the ultimate planning for the Bribie Island Sewage Treatment Plant for treatment of sewage from Donnybrook and Toorbul although alternative systems, such as composting or common effluent drainage schemes, may be considered. The latter also may be considered for other isolated, unsewered areas within the catchment (Tansley, 1992).

The major urbanised areas within Caloundra City and Caboolture Shire are sewered with treatment provided to secondary standard (WRC, 1991). Only one sewage treatment plant is located within the study area on the southern end of Bribie Island. Land disposal of effluent is used. Within Caboolture Shire, three treatment plants discharge to the Caboolture River. All provide secondary treatment. Treatment plants are reported to be overloaded (RPAG 1992) with strategies for augmentation currently under investigation including consideration of tertiary treatment.

Pumping stations within the catchment have no special provisions, other than the provision of standby pumps, to intercept overflows discharging to creeks or drains and ultimately into the estuary or to the ocean. Overflows are screened to prevent discharge of gross solids. All are checked daily and include remote dial-up facilities in the case of mechanical failure or overflow.

A.2.2 Wastewater from Primary Industries and Others

Agricultural wastewaters comprise effluents from feed lots including chicken farms and aquaculture, which are typically high in suspended solids, oxygen demanding substances, and nutrients. In the case of aquaculture, the review has estimated a phosphorus discharge of 200 kg/ha of ponds/annum.

Management practices should comprise screening, sedimentation, aerobic and anaerobic biological treatment, and filtration, with substantial recycling of treated wastewater.

The major source of industrial wastewater within the catchment is the abattoir at Landsborough. This uses a lagoon treatment system and recycles approximately 60 percent of its effluent. Treatment of the 2000-3000 mg/L BOD influent is achieved through two anaerobic and two aerobic lagoons with a total detention time of 40 days achieving a final effluent BOD of 50 mg/L. This effluent is irrigated to improved pasture. It has been reported (Kirwan 1992) that runoff does not occur even in rainfall events. No monitoring of groundwater at the improved pasture or downstream has been undertaken. The abattoir is not licensed to discharge to a watercourse and it is not planned at this stage for it to be connected to the proposed sewerage system for Landsborough (Gill, 1992).

A future potential generator of industrial wastewater might include a plywood manufacturing plant to be located near Beerburrum. Other industrial wastewater generators which might be considered as point sources are the existing quarry and the solid waste disposal sites adjoining Lamerough and trade wastes. The quarry is a potential major source of silt while leachate from the solid waste disposal sites, if uncontrolled, could be a source of heavy metals and other toxicants from household and industrial refuse.

The current landfill site near the Corbould Park race track is operated as a sanitary landfill under the Refuse Management Regulations with leachate control and receives all household refuse (including kerbside collections) and dry industrial waste from the immediate catchment. There is no provision at this stage for venting of landfill gases. Limited recycling of car bodies and garden waste (leaves, trees) occurs on the site with the woodchip/mulch mixed with soil and sewage sludge for use as a final cover material to completed areas of the landfill. The sludge is dried but not composted before transfer to the landfill site.

The old landfill site (now closed) east of the Caloundra airport is reported to have received only privately deposited household waste (i.e. not from kerbside collections) and thus leachate is not considered to be a problem (Clark 1992). Water samples taken from time to time have indicated no problems but monitoring is not undertaken on a regular basis.

Landfills are a potential source of pollutants which should be monitored and investigated on an on-going basis.

A.2.3 Selection of Best Management Practices

Wastewater Collection & Treatment Systems
These comprise sewers, pump stations etc designed to collect residential and industrial wastewater, for treatment at a wastewater treatment facility prior to discharge to receiving waters, or re-use for irrigation or other purposes.

The level of treatment provided should be determined by the nature and quantities of pollutants contained in the wastewater, and by the discharges which may be sustained consistent with protecting downstream environmental values.

Treatment technologies comprise physical (screening, sedimentation and filtration), chemical (lime or iron for phosphorus, chlorine for disinfection) or biological (transformation of carbonaceous material into inorganic components, and transformation of dissolved nutrients into solids which may be removed through the sludge handling processes).

The First Level BMPs identified in this study comprise 'biological nutrient removal' based processes, or Standard Biological Treatment followed by land filtration, or use of an artificial wetland to strip nutrients, with a capacity to reduce phosphorus in effluent to less than 2 mg/L. Land filtration or artificial wetlands may be impractical under conditions of high water tables or wet season conditions.

The Second Level BMPs comprise biological and chemical treatment - the addition of ferric chloride to reduce phosphorus in effluents to less than 0.5 mg/L.

Composting Toilets
Composting toilets provide a non-water based waste collection and treatment system for managing human wastes.

Common Effluent Collection Systems
Partially treated wastewater from domestic septic tanks is collected for more thorough treatment to a standard which is acceptable for discharge to a receiving water or for possible re-use.

Common effluent collection systems are used where soakage of septic tank effluents is not achievable.

Re-use of Treated Wastewater
The recycling of treated wastewater for irrigation, non-potable domestic use or industrial use reduces the volume of wastewater discharging into receiving waters. It has been shown to reduce the demand for potable water supply by up to 50 percent.

A.3 Water Supply

Treated water supply for the catchment is provided via the Baroon Pocket and Ewen Maddock Dams, Caboolture River, South-East Queensland Water Board (SEQWB) reservoirs and Bribie Island Groundwater Storage (RPAG, 1992b). Domestic tanks and groundwater also supply large areas of the catchment.

All sources, except rainwater and groundwater, are located outside the catchment with no storages planned to be located within it. Wastewater reclamation (except for the abattoir at Landsborough) is not practised within the catchment although the final effluent from the Bribie Island Sewage Treatment Plant does partially recharge the Bribie Island aquifer to provide a buffer against saltwater intrusion.

The groundwater on Bribie Island is high in BOD, nitrates, magnesium, manganese, nutrients (nitrogen and phosphorus) and tannins. Treatment is therefore expensive bringing the treated water price to a level comparable with SEQWB prices (Tansley 1992). John Wilson and Partners (1990) report that the groundwater recharge method of disposing of sewage effluent adjacent to the water supply groundwater harvesting field should not degrade water quality.

Farm irrigation within the catchment is undertaken using farm dams or bores. Groundwater on the mainland has a low pH and is generally not considered suitable for human consumption. It is also considered that the current volumes extracted from groundwater for irrigation are unlikely to detrimentally affect the integrity of the aquifer (DPI, 1992). Shuttleworth (1992) expressed the view that some signs of stress to the orchard at Roys Road are possibly a result of increased groundwater salinity caused by saltwater intrusion from the nearby estuary or from the leaching of salts from the parent aquifer as a result of irrigation. Such problems could arise through irrigation using water of low pH.

As outlined earlier, changing landuse, particularly to urban, is likely to increase runoff volumes and rates and decrease groundwater recharge. In turn this would decrease the availability of water for irrigation and cause further intrusion of saltwater into the aquifer. Both would be likely to detrimentally affect vegetation, its suitability for silviculture and cropping and increase the salinity of the estuary and the movement upstream of the saltwater/freshwater interface. In addition, there are likely to be increases in pollutant concentrations in surface waters and therefore in the streams. Conversely, clearing of native forest may lead to acidification of groundwater.

The impact of any proposed landuse change on groundwater and surface water would require detailed assessment prior to any such change. In addition, further exploitation of the groundwater resource will require careful monitoring.

A.4 Summary of Recommended Best Management Practices

The review concluded that the objective of the IMS would be best achieved by implementing BMPs for all land uses. The recommended BMPs for each land use, which were drawn from the range of available BMPs, are summarised as follows.

Conservation Zones

- clear designation of conservation zones associated with the protection of wetlands, buffer zones and riparian zones
- identification of significant and sensitive habitats and locations for designation as conservation zones
- provision of buffer zones around wetlands
- development of interpretative material on the values of native vegetation, wetlands and riparian communities

Urban

Developing

- stabilisation of constructed surfaces to reduce ersoion
- chemical stabilisation of exposed surfaces to reduce erosion
- management of drainage around and through the site
- use of buffer zones
- use of silt fences and silt traps
- use of temporary sediment control ponds
- staged construction to limit disturbance of a site
- identification of clearance zones around designated freshwater wetlands
- minimise sedimentation of tributaries, design edges to ponds and channels and construct runnels to minimise the potential for pools of water to be isolated from predators
- identification of pesticides which may be used safely with minimum risk

Developed

- protection of floodplains and riparian vegetation
- minimisation of areas of impervious surfaces
- establishment of swales and soakage pits
- use of grassed/landscaped floodways
- use of buffer zones
- use of retarding basins
- use of gross pollutant traps
- use of water pollution control ponds and lakes
- retention/establishment of wetlands
- provision of full sewerage service
- physical, chemical and biological treatment of wastewater
- re-use of treated grey water
- identification of clearance zones around designated freshwater wetlands
- minimise sedimentation of tributaries, design edges to ponds and channels and construct runnels to minimise the potential for pools of water to be isolated from predators
- identification of pesticides which may be used safely with minimum risk

Rural Residential

- exclusion of stock from drainage lines and associated floodways
- exclusion of development and stock from floodplains and riparian vegetation
- establishment of swales and soakage pits in suitable soils and terrain
- use of grassed/landscaped floodways
- use of buffer zones
- use of small water pollution control ponds
- adoption of composting toilets
- use of soakage pits and trenches in suitable soils and terrains
- use of common effluent collection in areas unsuited to local adsorption of treated wastewater
- physical, chemical and biological treatment of wastewater
- identification of clearance zones around designated freshwater wetlands
- minimise sedimentation of tributaries, design edges to ponds and channels and construct runnels to minimise the potential for pools of water to be isolated from predators
- identification of pesticides which may be used safely with minimum risk

Transport

- minimise affected areas by fencing to prevent disturbance and drainage management
- diversion of drainage around works areas
- stabilisation of affected drainage lines through transport corridor
- save topsoil for subsequent rehabilitation of the site
- use of buffer zones and silt fences and sediment ponds

Extractive Industries

- contain area of operation and collect/treat runoff prior to its discharge downstream
- avoidance of exposure of acid sulphate soils
- management of stockpile areas and access routes to prevent land degradation
- location of stockpile areas within areas serviced by sediment ponds/runoff treatment systems
- progressive rehabilitation as extraction proceeds using saved topsoil
- rehabilitation of site consistent with adjacent habitats and ecology
- exclusion of dredging operations from sensitive habitats
- protection of the stability of channels and waterways
- designation of sediment basins for the interception and dredging of material to maintain/rehabilitate habitats downstream of tributaries subject to high sediment loads

Pasture (Grazing)

- exclusion of stock from stream banks and drainage lines
- exclusion of stock from riparian zones
- management of stock on floodplains
- location of intensive stock holding areas away from major drainage lines
- provision of vegetated buffer zones around the periphery of holdings and beside drainage lines and streams
- use of ponds and wetlands to treat wastewater from stock

Forestry (Pine Plantations)

- improve design of roads and drainage to minimise soil erosion
- limit size of clearing coupes, with staged clearing operation
- exclusion of felling along stream and drainage lines and associated buffer corridors
- rehabilitation of eroded/degraded areas
- application of any pesticides/herbicides in locations, times and by methods to prevent/ minimise any water-borne or wind-borne transport of these substances to receiving waters

Horticulture

- direct drill based planting and/or contour-based tillage
- testing to assess optimum levels of fertiliser application
- exclusion of horticulture from riverine zones or groundwater recharge zones
- provision of vegetated buffer zones surrounding cultivated areas
- collection of runoff for recycling or treatment prior to discharge

Aquaculture

- exclusion of discharges from sensitive tributaries
- exclusion of facilities from shoreline zones, riparian zones, floodplains and areas of permeable soils
- avoidance of exposure of acid sulphate soils during pond or channel construction
- adoption of current discharge levels for BOD and TP as an interim ceiling of sustainable loadings

Recreation Boating

All vessels that have sleeping accommodation and are greater than 6 m in length or a galley or a toilet are required to store waste in collection tanks or potable toilet with a pump-out facility for disposal at designated pump-out stations.

- provision of pump-out stations to receive wastewater discharges from vessels using the Passage or its tributaries

Recreational and Commercial Fishing

- maintaining commercial and recreation catches within sustainable levels;
- driving vessels in shallow waters so as not to disturb the habitat;
- ensure fishing gear is kept under close observation and retrieved when fishing is complete; and
- quick release of undersized catch if inadvertently caught.

A.4 Pollutant Exports for Different Landuses and Best Management Practices

The level of pollutant exports from particular landuses can be substantially modified using a range of control measures (eg. use of buffer zones and the interception and treatment of runoff etc) or by adopting different management practices from those currently practised.

The range of available landuse management practices within the Pumicestone Passage catchment, including indicative export levels for each management practice are summarised in Tables A.1 and A.2. The data are drawn from published material on best management practices, and has been adapted to the local conditions. First level BMPs provide a level of treatment beyond conventional practice (zero level) i.e. primary treatment while second level BMPs provide an extra level of treatment beyond the first level i.e. secondary treatment, etc.

Table A.1 Pollutant Exports from Diffuse Sources as a Function of Landuse and Management Practices

Landuse and Management Practices	TP	BOD	TN	SS	BMP Level
Urban (tonnes/km^2/yr)					
- sewered	0.07-0.1	3-4	1-1.2	50-65	0
- sewered + stormwater controls	0.02-0.03	0.9-1.2	0.3-0.4	15-20	1/2
Rural residential (tonnes/km^2/yr)					
- septic tanks (ST)	0.05-0.07	2-30	0.5-0.7	20-26	0
- ST + effluent reticulation (ER)	0.03-0.04	1-1.5	0.3-0.4	9-15	1
- ST + ER + interception works	0.01-0.02	0.5-0.8	0.2-0.3	4-6	2
Horticulture (tonnes/km^2/yr)					
- cultivation / fertiliser (C/F)	0.09-0.15	1.5-3	1.2-1.8	30-50	0
- C/F + buffer systems	0.05-0.10	1-2	0.7-1	20-35	1
-C/F + buffers + wetlands / ponds	0.03-0.05	0.6-1.2	0.6-0.8	10-20	2
- direct drilling	0.03-0.05	0.6-1.2	0.6-0.8	10-20	0
- direct drilling + buffer systems	0.02-0.03	0.3-1.0	0.3-0.6	6-10	1
Pasture (tonnes/km^2/yr)					
- no controls	0.02-0.03	0.8-1.0	0.25-0.36	6-9	0
- buffer systems	0.015-0.02	0.4-0.7	0.2-0.3	4-6	1
Forestry (tonnes/km^2/yr)					
- standard practices	0.01-0.02	0.3-0.5	0.15-0.21	3.5-5	0
- standard practices + buffer systems	0.01-0.015	0.2-0.3	0.1-0.15	2-3	1

Note: First level BMPs provide a first level of treatment beyond conventional practice i.e. primary treatment
Second level BMPs provide an extra level of treatment beyond the first level i.e. secondary treatment

Table A.2 Pollutant Exports from Point Sources as a Function of Landuse and Management Practices

Landuse and Management Practices	TP	BOD	TN	SS	BMP Level
Municipal Wastewater (kg/head/yr)					
- septic tanks in urban areas	0.3	5	1.3	3	(0)
- standard biological treat (SBT)	1	3	4	3	0
- SBT + land filtration	0.5	1	0.5	1	1
- SBT+ nutrient removal	0.2	1.5	1	2	2
- advanced physical/chemical treat	0.01	0.2	0.2	0.5	3
Cattle feedlots (kg/head/yr)					
- screen/traps	9	500	40		1
- screen/traps + ponds + land filtration	3	50	15		2
Piggeries (kg/head/yr)					
- screen/traps	2.3	200	8		1
- screen/traps + ponds + land filtration	1	30	3		2
Dairies (mg/L)					
- traps + ponds + land filtration	55	2000	100		2
Abattoirs (kg/head/yr)					
- screen / trap	0.4	20	4		1
- screen / traps + ponds + land filtration	0.1	5	1		2
Aquaculture (kg/ha)					
- screen	6	250	1100	1700	1
- screen + ponds + reuse	2	80	400	500	2

Note: First level BMPs provide a first level of treatment beyond conventional practice i.e. primary treatment
Second level BMPs provide an extra level of treatment beyond the first level i.e. secondary treatment

A.5 Representative Costs for BMPs

Representative capital and annual costs for a range of BMPs to address pollutants from both diffuse sources and point sources are presented in Table A.3 and A.4.

Table A.3 Indicative Establishment and Annual Costs for Various Diffuse Source Best Management Practices

Activity/Practice	Establishment Cost ($/ha)	Annual Cost ($/ha/yr)
DIFFUSE SOURCES:		
Rural		
1.1 Grazing		
• No controls		
• Exclusion of stock from waterways and use of grassed buffer strips	$1460-2700	$230
1.2 Dryland cropping		
• Standard cultivation and fertiliser spreading		
Direct drilling of seed and fertiliser	$28	
Grassed waterways	$50-100	
Drainage controls	$120	$35
Fenced buffers to intercept runoff	$130-1000	$240
• Wetlands	$1180-3300	
1.3 Forestry		
• No controls		
• Buffer strips - pine		$990
1.4 Irrigated horticulture, cropping and pasture		
• Standard spray irrigation		
• Recycling of irrigation runoff	$389-562/ML	$5-7/ML
• Micro-spray & drip irrigation	$1500-6000	
Rural residential		
2.1 Septic Effluent		
• Adsorption pits		
• Effluent reticulationn & treatment	$2000-3000	$200-300
Urban		
3.1 Urban stormwater		
• Conventional		
• Minimise runoff at source	$3000-5000	$100-200
• Rubbish racks and sediment traps	$100-200	$20-30
• Wetlands and ponds	$500-1000	$10-20

Table A.4 Indicative Establishment and Annual Costs for Various Point Source Best Management Practices

Activity/Practice	Establishment Cost ($/ha)	Annual Cost ($/ha/yr)
POINT SOURCES		
Municipal wastewater		
• Biological nutrient removal	$60/cap	$10/cap/yr
• Advanced treatment - physical /chemical process	$150/cap	$20/cap
Intensive agriculture		
• Cattle feedlots	$11-20/hd	$6/hd/yr
• Piggeries	$21/hd	$4/hd/yr
• Dairying	$30/hd	
• Aquaculture (ha of pond)	$1000 -2000	

A.6 Assessment of Management Strategies

Tables 4.5, A.6 and A.7 summarise an analysis of the six alternative management strategies for the catchment draining to the PPASS4 basin. A comparison of the annual export estimates for each management strategy with the sustainable values under an "average" rainfall year indicates that for catchment landuse patterns based on the current Strategic Plan, either the extensive application of best management practices (BMPs) across all landuses as in Management Strategy 3, or some curtailment of the most highly polluting landuse activities as in Management Strategy 6 will need to be implemented to reduce pollutant exports to sustainable levels.

An economic assessment of the six management strategies was also undertaken assuming that the provision of sewerage services to urban areas currently discharging septic tank effluents to the Passage or its tributaries is common to all management strategies. The Net Present Values summarised in Table A.8 include both capital and recurrent costs (for a period of 20 years, discounted at an interest rate of 10 percent to Present Value).

Table A.5 Total Phosphorus Export and Weightings for Catchment Area Draining to PPASS4 Basin

Landuse	Urban	Rural	Pasture	Horticulture	Native Vegetation	Pine Forest	Aquaculture	Residential Unsewered	Residential Sewered	Net Tidal Inflow	Total (kg)
Area (km^2)	37.63	31.89	91.21	58.6	117.8	243.51	0.066	18.1	18.1		
Export Rate (kg/km^2)	85	60	25	120	10	15	600	600	2000	24000	
Total Export (kg)	3199	1913	2280	7032	1178	3653	40	10860	35200	2400	
Strategy No. 1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	0.5	1.0	61394
Strategy No. 2	0.3	0.6	0.7	0.6	1.0	0.8	0.3	0	0.5	1.0	54135
Strategy No. 3	0.3	0.2	0.6	0.3	1.0	0.7	0.3	0	0.2	1.0	39806
Strategy No. 4	0.3	1.0	1.0	0.2	1.0	1.0	0.3	0	0.1	1.0	39022
Strategy No. 5	0.3	0.2	1.0	0.2	1.0	1.0	0.3	0	0.1	1.0	37491
Strategy No. 6	0.3	0.2	0.6	0.1	1.0	0.7	0	0	0.1	1.0	34768

Table A.6 BOD Export and Weightings for Catchment Area draining to PPASS4 Basin

Landuse	Urban	Rural	Pasture	Horticulture	Native Vegetation	Pine Forest	Aquaculture	Residential Unsewered	Residential Sewered	Net Tidal Inflow	Total (kg)
Area (km^2)	37.63	31.89	91.21	58.6	117.8	243.51	0.066	18.1	18.1		
Export Rate (kg/km^2)	3500	2500	900	2000	300	400	25000	10000	6000	310000	
Total Export (kg)	131705	79725	82089	117200	35340	97404	1650	181000	108600	310000	
Strategy No. 1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	0.6	1.0	920273
Strategy No. 2	0.3	0.5	0.6	0.6	1.0	0.8	0.3	0	0.3	1.0	655286
Strategy No. 3	0.3	0.2	0.6	0.3	1.0	0.7	0.3	0	0.3	1.0	586468
Strategy No. 4	0.3	1.0	1.0	0.3	1.0	1.0	0.3	0	0.3	1.0	679724
Strategy No. 5	0.3	0.2	1.0	0.3	1.0	1.0	0.3	0	0.3	1.0	648524
Strategy No. 6	0.3	0.2	0.6	0.15	1.0	0.7	0	0	0.3	1.0	568393

Table A.7 Total Nitrogen Export and Weightings for Catchment Draining to PPASS4 Basin

Landuse	Urban	Rural	Pasture	Horticulture	Native Vegetation	Pine Forest	Aquaculture	Residential Unsewered	Residential Sewered	Net Tidal Inflow	Total (kg)
Area (km^2)	37.63	31.89	91.21	58.6	117.8	243.51	0.066	18.1	18.1		
Export Rate (kg/km^2)	1000	650	300	1500	150	200	110000	3000	6000	230000	
Total Export (kg)	37630	20729	27363	87900	17670	48702	7260	54300	108600	230000	
Strategy No. 1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0	0.5	1.0	531533
Strategy No. 2	0.3	0.6	0.8	0.6	1.0	0.7	0.3	0	0.3	1.0	414576
Strategy No. 3	0.3	0.4	0.8	0.3	1.0	0.7	0.3	0	0.3	1.0	384360
Strategy No. 4	0.3	0.4	0.8	0.3	1.0	0.7	0.3	0	0.3	1.0	384360
Strategy No. 5	0.3	0.4	0.8	0.3	1.0	0.7	0.3	0	0.3	1.0	384360
Strategy No. 6	0.3	0.4	0.8	0.15	1.0	0.7	0	0	0.3	1.0	368997

Table A.8 Economic Analysis (Nett Present Value 1993) of Mangement Strategies

Landuse	Urban	Rural	Pasture	Horticulture	Native Vegetation	Pine Forest	Aquaculture	Residential Unsewered	Residential Sewered	Net Tidal Inflow	Total ($million)
Area (km^2)	37.63	31.89	91.21	58.6	117.8	243.51	0.066	18.1	18.1		
BMP Costs ($/km^2$)											
First Level	130000	300000	13000	12000		20000	300000	1400000	25000		
Second Level	130000	300000	13000	15000		20000	300000	1400000	300000		
Strategy No. 1	-	-	-	-	-	-	-	-25340000	-		25.34
Strategy No. 2	4891900	9567000	1185730	703200	0	4870200	19800	25340000	452500		47.03
Strategy No. 3	4891900	9567000	1185730	879000	0	4870200	19800	25340000	5430000		52.18
Strategy No. 4	4891900	0		879000			0	25340000	5430000		36.54
Strategy No. 5	4891900	9567000		879000			19800	25340000	5430000		46.13
Strategy No. 6	4891900	9567000	1185730	439500	0	4870200	0	25340000	5430000		51.72

Appendix B Review of Comments on the Issues Paper

B.1 Introduction

An Issues Paper was distributed by mail using a mailing list composed from respondents to the Moreton Bay Strategic Plan, respondents to consultation exercises undertaken for the Management Planning for National, Environmental and Marine Parks of Bribie Island and Pumicestone Passage component study, Department of Environment and Heritage contact lists arising from previous work in the catchment and respondents to the newspaper advertisement in The Courier-Mail and local newspapers on (or about) 30 May 1992.

The comments which are reviewed include comments received directly in response to the Issues Paper, comments arising from public consultation and the pertinent parts of comments received in relation to the Management Framework, Constraints and Issues document prepared for the Parks component study. Issues pertinent only to Parks Management have not been reviewed. Responses are provided to each comment or set of comments and where appropriate the reader is referred to sections in the main body of the report for further information.

B.2 Overview

The comments range from issues relevant to particular locations, specific health and conservation issues through to broad conservation/environmental protection issues and to the need to provide for urban land development.

B.3 Issues

B.3.1 The Study Approach

Study Area
It has been suggested that the study area be increased to the south to extend from 27 degrees 10 minutes to South Point on Bribie Island to include the influence of the Caboolture River and Burpengary Creek.

The potential for discharges from the Caboolture River to impact on Pumicestone Passage was recognised (refer Page 78). Limited data on circulation patterns in Deception Bay were reviewed and found to not indicate direct movement of water from the Caboolture River into Pumicestone Passage . However the data did not include information on circulation patterns in response to flood flows from the Caboolture River. It was concluded that the study area be limited to the catchment draining into Pumicestone Passage.

Catchment versus Region
Concern has been expressed that while it is useful to use a catchment as the boundary for the study in terms of pollutant export, the impact of activities in the catchment on human activities will be regional and this should be addressed.

The regional implications were recognised through the formulation of an integrated management strategy for ecologically sustainable development which recognises the value of current landuses and maintains those landuses through the application of appropriate best management practices i.e. no current landuse is prohibited under the IMS.

Study Topics
It has been noted that most of the study topics are not covered by the component studies and that it is not clear how such issues are to be quantified, assessed and incorporated into the strategy in such a short time frame.

Pumicestone Passage Management Strategy should concentrate not only on future development but also existing development and not only land uses which require the approval of Council but also the "as of right uses" i.e. including agricultural production.

The study concluded that current landuses and management practices are already significantly impacting on the estuary to levels in excess of the Australian Water Quality Guidelines (refer Page 54). The best management practices which have been identified equally apply to all existing landuses within the catchment.

Ecological Sustainability
This is seen by some as "an important, worthwhile, attainable and respectable goal".

The IMS represents a rigourous application of ESDprinciples to achieve ecological sustainability.

B.3.2 Pumicestone Passage Values and Uses

Ecological Importance
It has been suggested that the Pumicestone Passage is important ecologically.

This is fully supported by previous studies and the current review.

Melaleuca Areas
There have been suggestions that there have been detrimental changes to melaleuca areas near the Toorbul Mobile Home Park. Other changes near Bell's Creek are attributed to lowering of the groundwater table or saltwater intrusion. It has been suggested that the melaleuca areas are not of real value to the bird population as this population is mainly waders.

Noted.

Mangroves
There is generally concern at the loss of mangrove areas. However, a commercial fisherman and the Estuarine Research Group report that the area of mangroves is as large as it has ever been with mangroves expanding into once freshwater swamp and heathland. Mangrove depletion along foreshores may contribute to instability problems.

Noted.

Seagrass
It has been reported that there is now more seagrass than in the past 60 years and that seagrass only grows out to about 1 metre depth of water. In September each year the seagrass dies back due to a brown slime growing on its surface. It regenerates by the end of December.

Noted.

It has been reported that seagrass beds have been disturbed by "worm diggers and amateur fishermen".

Saltwater Intrusion
It has been reported that, in recent years, orange trees at Roy's Road have been dying apparently either from groundwater level changes or saltwater intrusion. In addition, the melaleuca swamp from the orchard to Bell's Creek is changing. The trees are thinning out and, in fact, many are dying or dead. It has been suggested that this may be due to lowering of groundwater or from saltwater intrusion. Black wattle is beginning to become well established in these areas.

Noted for consideration by the Groundwater Component Study.

Fauna
Over the last 30 years there has been a decrease in the number and diversity of species in the catchment and within the Passage.

Noted.

Birdlife
Concern has been expressed that developments such as Bell's Creek Arterial Road and bridge will alter the creek hydrology and affect feeding and roosting areas of the shore birds. Concern has also been expressed at a perceived lack of commitment to the CAMBA, JAMBA and Ramsar agreements.

Noted.

Fish Abundance
A survey undertaken in July 1992 suggests that fish numbers were down on previous surveys and that two previously recorded species, *Nannoperca oxleyana* and *Pseudomugil mellis*, were absent. It has been suggested that siltation and defoliants may have contributed.

The decline in fish numbers may be as a result of changes in water quality in the estuary. Water quality and ecological processes are discussed in Section 4.2.

Gambusia attinis (an introduced species) seems to be adapting to the low pH environment and is becoming more abundant.

Noted.

Dredging
A number of respondents contend that dredging should be discontinued while others contend that limited dredging be allowed to preserve the navigational channel and to preserve the net northward water movement through the Passage. Others want the Passage and the mouths of the creeks dredged.

The inflows from Deception Bay and their net northward flow represent 50 percent to 67 percent of the total sustainable loading of pollutants on the Passage (Page 78). Any significant modification of the its geometry has the potential to significantly affect the water quality within the Passage.

Beach Replenishment
A number of respondents have suggested that beach replenishment be discontinued and that natural processes be allowed to operate. Others report a need for replenishment at Golden Beach and Banksia Beach.

Noted for consideration in the Coastal Processes Component Study.

Sand Dune Stability
It has been put forward that the main reason for the collapse of dunes at Kings Beach (leading to breaching of the Caloundra Bar) was the effective drainage of wetlands behind the dunes by filling and piping. This led to lowering of the perched water table in the dunes, the loss of dune vegetation and the loss stability under high winds and severe wave action.

The importance of wetlands in maintaining water quality within the Passage and its tributaries was confirmed by the review. It is recommended that riverine zones including wetlands be retained/established as buffer zones within the catchment. This may indirectly assist in the stabilisation of dunes.

Houseboats
Controls on houseboats in relation to effluent management (holding tanks, pumpout facilities) should be increased.

The need to improve effluent management practices within the catchment is one of the key conclusions of the review.

Canal/Marina Development
Concern has been expressed at mangrove destruction on the one hand and concern on the other that lack of planning and a protracted decision-making process have frustrated developers who have tried to force the issue.

The IMS provides a framework which will hopefully assist the decision-making process.

B.3.3 Catchment Values and Uses

Population Projections
Comment has been made that the actual population for the Moreton Region is significantly lower than "low" projections but that for the Sunshine Coast the "high" projections have been exceeded.

Noted.

Forest Industry
It has been suggested that land under forest remain under forest or that, where private landowners do not wish to continue in silviculture, the land should be acquired for such use by the State Government, except for the land on Bribie Island which should be rehabilitated to native vegetation.

In preparing the IMS a methodology for assessing the impacts of changes in landuses on water quality in the Passage has been developed which can be equally applied to any proposed landuse scenarios. Rather than prohibiting landuse changes ,the IMS identifies the best management practices which will need to be implemented to limit pollutant exports to ecologically sustainable levels.

It has also been suggested that "clearing of the pine forests be subject to financial assurance that logging guidelines be followed".

Noted for consideration by DEH. The need to apply BMPs to control runoff in forestry areas is recognised in the IMS.

Pine Forests
Concern has been expressed at possibility of acidic leachates from denuded harvested forest areas entering groundwater and that harvesting procedures ought to have tighter controls, particularly in relation to silt management.

The need to apply BMPs to control runoff in forestry areas is recognised in the IMS.

Future of the Pine Forests
It has been suggested that pine resin residues in the soil after pine forest harvesting may inhibit regeneration of such areas. Others have suggested that all pine forests be returned to native vegetation.

Noted.

Vegetation Protection
It has been submitted that vegetation protection orders (or similar) be implemented to protect streamside vegetation. Buffer widths from 10 metres to 100 metres have been suggested.

The retention/establishment of riverine zones along stream corridors and estuary foreshores as buffer zones is one of the key BMPs recommended in the IMS. The selection of appropriate buffer widths would be undertaken during the formulation of interim guidelines for all BMPs (Page 79).

Agricultural Land
It has been stated that soil erosion and agricultural runoff pose very real threats to the Passage and that current DPI programs aimed at better land and farm management have not been successful in reducing these problems to the extent that a more interventionist approach is necessary.

Good quality agricultural land should be preserved through appropriate Strategic Planning and farmers should not be permitted to subdivide "when times get tough or they get too old to farm".

On the other hand, farmers see the "right" to subdivide as providing their superannuation.

The IMS has identified the need to apply BMPs to horticulture and pasture. A range of legislative and administrative instruments are available to implement the recommendations of the IMS. Any potential change in landuse through subdivision is catered for via the requirement for BMPs for all landuses.

Resource Protection
The Department of Minerals and Energy seeks to ensure that the following receive adequate consideration:

1. The possibility of permitting exploration for heavy mineral sands (and if successful, the mining of these) within the areas covered by the exotic pine plantations on Bribie Island, after these are harvested. The main effects of such activities that would need consideration would be the possible disturbance to the groundwater regime by the dredge ponds. Any such disturbance would have to be weighed against the considerable advantage of using a mining operation to achieve quicker and more substantial native forest regeneration to supplement the nature conservation values of the adjacent Parks.

2. The need for continued access to foundry sand resources north-west of Woorim. These cover a relatively small area and the existing workings are unlikely to be significantly expanded. This issue has been satisfactorily addressed in the Lands Department's plan for Crown land on Bribie Island.

3. The need to protect resources of well-graded construction sand on the alluvial flats of several small mainland streams draining into Pumicestone Passage (e.g. Elimbah, Glass Mountain, Hussey, Coonowrin and Coochin Creeks), and the controls necessary to ensure that turbid water from such pits does not enter stream channels.

   The resources of such sand now appear much more substantial than revealed by the broadly spaced drilling of this Department in the 1970s, and with the exhaustion of supplies elsewhere, they could become a major source for both the Sunshine Coast and northern Brisbane markets. Unfortunately there is very little data on which to base specific planning recommendations over and above a general observation that all the alluvial flats of these streams downstream of the Bruce Highway may have potential.

4. The need to allow for the possibility of future clay mining in the low country east of the Bruce Highway, and the controls necessary to ensure turbid water does not enter streams.

   Reconnaissance surveys of this Department in the 1970s showed that suitable ceramic clays are present in this area, but a lack of demand from both the Brisbane and Sunshine Coast markets has resulted in little industry interest.

However some recent exploration activity suggests that it is possible that clay pits could be established in the future. At this stage it is not possible to predict where these might be.

5. The need to protect two existing major hard rock quarries, and potential deposits of quarry-rock, from closer settlement, and to minimise the impact on scenic and amenity values. Despite resource surveys by this Department in the 1970s and subsequently by consultants for the Caloundra City Council, a firm policy on protection of quarries and future resources is yet to be established by that Council.

The quarries and resources are chiefly west of the Bruce Highway. Any impact on water quality from run-off escaping from the properties would be very minor, and insignificant for Pumicestone Passage in comparison with the contribution from agricultural land, urban development, roadsides etc.

Noted.

Industrial Development
Industry producing significant waterborne pollutants should be excluded from the catchment.

Any landuse which generates waterborne pollutants will be required to implement BMPs to limit pollutant exports to sustainable levels.

Transport and Service Networks
It is considered by many that the new Bruce Highway has significantly degraded adjoining land and vegetation changing stream hydrology, groundwater recharge, lowering groundwater tables, downstream scouring streams to accept the concentrated flows from culverts and backing up water over upstream lands. It has been suggested that in the light of this degradation no future roads be planned and that all capacity increases be achieved along existing corridors (old and new highways).

Noted for consideration.

B.3.4 Water Quality and Ecological Issues

Surface Water Quality
The following concerns have been expressed:

1. Controls are required on golf courses in relation to nutrient and pesticide washoff into streams and the Passage. It has been suggested that any golf courses be remote from streams and the Passage.
2. Concern has been expressed at antibiotics used in aquaculture entering food chains and entering streams and the Passage leading to bacteria with multiple drug resistance.
3. Point and non-point source controls are required as well as a strategy to manage sullage/sewage in non-sewered areas. Controls need to be considered for agricultural uses.
4. Co-ordination of policies from all levels of government are required.

The quality of the waters of the Passage and its tributaries formed a major focus of the IMS and is discussed at length in the report and the Component Study on Environmental Objectives for Water Quality.

Public Health
The following concerns have been expressed:

1. The sediment from the creeks covering the sand at Toorbul (described as a black, slimy green mix) causes fungus infections in feet and toenails.

2. Large numbers of mosquitoes and midges increase the potential for disease.

Noted.

Water Quality in Passage
The following concerns have been expressed: increased turbidity leading to more sandflies and mosquitoes and sediments from the creeks are covering the sand around Toorbul to a depth of 3 cm.

It has been suggested that water quality monitoring of the Passage should be done as a basis upon which to plan and that future monitoring is necessary. It has been further suggested that any change in landuse be dependent on the proposer proving no net loss of water quality and that financial guarantees be required.

Concern has also been expressed that pollutants from Deception Bay (Caboolture River) will contaminate the Passage and that controls should be imposed on the discharge of pollutants into Deception Bay.

It has been suggested that clear felling of the pine forests on Bribie Island could lead to acidic runoff. Monitoring of sediments in the Passage and particularly the creeks on the western side for redox potential and total organic carbon and pH has been suggested.

Consideration should be given to creating artificial wetlands for water quality improvement in existing creeks.

All these issues are discussed in detail in the report.

Caboolture River
Concern has been expressed that the plume of the Caboolture River may significantly influence the water quality of the Passage.

The potential for discharges from the Caboolture River to impact on Pumicestone Passage were recognised (refer Page 78). Limited data on circulation patterns in Deception Bay was reviewed and found to not indicate direct movement of water from the Caboolture River into Pumicestone Passage . However the data did not include information on circulation patterns in response to flood flows from the Caboolture River. It was concluded that the study area be limited to the catchment draining into Pumicestone Passage.

Pollutant Sources
Potential pollutant sources have been identified as the old and new Caloundra Refuse Tips, chemical runoff from pineapple and sugar cane farms, intake water from Deception Bay, clear felling of pine trees, the existing abattoir, the future Landsborough Sewage Treatment Plant, chicken farm guano heaps and pre-sewerage heavy metal deposits from an electroplating works into Duck Hole Creek.

Noted for consideration.

Aquaculture
There should be more stringent controls on aquaculture in relation to water quality and a cautionary approach to future ventures. It has been suggested that antibiotics are used in the aquaculture farms.

Aquaculture discharges were recognised as a source of pollutants and were specifically included in the water quality modelling which was undertaken.

Golf Courses
The extensive use of fertilisers and pesticides on golf courses is of concern in relation to the water quality of the Passage. It has been reported that Kooralbyn Valley has taken extensive steps towards reduction of pesticide and fertiliser use.

Any reduction in fertiliser and pesticide usage on land which discharges runoff into the Passage or its tributaries is fully supported.

Erosion
The following concerns have been expressed:

1. Stormwater outfalls have caused erosion of the beaches.
2. Dredging within the passage for sand replenishment of Golden Beach contributes to increased erosion rates of up to 30 cm a year.
3. Uncontrolled clear felling for land development has contributed to erosion of those areas and downstream sediment transport and deposition.
4. Mainland streams are eroding badly and are also becoming blocked in places with fallen timber and debris from land clearing. It has been suggested that the silt is remaining within the creeks (particularly near the mouths) and is not being flushed into the Passage.

Noted for consideration.

Siltation
Silt is considered to be a problem both in relation to quantity (blocking of waterway to boat passage and northward water flow to clean Passage) and in relation to its covering of sand. However, one fisherman suggests that only minor changes have occurred within the Passage within the designated channel and that considered over an extended period (about 60 years) there has been no appreciable net change.

Noted.

B.3.5 Integrated Management Strategies

Environment Protection
There is general support for protection of the environmental qualities of the area from both development and conservation interests. There is some conflict in views between conservation and the treatment of the area "as a natural resource warranting careful husbandry and management of its use and attributes to ensure its long-term protection for both conservation and appropriate recreational use".

One respondent has suggested a criteria of "no net deterioration".

The IMS which is recommended is based on a rigorous application of ESD principles which will require an improvement management practices to reduce pollutant loads discharged from the catchment under existing conditions.

Ecologically Sustainable Development
Concern has been expressed that "the definition of the four principles of ESD are so heavily value-laden as to be incapable of a broad cross-sectional agreement as to their specific meanings, and are therefore largely incapable of translation into clear policy requirements.

To the extent that such "principles" can be understood, it has been suggested that they should not be the *only* ones to guide strategy for the Passage as other societal imperatives also warrant equal consideration (e.g. the need for provision of reasonably priced housing accommodation, access to employment and services, retention of a viable economy etc.)

The application of ESD principles has guided the formulation of a range of BMPs for current and future landuses. An economic assessment of the various management strategies has also indicates the broad cost of adopting the IMS. It should be noted for example that the implementation of ponds and wetlands in urban areas significantly enhances land values to the point where the financial return exceeds the cost of implementing such control measures. eg. Canberra, Forest Lake in Brisbane.

Population Limit Basis of Catchment Control
This was seen as ineffective and inappropriate by some and that fully planned comprehensive development proposals with appropriate controls should be assessed against the performance standards. Others see this as the only hope to save the Passage.

A population limit was not supported as the basis of catchment control.

Establishment of Performance Basis for Development Control
It has been suggested that "the catchment area is capable of multiple development activities without detriment to any of the important qualities of the Passage, *provided that such activities are undertaken on a fully planned basis in concert with the development of appropriate performance standards established to protect such qualities*".

Supported by the IMS.

Existing Approvals for Development
Concern has been expressed that there does not appear to be any attempt to "differentiate between committed and untouched land in the study area or where existing approvals are in place". Existing approvals should be protected.

There will be a need to progressively implement BMPs for all existing landuses.

Strategic Plan
Comments as follows: In recent amendments to the Caloundra Strategic Plan, it has been suggested that one of the reasons for siting the new Industry Zone to the west of Glasshouse Mountains Road in the present State Forest Reserve 561 which extends right down to the shore of Pumicestone Passage, is to maximize the advantage of the State Government being the only one who could legally report pollution of the area from factory effluent. This study should ensure that the Environmental Protection Legislation applies equally to all bodies, especially to State run enterprises, and that pollution does not occur and does not remain unreported.

Noted and supported.

Management Options and Implementation
Disappointment has been expressed at the "paucity and inherent negativity of the ideas put forward for public comment".

We would welcome any ideas from the community.

Consistent guidelines with enforceable effluent quality standards should be developed for wastewater disposal and stormwater quality management for application by local authorities within the Catchment Area.

These guidelines should be supported by State legislation requiring all development including State Government activities to conform.

Local Authority Strategic Plans should identify conservation zones along water courses and these zones should be protected by State legislation.

Assistance should be given to local authorities to cater for wastewater disposal by identifying sites for land disposal of sewage effluent and making land available through joint use with DPI Forest Service.

A number of these issues are directly addressed within the report.

Implementation of the Integrated Management Strategy
It has been suggested that the IMS should be overseen by one authority to avoid parochial decisions and new legislation should be introduced to give statutory powers to the Strategy.

Noted for consideration by DEH and the Steering Committee.

A co-ordinated approach is required from all levels of Government in monitoring and managing landuse and water quality within the Pumicestone Passage Catchment.

Fully supported.

Protection and expansion of environmentally sensitive areas and river, creek and watercourse systems should be a primary consideration in the Management Strategy.

The retention/establishment of riverine zones along stream corridors and estuary foreshores is one of key recommendation of the IMS.

Future planning and development of other land uses should be limited to that which is ecologically sustainable in terms of location, scale and format of development to possibly include an Optimum Population Level or Levels which may depend on various servicing and infrastructure scenarios (predominantly sewerage).

The application of ESD principles is fully supported. It is considered that the requirement for BMPs will guide the format of development.

Non-Point Source Pollution
It has been suggested that the greatest threat to the Passage is the "polluted runoff from the mainland" and that this will be revealed by testing water quality in the creeks. It has also been suggested that this has not been done. It has also been reported that "rubbish" has been dumped in Elimbah and Mellum Creeks.

The significance of catchment runoff on the water quality of the Passage has been confirmed by the review.

A Stormwater Management Policy should be developed for use within the catchment to mitigate the environmental impact of surface runoff.

Noted for consideration.

A Policy on Wastewater Disposal in Non-Sewered Areas should be developed for use within the catchment to appropriately manage the impact of effluent from on-site disposal.

Noted and supported.

Bribie Island Wastewater Treatment Plant Augmentation
Caboolture Shire Council has plans to augment the Wastewater Treatment Plant to cater for 29 000 e.p. by 2006 and 48 000 e.p. by 2021 thus increasing effluent volume five-fold over the current situation. Appropriate disinfection and nutrient removal has been suggested.

Noted.

Wetland Treatment of Sewage
It has been suggested that the use of wetlands for sewage treatment does not work and that it will be damaging to the ecology.

The use of constructed wetlands for sewage treatment is supported in principle. The use of natural wetlands for sewage treatment is not supported. Further research of the performance of wetlands under the climatic conditions experienced within the catchment would be advantageous.

Biting Insect Control
Concern has been expressed at the continued use of larvides and that only low impact methods such as runnelling be used for control.

Noted.

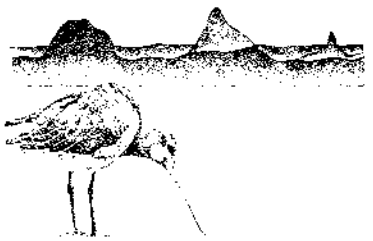
B.4 List of Respondents

The following organisations and individuals responded to the Issues Paper and/or the the Management Planning for National, Environmental and Marine Parks of Bribie Island and Pumicestone Passage (MP):

1. Bribie Island Ratepayers and Progress Association
2. Bribie Island Chamber of Commerce (MP)
3. Bribie Island Environmental Protection Association Inc.
4. Butler, Ald N.D.T. - The Esplanade, Golden Beach (MP)
5. Caloundra City Council
6. Clem & Trattles, Toorbul (MP)
7. Department of Minerals and Energy
8. Emanual Group, Brisbane
9. Henzells, Caloundra
10. Johnson & Mawer, 14 & 16 Yeenda Ave., Beliara
11. Jones, R.M. and I.R. - Morayfield (MP)
12. Landsborough Landcare Association
13. Le Fanu, Mr Stephen - Bribie Island (MP)
14. Leggett, Mr Ray - Aquatic Field Surveys
15. Queensland Conservation Council
16. Queensland Tourist and Travel Corp.
17. Queensland Naturalists' Club
18. Shields, A.E. - Mooloolah (MP)
19. Tanner, Ray and Patsy (MP)
20. Toorbul Progress Association (MP)
21. West Acton Pty Ltd (MP)
22. Wildlife Preservation Society

B.5 Issues Paper

The Issues Paper which was prepared and issued as part of the on-going public consultation process associated with the formulation of the Integrated Management Strategy is presented as follows.



Pumicestone Passage, its Catchment and Bribie Island

Issues Paper

June 1992

What is an Integrated Management Strategy?

The purpose of such a strategy is to integrate the management of land, water and related biological resources in order to achieve the sustainable and balanced use of these resources.

The continuing degradation and increasing demands on our land and water resources could reduce the ability of these resources to meet our needs. Increasingly we are encountering problems such as soil erosion, salinity, siltation of creeks and rivers, flooding, drainage, polluted water supplies, degraded water quality and damage to land and water based ecosystems.

An integrated management strategy (IMS) aims to provide a cooperative and coordinated approach to the resolution of these and other catchment problems. It aims to foster joint action by all interested persons and groups including those involved in primary production, environmental protection, land use planning, river engineering and natural resources management.

Sustaining land, water and life

The sound use of our land, water and related biological resources requires us to recognise that:

- ✔ land and water resources are basic and interactive parts of natural ecosystems;
- ✔ management of land and water resources is most effective when based on river catchments;
- ✔ river catchments continuously change in response to natural forces;
- ✔ successful management of land and water resources requires coordinated planning and action;
- ✔ land and water resource management decisions must be based on the best available information;
- ✔ development within river catchments must be ecologically sustainable.

Why an Integrated Management Strategy for Pumicestone Passage, its Catchment and Bribie Island?

A government policy to protect the environmental values of Pumicestone Passage and its environs and catchment has been in place since 1982. This policy was based on the recommendations of a 1982 study which identified specific catchment values and environment protection measures. The extent of the catchment is indicated in Figure 1.

The study found that Pumicestone Passage and its environs were important for conservation purposes, for fisheries and as a venue for recreational boating. The study also found the water quality in Pumicestone Passage was high but that it is very dependent on two factors:

- the quality of water flowing from the catchment into Pumicestone Passage, and
- the pattern of water movement within the Passage itself.

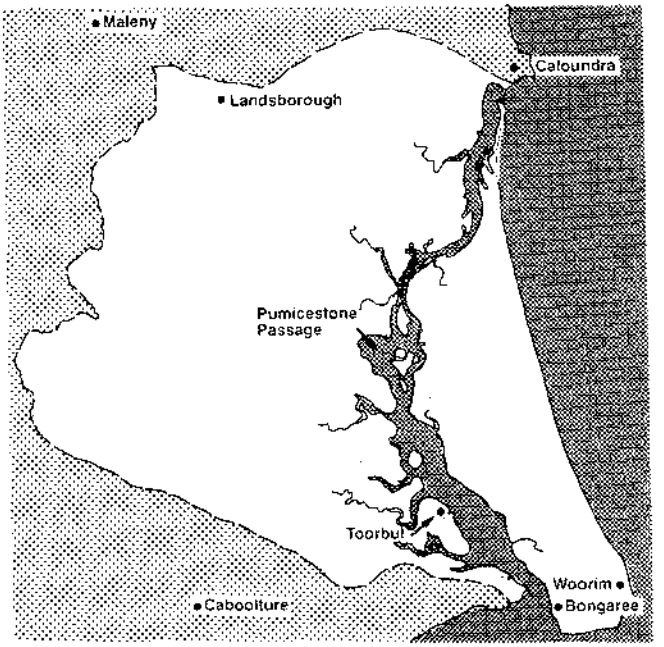


Figure 1 The study area

Protection measures which were identified included:

- reservation and management of the Passage itself,
- acquisition, reservation and management of significant areas within the catchment and on Bribie Island for conservation and recreation purposes,
- prescription of an upper catchment population limit of 50 000 to 75 000,
- retention of extensive State forests and private forests for productive forestry,
- Caloundra City Council and Caboolture Shire Council including consistent conservation policies in their respective strategic plans.

Events in recent years, however, have reduced the effectiveness of the protection measures. Opportunities for land acquisition are limited. Private forests have been sold to parties who are not interested in productive forestry. Primary production on land and in water is increasing.

Consequently a further study has been commissioned to produce an ecologically sustainable strategy for land use planning and resource management.

The Management Philosophy

Different ecosystems have different attributes and values and so have different conservation needs. Multiple use of a catchment and its waters means that conservation aims may include the protection of aesthetic, recreational, educational, ecological, biological, scientific, heritage and physical values.

The philosophy behind the Integrated Management Strategy is the concept of "ecologically sustainable development". The policies and management decisions will be guided by four principles:

- *Intergenerational equity* which aims to give future generations equal environmental choices by avoiding management strategies which substantially limit options available in the future;
- *Appropriate valuation of natural resources* to truly reflect the value to society of an environmental asset or a natural resource;
- *Dealing cautiously with uncertainty* to minimise the risk to the environment; and
- *Taking a global perspective* to ensure that catchment management decisions are consistent with ecological sustainability on a global scale.

Management of the catchment should also be consistent with broad conservation objectives including:

- to maintain essential ecological processes and life support systems;
- to preserve genetic and species diversity;
- to ensure the sustainable usage of species and ecosystems; and
- to maintain and enhance natural environmental qualities to provide for society's non-material needs.

How is the Study structured?

The aim of the study is to produce an ecologically sustainable strategy for land use planning and resource management . It aims also to ensure the conservation values and the productivity of the natural land and water resources of Pumicestone Passage, its catchment and Bribie Island.

The study proposes to:

- review previous studies and techniques and identify and evaluate alternative planning and management options;

- evaluate existing land and waterway use patterns and evaluate future options under the following topics:

  - conservation
  - sustained primary production
  - extractive uses
  - tourism and open space recreation
  - industrial and commercial
  - urban development
  - transport and service networks

- evaluate future population projections for the study area against land use options; and

- consult with relevant State authorities, Caloundra City and Caboolture Shire Councils, interest groups and the community.

What is the Study process?

The process being followed in preparing the IM Strategy is illustrated in Figure 2. Inputs will come from the extensive body of existing reports, advice from management authorities who are aware of existing issues and are well placed to identify future options, the results of a number of component studies, and inputs from the community.

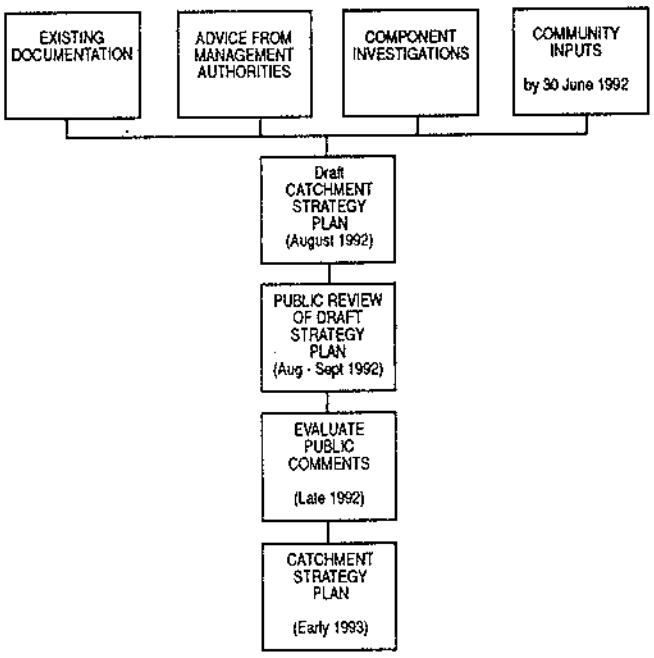
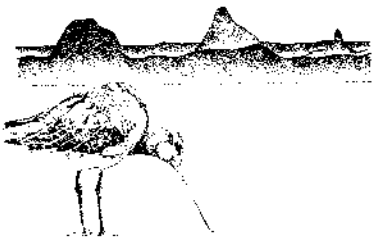


Figure 2 Process of IM Strategy preparation and review

Integrated Management Strategy

June 1992



What are the Component Investigations?
A series of Component Investigations have also been commissioned to provide additional data to supplement existing information on:

- groundwater resources;
- agricultural chemical (fertiliser and pesticide) usage;
- land resources and soil erosion;
- aquaculture;
- surface water quality in Pumicestone Passage and its major tributaries;
- coastal processes;
- sedimentation in the Passage and its tributaries; and
- management planning for existing and proposed conservation reserves on and in the vicinity of Bribie Island and Pumicestone Passage.

Who is responsible for the Study?

The responsibility for the study rests with the Queensland Department of Environment and Heritage. A Steering Committee is overseeing the study. The Steering Committee includes representatives from the Department of Environment and Heritage, Department of Primary Industries, Department of Transport, Department of Lands, Department of the Premier, Economic and Trade Development, Caloundra City Council and Caboolture Shire Council.

Community Inputs

The present phase of public consultation is intended to invite inputs to the Draft Strategy at the earliest possible opportunity.

This issues paper has been prepared to assist in the early consultation process by providing information about the study and identifying the main management issues.

The Draft Strategy is expected to be released in August 1992. It will be displayed at Caloundra City and Caboolture Shire Council offices and Bribie Island Library for a period of two months. At this stage further community comment on the Draft Strategy will be invited.

These further comments will then be considered in preparing the "final" Strategy.

What are the Management Issues?

As part of the evaluation of existing land and waterway use patterns and the formulation of future options a range of possible management issues have been identified. These issues are outlined below under the study topics.

The order of issues does not indicate a priority.

Conservation

- maintenance of wetlands
- preservation of natural habitats especially nursery and breeding areas
- preservation of areas of high biological activity
- maintenance of coastal processes
- maintenance of natural vegetation
- protection of water quality in Pumicestone Passage and its tributaries
- protection of surface water resources
- protection of groundwater resources
- protection of sites of natural significance
- protection of significant Aboriginal and European cultural heritage sites

Sustained primary production

- maintenance of the productivity of natural land resources
- management of changes in rural land use including forestry
- management of chemical and pesticide use
- control of soil erosion
- maintenance of the productivity of aquatic resources
- protection of water quality in streams and Pumicestone Passage
- management of aquaculture to limit effects on water quality
- limitation of commercial fishing to ecologically sustainable levels

Extractive uses

- access to reserves of minerals and construction materials
- environmentally compatible extraction processes
- control of air and water pollution
- protection of adjacent habitats
- protection of landscape values

Tourism and open space recreation

- maintenance of natural features of the catchment and its waters for tourism
- control of tourism and recreation in environmentally sensitive areas
- zoning of land and water areas for recreation and tourism
- provision of adequate supporting services

Industrial and commercial

- catchment compatible industrial and commercial development
- transport facilities and infrastructure
- control of air and water pollution
- control of solid and liquid waste disposal
- control of stormwater disposal
- allowance for sea level rises

Urban development

- population growth
- coastal residential development including marinas, canals and reclamations
- provision of infrastructure
- provision of public amenities
- control of stormwater disposal
- control of stormwater pollution
- flooding and storm surge inundation
- allowance for sea level rises

Transport and service networks

- safety of boating
- location and design of transport and services infrastructure
- construction controls to limit air and water pollution
- increasing demands for services by residents and visitors

What are the Management Options?

There is a wide range of management options available to implement the IM Strategy. In broad terms they include:

- limiting the growth of pollution generating activities by:
  - constraining permissible land uses
  - reserving land as National Parks and/or Reserves
  - limiting urban growth
- lessening of possible impacts by:
  - land use capability assessments to guide permissible use and management requirements
  - retention of buffer zones between land use activities and estuary shorelines and wetlands
  - retention of corridors along tributary streams
  - adopting best management practices as condition of land use
  - providing infrastructure to intercept and treat wastewater to standards consistent with protection of environmental values
- management of receiving waters by zoning water based activities to safeguard natural ecosystems

How might they be implemented?

The mechanisms available to implement the IM Strategy are wide ranging. In broad terms they include:

- an administrative structure which identifies the agency or agencies having responsibility for administrating the Strategy
- new legislation:
  - would give statutory power to the Strategy
  - possible creation of new National Parks, Reserves and/or Conservation Zones
- a planning process linking and using the powers and resources of existing agencies. Local authorities considering development could be obliged to consider the intent and recommendations of the Strategy. The approach may include:
  - amendments to the Caloundra City and Caboolture Shire Councils' Strategy Plans
  - amendments to Town Planning Schemes
  - preparation of Development Control Plans
- a set of guidelines and standards which satisfy the goal, aims and objectives of the Strategy. Standards would set out mandatory performance criteria. Guidelines would set out desired performance criteria.
- public education and provision of information.

Submissions

The present phase of public consultation is intended to invite inputs to the Draft IM Strategy at the earliest possible opportunity.

Members of the community either individually or as interest groups, are invited to contribute any factual material, suggestions on management objectives and processes or other matters which they feel would be of value in the preparation of the Strategy.

Written submissions should be forwarded by 30 June 1992 to:

Queensland Department of Environment and Heritage

Project Officer
Pumicestone Passage IM Strategy
Queensland Department of
Environment and Heritage
PO Box 155
NORTH QUAY QLD 4002