Western Port Research Coordination: Stage 1

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Coastal CRC

CSIRO

Central Coastal BOARD

State Government Victoria Department of Sustainability and Environment

EPA VICTORIA

Melbourne Water

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Western Port Research Coordination Project – Stage 1

Preface

The Western Port Research Coordination Project was initiated because the stakeholders of Western Port are concerned about the threat of human activities (direct or indirect) upon the ecology and function of the bay. A coordinated and cooperative approach is needed to address the impacts to, and management of, Western Port via identification of priority research needs. A coordinated research program that addresses management needs must be underpinned by an understanding of the key ecological systems and drivers within the bay, and an assessment of current research activity relating to the bay.

This project (Stage 1, Western Port Research Coordination project) was commissioned to synthesise existing science describing the Western Port marine environment to provide a holistic representation of the important processes and elements of this ecosystem. By taking a participatory approach to developing these models, important gaps in the understanding of the Western Port marine ecosystem were identified.

In cooperation with stakeholders and expert scientists, a series of models describing the holistic and conceptual understanding of the Western Port marine environment have been developed. These models communicate in a graphical way, the important physical, chemical and biological processes forming the foundation of the marine ecosystem in Western Port.

The conceptual models provide a mechanism to synthesise the substantial quantities of existing science into a single location. If held in 'trust' by a central organisation, dissemination of the models amongst stakeholders typically encourages more, and often difficult-to-access, science to be revealed and centralised. It is important that the conceptual models are considered as "living" documents, and are regularly updated as new or other existing science emerges.

By providing a common foundation of knowledge, the models can be used by organisations to promote and enable discussion and scientific debate with all stakeholders (i.e. participatory approaches to science and management). A common understanding among stakeholders of important ecosystem processes, according to the best information available, allows discussion and identification of critical gaps in the scientific knowledge and options for management intervention.

In addition, the conceptual models will enable a holistic approach to research and management. Relationships of a proposed research project or management action to other ecosystem processes or components can be examined.

There has been considerable historic and current research in Western Port, making it one of the better-studied embayments in Australia. Despite this, there are some knowledge gaps that are important to the understanding and effective management of the Western Port ecosystem. The adaptive management approach recognises the need to improve ecosystem understanding to identify additional management options and refine best practices. However, use of an adaptive management approach allows some management actions may be implemented immediately on the basis of the best knowledge currently available.

It was not an objective of this project (Stage 1 of the Western Port Research Coordination Project) to assess current management actions in Western Port in relation to the science synthesised here. While the relative importance of some processes are difficult to assess because of a lack of knowledge describing them, this project provides support for recommendations by others that the connectivity of the catchment with the bay, and coastal processes such as shoreline erosion, should be important considerations for management activity.

The goal of the Western Port Research Coordination Project (to coordinate research for better management) was supported by stakeholders from a range of 'roles' (managers, researchers, interest / user groups or coordinators). There was a strong perception that despite good research being undertaken presently and some recent examples of good collaboration, there was a need for better coordination of research, especially that relating to management needs. Many stakeholders also identified the need for better access to and sharing of scientific knowledge.

Key Recommendations

1. **The holistic approach to management and research activity in Western Port should be continued and reinforced amongst stakeholders**. The State Environment Protection Policy (SEPP) (Western Port) (EPA, 2001) specifies a broad framework that supports an adaptive, holistic and collaborative approach to managing Western Port, thus providing a legislative mechanism for achieving effective management and research of Western Port. The SEPP (Western Port) is an important mechanism for anchoring the research needs to management objectives; this policy has defined the beneficial uses that should be protected, and aspirations to be progressing towards, by the stakeholders of Western Port.

2. **The conceptual framework for collating, reviewing and synthesising the past research needs to be maintained and updated regularly as an agreed basis for ongoing discussions and decisions to fulfil the requirements of the SEPP (Western Port)**.
    a. System provided includes stakeholder database, information database, and conceptual models
    b. An agency or joint group be assigned the lead role to do this with annual updates based on a workshop to review and resolve issues and appropriate wide scientific and stakeholder peer review to minimise litigation on poorly framed interpretations of the underpinning science

3. **Gaps in scientific knowledge of Western, as identified in this report, be confirmed or modified with key stakeholders who were not involved in the process to date** as a basis for priority setting and decision-making on future activities. These represent gaps in scientific knowledge of the whole ecosystem dynamics and those linked to current or potential threats to Western Port.

4. **A process to achieve agreement on the priorities for research to address the gaps in understanding for management** is proposed to ensure efficient and targeted research. Critical principles to consider, and tools that could be used in this process are outlined in Section 8. These tools include: a **modelling approach**, **multiple objective decision support tools**, and tools for **citizen participation**.

5. **Future research in Western Port needs to be coordinated and brokered by a science group** (or modification of existing structures) where all researchers including students working in the catchment have a commitment to provide data, metadata, research results and publications for inclusion under recommendation 1 on an annual basis.

6. **Tools for ongoing information and knowledge exchange and access become a basis for ongoing stakeholder awareness.** These could include the conceptual models provided in

this report. This will provide a formal basis for equity of access to knowledge and a transparent process for involvement in issue identification and resolution.

7. **A communication plan for the science outcomes and implications be prepared for Western Port stakeholders.**

8. **Concurrently with implementing the research program (and other initiatives arising from Stage 2) should be a 'monitoring and review' stage.** This should assess the effectiveness of the research program to achieve its objectives relating to scientific understanding and knowledge for management of Western Port, and should include an objective to update the conceptual understanding using the newly acquire knowledge.

10. Appendices

10.1. Consultation: process and interviewees

Process:

Western Port Research Coordination Project - Stage 1

The Coastal CRC and CSIRO are undertaking a project to assist in the development of a conceptual understanding of the bay ecosystem and the research needed to underpin effective management of the bay.

This work is being undertaken for the Western Port Portfolio Coordination Group, which consists of representatives from the Port Phillip and Western Port Catchment Management Authority, the Central Coastal Board, Melbourne Water, the Department of Sustainability and Environment and the Environment Protection Authority.

Western Port bay is one of Victoria's most valuable assets. The bay and its surrounding catchment are highly regarded as a recreational and commercial resource and as an area of conservation significance.

The protection and ecologically sustainable development of Western Port and its catchment is guided by the State Environment Protection Policy (Waters of Western Port and Catchment) 2001. This Policy provides a statutory framework to protect the environmental qualities of Western Port and to ensure those who live and work in, and visit the area, both now and in the future can safely use and enjoy it.

What is the Western Port Research Coordination Project?

The stakeholders of Western Port are concerned about the impacts of human activities upon the ecosystem of the embayment. A coordinated and cooperative approach to management is required to ensure the values of Western Port described above are protected. This approach must be underpinned by an understanding of the key ecological systems and threats to the bay. Organisations with an interest in research, management and policy in Western Port have been considering how coordination and information sharing of research in Western Port might be improved in a cooperative manner to deliver further benefits.

What is the objective of Stage 1?

This stage of the project proposes to collate and identify the past and present research effort as well as the important threats relating to the Western Port bay ecosystem. The project team, in consultation with scientific experts, will also develop a conceptual understanding of the ecosystem processes within the bay. This conceptual understanding will be compared with the assessment of research effort and key threats to Western Port, to assist in identifying research needs.

Who is undertaking the project?

The Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) and CSIRO are undertaking Stage 1 of the Western Port Research Coordination Project in partnership with the Central Coastal Board, the Port Phillip and Western Port Catchment Management Authority, Melbourne Water, EPA Victoria and the Department of Sustainability and Environment.

How can you be involved?

As a stakeholder of Western Port, we would like to document your interest in Western Port, your involvement in collecting environmental information relating to the Western Port marine ecosystem and your thoughts on the research needs and threats to Western Port. More details of the information we are interested are overleaf.

Western Port Bay Research Coordination Project- Stage 1

1. **What are your own and/or your organisation's interests in Western Port?**
   (e.g. user, management, research; social, economic, environmental interests)

2. **What involvement have you had in research relating to the bay and catchment of Western Port?**
   (Research here is defined broadly to include the collection of any environmental data - past, present, and or proposed)
   - reason / objective
   - participants
   - approach / general methods
   - location
   - timing
   - outputs
   - outcomes

3. **What do you consider are the significant threats to the bay ecosystem, presently and in the near future?**
   What do you think will be the associated response by the ecosystem?
   Do you believe there is sufficient knowledge to manage these threats (explain)?

4. **What comments do you have with respect to the coordination and application of research to the management of Western Port?**

Contacts for Further Information:

If you would like more information about Stage 1 of the Western Port Research Coordination Project, you can contact the project team through:

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Table 11. Stakeholder perceptions of threats to the Western Port ecosystem, and gaps in science needed to address these threats.

The following table provides an account of the response by stakeholder participants to question 3 in the survey (see above). Here the responses have been grouped into broad categories of related threats. Every response has been included: the number of responses in the table below indicate the amount of concern or interest by stakeholders.

Broad category	**Threat**	**Ecosystem Response or action**	**When**	**Status of Knowledge**
Aquaculture	Aquaculture - hygiene -> imported food ->risk			
Aquaculture	Aquaculture - may increase in near- future - use of non-native species - use of chemicals	- Nutrient accumulation - Spread of disease - Shading of benthos - changes to community structure	Current + future	
Aquaculture	Aquaculture of mussels	Possible translocation of pests from Port Phillip	Current	
Aquaculture	Marine pests: translocation of pests from Port Phillip Bay via- boating, aquaculture	Competition with native species	Current + future	
Boating	Boating/Shipping -commercial -recreational	-Marine Pests: transfer from Port Phillip to Western Port -sewage discharge from vessels	Current + future	
Boating	Recreational boating Increased	Physical damage to intertidal flats	Current + future	Limited
Fishing	Bait pumping	Not only does it reduce shrimp numbers, but also changes sediment properties of accessible intertidal mudflats - compaction, resuspension	Current + future	
Fishing	Commercial and recreational fisheries		Current + future	
Fishing	Commercial fishing		Current + future	
Fishing	Fishing: over fishing by commercial and recreational fishing	Fish loss, seagrass loss caused by power winch trawlers	Current	
Fishing	Recreational fishing		Current + future	Limited
Fishing	Recreational fishing Increased	-Physical damage by nets, boats to intertidal flats and seagrass - Decline in fish stocks	Current + future	Some
Fishing	Recreational fishing, commercial fishing	over fishing?	Current + future	None
Recreation	Environmental limitations on tourism -> limited tourism	economic and social impacts from limited tourism	Current + future	Limited
Recreation	Recreation: One public access to NE area of Western Port (surrounded by farming): no coastal management plan.	Need Coastal Management Plan.	Current + future	Some

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Recreation	Physical disturbances associated with fishing, bait collection and boating activities.	Increases turbidity and direct damage of benthic habitat. But as part of Bays and Inlet review, WBM Oceanics (sub-task) concluded that physical impacts from fishing were negligible.	Current + future	Some
Recreation	Recreational access points and numbers of visitors on WP(need visitor number estimates).		Current + future	
Recreation	recreational boating (yachting) - increased pressure in the absence of ballast and hull controls	marine pests	Current + future	
Recreation	recreational boating and fishing	impact on fish stocks, also the inappropriate disposal of litter	Current	None
Recreation	Recreational usage Increasing. (e.g. boating and fishing) is increasing with urban expansion on the Mornington Peninsula (increasing the travel time to PP Bay).	Ecosystem Response? Facilities response?	Current + future	None
Other	Low dissolved oxygen - events have been reported in Corinella region. Frequency and spatial extent not well known.	Impacts on fish and health of other biota.	Current + future	Limited
Other	Seagrass harvest	Erosion and increased sediment movement, with further contribute to seagrass loss.	Historic	
Other	Sediments and nutrients	Declined light penetration and declined seagrass growth	Potential	Some
Other	Turbidity - monitoring indicates highest on the eastern side, however limited sampling makes it hard to assess. Main causes are catchment loads and resuspension.	Has the potential to reduce benthic vegetative habitat. Historically turbidity is a likely cause of seagrass decline, and in a turbid environment regrowth is difficult. Loss of benthic habitat leads to changes in bottom topography.	Current	
Pests	Feral pigs on saltmarshes		Current + future	Some
Pests	Marine exotic species	Has the potential to alter the biological balance and reduce biodiversity.	Near future	Some
Pests	Spartina spreading into Western Port (from Bass River) - inhabiting the muddy intertidal area	changed habitat structure of muddy intertidal area - threat to intertidal invertebrates, and therefore to birds feeding here.	Current + future	Some
Pests	Marine Pests - Animal and plant from shipping		Current + future	
Pests	Marine Pests from Port Phillip Bay and internationally Action: Need monitoring and surveillance		Potential	Some

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Pests	Marine pests: migration of IMPs from PP, Commercial ballast water		Current + future	
Pests	Spartina: growing in the Bay (Moody's Inlet)	Cloggs waterways, overgrowing other species. Biocontrol of the pest being investigated	Current	
Pests	With the increase in shipping and aquaculture there is a possibility that the Pacific seastar is translocated to Western Port.	To predict impacts and risks associated with the seastar there needs to be a change in management - increased rigor.	Potential	Limited
Shipping	Dredging	impacts to subtidal invertebrates?	Current	Limited
Shipping	Dredging channels - especially near Port facilities --> stirring sediments and associated contaminants (e.g. TBT)	loss of seagrass	Current + future	Some
Shipping	Oil facility at Hastings	Oil spills	Current + future	
Shipping	oil spill risk		Current + future	
Shipping	Oil spills		Current + future	Enough
Shipping	oil spills		Potential	Some
Shipping	Oil spills (Minor) at shipping terminals: these are reported in the EPA annual Report	Because of the tidal range and water movement the spread of oil would be very quick. Has been modelled. Effects on mangroves?	Current + future	Some
Shipping	Oil spills from shipping and chronic pollution from shipping			
Shipping	Port development if PPB deepening does not proceed - increased risk of pests, oil spills, pollution, proportional to increase	numerous - habit loss and impact to fauna and flora.	Near future	Enough
Shipping	Port expansion	mangroves impacts and removal; oil-> ecosystem	Current + future	
Shipping	Port expansion - increased shipping, disposal of dredge spoil	Potential movement of sediment	Potential	Enough
Shipping	Port expansion, increased shipping	Oil spills	Potential	
Shipping	Port: Upgrade of port		Potential	Limited
Shipping	Private port at the bluff - build boats and slipways, through RAMSAR wetlands		Current + future	
Shipping	Shipping	Marine pest introductions	Current + future	
Shipping	Shipping	Increased presence of introduced marine pests	Current + future	

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Shipping	Shipping: marine pests, TBT/antifoulants (especially from the naval base), physical damage to mud banks and coastline erosion	Competition with native species from exotic pests. Need to know more on the interaction of pests and antifoulants with biota,	Current + future	Enough
Coastal Processes	Coastal Erosion	loss of habitat	Historic	Some
Coastal Processes	Coastal levy banks (built in the 1920s-1930s) parallel to the coast to limit the influence of tides on agricultural lands.	Water drainage of foreshore area is through levy banks: results in one way flow of water (no tidal exchange).	Current	
Coastal Processes	Unknown?	Loss of threatened species	Current + future	None
Coastal Processes	Artificial waterways: Levy bank erosion	Erosion of coast line	Current + future	
Coastal Processes	Erosion near Merricks Creek		Current	None
Foreshore	foreshore: Permanent dwellings on foreshore (e.g. Caravan Park at Lang Lang).	Sewage and litter discharge - not managed. Is some action now - Crown land management is taking responsibility for developing		
Foreshore	Foreshore: No fencing on some foreshore: grazing occurs. In water and saltmarsh areas	Loss of coastal vegetation e.g. saltmarsh. Increased roosting by waders (can lookout)	Current + future	
Catchment	Catchment Nutrient loads?	unknown	Current	Limited
Catchment	Catchment run-off	It appears the system is in a state of adjustment since draining of the swamp, and increased agriculture. Need to understand	Current + future	Some
Catchment	Catchment: rural use of fertiliser		Current + future	
Catchment	Catchment: Pollution from diffuse sources (catchment) - agricultural chemicals, urban run-off.	Toxicants can reduce food availability for important fish species by reducing the abundance of prey species. It can also reduce the suitability of fish for human consumption.	Current	Limited
Catchment	Fish barriers	-no fish gong upstream -no native fish in the waterways?	Current + future	
Catchment	Groundwater discharges altering salinity balance, and delivering contaminants including nutrients and possibly toxicants.	Altered salinity concentration in estuarine waters, favouring various biota.	Historic	Some
Catchment	Land clearing	Increased Sediment loads	Current + future	
Catchment	Land management practices (European landuse practices) resulting in increased salinity	Science needed for managers to choose appropriate land practices for Australian Environment	Current + future	Some
Catchment	Landuse practices in catchment - clearing --> erosion and increased sediment; fertiliser use --> increased nutrient loads	loss of marine vegetation	Current + future	Some

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Catchment	Landuses - some intense hotspots (e.g. agriculture, dairy and beef). Problems caused by livestock access into waterways, Private landholders -> no power to manage and lack of education, There are rewards for mismanagement of the land e.g. drought relief	Altered waterway condition: increased nutrient levels from feacal matter, increased sediment loads from bank erosion	Current + future	Some
Catchment	native vegetation: Incremental loss and fragmentation of terrestrial vegetation, loss of corridors		Current	Enough
Catchment	Population growth	Enough science to start managing: but need will and commitment to act	Near future	Enough
Catchment	Reuse of water from Carum STP onto farming lands in Koo-Wee-Rup area (additional water loads to bay?).	Toxicants? Change water flows - change sediment loads?	Potential	None
Catchment	Salinity process in the catchment		Emerging	Not enough
Catchment	Sediment and nutrient loads from development	Sediment inundation and nutrient enrichment	Current + future	Enough
Catchment	Sediment and nuts loads from catchment, entering NE WP bay (toxicants not so much an issue). This is caused by land clearing for agriculture and intensification of agriculture (--> increased nutrients and fertilisers)	Seagrass loss (in 70's?) and decreased resilience	Current + future	Some
Catchment	Sediment Increased and changed freshwater flows	Mangrove encroachment, loss of saltmarsh	Current + future	Some
Catchment	Septic tanks - lots of old systems - leakages?	nutrients	Current + future	None
Catchment	Septic tanks leakage (some are being removed)		Current + future	Limited
Catchment	Sewage treatment plant discharge into Phillip Island	Groundwater contamination?	Current + future	None
Catchment	stormwater - need research for management of this threat.		Current + future	
Catchment	Stormwater from catchment: urban, agricultural, rural, industrial.	elevated nutrients and toxicants: altered species composition and smothering of seagrass by epiphytic growth	Current + future	
Catchment	Stormwater runoff	Is some current research activity	Current	Some
Catchment	Stream-side management - lack of revegetation (river health strategy) and outdated knowledge for management		Current + future	Limited
Catchment	Vegetation: Loss in the catchment	Reduced filtering of water. Need to prevent clearing and rehabilitate	Current + future	Enough
Catchment	Vineyards - promoting recycled water This water may not be appropriate, it may be better to change practices	unknown	Current + future	None

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Catchment	Watson's creek very high nitrogen: 60mg/L nitrate from subsurface flow from horticulture.	Currently management actions being undertaken	Current	Some
Catchment	Community expectations of why rural areas exist		Current + future	Limited
Catchment	Fire - consequences, history?	unknown	Current + future	None
Farming	Agricultural runoff	Change to turbidity and sediment movement dynamics		
Farming	agricultural runoff: Input of sediments, nutrients, toxins into the bay		Current	
Farming	Agricultural/Horticultural irrigation impacts	pollutants enter the mud banks of Western Port	Current + future	
Farming	agriculture and horticulture (Intensive): farmers don't see the link with these activities to the bay	need more education and action, need better knowledge and monitoring of herbicides and pesticides (see RMIT/Doug Newton)	Current + future	Enough
Farming	Agriculture and Viticulture: Lack of education of wine-makers and farmers about impact of their properties on the bay.	many.	Current	Enough
Farming	Broiler industry in crease in WP: increased chicken manure	Increased nitrogen Research needed.	Near future	Limited
Farming	Cattle grazing is compacting saltmarsh	loss of saltmarsh change to run-off - sediments and nutrients	Current + future	Limited
Farming	Dairy hotspot: in top of catchment (Laber Tousche) - hotspot for runoff in the catchment into WP	high nitrogen?	Potential	Limited
Farming	vegetables and chicken growers -> toxicants (herbicides and pesticides)	Action: Need regulation and enforcement	Current + future	Enough
Urban	Designated urban growth corridor	There is need for remedial research	Current + future	Limited
Urban	Urban development encroaching : stormwater, disturbance of land/clearing, inputs/pollutants		Current + future	
Urban	urban development Increased resulting in changed hydrology		Emerging	Some
Urban	Urban expansion in the catchment	Changed sediment and nutrient loads via stormwater runoff	Current + future	
Urban	urban expansion in the northern WP catchment may increase: unsealed roads and recreation - both threatening WP bay.	runoff Research needed,	Current + future	Limited
Urban	Urban expansion in the upper catchment will result in increased use and intensification of use of unsealed roads which will result in run-off.	This will result in a change in the water cycle in terms of the quantity of water available, the quality of water and the water	Near future	Limited

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Urban	urban growth corridor across top of WP catchment: - physical impacts caused by development (e.g. land clearing etc) - increased		Near future	None
Urban	-Urban run-off (visible during rainfall): oils off roads, litter.	Increased turbidity Need to change engineering Need education and money	Current + future	Enough
Urban	Urban: Northern WP urban expansion: 600 000 population in next 20 years: With increased population, stormwater quantity and quality		Current + future	Enough
Urban	Urban: Shift and expansion of urban pressure from Port Phillip Bay to Western Port Bay	changed run-off (water quantity, flow regimes, quality)	Current + future	None
Historical	Artificial drainage systems - erosion from catchment waterways	increased sediments	Current + future	Some
Historical	Mangrove clearing and removal	increased sediment load and turbidity in bay. Difficult to rehabilitate marine vegetation (need to identify stable areas, and	Historic	
Historical	Mangrove removal In the late 1800s. This has resulted in the erosion of the shoreline in the eastern WP, increasing sedimentation of the water in WP.	-seagrass loss -loss of fringing ecosystems which are already minimal	Historic	Limited
Historical	Mangroves loss: Modification of fringing habitat - artificial walls substituted	mangrove loss	Historic	Some
Historical	Straightening of estuaries (Historical): modified mouths "cut" forming tributaries though Koo-Wee-Rup.	Increased sedimentation and seagrass loss	Current + future	
Industry	Industrial discharge	elevated nutrients and toxicants: -altered species composition and smothering of seagrass by epiphytic growth	Current + future	
Industry	Industrial use of the port is increasing (i.e. aquaculture , shipping, transport of oil etc). With this comes the threat of increased port traffic	Spread of marine pests.	Current + future	Limited
Other	Bypass Proposed through wetlands		Potential	None
Other	Changes to migratory bird populations due to actions in northern hemisphere affecting breeding, survival, condition etc.	Alters biological balance - food sources etc	Near future	Limited

Broad category	Threat	Ecosystem Response or action	When	Status of Knowledge
Other	sea level rise - impact unknown	unknown	Potential	None
Management	Cumulative impact of decisions	??	Current + future	Limited
Management	Lack of integration across landscapes and a lack of rigour of management actions and planning.	unknown	Current	None
Management	management arrangements Inadequate?		Potential	None
Management	Management arrangements: gaps in jurisdictional boundaries. This is less so now given that the Catchment Management Authority has increased responsibility and is increasing communication with the Central Coastal Board		Current + future	
Management	Management is poor- basic physics/ hydraulics/circulation not well understood, so the dispersion and impact of sediment and other pollutants not well understood	Cause and effect not clear	Current	Limited
Management	Management: need clear targets for management related to ecosystem function and health. Underlying SEPP science not adequate.		Current + future	
Management	SEPP(Western Port) indicators are imprecise e.g. macroinvertebrates.		Current	Limited

Response to Q 4 of the survey: Comments on Research in Western Port Bay Grouped by Primary Role (Coordinator, Management, Research, User (including conservation and interest groups). (Groupings were selected by the interviewees).

Primary Role: Coordinator

InterviewID: RC3

Coordination: -Currently research coordination is done in institutional context, not with respect to management needs
- Need research to dovetail with management needs
-Avoid duplication
-Don't do research not useful to management
-Currently there is no formal coordination of research application: - science perhaps not appropriate
-Unwillingness researchers to be involved in management -> changing in future?

Primary Role: Management (formal responsibility)

InterviewID: RC9

coordination: Research is fragmented and difficult to access
-aware of some environmental problems, told that the environment is vulnerable but, no coordinated research program bringing groups of interest together. Want this before environmental disaster is needed to trigger coordinated research.
Presently much ownership of WP bay by catchment members (this is evidenced by activities such as the Biosphere).
-There is several groups doing things (effort, interest exists) but need to make sure it is coordinated
Application: research proposed is very useful for priority actions in catchment.
But present management is guided by historical knowledge and gut feelings -> need good science to underpin this.
- want to see effective research, well targeted, on priority issues, and including all stakeholders.

InterviewID: RC11

-application -> get some science through research partnership arrangements if ask a specific question (not too broad)
-lots research being done - no one knows about it
-need better coordination of research
-need central brokers e.g. CIC, CMA, CCB for research plan (there are existing options for broker-role).

InterviewID: RC12

-need of coordination for a long time - existing effort should be coordinated
-future education - need to educate people to think and act smarter
-don't use much research directly in management

InterviewID: RC13

-lots of information accumulated within governments (all tiers) -> access is difficult -> could increase efficiency by sharing information
-not sure want to see research too constrained – i.e. still see value in pure research and still need this type of investigation to go on
-protocols for information sharing and collection across tiers of government -> should be free and users add in new information
-need more communication between state and local governments
state agencies - reveal intent (needs to be reflective of reality) of monitoring e.g. beach samples
-need to take local government into confidence

InterviewID: RC14

-Don't share environmental data between agencies
-wealth of information in WP - but not distilled to something referred to for strategic planning

-Western Port Catchment Implementation Committee has potential for better sharing
-Need to identify the causes of ecosystem changes
-still not clear on cause and effect (e.g. landuse -> sediment -> seagrass -> fishing)
-Need to prioritise causes
-Need a focus and driver for research and management e.g. CMA

InterviewID: RC15

-need coordinated program -> high profile study
- need organisation to approach in coordinated manner
- don't have access to other information e.g. Melbourne Water
- EPA has broadscale information, but we need localised information
- if could combine the broadscale with localised info would have better direction of action / work in the localised spots.

InterviewID: RC2

Keen to see partnerships for research
Previous view (until we understand the system, we cant do anything to improve it) is changing now (e.g. previous view - don't replant seagrass until fix cause).
Research has been disjointed thus far.
Progress to coordinate research is good.
Identifying gaps, priorities and synthesis is important
translate research into management and ACTION (important for community stakeholders)

InterviewID: RC4

Coordination:
- some evidence of coordination e.g. sediment study (?)
- Marine environmental research - over past decade or so has become focused on Fisheries because it has an economic driver.

Application:
- Melbourne Water undertake / commission research specifically for management
-take advantage of other useful research for management
-some capacity to undertake management actions arising from research ->use science to underpin decision-making and management
-integrated management - increase in interest and focus (across landscapes)

InterviewID: RC5

-Some organisations have a goal of coordination but tend to focused upon an issue- not holistic.
-need research agenda
-WP management authority - coordinated program versus lots small organizational and targeted WP group
-WP often overlooked
-research not coordinated
-sediment study - first good management driven research
-AMF loop closed
-research done in small bits
-limited knowledge of research for management - not going on or not accessible
-research not WP issue driven - was in the 1970s not since. Now WP driven by issues and interest external to WP.
SEPP will be reviewed every 10 years - this is a driver for reviewing the WP ecosystem.

InterviewID: RC1

Need research targeted for management needs.
Needs to be better coordinated - some existing research networks work well - could build upon these.
WP could provide a model framework for other catchments.
Framework needs clear management and coordination responsibilities defined.

InterviewID: RC7

Coordination:- People doing bits and pieces - no whole picture view

-there is a lack of focus

-attempts to get things happening - fragmented and consensus needed.

CCB - driver for bringing EPA, MW and DSE together

- application - sectoral approach - OK

-holistic / integrated - no

-need to identify a key issue as driver

Primary Role: Management (formal response)

InterviewID: RM9

Standards and expectations have improved significantly over the past decade (hence developments that don't meet environmental standards don't proceed past the idea stage). Further urban expansion will now come under stringent guidelines (see Melbourne 2030).

There is significant volumes of information - priority should be coordination, and giving access to it.

Need to make use of softer science (e.g. Bird Observer counts). Also need to link science and community knowledge. This has been happening and was reflected in the Biosphere nomination, but needs to be further developed.

Overall we are doing things better, and will do better in the future - looking for net progress.

10.2. Workshop process and participants

Process used:

1. Produce generic conceptual models for sediment, nutrient and hydrodynamics to focus constructive discussion during the workshop on these underlying and important processes.
2. Produce a summary of pertinent information (qualitative and quantitative) for Western Port, in a format directly related to the generic conceptual models. This summary was gained primarily from literature scans, but also from stakeholder interviews.
3. Supplement the provided information with new information provided by the workshop participants (in a format directly applicable to the development of the western Port conceptual models).
4. This information formed a basis for discussion of the relative importance of different ecosystem components and processes in the Western Port ecosystem. These group discussions were captured by the project team.

Subsequent to the workshop, the project team developed draft conceptual models for each of the 5 basins, and for Western Port marine environment as a whole. These were circulated to the workshop participants (as well as other relevant external scientists) for review and comment.

Excerpt from the background material provided to workshop participants prior to the workshop.

Western Port conceptual models

In the pages following, four conceptual models are graphically represented.
Three of these models represent key components and processes for each of:

- Sediment dynamics
- Nutrient dynamics
- Hydrodynamics.

The fourth model 'Western Port Biota' identifies dominant and important flora and fauna assemblages. The processes driving these biotic components are not represented. Some direct anthropogenic threats are indicated.
The geographical boundary of the conceptual models is the bay of Western Port. This does not extend into the tributaries entering the bay -these are represented as inputs into the basins, but the processes and components within the tributaries are not represented).
The themes of these models have been selected based upon an initial assessment of the most important ecosystem processes (based upon literature). However, some ecosystem components and processes not included may be important (e.g. contaminants other than nutrients, food webs). There will be opportunity to discuss the relative importance of these during the workshop.
Each conceptual model is accompanied by a brief description of the numbered components and processes.
Following the 'generic' conceptual models is a basin-by-basin account of information relevant to developing a conceptual understanding for that basin. Information is presented using the same numbered component/processes as represented in the conceptual models. The information is primarily specific to Western Port, but where appropriate, findings of other scientific studies are included.
The information included is based upon an initial assessment of existing literature and is, at this stage, not comprehensive. It is expected that workshop participants will reveal additional information regarding Western Port ecosystem processes and components.

Objective of the workshop:

To develop scientifically robust conceptual models (for sediments, nutrient, hydrodynamics) for each of the five Western Port basins.
This will be achieved by modifying the generic models based upon basin-specific information (included in this document, and revealed during the workshop by participants).
These basin-specific models (3 for each basin) will later be simplified into a single basin conceptual model, and potentially a single Western Port model, showing only the most influential ecosystem processes and components.

Participants:

Andy Longmore	Greg Parry	Rob Molloy
Anthony Boxshall	Ian Webster	Ron Johnstone
Brett Light	John Parslow	Steve Arquitt
David Scheltinga	Jon Hinwood	Steve Blackley
Di Rose	Peter Attiwill	Sue Harris
Graeme Batley	Peter Wallbrink	Tim Ealey
Graham Rooney	Regina Counihan	
Liz Morris	Rob Fearon	

Workshop discussion about threats/issues for the bay and basins

In addition to stakeholder interviews, an invitation to comment on threats to Western Port was extended to the participants at the scientific workshop. The following are comments raised by the scientific workshop participants relating to issues, threats or impacts to Western Port. In some cases, these are specific to different areas of Western Port.

Whole of bay issues, threats or impacts

- Seagrass dieback:
  - Causes of historical loss remains unclear
  - Obviously a past, but potentially also a future impact
  - Spatial variability of loss– occurred in all basins except Western Entrance
  - Dieback in patches in Coronet bay
  - Effects on other biota e.g. whiting juveniles' habitat loss?
- Catchment erosion and sediment accumulation and turbidity in bay
  - Increased turbidity in bay? Increase in fine sed?
  - Is turbidity naturally high? Tidal range perhaps not large enough to sustain naturally high turbid environment. Now more frequently turbid. Previously little or no turbidity except during storm events
  - Current turbid zones where historical loss of seagrass
  - Upper catchment land management (e.g. urban growth corridor)
- Algal (phyto and macro) blooms:
  - Potential future threat: Nutrient and chlorophyll levels – currently elevated, heading towards blooms?
  - Eastern side of bay close to N and P levels that if increase by only a little may cause algal blooms
  - Macro/epiphytic algae – where better flushing (Shallow and high flow)
  - Phytoplankton – where poorer flushing (Shallow and low flow)
  - Intertidal areas?
- Exotic pests
  - Future impact? Lower risk because of heterogeneous environment
  - Not big problem in WP, less than in PP, because of type of environment (not 'port' like esp. with respect to sediments) - (but Rhyll greater risk with more areas of possible habitats for pests? A lot of fine sed, less flushing).
- Biodiversity of fauna, decreasing Fish populations, other fauna?
  - Commercial fishery currently not big
  - Recreational – transient fisher population with Port Phillip bay?
  - Critical linkages with underlying processes? e.g. feeding, habitat usage (e.g. whiting and seagrasses)? Food webs? Role of fish in maintaining health of intertidal areas (e.g. grazing pressures, predation pressures), and other significant ecological roles? Knowledge gap – fish may have significant effects on other processes in the bay but we don't know enough about their biology
- Important biodiversity habitats located throughout the bay. Biodiversity/conservation zones (Links to ecosystem processes?):
  - Seal rocks

    - Between Crib pt and Hastings
    - Quail Island
    - French Island
    - Rhyll
    - Stockyard Pt
- Water Exchange rates / Residence times need to be checked / validated
- Oil spill response – potential threat: minimising impacts of spill responses (if not to plan)
- Consequences of Climate change? (reports – Di Rose, CSIRO, ports) Evolution of habitats? Erosion? Koo-Wee-Rup swamp - fall in elevation is 1m in 4 km – consequence of climate change may be significant.

<u>Western Entrance</u>
- Limited WQ monitoring (some associated with aquaculture) → difficult to identify current issues.
- Aquaculture – mussel translocations from Port Phillip bay.
- Least connected to catchment influences (more oceanic) – most different / discrete from other basins. Issues are different e.g. seagrass not significant component of ecosystem.
- Don't expect large impacts, but boundary effects and role as exchange zone important for system understanding.
- For many issues Western Entrance can be excluded from consideration due to its distinct hydrological regime.

<u>Lower North Arm</u>
- Shipping – most likely impact
    - Ballast water release, and potentially exotic pests
    - Oil spills
    - Dredging – minimal currently with no dredging for over 10 years (historically dredging in swing basins)
    - Resuspension of sediment?
- Potential future coastal development – industrial (increase shipping, infrastructure)
- Point sources – some industry located on foreshore.

<u>Upper North Arm</u>
- Corinella / North Arm region: Is it evolving to saltmarsh / mangrove habitat?
- Urban growth corridor in upper catchment
- Historical swamp drainage has changed hydrological regime in coastal catchment areas.
- Benthic community structure shift – has happened, shift again towards macroalgae replacing seagrass?
- Sediment: 90% of fine sediment in Western Port enters through this basin → need to manage catchment. But time lag for change in loads? Time lag in response / changes within bay? (Catchment storage and delivery times of sediments and its contaminants). How long does it take after management of catchment before see benefits in the bay?
    - Contaminants within sediments– not significant issue
    - ASS – potential in northern catchment. Currently exposed soils (some mapping).
- Potential major airport in catchment

<u>Corinella</u>
- Long lag of effects relating to sediment and nutrient dynamics (and interactions between), in response to input changes. There is now a large internal load; even if stop all catchment inputs may still supply bay 'sediment hotspot / sink'
- Storage capacity - high spatial variability within basin?
- Highest sedimentation rates within Western Port.
- High risk for future / long term – high loads of nutrients and sediments here, is it close to the boundary of flipping to another community structure (how much resilience is left?)
- Maybe evolving into mangrove / saltmarshes

Rhyll
- If long flushing times, will have similar lag issues to Corinella.
- Water exchange data questioned (need flushing and exchange rates)

Workshop discussion about biophysical processes for the bay and basins

Nutrients (bay-wide v spatial variation)
- Landscape template

Bay-wide needs
- Loads :
  - not enough temporal and spatial variability data – pulse events (storms), base loads (constant) etc, which more important?
  - Volumes – ok from hydro
  - Units of loads (no consistency in units used)
  - Composition e.g. P, N content.
  - Total N, P measured but not species so much – more use for understanding processes
- Have N and P data – but some limitation on species (need differentiation of bioavailable and dissolved forms)
- Even less carbon data (carry capacity)
- Silicate – little data – but may be important (if N and P present in appropriate rations)
- Point sources – good knowledge – location, but loads not so good (but EPA licences should give amounts from point sources?). Historical inputs important (e.g. changes due construction projects / developments)
- Stormwater data – quantity but not quality
- Erosion: coastline erosion not well understood / patchy
- ASS? With respect to point sources and interaction with water bodies
- Linkages with other basins – nutrient import from Strait (modelling CSIRO).
- Nutrient bay budget – useful for future. ‘coarse resolution
- Basin-basin issues and linkages: Western entrance and Rhyll – little monitoring data therefore hard to make budget for bay (amounts export to Bass Strait??)
- Groundwater – limited / no impact on hydrodynamics or water quality (Melbourne water – GR).
- Atmospheric: numbers from PP – not robust / unknown?. Species not identified (bioavailability perspective, what % bioavailable?) – at least comparable to other sources
- Primary productivity:
  - Important for budgets
  - Epiphytes – nutrient impact, role with seagrasses? No real information on epiphyte primary production. Epiphyte data needed for each basin as differences have been demonstrated (Andy Longmore)
  - need to include macroalgae (different assemblages)
  - benthic micro algae
  - impact of light important
- faunal consumption – fisheries take most from benthic sources (AL – MAFRI). Not much other data on rates of consumption. Could compare fisheries productivity with grazing rates and develop some picture. Benthic fauna important – maintain benthic environment (influence on processes)
- burial – ok, some data exists
- Suspended Sediments release of nutrients - ??. Role of SS in providing dissolved nutrients or flux. Role of resuspension in releasing / transporting nutrients not clear, which nutrients?
- Transport in benthic – unknown
- Remineralisation – some flux measurements made.
  - Gap in N fixation and denitrification
- Exchange – revisit hydro models using EPA nutrient data.
- Water column data – historically better data coverage than now – limited basin coverage
- Benthic standing stocks – limited pore water data, some solid phase data → important to understanding importance of resuspension in contribution of nutrients to water column.
- N fixation and denitrification are key knowledge gaps.

Discussion

- o Epiphytes – in Corinella Arm – dying off this time of year (Tim Ealey)
- o Sediments – need local movement, as well as large scale movement of sediments and nutrients (Tim Ealey)

<u>Sediments (bay-wide v spatial variation)</u>

Gaps:

- o Resuspension major driver:
  - o Relationship between sediments and biophysical processes especially seagrass health:
    - ▪ Effect of sediment on smothering (types of smothering), mortality rates
    - ▪ Light penetration
    - ▪ What are benefits of seagrass in stabilisation? How / where best rehabilitate?
    - ▪ If seagrass re-established, what will the benefits be in terms of abating turbidity?
    - ▪ Where can replanting most effectively be done? Replant Upper North Arm, therefore hypothesis that it would decrease sediment resuspension and transport clockwise around bay.
- o Nature of accumulation (erosion of mudflats not clear in upper north arm)
- o Need good hydrodynamic model to model sediment transport
- o Need: Marine sediment budget for entire bay – total loads and exports, and movements within bay (some knowledge). Biggest gap – how much is exported and imported from Bass Strait.
- o Bay's capacity to flush out 'excess / oversupply' sediment (overstorage) is unknown → influence on whether / how to replant seagrass
- o Large historic load (from swamp drainage) therefore excess sediment load now present
- o Can bay get rid of sediment? Possibility exists that seagrass may never re-establish due to changes in turbidity

Discussion:

- o Given large historical loads – should / will the system return though flushing, or acquire a new state? Time scale for demobilisation of suspended sediment may be long? And different from flushing. i.e. which is likely to happen? Is there a way to demobilise the fine sediment do it's no resuspended and redistributed.
- o Bay is moving around and trying to shunt out historical loads. May never be flushed naturally. Consequence may be no seagrass recovery.
- o Need quantitative time frame for sediment movement – coupled sediment hydrodynamic model.

<u>Hydrodynamics (bay-wide v spatial variation)</u>

- o tidally driven – bay wide
- o exchange of water (and components) tidally driven
- o shallow areas: tidal currents, wind driven circulation (may upset tide in upper bay), wind waves, rainfall (in some areas)
- o no thermohaline stratification (maybe little in NE near creeks, Quail island – very localised small areas)
- o Fresh inflows – saline water in creeks usually (Sediment flocculation occurring in creeks), during floods, salt water pushed out into bay
- o Freshwater inflows important only locally
- o Large tidal range, increasing further into bay
- o Shallow areas – exposure / drying
- o Few areas v high currents (e.g. north arm) – capable of sediment transport. Little vertical variability – at least
- o Many factors affecting currents:
- o Small net flow around islands clockwise. Numerical modelling - cross section and depth variation
- o Currents capable of suspending and transporting fine sands
- o Basins still quite heterogeneous

State of knowledge:
For:

- Resuspension / lifting – current speed important, in deep water, tidal dominated – have knowledge. Shallow water: tidal – have knowledge, waves – limited knowledge, freshwater?
- Transporting – currents and mixing important – for deep water: tidal info, vertical mixing, little on lateral mixing (wind?).

State of knowledge		
	Deep water	Shallow water
Lifting (currents)	Tidal (ok)	Tidal (ok) Waves (wind) (gap) Freshwater (ok)
Transporting (currents, mixing)	Tidal (ok) Vertical mixing (ok) Lateral mixing (adequate)	Tidal (ok) Lateral mixing (gap) Wind (gap)

Priorities:
Need to clarify issues to be resolved by modelling
Waves – some localised examination of issues e.g. erosion
Shallow water areas – hydrodynamic processes (e.g. lifting?)

"A good general model is a contradiction in terms"

10.3. Environmental values identified during development of the SEPP (Western Port)

The following is an excerpt from "POLICY IMPACT ASSESSMENT: PROTECTING THE WATERS OF WESTERN PORT AND CATCHMENT: STATE ENVIRONMENT PROTECTION POLICY (WATERS OF VICTORIA)– SCHEDULE F8 WESTERN PORT AND CATCHMENT"
(EPA, 2001, Publication 797).
Pp 14-21.

Biodiversity of Western Port

There are an unusually wide variety of habitat types in Western Port, ranging through deep and shallow waters. Western Port supports vast areas of algae and reefs and a unique seagrass-mangrove-saltmarsh habitat. Approximately 90 km^2 of seagrass, 37 km^2 of mangrove and 310 km^2 of saltmarsh exist in and around Western Port. The seagrass-mangrove-saltmarsh landscape is a critical part of the ecosystem and plays an important role in maintaining the ecological processes and protecting the range of beneficial uses that can be supported in Western Port. These vegetation communities maintain water clarity through stabilising coastal zones and mud banks and preventing erosion, and assist in the recycling of nutrients that enter Western Port from its catchment (Winfield, 1987). Coastal and marine vegetation also provides food and shelter for invertebrates, insects, crabs, reptiles, fish and birds. In fact, Western Port supports a considerably more diverse array of creatures than Port Phillip bay, many of which were new to science at the time of their discovery in Western Port (Shapiro, 1975). These creatures form more than 80 per cent of the food source for Western Port; a large proportion of this is the invertebrates and insects that inhabit the seagrass meadows (Shapiro, 1975). These seagrass meadows are consequently the feeding grounds and nurseries for a range of commercial and recreational fish species including flathead, whiting and calamari (Larkum *et al*., 1989). In particular, these vegetation communities support some of Western Port's more famous inhabitants, the 15,000 migratory birds that visit Western Port each year in search of food and shelter. The viability of recreational and commercial fisheries and nature based tourism activities, and the protection of biodiversity and internationally significant bird habitats are directly dependent on Western Port's highly productive vegetation, particularly seagrass communities. Port is an important habitat for many bird species, especially eight wader bird species, the Eastern Curlew (*Numenius madagascariensis*); Whimbrel (*Numenius phaeopus*); Grey-tailed Tattler (*Tringa brevipes*); Curlew Sandpiper (*Calidris ferruginea*); Red-necked Stint (*Calidris ruficollis*); Doublebanned Plover (*Charadriusi*); Bar-tailed Godwit (*Limosa lapponica*) and Greenshank (*Tringa nebularia*). There are also a number of bird and mammal species listed under the Flora and Fauna Guarantee Act 1988 which are 'threatened' and require protection in Western Port and its catchment.

Economic and Social Values

The information detailed in this segment gives an indication of the more significant economic and social values of the region.

Agriculture

An estimated 1,840 farming enterprises (NRE, 1999) primarily devoted to cattle and sheep grazing and dairying occupy the majority of the Western Port catchments agricultural landuse with smaller areas devoted to orchards, market gardens, viticulture, poultry and nurseries (ABS, 1996).

The Koo-Wee-Rup horticultural district has an agricultural production rate of $2,993 per hectare, which is the second highest rate (per hectare) of agricultural production in Victoria (Office of the Environment, 1995). In addition, Western Port catchment accommodates 70 per cent of Victoria's broiler chicken industry and 40 per cent of Victoria's market gardening, including 25 per cent of the State's potato growing. Overall, the total gross value production for the Western Port's agricultural industries in 1994 was $430 million, which was 32 per cent of Victoria's total gross value for agricultural production (Phillips Agribusiness, 1993).

Commercial Fishing

Western Port is a popular commercial fishing area with the main catch including Garfish, Yellow-Eye Mullet and Rock Flathead. Commercial fishing catches have slowly declined during the past 20 years with a 46 per cent catch reduction (based on tonnes of fish caught) between 1978 and 1997. The wholesale market value of Western Port's commercial fishing industries in 1995 to 1996 was $438,000, accounting for approximately seven per cent of Victoria's bay and inlet commercial catches (pers. comm. Victorian Fisheries Research Institute, 1997).

Aquaculture

Aquaculture is at present a small industry within Western Port. An aquaculture zone exists in Western Port near Flinders, which is primarily used for production of molluscs, but there is the potential for diversification of the industry within the zone and throughout Western Port and its catchment. The current value of Western Port's aquaculture industry is approximately $1.2 million per annum (pers. comm. Anthony Forster (NRE, Victoria)). However, diversification into abalone, scallop and rock oyster production in Western Port could potentially generate more than $38 million per year with additional economic benefits to the community through direct and indirect employment opportunities (pers. comm. Anthony Forster (NRE, Victoria)).

Tourism

Landscape and wildlife based tourism is one of the most important economic activities occurring in Western Port and its catchment. The majority of tourist destinations in the region are concentrated on the Mornington Peninsula and Phillip Island. The Penguin Parade is the most popular tourist destination in the region, attracting more than 520,000 visitors in 1995–96, including more than 300,000 international visitors. The Penguin Parade returns about $5 million per year, generates 1,000 jobs and is worth about $96 million to the Victorian economy (Victorian Coastal Council, 1996).

Recreation

The streams of the catchment and the waters and shoreline of Western Port are an important focus of recreational activities. Western Port and its catchment are popular for water-based recreation activities including boating, fishing, surfing, swimming, walking, bird watching, and picnicking. Most recreational fishing is conducted in Western Port with the remainder occurring in freshwater and estuarine areas. A 1997 study estimated consumer expenditure attributable to recreational fishing in Western Port was between $106 and $140 million per year (DSD, 1997).

Shipping and Port Activities

Western Port is a significant port because of its easily navigable entrance and deep channels that can accommodate the large tankers and ships now used to transport many commodities. In the 1960s, extensive port facilities for deep draft shipping were developed near Hastings (at Crib Point and Long Island Point). The Port of Hastings supplies large industries (for example, Esso and BHP) with raw materials and deliver exports elsewhere in Australia and overseas. Stony Point Jetty services some coastal shipping carrying livestock and small quantities of other goods. There are also facilities for harbour support vessels such as tugs, pilot boats and the like and for the ferry services to French Island.

At present the value of exports from the Port of Hastings is primarily related to Oil and Gas extraction ($61 million) (pers. comm. ESSO, 1999) and metal product manufacturing ($146 million) (pers. comm. BHP, 1999). However, port facilities in Western Port are well placed for expansion, which could lead to considerable social and economic benefits for the region. For example, the recommissioning of No. 1 Berth at Crib Point Jetty is expected to expand the import of refined petroleum product by 12 vessels and more than 300,000 tonnes of cargo per year to the port initially, with prospects for increased expansion in the future (pers. comm. BHP, 1999).

The Port of Hastings operators have recognised and managed the environmental impacts of port activities. The current manager and operator, Toll Westernport, is committed to continue this through the development and implementation of an environment management system, and with support from the Victorian Government, is developing an environment management plan for the port. Furthermore, Toll Westernport is cooperating with government partners in trialing the development of an operational ballast water management system as part of an integrated national and State approach. Continued implementation of such environmental leadership and performance should help to ensure that potential port expansion is done in an ecologically sustainable manner while providing for significant social and economic benefits.

Major Industry

The Western Port region is well suited for industrial development with a deep water port, the availability of large tracts of flat land and the proximity to Melbourne. By the mid-1970s, several major industries had located on the western side of Western Port. Major industries in Western Port include a BP oil refinery, a gas fractionalisation plant and John Lysaght (Aust)/BHP Steel Works which currently employs approximately 1,500 staff (pers. comm. BHP, 1999). Raw materials are imported into Western Port from around the world and product is exported throughout Australia and to other countries from the Port of Hastings.

Extractive Industries

Western Port's catchment contains significant sand and gravel resources, which are likely to be in great demand in the near future. There are a number of existing quarries already open within the catchment area. The Lang Lang to Grantville area has been identified as containing more than 400 million tonnes of sand suitable for extraction and is likely to become a major source of sand to Melbourne (AGC Woodward-Clyde, 1996). Economic benefits resulting from the extraction of sand resources include revenue from sales and provision of employment either directly in the industry or from associated business opportunities in the region.

Western Port's catchment also contains land which has been identified as being likely to contain stone resources of sufficient quantity and quality to support a commercial extractive industry operation. Such land is covered by an 'extractive industry interest area' designation and is identified in relevant planning schemes.

Forestry

In the northeast of the catchment, 14,000 ha of State forest is managed for water production (Bunyip and Tarago Rivers) and within this about 80 ha is logged each year in the Tarago State Forest (Salkin, 1998).

10.4. Scientific information underpinning the conceptual models

Hydrodynamics

<table>
<tr><th></th><th>Western Entrance basin</th><th>Lower North Arm basin</th><th>Upper North Arm basin</th><th>Corinella basin</th><th>Rhyll basin</th></tr>
<tr><td rowspan="2">1 Catchment input</td>
<td>o Minor catchment surface inflow via waterways.
o Shapiro (1975) calculated daily flows for the four most significant waterways.
<table>
<tr><th></th><th>Daily Flow (ML/day)</th><th>Derived annual flow (ML/yr)</th></tr>
<tr><td>Merricks Ck</td><td>17.0</td><td>6205</td></tr>
<tr><td>East Ck</td><td>7.8</td><td>2847</td></tr>
<tr><td>Stony Ck</td><td>6.4</td><td>2336</td></tr>
<tr><td>Manton Ck</td><td>9.5</td><td>3468</td></tr>
</table></td>
<td>o Minor catchment surface water inputs via waterways. Shapiro (1975) calculated daily flows for the three most significant waterways.
<table>
<tr><th></th><th>Daily Flow (ML/day)</th><th>Derived annual flow (ML/yr)</th></tr>
<tr><td>Langwarrin Ck</td><td>14</td><td>5110</td></tr>
<tr><td>Watson Ck</td><td>14</td><td>5110</td></tr>
<tr><td>Warrangine Ck</td><td>10</td><td>3650</td></tr>
</table></td>
<td>o Three significant freshwater inflows, but net input is relatively low (1100 ML per day total bay) (Shapiro, 1975).
<table>
<tr><th></th><th>Annual input (ML/yr)</th><th>Daily input (ML/day)</th></tr>
<tr><td>Lang Lang River</td><td>68630</td><td>187</td></tr>
<tr><td>Bunyip Drain</td><td>100718</td><td>274</td></tr>
<tr><td>Yallock Ck</td><td>63145</td><td>173</td></tr>
<tr><td>Cardinia Ck</td><td>17575</td><td>49</td></tr>
</table></td>
<td>o No significant waterways, some artificial drainways. Local surface water run-off?</td>
<td>o Bass River only major river inflow. Contributes approximately 54000 ML per year (150 ML per day) (Shapiro, 1975).</td></tr>
<tr><td colspan="5">o Freshwater input is minimal in respect to the whole basin. Will have isolated effects near the input river. Storm events will increase the total area influenced/affected (still very small and isolated effects) (John Hinwood). Tidal cycle (i.e. high or low tide) will also influence the effect of freshwater.</td></tr>
<tr><td rowspan="2">2 Groundwater input</td>
<td>o Nepean Peninsula aquifer. Flow rates?</td>
<td>o ?</td>
<td>o Saline intrusion occurring between Tooradin and Harewood airport (Lakey, 1991)</td>
<td>o ?</td>
<td>o ?</td></tr>
<tr><td colspan="5">o Water inputs through freshwater aquifers is decreasing/minimal/stopped (Graham Rooney). Saltwater is moving into the groundwater (loss?).</td></tr>
<tr><td rowspan="2">3 Precipitation into basin</td>
<td>o Annual precipitation is approximately 750mm; most falls in winter and spring.</td>
<td>o Annual precipitation is approximately 750mm; most falls in winter and spring.</td>
<td>o Annual precipitation is approximately 750mm; most falls in winter and spring.

Some minor effects on Saltmarshes (John Hinwood).</td>
<td>o Annual precipitation is approximately 750mm; most falls in winter and spring.</td>
<td>o Annual precipitation is approximately 750mm; most falls in winter and spring.</td></tr>
<tr><td colspan="5">o Tidal cycle (i.e. high or low tide) will also influence the effect of freshwater.</td></tr>
<tr><td>4 Adjoining basin exchanges</td>
<td>o Large tidal range approximately 1.6m (Sternberg and Marsden, 1979) – strong tidal currents.
o High flood and ebb water velocities (see below, lateral mixing) result in high exchange rates with Bass Strait, the Lower North Arm and Rhyll basins.</td>
<td>o Large tidal range: 1.6 – 2.2 m (Sternberg and Marsden, 1979)</td>
<td>o Net flow of surface and bottom water is east and south to Corinella basin (Sternberg and Marsden, 1979).</td>
<td>o Net water flow from Upper North Arm basin, during flood and ebb tides. Flow rates?</td>
<td>o Oceanic water is exchanged with Bass Strait via Western Entrance basin, and directly via the Eastern Entrance (Sternberg and Marsden, 1979)
o Large tidal range: 1.6 – 2.2 m (Sternberg and Marsden, 1979)
o Tidal currents dominate water movement (Sternberg and Marsden, 1979)
o Net water flow through Eastern Entrance is > 3m/sec (Hinwood, 1970)</td></tr>
</table>

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
5 Point sources	o No discharge or extraction known	o Industrial uses: cooling water. Volumes? o Industrial discharge? o BHP allowed to release a maximum of 1.7 ML/day (=620 Ml/yr) o ESSO allowed to release a maximum of 4.5 ML/day (=1642 ML/yr) and an extra 20 ML/day of ballast water discharge allowed. Maximum total = 2262 ML/yr.	o None?	o None?	o None?
	o Check with EPA (Di Rose), some smaller sewage plants.				
6 Evapotranspiration – saltmarsh	o Small area of saltmarsh – evapotranspiration likely to be minimal	o Significant coverage – transpiration rates?	o Saltmarsh coverage and transpiration rates?	o Likely to be minimal, very little saltmarsh coverage.	o Small area of saltmarsh – evapotranspiration likely to be minimal
	o Minimal effects on whole basin but will be isolated/localised effects.				
7 Evapotranspiration – mangrove	o Small area of mangrove – evapotranspiration likely to be minimal	o Significant coverage – transpiration rates?	o Mangrove coverage and transpiration rates?	o Likely to be minimal, very little mangrove coverage.	o Small area of mangrove – evapotranspiration likely to be minimal
	o Minimal effects on whole basin but will be isolated/localised effects. o Maximum rate of water loss through evapotranspiration by mangroves is 30 mgm^{-2}s^{-1} (Attiwill and Clough, 1980).				
8 Evapotranspiration – seagrass at low tide	o Most seagrass is subtidal – small coverage of intertidal seagrass – minimal evapotranspiration.	o Significant coverage – transpiration rates? o Total seagrass area: 24 km^2. Proportion of intertidal coverage?	o Evapotranspiration rates? o Total seagrass area: 42 km^2. Proportion of intertidal coverage?	o Likely to be minimal, very little seagrass coverage (5 km^2).	o 21km^2 of seagrass, most in intertidal area – minimal evapotranspiration
	o Minimal effects on whole basin but will be isolated/localised effects.				
9 Evaporation	o Average air temperature for Western Port is 24 ^{o}C in summer, 14 ^{o}C in winter (BoM, 2003)	o Evaporation rates? o Average air temperature for Western Port is 24 ^{o}C in summer, 14 ^{o}C in winter (BoM, 2003) o Average wind speed	o Average air temperature for Western Port is 24 ^{o}C in summer, 14 ^{o}C in winter (BoM, 2003)	o Average air temperature for Western Port is 24 ^{o}C in summer, 14 ^{o}C in winter (BoM, 2003)	o Average air temperature for Western Port is 24 ^{o}C in summer, 14 ^{o}C in winter (BoM, 2003)

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
	o Minimal/no effects on whole basin.				
10 Bottom water flows	o Some bottom wave action from Bass Strait - net inflow (Sternberg and Marsden, 1979). o Bottom currents are primarily induced by tides, and therefore vary in intensity throughout the tidal cycle. Velocity varied between 25 – 70 cm/sec. (Sternberg and Marsden, 1979).	o Bottom currents are induced by tides, and therefore vary in intensity throughout the tidal cycle (Sternberg and Marsden). Net direction is north.	o Net flow of surface and bottom water is east and south to Corinella basin (Sternberg and Marsden, 1979).	o Net flow is south to Rhyll basin (Sternberg and Marsden, 1979).	o Strong ebb and flood currents form channel systems (Sternberg and Marsden, 1979) o Bottom currents at eastern border (adjoining the Western Entrance basin) are induced by tides, and therefore vary in intensity throughout the tidal cycle (Sternberg and Marsden, 1979) o Shallower dendritic channels drain into larger channels during the ebb tide (Sternberg and Marsden, 1979)
11 Lateral mixing	o Large tidal range approximately 1.6m (Sternberg and Marsden, 1979) o Tidal currents dominant driver of water movement, although strong swells and wave action in Bass Strait influence bottom currents and water column hydrodynamics near the confluence with Bass Strait. (Sternberg and Marsden, 1979) o Exchange rate ~0.5 day (Sternberg and Marsden, 1979) o Winds – minor effect on spatial and temporal variability of tides o Net surface water flows (cm/sec): relative importance of flood and ebb tidal currents is bisected along long axis of the basin into north and south sections: dominant current in northern section is NE, indicating the dominant influence of the flood tide; southern section the dominant current is SW, indicating the dominant influence of the ebb tide. o At confluence with Bass Strait: eastern side of entrance: 3.4 cm/sec, south-west direction (i.e. dominated by the ebb tide); western side of entrance: 2.9 cm/sec in north-east direction (i.e. dominated by the flood tide). o Mid-major channel: 7.4 cm/sec in southwest direction (i.e. dominated by the ebb tide o At confluence with Rhyll basin: south confluence: 2.6 –3.8 cm/sec east direction (i.e. dominated by the flood tide), north confluence: 3.9	o Residence time: order of days o Tidal currents are the dominant driver of water movement. o Large tidal range: 1.6 – 2.2 m (Sternberg and Marsden, 1979) o Net flow surface water is north and northeast to Upper North Arm basin. o Winds – minor effect on spatial and temporal variability of tides o Net flow velocities (Sternberg and Marsden, 1979), measured in the major channel: 4.3 cm/sec in south of basin (north direction), 5.3 cm/sec in mid-north of basin (north direction) – both are flood dominated rather than ebb dominated.	o Tidal divide: ebb tide flows away from. o Exchange rate (residence time) weeks – months (in Hancock *et al*., 2001) o Shallower dendritic channels drain into larger channels during the ebb tide. o Large tidal range: approximately 2.2m, up to 3m during spring tides (Sternberg and Marsden, 1979). o Tidal currents are the dominant driver of water movement. o Winds – minor effect on spatial and temporal variability of tides o Net flow of surface and bottom water is east and south to Corinella basin (Sternberg and Marsden, 1979).	o Large tidal range: approximately 2.2m, up to 3m during spring tides (Sternberg and Marsden, 1979) o Tidal currents is the dominant driver of water movement. o Tidal currents dominant driver of water movement. o Winds – minor effect on spatial and temporal variability of tides o Net flow of surface and bottom water is south to Rhyll basin (Sternberg and Marsden, 1979). o Exchange rate: weeks – months o Strong ebb and flood currents form channel systems. Shallower dendritic channels drain into larger channels during the ebb tide.	o Large tidal range: 1.6 – 2.2 m (Sternberg and Marsden, 1979) o Exchange rate: weeks – months (EPA, 1996) o Winds – minor effect on spatial and temporal variability of tides (Sternberg and Marsden, 1979)

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
	cm/sec in west direction (i.e. dominated by the ebb tide)				
	o Some question of accuracy of residence times/exchange rates?				
12 Vertical mixing	o Large tidal range approximately 1.6m (Sternberg and Marsden, 1979) o Wave action from Bass Strait (predominantly from the southwest) contributes to vertical mixing o Bathymetry: Some deep channels (~20m)– lateral mixing (due to strong tides) greater than vertical mixing? Water in shallow areas (intertidal and subtidal sand banks) is likely to be well-mixed.	o Bathymetry: Some deep channels (~20m)– lateral mixing (due to strong tides) greater than vertical mixing? Water in shallow areas (intertidal and subtidal sand banks) is likely to be well mixed.	o Large tidal range: approximately 2.2m, up to 3m during spring tides (Sternberg and Marsden, 1979).	o Large tidal range: approximately 2.2m, up to 3m during spring tides (Sternberg and Marsden, 1979)	o Large tidal range: 1.6 – 2.2 m (Sternberg and Marsden, 1979)
	o Good vertical mixing throughout basin.				
	South facing coastline are high energy shores characterised by cliffs, wave cut platforms and reefs, dune systems and pocket sandy beaches (AGC Woodward-Clyde, 1993).	Coastlines are moderate to low energy shores with some rocks and cliffs interspersed with sandy beaches and mudflats (AGC Woodward-Clyde, 1993).	Coastlines are low energy shores with extensive intertidal mudflats with deeper tidal channels cut into them, and occasional rocky platforms, cliffs and sandy beaches (AGC Woodward-Clyde, 1993).	Coastlines are moderate to low energy shores with some rocks and cliffs interspersed with sandy beaches and mudflats (AGC Woodward-Clyde, 1993).	Eastern Entrance has high energy shores characterised by cliffs, wave cut platforms and reefs, dune systems and pocket sandy beaches (AGC Woodward-Clyde, 1993).

- Critical Knowledge – Bathymetry (especially with changing environment, i.e. changing channels, intertidal flats, etc.).
- Model of wind effects on hydrology has been done (John Hinwood) but to “technical/hard” for the Shapiro report.
- Hydrology well known for each basin except at the smaller scale/regions (i.e. onshore/offshore exchange, hydrology within the shallows e.g. Tim Ealey observed sand move one way up the beach but 50 m further up the beach the sand will move another way (effects of wind)).
- Very little salinity layering – only at the mouth of a few rivers but even then only very minimal.
- Little use in remodelling hydrology unless you want a specific question answered.
- Marsden report has most of the information in it.
- Western Entrance – a lot of sand has been lost (erosion) along the northern shoreline (John Hinwood).
- John Hinwood did a lot of work on tidal flow and variation in tidal constituents. He has a copy of the report.
- Very minimal dredging (only in Lower North Arm) (John Hinwood).
- Wind has a large effect on sediment resuspension (Tim, Ealey), especially in Upper North Arm, Corinella and Rhyll basins. Maybe more important than tidal influence (at certain times anyway).
- Wind effects the ‘node’ of tidal meeting point within Upper North Arm.
- Wind effects flow change over, and position of sand bank within Western Entrance.
- Meteorology (wind) data may not be very accurate as both meteorology stations are in leeward locations (Tim Ealey).
- Water and sediments have a net clockwise flow but there are many smaller scale movements (John Hinwood).
- No general study on wind (waves) – quite a few recent studies on erosion of the coastline (John Hinwood).
- Shallow areas varying in significance – tidal force, wind driven (top bay) upsets tidal flow, rainfall.
- No stratification - ???? localised deeper slower areas (not measured).
- Freshwater flows locally important – flocculation at river/creek mouths.

- Overall circulation – small net flow clockwise (quantified). Project reports have basin flows and cross-section variation.
- Deep areas – Tidal currents dominate resuspending. Tidal and vertical mixing data available for transport estimation – lateral mixing less developed.
- Shallow water – resuspension – tidal and wave effects (no wind/wave data). Freshwater inflow locally important – some data.
- Transport – No lateral mixing or wind data. Tidal data available.
- Gaps – Need to define the issues better for the model and its use. Wave data very limited. Collation of processes and hydrodynamic interactions is still needed.
- Overall tidally driven.
- Long term exchange tidally driven. Tidal action has cut deep channels into mudflats.
- Shallow areas tidal, wind driven, wind waves, rainfall.
- No real thermohaline stratification. Some effects locally.
- Freshwater inflows important only locally; saline water in creeks causes flocculation.
- Large tidal range and extensive shallows – drying.
- Priorities – need to clarify issues for modelling; waves – shallow water areas.
- Currents in North Arm strong. Lifting dependent on current speed.
- The 5 basins are still relatively quite heterogeneous.

State of knowledge

Uses of hydrodynamics	**Deep Water**	**Shallow water**
Lifting (currents)	Tidal (Good data)	Tidal (Good data) Waves (wind) (no data) Fresh (some data)
Transporting (current mixing)	Tidal (Good data) Vertical mixing (Good data) Lateral mixing (some data)	Tidal (Good data) Lateral mixing (no data) Wind (no data)

Nutrients

1. Catchment surface waters

Western Entrance basin

- Minor catchment surface inflow via waterways
- Merricks Creek (Coleman *et al*., 2000)

Annual median concentrations	TN (mg/L) 1998, 1999	TP (mg/L) 1998, 1999
Merricks Ck (Merricks)	1.01, 1.41	0.13, 0.18

- Shapiro (1975) estimated daily loads. Annual loads have been derived below:

Derived annual load (t/yr)	TN	Amm-onia	Nit-rate	TP	DP
Merricks Ck	2.9	0.4	1.1	0.4	0.2
East Ck	3.3	0.2	0.2	0.3	0.1
Stony Ck	1.8	0.1	0.7	0.4	0.1
Manton Ck	1.1	0.0	0.4	0.1	0.0

Lower North Arm basin

- Melbourne Water (Coleman *et al*., 2000) monitoring:

Annual median concentrations	TN (mg/L) 1998, 1999	TP (mg/L) 1998, 1999
Warrangine Ck (Hastings)	1.03, 1.04	0.05, 0.05
Watsons Ck (Somerville)	15.51, 37.03	0.28, 0.39

- Shapiro (1975) estimated daily loads. Annual loads have been derived below:

Derived annual load (t/yr)	TN	Amm-onia	Nit-rate	TP	DP
Langwarrin Ck	11.7	0.4	3.7	1.1	0.4
Watson Ck	16.8	9.1	17.2	5.1	4.0
Warrangine Ck	8.0	0.4	1.1	0.7	0.7

Upper North Arm basin

- Concentrations of nutrients are correlated with sediment loads. (Coleman *et al*., 2000)

Annual median concentrations	TN (mg/L) 1998, 1999	TP (mg/L) 1998, 1999
Bunyip River (Koo-Wee-Rup)	0.68, 0.94	0.05, 0.04
Yallock Ck (Monomeith)	3.5, 3.27	0.42, 0.77
Lang Lang River (Lang Lang)	1.51, 1.76	0.12, 0.13

- Shapiro (1975) estimated daily loads. Annual loads have been derived below:

Derived annual load (t/yr)	TN	Amm-onia	Nit-rate	TP	DP
Lang Lang River	132	7	113	20	11
Bunyip Drain	116	8	45	12	12
Yallock Ck	154	10	94	30	21
Cardinia Ck	26	1	12	5	2

Estimated Phosphorus loads from waterways into basin (estimated by Sednet) (Wallbrink *et al*., 2003):

	Phosphorus t/yr
Lang Lang River	26.2
Bunyip Drain	16.3
Yallock Ck	7.6
Cardinia Ck	1.7

Corinella basin

- No significant waterways, some artificial drainways. Local surface water run-off?

Rhyll basin

- Via the Bass River. Shapiro (1975) calculated daily loads for the Bass River:

	Annual load (kg/day)	Derived annual load (t/yr)
Total Nitrogen (TN)	281	102.6
Ammonia	16	5.8
Nitrate	307	112.1
Total Phos-phorus (TP)	38	13.9
Dissolved Phosphorus (DP)	19	6.9

Estimated Phosphorus loads from Bass River into basin (estimated by Sednet) equals 16.1 t/y (Wallbrink *et al*., 2003):

All basins

- NOTE: The following applies across Western Port: 1. See Analysis of water quality in Western Port 1973-1997 in relation to protection of beneficial uses (author Longmore, MFRI, internal report No. 4). 2. Gap: need temporal data across bay (Johnstone). 3. Terrestrial C loads probably unimportant across bay (John). 4. Bioavailability of incoming nutrients an important distinction which should be made (Attiwill).

2. Local point sources

Western Entrance basin

- None known?
- Aquaculture – effectively none.

Lower North Arm basin

- -Industrial effluent? Some (little nutrients) from Hastings Port and industrial area.

Upper North Arm basin

- None known?

Corinella basin

- None?

Rhyll basin

- None known?

All basins

- Covered for all basins. Licensed discharges (EPA database). Historically some significant point sources (see Marsden). Upper North Arm and Corinella main recipients. Stormwater data held by councils – location but no data.
- Locations of drains for urban runoff available across Western Port. Data on nutrient content of runoff very limited. (Brett Light EPA)

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
3 Erosion of coastal sediments	o Erosion of silt and clay from Basalt cliffs between Flinders and Balnarring (Bird, 1993) → likely to contribute phosphorus Western Entrance – a lot of sand has been lost (erosion) along the northern shoreline (John Hinwood).	o ?	o Minimal erosion?	o Erosion of fine sediments from cliffs near Corinella (Bird, 1993) likely to contribute phosphorus.	o Erosion of fine sediment (silt and clay) from cliffs on Phillip Island. (Bird *et al*., 1993) likely to contribute phosphorus.
	o Coastline erosion information patchy. Report by Eric Bird – descriptive not quantified. o Eric Bird conducted research on coastal erosion across Western Port and possible link with phosphorous (Andy).				
4 Inputs from adjoining basins	o Nutrient concentrations in Bass Strait low minimal input into Western Entrance. (Boags Rocks report?) o Some net nutrient inputs from Lower North Arm and Rhyll basins likely Possible input from Cape Shanks (CSIRO plume work suggests this may be possible (Bass Strait input).	o Concentrations in Upper North Arm basin similar to this basin. Catchment loads to this basin relatively small. Probably nutrients in this basin originate in Upper North Arm basin?	o Probably minimal: Net water flow from Lower North Arm basin, where nutrient concentrations are similar. With respect to Corinella basin, net water flow is towards Corinella basin.	o Due to net water flow from Upper North Arm basin, likely net input of nutrients from that basin.	o Net water flow from Corinella basin. Suspended sediment concentration in Corinella water: median = 3 mg/L (range = 1-199 mg/L). o Minimal input from Bass Strait waters.
	o Historical budgets a good start (see Andy Longmore for budgets). o Nutrient budgeting will be dominated by flushing in this basin. Budgets may now be roughly quantified with existing load data (John, load data available through Andy).				
5 Groundwater inputs	o Groundwater inputs – Port Phillip Study referred to low loads of nutrient inputs into Port Phillip bay from the Nepean Peninsula aquifer (approximately 17t P and 19t N). (see Harris *et al*., 1996). The same aquifer is likely to contribute to nutrients in the Western Entrance basin of Western Port 1. Andy recalls that some data may be significant in this portion of Western Port. Andy may have some data on this. 2. Groundwater data may be available from risks assessment related to aquaculture (Brent Light).	o Groundwater inputs – Port Phillip Study referred to low loads of nutrient inputs into Port Phillip bay from the Nepean Peninsula aquifer (approximately 17t P and 19t N). The same aquifer is likely to contribute to nutrients in the Upper North Arm basin of Western Port.	o ?	o ?	o Unknown?
	o Unknown data. Rumour of groundwater inputs. Estimates of flow? Concentrations some data. Coastal geomorphology. Melbourne water have a 'model'. Groundwater data for aquaculture areas on Flinders (DPI).				

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
6 Atmospheric input	o Contributions of nitrogen to Port Phillip bay were estimated as 800-1300 N t/yr (see Harris *et al*., 1996). Based upon a per area equivalent, the Western Entrance basin of Western Port would receive approximately 68-110 N t/yr (Western Entrance basin is approximately 8.5% the surface area of Port Phillip bay). o Atmospheric inputs of phosphorus are also unknown for either Western Port or Port Phillip bay, but are likely to be minimal, except during episodic dust storms when they may be significant (Harris *et al*., 1996).	o Atmospheric inputs – unknown for Western Port. Contributions of nitrogen to Port Phillip bay were estimated as 800-1300 N t/yr (see Harris *et al*., 1996). Based upon a per area equivalent, the Lower North Arm basin of Western Port would receives approximately 48-78 N t/yr (Lower North Arm basin is approximately 6% the surface area of Port Phillip bay). o Atmospheric inputs of phosphorus are also unknown for either Western Port or Port Phillip bay, but are likely to be minimal, except during episodic dust storms when they may be significant (Harris *et al*., 1996).	o Atmospheric inputs – unknown for Western Port. Contributions of nitrogen to Port Phillip bay were estimated as 800-1300 N t/yr (see Harris *et al*., 1996). Based upon a per area equivalent, the Upper North Arm basin of Western Port would receives approximately 63-102 N t/yr (Upper North Arm basin is approximately 8% the surface area of Port Phillip bay). o Atmospheric inputs of phosphorus are also unknown for either Western Port or Port Phillip bay, but are likely to be minimal, except during episodic dust storms when they may be significant (Harris *et al*., 1996).	o Atmospheric inputs – unknown for Western Port. Contributions of nitrogen to Port Phillip bay were estimated as 800-1300 N t/yr (see Harris *et al*., 1996). Based upon a per area equivalent, the Corinella basin of Western Port would receives approximately 41-67 N t/yr (Corinella basin is approximately 5% the surface area of Port Phillip bay). o Atmospheric inputs of phosphorus are also unknown for either Western Port or Port Phillip bay, but are likely to be minimal, except during episodic dust storms when they may be significant (Harris *et al*., 1996).	o Atmospheric inputs – unknown for Western Port. Contributions of nitrogen to Port Phillip bay were estimated as 800-1300 N t/yr (see Harris *et al*., 1996). Based upon a per area equivalent, the Rhyll basin of Western Port would receives approximately 61-100 N t/yr (Rhyll basin is approximately 7.5% the surface area of Port Phillip bay). Atmospheric inputs of phosphorus are also unknown for either Western Port or Port Phillip bay, but are likely to be minimal, except during episodic dust storms when they may be significant (Harris *et al*., 1996).
	o Available data a bit rubbery. Check numbers with the biological availability considered. Sea spray in south for N (units of input?). Atmospheric may be dominant in Western Port. Actual availability of nutrients unknown. o Knowledge gap across Western Port.				
7 Primary productivity	o Small areas of mangroves and saltmarshes – minimal consumption of dissolved nutrients o Phytoplankton biomass. Mean concentration 1.2 µg/L (Bulthuis, 1977). Highest productivity rates within Western Port (Bulthuis, 1977), probably associated with the relatively good water clarity and oceanic flushing. Both P and N limited? (Bulthuis, 1977). o Seagrasses – biomass? Productivity rates?	o Mangrove area: Rates of consumption of dissolved nutrients? o Saltmarsh area: Rates of consumption of dissolved nutrients? o Phytoplankton biomass: median concentration = 1.1 µg/L (see below, water column nutrients, EPA). Both P and N limited? (Bulthuis, 1977). o Seagrasses –24 km^2 coverage. Rates of consumption of dissolved nutrients? Seagrass productivity data available for this section of Western Port (Attiwill).	o Phytoplankton concentrations: median 1.4 µg/L. Productivity/consumption dissolved nutrients rates? o Significant mangrove coverage. Productivity/consumption dissolved nutrients rates? o Significant seagrass coverage (42 km^2). Productivity/consumption dissolved nutrients rates? o Significant saltmarsh coverage. Productivity/consumption dissolved nutrients rates?	o Phytoplankton concentrations: median 3 µg/L. Productivity/consumption dissolved nutrients rates? o Small coverage of mangrove, saltmarsh or seagrass, consumption of dissolved nutrients likely to be minimal.	o Phytoplankton biomass? In adjoining Corinella basin, 3 µg/L, relatively high. o Very little saltmarsh, mangroves. o Seagrass: 21 km^2
	o Seagrass data good. Phytoplankton data less good. Could estimate from literature. Need to include for the macro-algae (diff. types!) and phyto-benthos. Status and productivity of epiphytes unknown across basins (some local data – Northern bay – Macro-algae and epiphytes (basin differences)). Impact of light (sediment model) on benthic primary production and nutrient dynamics is important to capture (UQ light attenuation model could be used here). Epiphyte significance in different basins unknown. Seagrass production numbers from few locations (mostly NE arms). NRE web site contains seagrass distributions. o 1. Phytoplankton data available across Western Port (Andy). 2. Macroalgae and microphytobenthos data is a gap knowledge across Western Port (Brent Light EPA). 3. An important question is: across Western Port has macroalgae filled in gaps created by seagrass loss (Brent Light EPA). 3. Another question: has seagrass detritus contributed to nutrient budgets across Western Port (Steve Blackley). o Seagrass (Zostera Muelleri) annual net primary production = $4.3x10^8$ g dry wt/km^2 (Clough and Attiwill, 1980).				

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
8 Faunal consumption of primary productivity. Release of particulate, and ammonia.	o Benthic faunal biomass: o Edgar *et al*., 1994 (for Western Port) ▪ Epifauna production in intertidal seagrass areas = 17.2 $g/m^2/yr$ ▪ Epifauna production in intertidal unvegetated areas = 3.3 $g/m^2/yr$ ▪ Infauna production in intertidal seagrass areas = 62 $g/m^2/yr$ ▪ Infauna production in intertidal unvegetated areas = 54 $g/m^2/yr$ o Planktonic fauna? o Transport of organic matter through food web? o Consumption and waste rates for different biota.?	o Benthic faunal biomass: o Edgar *et al*., 1994 (for Western Port) ▪ Epifauna production in intertidal seagrass areas = 17.2 $g/m^2/yr$ ▪ Epifauna production in intertidal unvegetated areas = 3.3 $g/m^2/yr$ ▪ Infauna production in intertidal seagrass areas = 62 $g/m^2/yr$ ▪ Infauna production in intertidal unvegetated areas = 54 $g/m^2/yr$ o Planktonic fauna? o Transport of organic matter through food web? o Consumption and waste rates for different biota?	o Benthic faunal biomass: o Edgar *et al*., 1994 (for Western Port) ▪ Epifauna production in intertidal seagrass areas = 17.2 $g/m^2/yr$ ▪ Epifauna production in intertidal unvegetated areas = 3.3 $g/m^2/yr$ ▪ Infauna production in intertidal seagrass areas = 62 $g/m^2/yr$ ▪ Infauna production in intertidal unvegetated areas = 54 $g/m^2/yr$ o Planktonic fauna? o Transport of organic matter through food web? o Consumption and waste rates for different biota.?	o Benthic faunal biomass: o Edgar *et al*., 1994 (for Western Port) ▪ Epifauna production in intertidal seagrass areas = 17.2 $g/m^2/yr$ ▪ Epifauna production in intertidal unvegetated areas = 3.3 $g/m^2/yr$ ▪ Infauna production in intertidal seagrass areas = 62 $g/m^2/yr$ ▪ Infauna production in intertidal unvegetated areas = 54 $g/m^2/yr$ o Planktonic fauna? o Transport of organic matter through food web? o Consumption and waste rates for different biota?	o Benthic faunal biomass: o Edgar *et al*., 1994 (for Western Port) ▪ Epifauna production in intertidal seagrass areas = 17.2 $g/m^2/yr$ ▪ Epifauna production in intertidal unvegetated areas = 3.3 $g/m^2/yr$ ▪ Infauna production in intertidal seagrass areas = 62 $g/m^2/yr$ ▪ Infauna production in intertidal unvegetated areas = 54 $g/m^2/yr$ o Planktonic fauna? o Transport of organic matter through food web? o Consumption and waste rates for different biota?
	o Fisheries appear to get most from benthic fauna and saltmarshes. o Food web data available in regard to consumption of seagrass and macroalgae by fish (Andy).				
9 Settling and resuspension, burial.	o ?	o High sediment resuspension rates → likely to be high particulate nutrient resuspension rates.	o Burial of phosphorus evident in cores (Hancock *et al*., 2001) -likely for all nutrients.	o Burial of P evident in cores (Hancock *et al*., 2001), therefore likely for all nutrients. o Concentration of P in benthic sediment decreases with depth (Hancock *et al*., 2001), indicating and increase contribution of P to this basin over the last 40 years, but elevated concentrations are still not high in comparison to natural concentrations of P in soils. Source of P is unknown – could be catchment-derived, increased biological activity, or increased amounts of organic matter (see Hancock *et al*., 2001).	o Burial of P evident in cores (Hancock *et al*., 2001), therefore likely for all nutrients. o Concentration of P in benthic sediment decreases with depth (Hancock *et al*., 2001), indicating and increase contribution of P to this basin over the last 40 years, but elevated concentrations are still not high in comparison to natural concentrations of P in soils. Source of P is unknown – could be catchment-derived, increased biological activity, or increased amounts of organic matter (see Hancock *et al*., 2001).
	o Possibly enough data for burial rates?? Suspended sediments and nutrient correlation not resolved bay wide – dissolved Vs particulate (effects how we see the system as wind driven or tidal driven and how this may effect management/monitoring). May have N or P – Both?? Transport via sediments is unknown. Rate of absorption/desorption is unknown. Basin level knowledge low or variable. Accumulation bays likely to have higher burial rates. o Important questions across Western Port: What is the relationship between nutrients concentrations and suspended solids? Are nutrients derived from mixing of porewater or resulting from breakdown of organic materials in water column?. What is the importance of sorption/desorption in regulating P? (John). 2. A study in the 1970s investigated sorption/desorption (Andy).				

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
10 Remineralisation	o Benthic flux rates?	o Benthic fluxes not known, but likely to be high given high sediment resuspension rates. Benthic chamber studies have been done for this basin, uncertain of when (Andy).	o Likely to be high, due to very high sediment resuspension rates. Benthic chamber studies have been done for this basin, uncertain of when (Andy).	o Likely to be high, due to very high sediment resuspension rates.	o Benthic flux unknown, but high percentage of fine sediments and high resuspension rates → likely to be high? Benthic chamber studies have been done for this basin, uncertain of when (Andy).
	o Benthic fluxes (chambers) - resuspension? - bio-irrigation? – Rhyll, Lower North Arm, Corinella – de?it by stoichiometry.				
11 Bacterial processing of waste	o Ammonification rates? o Inorganic phosphate fluxes?	o Ammonification rates? o Inorganic phosphate fluxes?	o Ammonification rates? o Inorganic phosphate fluxes?	o Ammonification rates? o Inorganic phosphate fluxes?	o Rates unknown? o High percentage of fine sediments, oxygenated sediments (considerable sediment mixing), but organic matter input low (?).
12 Denitrification	o Biomass of denitrifying bacteria? o Concentration of dissolved nitrogen in water column, sediment layer? o Nitrogen gas flux rates?	o Biomass of denitrifying bacteria? o Concentration of dissolved nitrogen in water column, sediment layer? o Nitrogen gas flux rates? Denitrification investigated in 1980s for this basin (Andy).	o Biomass of denitrifying bacteria? o Concentration of dissolved nitrogen in water column, sediment layer? o Nitrogen gas flux rates? Denitrification investigated in 1980s for this basin (Andy).	o Biomass of denitrifying bacteria? o Concentration of dissolved nitrogen in water column, sediment layer? o Nitrogen gas flux rates?	o Biomass of denitrifying bacteria? o Concentration of dissolved nitrogen in water column, sediment layer? o Nitrogen gas flux rates? Denitrification investigated in 1980s for this basin (Andy).
	o No direct measurements – Gap.				
13 Nitrogen fixation	o Biomass of nitrogen fixing bacteria? o Rates?	o Biomass of nitrogen fixing bacteria? o Rates? 1972 – Lower North Arm only.	o Biomass of nitrogen fixing bacteria? o Rates?	o Biomass of nitrogen fixing bacteria? o Rates?	o Biomass of nitrogen fixing bacteria? o Rates?
	o No direct measurements – Gap. o Some limited data exists. Unsure for what areas. This is a gap across Western Port (Andy).				
14 Nitrification	o Biomass of nitrifying bacteria? o Rates of nitrification?	o Biomass of nitrifying bacteria? o Rates of nitrification?	o Biomass of nitrifying bacteria? o Rates of nitrification?	o Biomass of nitrifying bacteria? o Rates of nitrification?	o Biomass of nitrifying bacteria? o Rates of nitrification?
	o No direct measurements – Gap.				
15 Export to adjoining basins	o Exchange rate is 0.5 days. Likely net export of nutrients to Bass Strait?	o Likely net export to Western Entrance (and Bass Strait) during ebb flows.	o `Net water flow is towards Corinella basin – net export of nutrients likely?	o Due to net water flow to Rhyll basin, likely to be net export of nutrients?	o Net water flow and sediments to Western Entrance: likely to be net export of nutrients.
	o Budgets need to be revisited. Hydrodynamics model outputs or salinity – 1st ???? on EPA monitoring data. o Rough budget possible across Western Port with existing EPA data and hydrological flux data (John).				

Water column nutrients

Western Entrance basin

- The following data comes from an analysis of water quality in Western Port between 1973 and 1977 (pers. comm. Andy Longmore, 2003). However, as it has been shown that there has been a significant increase in oxidised nitrogen, phosphorus and total phosphorus within the bay between 1973-77 and 1984-97 (pers. comm. Andy Longmore, 2003) the values are probably not accurate for present day water quality of Western Entrance.

	Mean
Phosphorus (P) (µg/L)	8
Total Phosphorus (TP) (µg/L)	14
Ammonium (µg/L)	9
Oxidised Nitrogen (N) (µg/L)	1.1
Dissolved Oxygen (% saturation)	104
Silicate (µg/L)	33
Chlorophyll *a* (µg/L)	0.77

Lower North Arm basin

- Long term EPA monitoring at one site showed a lack of relationship between salinity and nutrient levels, indicating that nutrient loads are primarily attributable to factors other than freshwater (catchment) input. Dissolved inorganic phosphorus and total phosphorus concentrations were correlated with suspended solids. These observations indicate water column nutrients originate from resuspended sediment (EPA, draft, 2003).
- Median concentrations (1984-2001, Hastings site) (bd= below detection) (EPA, draft, 2003).

	n	Median	Range	20%-ile	80%-ile
Inorganic P (µg/L)	140	5	1-17	3	8
TP (µg/L)	141	13	1-41	10	17
Ammonium (µg/L)	109	6	0-20	4	9
Oxidised N (µg/L)	95	2	bd-29	1	6
TN (µg/L)	96	133	81-263	113	168
Silicate (µg/L)	142	72	bd-379	42	106
Chlorophyll *a* (µg/L)	138	1.1	0.5-3	1	2

Upper North Arm basin

- Long term EPA monitoring at one site showed a lack of relationship between salinity and nutrient levels, indicating that nutrient loads are primarily attributable to factors other than freshwater (catchment) input. Dissolved inorganic phosphorus and total phosphorus concentrations were correlated with suspended solids. These observations indicate water column nutrients originate from resuspended sediment (EPA, draft, 2003).
- Median concentrations (1984-2001, Barralliar Island site) (bd= below detection) (EPA, draft, 2003).

	n	Median	Range	20%-ile	80%-ile
Inorganic P (µg/L)	142	3	1-32	2	5
TP (µg/L)	142	11	1-67	8	15
Ammonium (µg/L)	109	6	0-43	4	9
Oxidised N (µg/L)	94	1	bd-174	1	4
TN (µg/L)	96	157	87-357	123	190
Silicate (µg/L)	142	118	16-390	66	190
Chlorophyll *a* (µg/L)	137	1.4	bd-5	1	2

Corinella basin

- Long term EPA monitoring at one site showed a lack of relationship between salinity and nutrient levels, indicating that nutrient loads are primarily attributable to factors other than freshwater (catchment) input (EPA, draft, 2003). Dissolved inorganic phosphorus and total phosphorus concentrations were correlated with suspended solids. These observations indicate water column nutrients originate from resuspended sediment.
- Median concentrations (1984-2001, Corinella site) (bd= below detection) (EPA, draft, 2003).

	n	Median	Range	20%-ile	80%-ile
Inorganic P (µg/L)	139	5	1-18	3	8
TP (µg/L)	139	27	3-215	15	63
Ammonium (µg/L)	108	8	bd-83	5	16
Oxidised N (µg/L)	96	11	bd-174	2	23
TN (µg/L)	96	269	139-1144	194	446
Silicate (µg/L)	139	327	20-902	246	496
Chlorophyll *a* (µg/L)	133	3	bd-14	2	5

Rhyll basin

- The following data comes from an analysis of water quality in Western Port between 1973 and 1977 (pers. comm. Andy Longmore, 2003). However, as it has been shown that there has been a significant increase in oxidised nitrogen, phosphorus and total phosphorus within the bay between 1973-77 and 1984-97 (pers. comm. Andy Longmore, 2003) the values are probably not accurate for present day water quality of Rhyll basin.

	Mean
Phosphorus (P) (µg/L)	5
Total Phosphorus (TP) (µg/L)	14
Ammonium (µg/L)	12
Oxidised Nitrogen (N) (µg/L)	1.4
Dissolved Oxygen (% saturation)	102
Silicate (µg/L)	107
Chlorophyll *a* (µg/L)	1.22

- Historically stronger data references. Currently two basins no data. Andy Longmore report covers a bit of this (Added: see WE and Rhyll above).
- Across Western Port, EPA data set available. Some broader historical data also available (Andy).

Benthic Sediment Nutrients

Upper North Arm basin

- Concentration of P in benthic sediment decreases with depth (Hancock *et al.*, 2001), indicating and increase contribution of P to this basin over the last 40 years, but elevated concentrations are still not high in comparison to natural concentrations of P in soils. Source of P is unknown – could be catchment-derived, increased biological activity, or increased amounts of organic matter (see Hancock *et al.*, 2001).

- If look at resuspension then this is important. Little or no ????water data.
- Major knowledge gap but highly relevant if resuspension is releasing nutrients (John).

Loads into bay – time

- temporal nature of delivery
- at what temporal scale should model be constructed?
- especially NE is event influenced
- agree to use certain unit for load ($mg/m^3/d^{-1}$)
- time and space – episodic events.

- Temporal and spatial data – little known. Whether loads come in bursts (episodic events) or constant? Which is more important?
- Volume estimates for each basin is needed.
- Composition of load important to consider – availability – residence time.
- MAFRI report (Andy Longmore) Analysis of water quality, Western Port bay, 1973-1997 (EPA access – Brett Light)
- Know little about P dynamics. Need to identify (where feasible) longer term trends in concentration and loads.

- <u>Across Catchments</u>
- Loads info OK.
- Temporal and spatial data aspects unclear.
- Historical and expected trends ?????
- Considerable N and P info. And Si. Si – Bay wide, the levels are not controlled by inputs.
- Limited C data.
- Terrestrial C probably not significant but not known.
- Prepare at least 3 budgets C, N and P.
- *Important to consider residence times when deciding significance.
- ASS – erosion and point sources. 1:25k maps. Upper North Arm is the primary area of receipt.
- Take current residence times and work out nutrient budgets for bay – Andy Longmore has historic data and budgets for bay.
- Basin budgets possible (coarse) BUT lack of data for Rhyll and Western Entrance prevents whole bay budget currently (no modern data).
- Budgets for Western Entrance and Lower North Arm are flushing dominated but other basins probably not.
- Move away from only TN and TP and move more consistently into SRP and DIN.
- TN and TP levels known but dissolved and bio-useable data limited.
    - Limited C data.
    - EPA database – license to discharge (give amounts for point sources).
    - Patchy erosion information.
- Groundwater limited/no impact.
- Compounds in atmosphere unknown – what % are bioavailable? Atmosphere inputs may be just as important as other basins input.
- No real information on epiphyte primary production.
- Lack of data on faunal production – though good data on fish production.
- Role of suspended sediments in transporting nutrients, which nutrients, etc.
- Gap in N fixation and denitrification.
- Corinella Arm – epiphytes dying off.
- Andy Longmore – has a good knowledge of Western Port and nutrient stuff, talk to.

Sediments

1 Catchment (surface water) inputs

Western Entrance basin

- Minor catchment surface inflow via waterways
- Merricks Creek (Merricks): Annual medians for 1998, 1999 (Coleman *et al*., 2000): Turbidity: 17, 15 (NTU) Suspended Sediment: 7, 12 (mg/L)
- Daily Suspended Sediment (SS) loads calculated by Shapiro (1975)

	Daily SS loads (kg/day)	Derived annual SS loads (t/yr)
Merricks Ck	250	91.3
East Ck	427	155.9
Stony Ck	285	104.0
Manton Ck	72	26.3

Lower North Arm basin

- Melbourne Water (Coleman *et al*., 2000) monitoring:

Annual median concentrations:	Turbidity (NTU) 1998, 1999	SS (mg/L) 1998, 1999
Warrangine Ck (Hastings)	16, 14	6, 6
Watsons Ck (Somerville)	27, 24	13, 12

- Daily Suspended Sediment (SS) loads calculated by Shapiro (1975)

	Daily SS loads (kg/day)	Derived annual SS loads (t/yr)
Langwarrin Ck	556	203
Watson Ck	996	364
Warrangine Ck	216	79

Upper North Arm basin

- Catchment inputs (Hughes *et al.,* 2003):

Source	Fine sediment (kt/yr)	Coarse sediment (kt/yr)	Total sediment (kt/yr)
Bunyip Drain	22	16	38
Lang Lang River	20	6	26
Cardinia Ck	6	2	8
Yallock Ck	6	2	8
Total	54	26	80

- Melbourne Water monitoring (Coleman *et al*., 2000):

Annual median concentrations	Turbidity (NTU) 1998, 1999	SS (mg/L) 1998, 1999
Bunyip River (Koo- Wee-Rup)	18, 19	16, 15
Yallock ck (Monomeith)	88, 88	68, 72
Lang Lang River (Lang Lang)	24, 18	12, 9

- Daily Suspended Sediment (SS) loads calculated by Shapiro (1975)

	Daily SS loads (kg/day)	Derived annual SS loads (kt/yr)
Lang Lang River	23780	8.7
Yallock Ck	8100	2.9
Bunyip Drain	19915	7.3
Cardinia Ck	18594	6.8

Total suspended sediment export of waterways into Western Port as calculated by Sednet (Wallbrink *et al*., 2003):

	SS kt/y
Lang Lang River	20
Bunyip Drain	22
Yallock Ck	6
Cardinia Ck	6

Corinella basin

- No significant waterways, some artificial drainways. Local surface water run-off?

Rhyll basin

- Estimates of sediment from the catchment via the only significant river discharge, the Bass River, (Hughes *et al.,* 2003) are 8 kt/yr fine sediment, and 2 kt/yr coarse sediment.

Total suspended sediment export of Bass River into Western Port as calculated by Sednet is 8 kt/y (Wallbrink *et al*., 2003).

<table>
<tr><th></th><th>Western Entrance basin</th><th>Lower North Arm basin</th><th>Upper North Arm basin</th><th>Corinella basin</th><th>Rhyll basin</th></tr>
<tr><td></td><td colspan="5">• A bay-wide sediment budget is required – captures catchment inputs for each basin – but requires calibration. (pers. comm. Wallbrink)
• Size range of sediments coming in from catchment not relevant as resuspension of suspended matter is a driver of turbidity.
• There is also a change at the saltwater interface -precipitation etc
• What's needed is a light penetration model (pers comm. Parry).
• How do different sediments affect water quality, light penetration, and productivity? (pers comm. Parry).
• Are there any contaminants bound to sediments, and are they released in the salt water?
• There were elevated concentrations of some metals (inc Chromium and Magnesium) in the sediment cores, but no likely source found in the catchment. (in CSIRO sediment reports)
• Some species of ascidians are known to concentrate metals, which might explain elevated concentrations in cores (pers comm. Parry)
• Unmade roads in catchments need to be considered when looking at sediment sources (pers comm. Harris). The CSIRO modelling work estimated that they contributed 3% (Wallbrink).
• Sediment load is influenced by topography of the catchments (size of gullies, streams etc)</td></tr>
<tr><td>2 Point sources</td><td>o Dumping of dredge spoil?

Dredging of channel has stopped. When the Port of Melbourne Authority did dredge, they dumped the spoil in the channel, where it was moved via currents.

Aquaculture sites will have discharges – there are mussel farms at Flinders. Not sure about anywhere else.</td><td>o Dredging? Dump of spoil from dredging outside this basin?
o ESSO allowed to release 100mg/L. They can discharge between 4.5 to 24.5 ML/day. Therefore can discharge from 0.167 to 0.89 kt/yr of sediments.

Dredging of channel has stopped. When the Port of Melbourne Authority did dredge, they dumped the spoil in the channel, where it was moved via currents.
There was some dredging of births at Long Island, plus for the marina at Hastings.

The EPA has info on licensed discharges – e.g. Steelworks at Hastings

Reclaimed lands (foreshore tip) at Hastings not considered a point source, however, the hydrodynamics would have been altered by construction of levy bank and removal of mangroves.</td><td>o Sand mining at Lang Lang?

Impact of sand mining would be picked up in catchment loads, if it were still happening.</td><td>o None?</td><td>o None known?</td></tr>
<tr><td></td><td colspan="5">• Other point sources include local impacts from boat ramps – trampling, benthic disturbance, and contribution to turbidity
• Fish netting was suggested as a point source by Parry (but it wouldn't be fixed - Molloy)</td></tr>
</table>

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
3 Coastal erosion	o Groynes and rock walls – affected sediment movement by changing water currents (increasing some scouring) (EPA, 1996) o Erosion of silt and clay from Basalt cliffs between Flinders and Balnarring where mangroves were historically removed (Bird, 1993).	o None? Loss of saltmarsh would be expected in this region, but it unlikely to have contributed to erosion. However, it may remove the filtering function for catchment run-off.	o Lateral transport of sand from eroding coastline is a possible source of old sand. (in sed cores) (Hancock *et al.,* 2001) Reg, Rob M. deleted this point. o Erosion of cliffs sand, clay (Red Bluff at Lang Lang) resulting in northward movement of sand. And erosion of fine sed from saltmarshes. (Bird, 1993). Mangroves removed from these areas. o Saltmarsh areas eroding (Bird, 1993) Not sure why saltmarsh mentioned. Clay banks (as opposed to cliffs) are an important source of fines (Wallbrink). o Clay banks contribute 32% of 4µm sediments into bay (Wallbrink *et al*., 2003) Coastal levy banks were built and continue to be maintained on private lands across the northern shore. Reduces inundation and the retention of sediment in high tides and other storm induced surges (Harris). Not sure what role they play during flood events.	o Erosion of fine sediments from cliffs near Corinella (Bird, 1993)	o Erosion of sand from SE coast of French Island Is this Rhyll basin??? o Erosion of fine sediment (silt and clay) from cliffs on Phillip Island. (Bird *et al.,* 1993)
4 Coastal sediment drift	o Movement: predominantly south-westerly waves, resulting in an eastward movement of sand from Balnarring to Somers to Sandy Pt, and the formation and migration of beach lobes (e.g. Cormorant Pt). Suggested that sand moves from Sandy Pt across the channel (south east) and is deposited towards Rhyll (pers comm. Parry)	o Sand movement north from Sandy Pt due to tides The observation of intertidal mud flats displaying a convex rather than concave surface (water flows off, rather than pooling) was mentioned (also in WP fish habitat report p31, pers comm. Stuart Campbell). The profile of intertidal mudflats coastal banks became steeper after loss of seagrass (Parry)	o ? Lateral transport of sand from eroding coastline is a possible source of old sand. (in sed cores) (Hancock *et al.,* 2001)	o French Island, Corinella bay beaches? Erosion of sand from SE coast of French Island	o ? Erosion of sand from SE coast of French Island Suggested that sand moves from Sandy Pt across the channel (south east) and is deposited towards Rhyll (pers comm. Parry)

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
5 Adjoining basin – suspended sediments	o Some sand enters the basin from Bass Strait through the western entrance, and there is likely to be small export of sand to Bass Strait. The sediment exchange is as yet unquantified (Hancock *et al*., 2001). o Middle of confluence with Bass Strait: net bedload transport is neutral (using tidal velocity and sediment carrying capacity data), but additional inward transport of sediment due to bottom wave action results in net inward transport of coarse sediment (Sternberg and Marsden, 1979).	o Some input from Upper North Arm basin likely during ebb tides (high suspended sediment loads in Upper North Arm basin).	o Net water flow from Lower North Arm basin during flood tides (although significant flow in reverse direction during ebb tides). But minimal sediment input likely relative to catchment loads.	o Significant net import of fine sediment from Upper North Arm segment (Hancock *et al.,* 2001).	o Load of coarse sediment (sand) from Bass Strait entering via the Eastern entrance is unknown. o Deposited sediment: some contribution from the Bass River, but majority originates from the rivers draining into the Upper North Arm basin. The sediment is transported via daily resuspension cycles through the Upper North Arm basin, Corinella basin to the Rhyll basin. (Hancock *et al.,* 2001)
	• What is the timescale for meeting equilibrium of load verses flushing and resuspension? (Parry) • Wallbrink is confident that we can measure light penetration based on suspended solids – ref: CSIRO, Hughes *et al*., 2003				
6 Atmospheric inputs	o Probably minimal, except during episodic dust storms	o Probably minimal, except during episodic dust storms	o Probably minimal, except during episodic dust storms	o Probably minimal, except during episodic dust storms	o Probably minimal, except during episodic dust storms
	• Need to review work by the EPA on atmospheric deposition, which covers Western Port (Di Rose). But there was consensus on the assumptions that is likely to be minimal? But Sue Harris mentioned the asparagus at Koo-Wee-Rup are impacted by dust. • Need to drop the word "significantly" from "can contribute" in the summary.				
7 Fractionation of sediment	o Coarser sediment in deeper channels	o Deep channels (>20m) with coarse sediment	o Deposition fans/lobes evident at mouths of Bunyip, Yallock, Lang Lang, and SE along coast from Lang Lang to Stockyard Pt. (Hancock *et al.,* 2001, Hughes *et al.,* 2003) o Deposition of fine sed on eastern side of basin. Concentrated in deep channels. (Hancock *et al.,* 2001) o Significant lateral transport of fine sediments (Hancock *et al*., 2001)	o Sediment layers: mostly fine sediment (mud), some coarse (sand). Very few large coarse (shells); these exist in a distinct 20cm thick layer.	o Sand deposition 'fan' evident at the mouth of the Bass River Likely to be only example occurrence in Western Port o Deposition of sediment is mostly fine sediment, concentrated in the deep channels near the Bass mouth. o Sediment layers (at one site, mid-basin): no sand, almost all fine sediment (mud), very little shell debris, but some as a distinct layer of fragmented shells at 35-45 cm depth. (Hancock *et al.,* 2001).

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
8 Fine sediment deposition in saltmarshes	o Area of saltmarsh is small – deposition likely to be minimal.	o Significant saltmarsh area. Inundation rates? Sediment trapping rates, resuspension rates?	o Saltmarsh coverage and sediment trapping and resuspension rates?? The northern coastline is protected from the sea by levy banks which might impact on the sediment trapping and resuspension capacity of the salt marsh.	o Likely to be minimal, very little saltmarsh coverage.	o Small saltmarsh area – minimal net sediment trapping.
	• Need latest report by Saintilan – the one provided by Laurie Ferns is 2001 (Saintilan and Rogers, 2001).				
9 Mangroves – accumulation and resuspension rates	o Area of mangroves is small – deposition likely to be minimal.	o Significant mangrove area. Trapping rates, resuspension rates? Mangroves were buried as part of land reclamation along Hastings foreshore (tip) plus adjacent the Steel works wharf at Long Island.	o Mangrove coverage and sediment trapping and resuspension rates? Three mangrove and salt marsh monitoring sites: 1. east side of Quail Island 2. Koo-Wee-Rup 3. northern French Island the 4th site is at Rhyll see Saintilan and Rogers (2001)	o Likely to be minimal impact of mangroves on sedimentation, very little mangrove coverage.	o Few mangroves – minimal net sediment trapping. o Increased abundance of tussock grass, *Spartina*, may have increased sediment trapping and reduced resuspension rates. Mangrove and salt marsh monitoring site at Rhyll see Saintilan and Rogers (2001)
	• The summary makes reference to "Large and intense inputs of …." This sentence should be deleted as these don't occur in Western Port.				
10 Seagrass – sediment trap (detrimental at high rates), resuspension rates	o Area of seagrasses? o Sediment trapping and resuspension rates? *Amphibolis antarctica* dominant species in this basin, but *Zostera* occur in patches. Not sure about the sediment trapping capabilities or differences for these species in WP.	o Seagrass area = 24 km^2). Trapping rates, resuspension rates? Loss of seagrass in this area is likely to have contributed to destabilizing the bottom sediments.	o Seagrass coverage = 43 km^2. Sediment trapping rates? Loss of seagrass in this area is likely to have contributed to destabilizing the bottom sediments.	o Likely to be minimal, very little seagrass coverage (5 km^2) Loss of seagrass in this area is likely to have contributed to destabilizing the bottom sediments.	o 21 km^2 of seagrass – some sediment trapping likely.
	• t was pondered that bed stabilisation was required before seagrass would colonise and area. It was mentioned (Di Rose) that a project in Botany bay where a trial of sediment retention methods was in progress had shown that seagrass was growing. (Sue Harris had read something in Rip Rap) (Later in the day Di Rose was questioning the logic of mentioning this as all it would do is encourage seagrass planting, an activity that had been shown numerous times to be a waste of money.)				

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
11 Lateral movement of benthos	o Some dredging in berth areas – dump of spoil location? o The main Western Entrance channel is usually deeper than 20 m, containing coarse sediment, mostly sand with some gravel (Sternberg and Marsden ,1979) o High spatial and temporal resolution bathymetry not available? o Large offshore sand bank "Middle Bank") has mobile surface and peripheral sediment (sand). Overall it is morphologically stable (Sternberg and Marsden, 1979). o Annual bedload transport estimated at 0.1-1 kg/cm/yr in south of basin, to 10kg/cm/yr at Middle Bank Sand waves work has been undertaken in the channel – thought was that it indicated the system was in equilibrium (Parry).	o High spatial and temporal resolution bathymetry not available?	o High spatial and temporal resolution bathymetry not available? o Dendritic and other channels – formed by ebb and flow tidal currents o Tidal divide: exposed tidal flat at low tide o Infilling of eastern channel (stockyard point) with coarse sediment over 20 years. (Hancock *et al.,* 2001) o Slumping of dendritic channels near tidal divide by infilling and resuspension. (Hancock *et al.,* 2001)	o High spatial and temporal resolution bathymetry not available?	o High spatial and temporal resolution bathymetry not available?
	• Need to quantify the change in intertidal mudflats over time – are they accumulating sediment, or is it being exported, or is it filling up the channels. The sediment budget work might assist in some of these questions, however, a detailed bathymetric survey and or topographic survey for the intertidal and shallow parts using laser might be a good thing. • As tides are strong, movement is likely to be a natural event in most parts, however, it would be exacerbated in areas of seagrass loss. • The convex/concave process for mud flats was mentioned. • In the summary text it was suggested that "bottom currents" be used instead of "benthic water flow rates".				

	Western Entrance basin	Lower North Arm basin	Upper North Arm basin	Corinella basin	Rhyll basin
12 Resuspension and accumulation rates	o Resuspension – bay average = 6000kt/yr (Hancock *et al*., 2001). o Daily cycle of resuspension of sediments (Hancock *et al*., 2001) o Sediment resuspension and benthic mixing caused by shipping (propellers) – caused sediment changes and changes in infauna on swing basins (density and community structure) o Sediment cores: evidence of seagrass o Accumulation rates?? o Occasional dredging contributes to suspended sediment.	o Resuspension rates high: average: 6000kt/yr for whole bay.	o Resuspension rates – average for bay: 6000 kt/year (based upon difference between suspended sediment concentrations and input loads)(Hancock, *et al*., 2001) o Speculation: loss of seagrass would have increased resuspension rates, but no evidence of seagrass in cores (Hancock *et al*., 2001) o Sediment layers: mix of fine sediments (silt, clay), sand and shells. Shells are dispersed through upper layer. o Sediment accumulation rates: ~0.4 cm per year (from 4 sites in basin) (Hancock *et al*., 2001) o Sediment residency time: 0.78 – 0.95 days (reflective of high resuspension, rather than removal from basin)(Hancock *et al*., 2001) o Change in benthic sediment composition: increased sand and decreased mud. Due to one or both: increased sand load from catchment, and/or increased resuspension and lateral transport of fine sediment resulting in net loss of fine sediment. o In intertidal areas, wind action would increase resuspension rates (Sternberg and Marsden, 1979)	o Sediment accumulation rates: south basin: 0.21 cm/yr; north basin: > 1.6 cm/yr (historically [1890-1958] accumulation rates in the north basin were ~0.3 cm/yr) (Hancock *et al*., 2001) o Sediment residency time: 0.6 days in mid basin, 0.9-1.4 days in south basin. (Hancock *et al*., 2001)	o Sediment accumulation rates (one site, mid basin) = ~ 0.5 cm/yr (Hancock *et al*., 2001). o Residency time of sediments = ~0.8 days (Hancock *et al*., 2001)
	• Resuspension rates were calculated for selected spots by CSIRO • The efficiency of seagrass binding has not been quantified for Western Port • The influence of wind and waves will vary across the system, depending on catchment topography, weather patterns, and the bathymetry. • A high energy storm ("a real good storm") will dig up the seagrass, which is then washed up on the shore, and the water is left turbid for days (comment from Tim Ealey)				
13 Benthic sediment mixing	o Unknown	o Unknown?	o Mixing in upper layer (Hancock *et al*., 2001): Lang Lang mouth: few centimetres, to 12-14 cm near Yallock and Bullock creeks, and 18 cm near Charing Crossing. But may be overestimated due to high rates of resuspension and deposition causing lateral movement of sediment. (Hancock *et al*., 2001)	o Sediment mixing layer, due to bioturbation: south basin: 22cm; north basin: 62cm, but this is likely to be an overestimate due to rapid accumulation of sediment. Layer below mixed layer in anaerobic.	o Sediment mixing layer: ~ 18 cm (Hancock *et al*., 2001)
	• The spatial extent to which bait pumping has an affect is not known, however, it was assumed to be localised and generally in close proximity to accessible shorelines. • Most research has focussed on ghost shrimps, however, Western Port has large populations of snapping prawns which have been implicated (but not substantiated) in seagrass decline. Fiona Bird's work is on ghost shrimps. • Is there a link between seagrass growth and benthic sediment mixing?				

<table>
<tr><th></th><th>Western Entrance basin</th><th>Lower North Arm basin</th><th>Upper North Arm basin</th><th>Corinella basin</th><th>Rhyll basin</th></tr>
<tr><td><u>14 Export of suspended sediment</u></td>
<td>o Some dredging in berth areas – spoil dumped outside basin?
o High exchange rates and water velocities during flood and ebb tides → capacity to export sediment. Suspended sediment loads low?
o Small export of sand to Bass Strait (net import).

There was only historical dredging in the channel, and the spoil was disposed of within the basin</td>
<td>o Likely to be net export to Western Entrance basin?

See CSIRO report for movement of sediment.</td>
<td>o Suspended sediment concentration (median 6mg/L), net export of fine sediment to Corinella and further south, Rhyll basin.</td>
<td>o Transport of fine sediment from Upper North Arm basin to Rhyll basin via daily resuspension cycle. Net direction south.</td>
<td>o Net export to Bass Strait likely, but probably minimal, due to minimal flows.

Large volume of water flows through Eastern Entrance, and at a high velocity - direction depending on the tide. So it would have the potential to carry large volumes.</td></tr>
<tr><td><u>Water column sediments</u></td>
<td>o Suspended sediment is less than in other basins (Sternberg and Marsden, 1979)</td>
<td>o Water column sediments: Median concentrations (1984-2001, Barralliar Island site) (EPA, draft, 2003).
<table>
<tr><th></th><th>n</th><th>Median</th><th>Range</th><th>20%-ile</th><th>80%-ile</th></tr>
<tr><td>Secchi depth (m)</td><td>138</td><td>3</td><td>1-8</td><td>2</td><td>4</td></tr>
<tr><td>SS (µg/L)</td><td>103</td><td>5</td><td>1-22</td><td>4</td><td>9</td></tr>
</table></td>
<td>o Median concentrations (1984-2001, Barralliar Island site) (EPA, draft, 2003).
<table>
<tr><th></th><th>n</th><th>Median</th><th>Range</th><th>20%-ile</th><th>80%-ile</th></tr>
<tr><td>Secchi depth (m)</td><td>139</td><td>2</td><td>1-7</td><td>2</td><td>4</td></tr>
<tr><td>SS (µg/L)</td><td>104</td><td>6</td><td>bd-35</td><td>4</td><td>10</td></tr>
</table></td>
<td>o Median concentrations (1984-2001, Corinella site) (EPA, draft, 2003).
<table>
<tr><th></th><th>n</th><th>Median</th><th>Range</th><th>20%-ile</th><th>80%-ile</th></tr>
<tr><td>Secchi depth (m)</td><td>137</td><td>1</td><td>0-4</td><td>0</td><td>1</td></tr>
<tr><td>SS (µg/L)</td><td>103</td><td>37</td><td>3-199</td><td>13</td><td>79</td></tr>
</table></td>
<td>o</td></tr>
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- Gaps in sediment inputs is limited around bay – light, smothering, nutrient roles.
- Benefits in seagrasses controlling sediment dynamics.
- Nature of accumulation/erosion of mudflats not clear – especially in Upper North Arm – influence replanting initiatives.
- How does hydrodynamics model interact with sediment observations?
- Don't know the marine sediment budget.
- Resuspension the major driver.
- Seagrass – replant Upper North Arm therefore hypothesis that it would decrease resuspension and therefore decrease sediment transport clockwise around bay.
- How much sediment leaving bay is still unknown.
- Bay's ability to flush 'oversupply' of sediment is unknown.
- Large historic load (swamp draining) therefore excess sediment loads present now.
- Can bay get rid of excess sediment? If not can seagrass ever be regrown to past levels?
- Tim Ealey – need to look at very localised effects of sediment movement.
- Need to link sediment dynamics to biophysical processes especially seagrasses e.g. smothering either whole plant or part – leaves; light penetration – size particles need to measure in a meaningful way for seagrass; binding by seagrass of benthos and reduction of turbidity.
- Sediment movement within the bay is largely associated with tidal currents.
- Winds are predominantly North to North-West between April and September, and Southerly between October and March (Shapiro, 1975).

Biota

	Western Port	Specific basin information
1 Salt marshes	Salt marshes occur between the intertidal zone and the hinterland, being characterised by a distinct area of salt tolerant shrubs and grasses. The vegetation helps stabilise sediments and plays an important role in nutrient cycling. Salt marsh communities include: *Stipa*, *Juncus*, *Puccinellia*, *Suaeda*, *Arthrocnemum*, *Sarcocornia* and *Spartina*. The total area of salt marshes in Western Port has been reduced through grazing, erosion through boat wash, and infilling for coastal development. Some terrestrial fauna utilise saltmarsh habitats during low tide (e.g. swamp wallaby (*Wallabia bicolor*), swamp rat (*Rattus lutreolus*) and skinks (*Egernia* and *Leiolopisma*)).	Little/none – Corinella, Western Entrance Moderate – Rhyll Large amounts – Lower North Arm and Upper North Arm
2 Mangroves	Western Port marks one of the southern most limits of mangrove distribution. Mangroves occur in sheltered intertidal areas. They provide habitat for fauna, particularly a nursery for fish, and help stabilise sediments. Mangroves also play an important role in nutrient cycling. The main mangrove species to occur in Western Port is the White mangrove *Avicennia marina*. It has relatively low productivity and a slow reproductive cycle. The area covered by mangroves in Western Port has been reduced through clearing for drainage and coastal access, and erosion. Some terrestrial fauna utilise mangrove habitats during low tide (e.g. swamp wallaby (*Wallabia bicolor*), swamp rat (*Rattus lutreolus*) and skinks (*Leiolopisma*)).	Little/none – Corinella, Western Entrance Moderate – Rhyll Large amounts – Lower North Arm and Upper North Arm
3, 4 Intertidal (3) and subtidal (4) seagrass	Seagrasses occur on intertidal flats and subtidally. They provide habitat for both plants and animals as well as providing food directly (grazing) or indirectly (animals living within the seagrass beds) to animals. Species present in Western Port include *Zostera muelleri*, *Amphibolis antarctica* and *Heterozostera tasmanica*. Loss of seagrass has been linked to increased turbidity and a decrease in fish populations. Possible causes of seagrass loss include: increased sedimentation, turbidity and shading, desiccation, industrial waste, biocides, and/or natural events.	Little – Corinella Moderate – Rhyll, Western Entrance Large amounts – Lower North Arm and Upper North Arm
5 Fish	Important species present for commercial, recreational and aquaculture use. Commercial fish catches appear to be declining. The majority of recorded fish species are small, economically unimportant species such as gobies (Gobiidae), Pipefish (Syngnathidae) and Weedfish (Clinidae). Recreational and commercially important species include: Leatherjackets (Monacanthidae), Whiting (Odacidae and Sillaginidae), Flathead (Platycephalidae), Pilchards (Clupeidae), Trevally and Mackeral (Carangidae), Snapper (Sparidae), Mullet (Mugilidae) and Flounder (Pleuronectidae).	
6 Macro-algae	Forms habitat and food for other biota. Includes: *Ecklonia*, *Caulerpa*, *Scabaria*, *Sargassum*, *Claudia*, *Griffithsia*, *Myriogramme*, *Rhodymenia* and *Gracilaria*.	
7 Benthic fauna	Comprise both infauna (animals burrowing into the seabed) and epifauna (animals living on the seabed). Benthic animals include: *Anadara*, *Katelysia*, *Neotrigonia*, *Pronuncula*, *Pholas*, *Notocallista*, *Bellucina*, *Homalina* and *Laternula* (bivalves); *Alpheus*, *Trypea*, *Paratanais*, amphipods, *Macrobrachium*, *Halicarcinus* and *Litocheira* (crustaceans); *Ammotium* and *Trochommina* (foraminiferans); *Abarenicola*, *Barantolla*, *Armandia*, *Nepthys*, *Lumbrineris*, *Platnereis* and *Pista* (polychaetes); *Pterynotus*, *Amorena*, *Sigapatella*, *Salinator*, *Nassarius* and *Polinices* (gastropods); *Virgularia* (seapen); grazing molluscs (e.g. Trochidae); *Ancorina*, *Geodia* and *Ircinia* (sponges); *Pennaria*, *Eudendrium*, *Aglaophenia*, *Setularia* and *Pumularia* (hydroids); *Amathia*, *Bugula*, *Cellepraria* and *Triphyllozoon* (bryozoans); *Didemnum* and *Amphicarpa* (ascidians); *Magellania* (brachiopod); *Goniocidaris*, *Nectria*, *Patiriella* and *Tosia* (echinoderms).	

	Western Port	Specific basin information
8 Zooplankton	Including: *Acartia fancetti* (dominant species), *Pseudodiaptomus*, *Bestiola*, *Paracalanus*, *Calanus*, *Oithona*, ctenophores and larvaceans.	
9 Phytoplankton	Mainly diatoms, but minimal information on species present and abundance. No toxic algal blooms reported.	
10 Migratory and wading birds	Western Port is an important habitat for migratory and wading birds. Species include: caspian tern, crested tern, pacific gull, ruddy turnstone, pied oystercatcher, masked lapwing, little pied cormorant, lesser golden plover, double-banded plover, eastern curlew, whimbrel, bar-tailed godwit, grey-tailed tattler, greenshank, curlew sandpiper, red-necked stint, sharp-tailed sandpiper, red knot, great egret, white-faced heron, black swan, black duck, chestnut teal, grey teal, musk duck, albatrosses, petrels, shearwaters, pelicans, ibis, spoonbills and shags. A fairy penguin (*Eudyptula minor*) colony occurs on Phillip Island.	
11 Marine mammals	Marine mammals frequent Western Port. A major Australian fur seal colony occurs at Seal Rocks (wildlife reserve), at the south-west tip of Phillip Island. Mammals recorded include: seals (*Arctocephalus* and *Hydrurga*); whales (rarely); and dolphins (*Tursiops* and *Delphinus*).	
12 Shipping and Fishing	Both recreational and commercial boating and fishing have the potential to affect biota within the bay. They can affect fish stocks and be a source of pest introduction, oil/chemical spills, erosion (wash), turbidity (wash, propeller), boat strike and anchor damage to the substrate. Boats, hovercraft and especially jet-skis disturb water bird roosting sites during high tide.	

10.5. Threats to Western Port – identified in Western Port Perspectives (PPK, 2000)

The values of Western Port are at risk from a range of activities and threats. Those identified in this investigation were:

- Oil Spills
- Chemical and Fuel Spills
- Antifouling Paints
- Ballast Water
- Dredging Activities
- Litter
- Industrial Waste
- Urban Stormwater
- Seepage from Septic Tanks
- Land Reclamation
- Coastal Erosion
- Vegetation Clearing
- Pest Plants
- Pest Animals
- Sedimentation from Non Urban Areas
- Nutrient Input from Non Urban Areas
- Fire
- Overexploitation of Marine Species
- Recreational Activities
- Sea Level Rise

The risks related to shipping are more prevalent in the western part of the bay. Most other risks operate to varying degrees over most of the bay. Catchment related risks (e.g. sediment and nutrient inputs) are particularly noticeable in the eastern arm of the bay. Urban development is more prevalent in the western part of the bay where water quality is more likely to be affected by urban stormwater runoff. A more detailed account of each risk is provided in the main report.

10.6. Causal loop modelling: examples and principles

Causal loop diagrams

Causal loop diagrams (CLDs) are a tool to help explain how and why a system changes through time. In essence, a CLD is a hypothesis of dynamic system behaviour. The word *causa*l refers to causal relationships, or to what are believed or postulated to be causal relationships. The word *loop* refers to closed chains of cause and effect, "feedback loops" (Ford, 1999; Sterman, 2000).

CLDs consist of an array of variables connected by arrows ("causal linkages") indicating the causal influence between the variables. Important feedback loops are also indicated in the diagrams. The arrows are assigned a polarity, a plus or minus sign, indicating how the dependent variable (at the point of the arrow) changes with a change in the independent variable (at the base of the arrow). A positive causal link indicates that if the cause increases (decreases), the effect increases (decreases) *above what it would otherwise have been*. A negative link indicates that if the cause in creases (decreases), the effect will decrease (increase) below *what it would otherwise have been*. The phrase *above (or below) what it otherwise would have been* is important to keep in mind when interpreting causal loop diagrams for two reasons. First, because many variables have more than one input and one input's influence may dominate over another. Second, the independent variable is often a material flow which influences a stock of resources, decreasing the independent variable in this instance will not necessarily result in an absolute decrease in the value of the dependent variable (Sterman, 2000). Feedback loops are identified by a circular arrow and are designated as either reinforcing or balancing. Reinforcing feedback loops generate growth or decline. Balancing feedbacks seek out an equilibrium, and moderate the system's behaviour. Balancing feedbacks often act in concert with reinforcing loops to produce s-shaped patterns of growth or decline. Figure 15 below displays the notation used in causal loop diagrams.

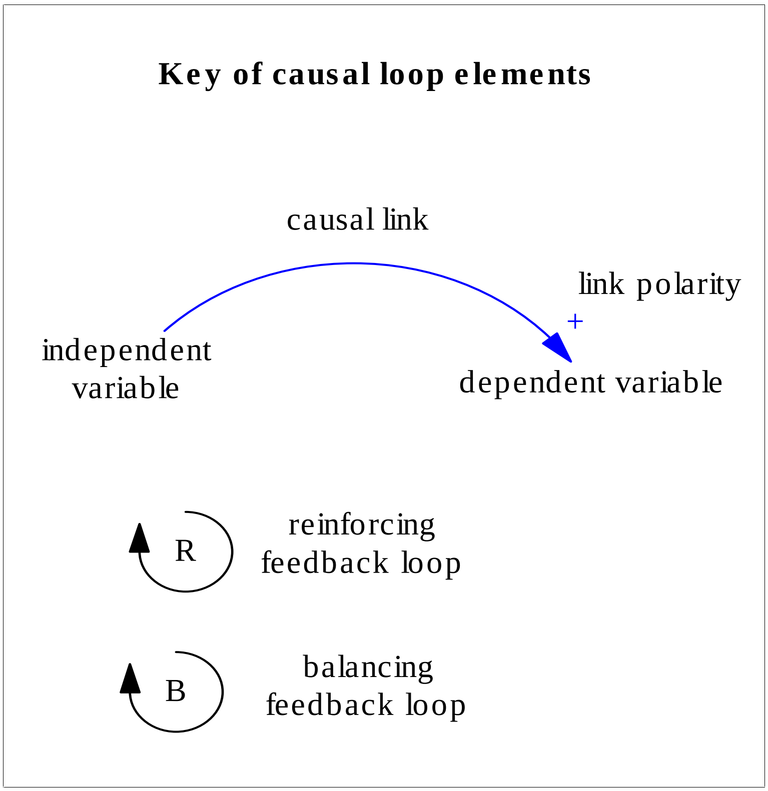

Figure 15. Causal loop diagram notation (source: Sterman, 2000).

Causal loop diagrams for Westernport

This section presents and describes causal loop diagrams developed for Westernport. The diagrams communicate a postulated systems hypothesis of seagrass loss, and are meant to correspond to bay segments in which seagrass loss has been or is a concern.

The diagrams are not intended to be comprehensive and out of necessity focus on one problem issue, i.e., seagrass loss. It should be borne in mind that the hypotheses embodied in the diagrams are tentative. The purpose of the approach is to facilitate communications and debate, and to provide focus for identification of relevant knowledge gaps.

The diagrams are developed sequentially, each diagram adding a layer of complexity to the former. Under each diagram is a detailed description of the causal structure and the behavioural and management implications of the structure. Also, a number of suggestions have been made in regards to the identification of knowledge gaps.

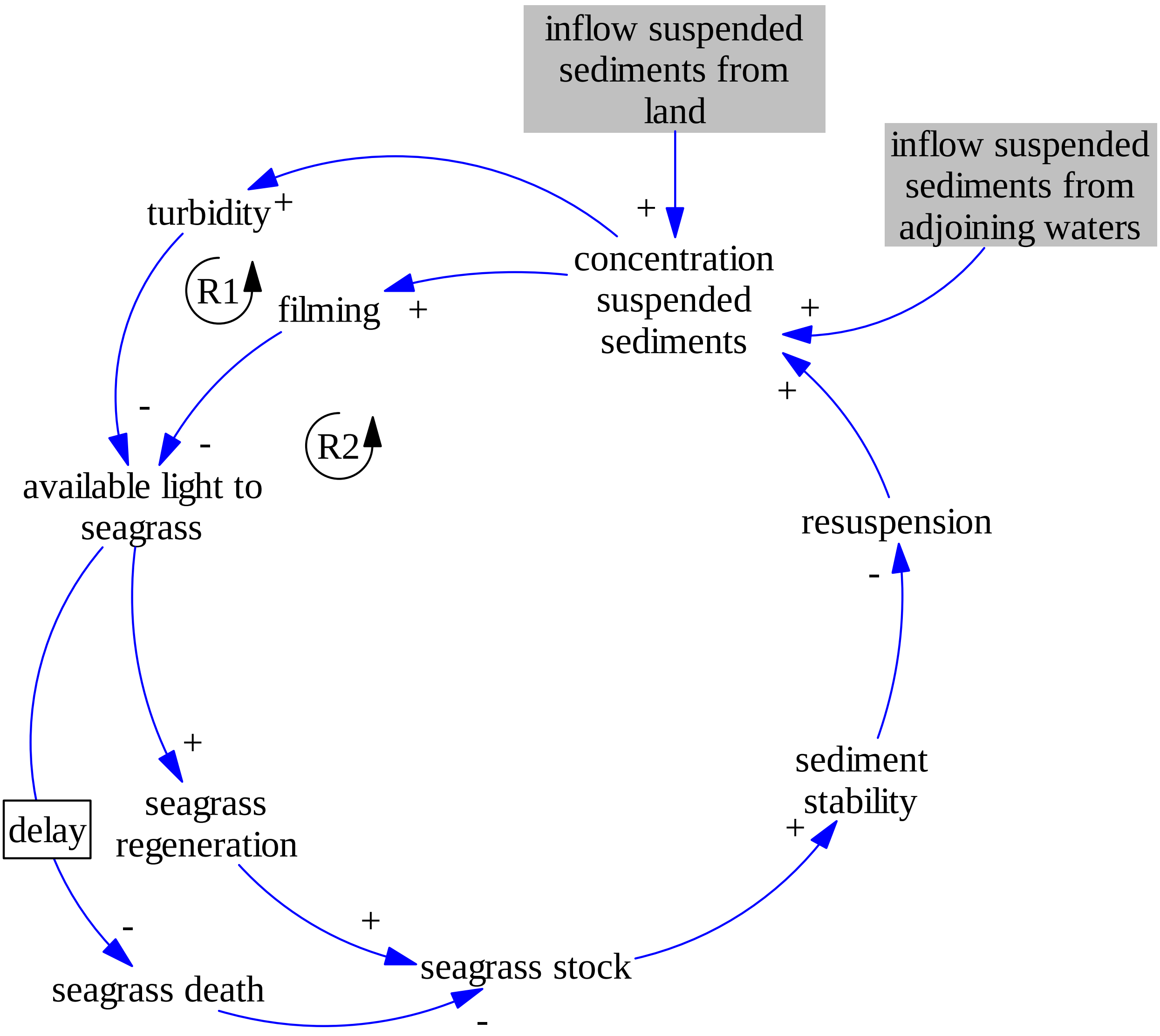

Figure 16. Postulated feedback structure linking suspended sediments with seagrass loss.

Figure 16 shows a postulated self-reinforcing relationship between suspended sediments and seagrass loss driven by two reinforcing feedback loops, designated in the diagram as R1 and R2. The concentration of suspended solids is increased by exogenous (in shaded rectangles) influxes of suspended solids from adjacent land and from adjoining bay segments. In feedback loop R1 increased concentration of suspended solids causes increased water column turbidity, which reduces the amount of light available to seagrass. The reduction in available light increases the seagrass mortality rate and constrains regeneration of seagrass. The delay marker indicates that seagrass loss is a gradual process driven by persistent shortage of light. As the seagrass stock declines, the sediments become less stable, resulting in resuspension and increased suspended solids (Westernport State of the Environment Report), which, in turn, decreases the light available to seagrass, and creates a downward spiral of seagrass loss.

Feedback R2 is identical to R1 with the exception of one linkage. In feedback R2 light is decreased by the "filming" effect of suspended sediments. This linkage is based on scientific speculation that, under chronically turbid conditions, films of sediment may cling to seagrass blades when seagrass is exposed at low tide, blocking sunlight and causing accelerated seagrass mortality (Westernport State of the Environment Report).

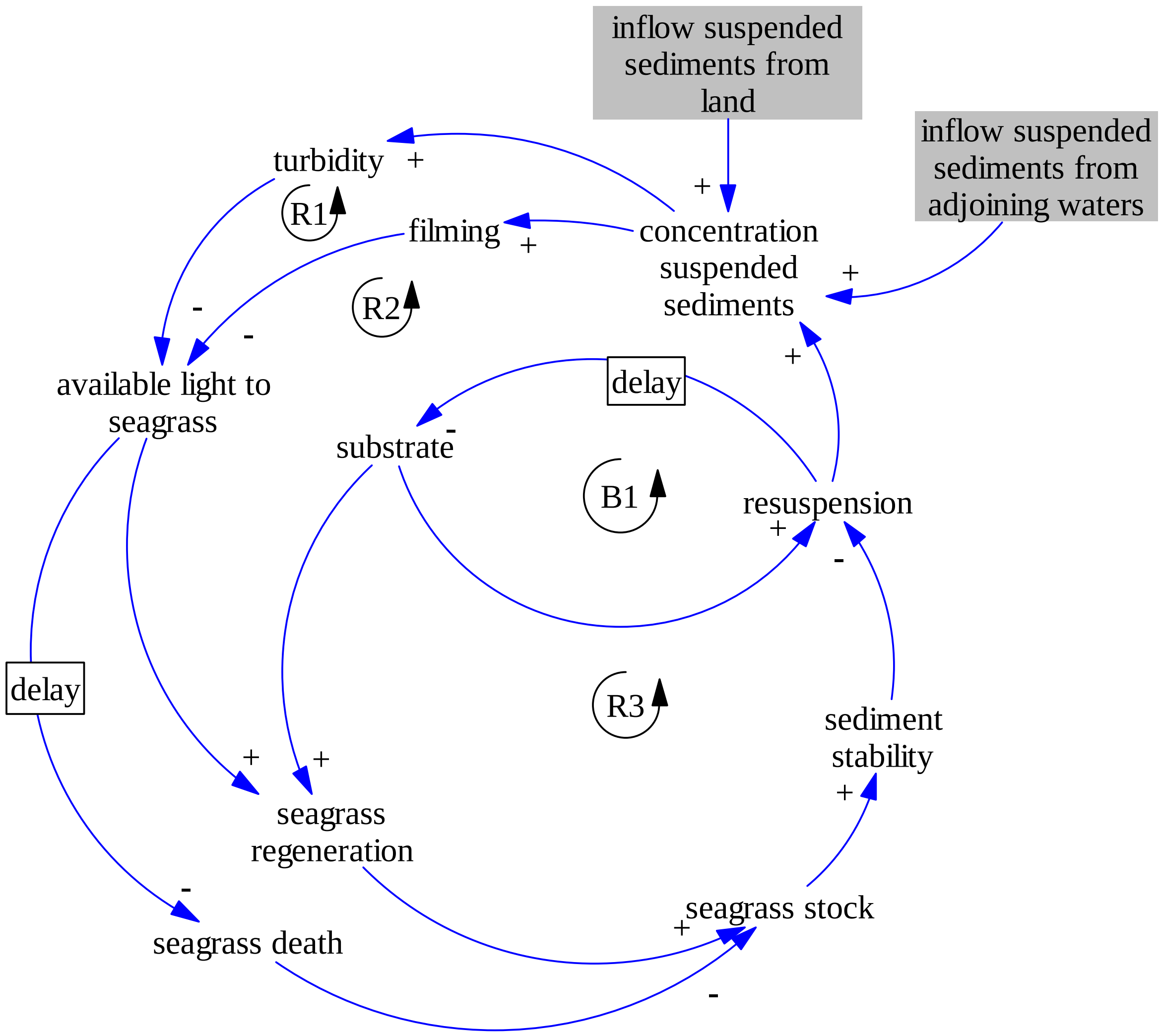

Figure 17. Postulated feedback mechanisms linking suspended solids, seagrass, and substrate.

In Figure 17 two additional feedbacks have been added to the causal structure. Feedback R3 takes into account the benthic substrate. When resuspension is accelerated due to loss of seagrass and sediment instability, substrate is lost. Loss of substrate constrains seagrass regeneration, and thereby causes further substrate loss through its influence on sediment instability and accelerated resuspension. B1 is a balancing feedback loop. As the substrate gradually erodes away, the resuspension rate declines. The delay marker between resuspension and substrate indicates that substrate erosion is a relatively slow process.

The feedback structure represented in Figure 17 suggests that increased exogenous influx of suspended solids will cause seagrass loss, setting into motion reinforcing feedbacks that will generate additional suspended sediment through accelerated resuspension and further seagrass loss. As the substrate is lost through benthic erosion resuspension will slow, however, seagrass will be unable to re-establish itself due to loss of adequate substrate. The hypothesised causal structure implies that seagrass replanting projects may not succeed, even with reduced exogenous influx of suspended solids, if heavy loads of resuspended solids are being maintained by accelerated resuspension from areas of the benthic surface denuded of seagrass cover.

It should be borne in mind that the causal structure shown in Figure 17 is a hypothesis subject to refutation and/or alteration. The purpose of the diagram is to facilitate debate and to provide focus for the identification of relevant gaps in knowledge. The structure suggests that key foci for research are quantification of: (1) the quantities and temporal patterns of suspended sediment influx from the two exogenous sources, (2) the relationship between these fluxes and turbidity, (3) the impacts of turbidity and sediment filming on seagrass mortality and regeneration, and (4) the relationship between seagrass cover and the rate of sediment resuspension and substrate erosion.

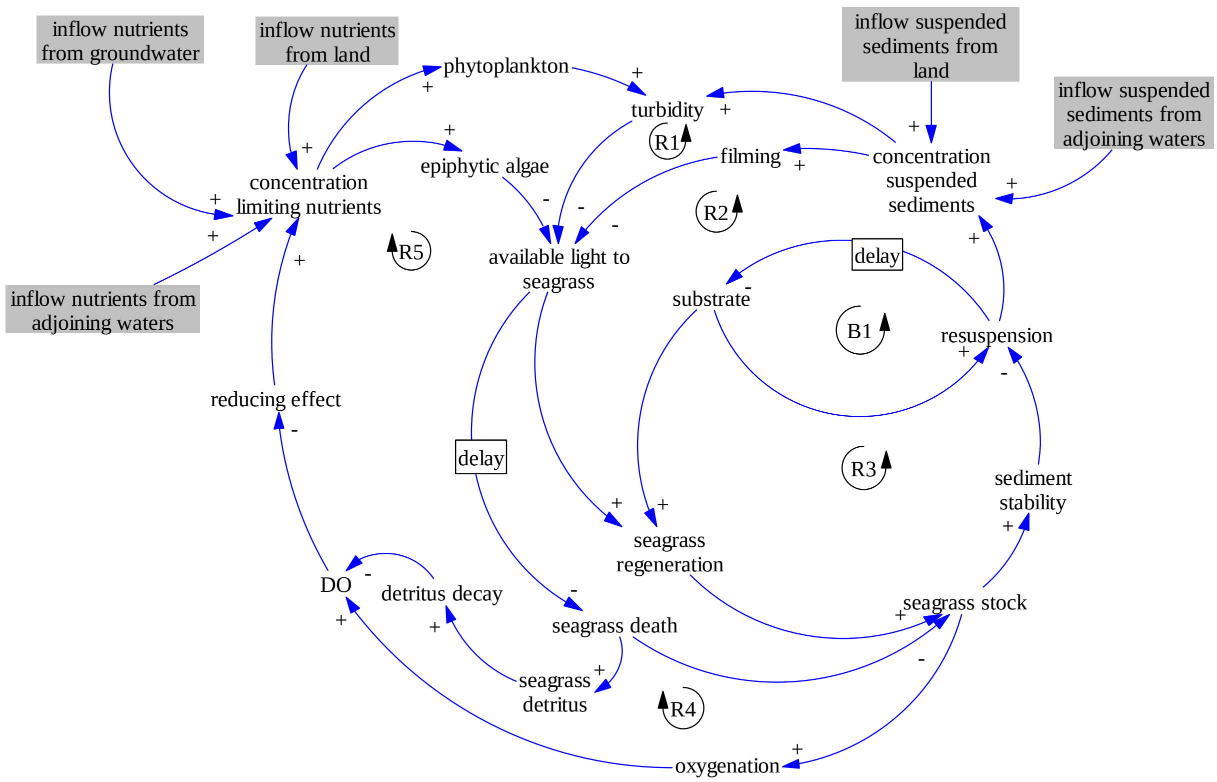

Figure 18. Postulated nutrient feedbacks linked to dissolved oxygen and reducing conditions, coupled with suspended solids.

In Figure 18 nutrients have been added to the feedback structure. There is some evidence that increased nutrient loads have resulted in higher concentrations of phytoplankton and seagrass epiphytes in Westernport (Westernport State of the Environment Report, workshop discussions), and that resulting increases in turbidity and epiphyte cover may contribute to seagrass loss (Westernport State of the Environment Report). In Figure 18 nutrients enter the system through three exogenous influxes (also in shaded rectangles): catchment surface water, groundwater, and water exchange with adjoining bay segments. Elevated nutrient concentrations in the water column result in higher concentrations of phytoplankton and epiphytic algae. Phytoplankton contributes to turbidity and epiphytic algae blocks sunlight directly. The resulting loss in available light feeds into the reinforcing feedback loops causing seagrass loss shown in Figures 15 and 16. However, nutrient concentrations may also be self-reinforcing. The combined influence of seagrass detritus decay and reduced oxygenation through seagrass loss may create anoxic or hypoxic conditions causing increased concentrations of bioavailable nutrient species that may be limiting for some species of algae and cyanobacteria. For example, under anoxic conditions iron oxyhydroxides are known to reduce, liberating bioavailable phosphates (the so-called iron curtain effect) and ferrous iron (DiToro, 2000). Feedback R4 demonstrates the proposed self-reinforcement of nutrient concentration through the relationship of seagrass to oxygenation and dissolved oxygen. Feedback R5 links seagrass mortality to detritus, detritus decay, and dissolved oxygen.

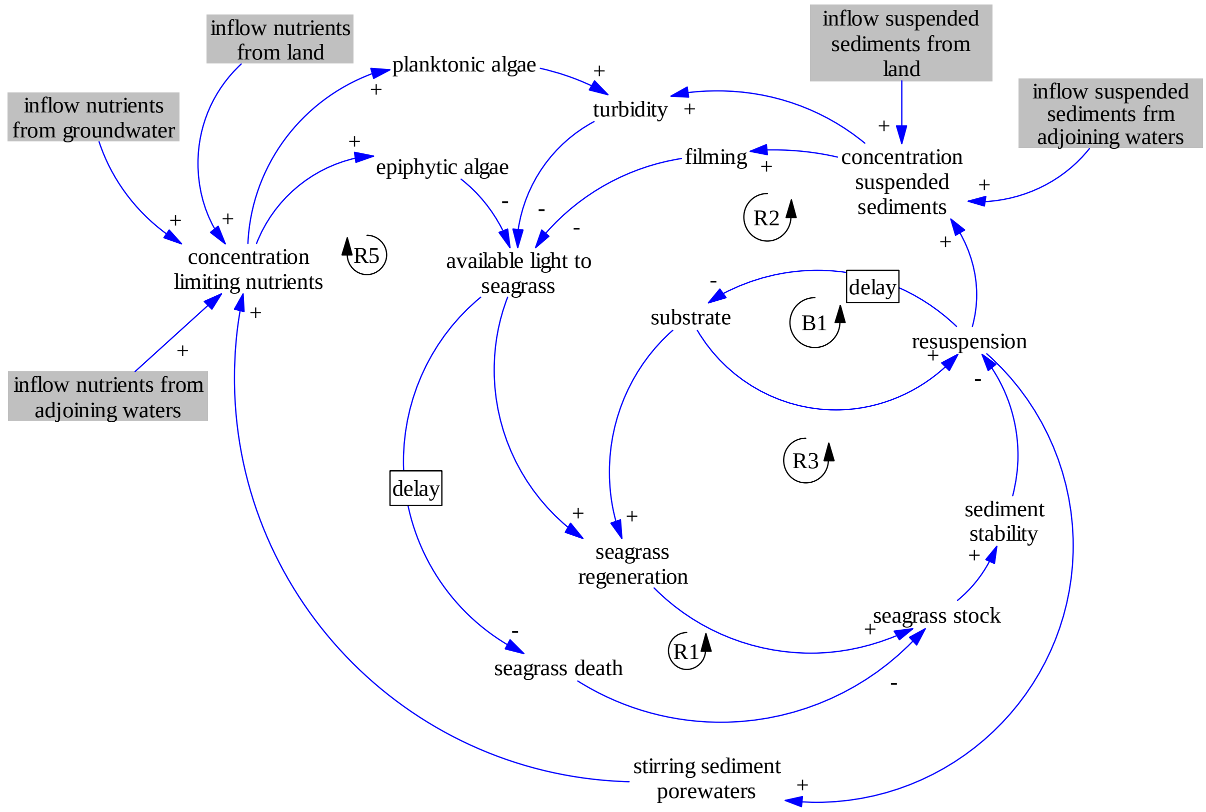

Figure 19. Postulated nutrient feedbacks linked to porewater stirring, coupled with suspended solids.

If the water column is well mixed, it is unlikely that anaerobic or hypoxic conditions will exist. An alternate mechanism for nutrient self-reinforcement is demonstrated by feedback R5 in Figure 19. If the seagrass stock and sediment stability decrease, increased sediment resuspension may release sediments into the water column through stirring of sediment porewaters (workshop discussion).

The causal loop structures shown in Figures 18 and 19 imply a wide range of possible scenarios. The structure implies that either nutrients or suspended solids could be the dominant factor in seagrass loss and that dominance could shift through time.

Key research areas related to nutrients are (1) quantification and speciation of inflowing nutrients from the three exogenous sources, (2) relationships between nutrient concentrations and concentrations of phytoplankton and epiphytes, (3) the contribution of phytoplankton to turbidity, (4) the impact of epiphyte concentration on seagrass mortality and regeneration rates, (5) dissolved oxygen profile and occurrence of reducing conditions, (6) quantification nutrients release through resuspension and porewater stirring.

Figure 20 integrates management perceptions, recognition, and actions with ecosystem dynamics. The management causal structure is delineated with dotted lines to distinguish from the purely biophysical system structure. Adding management feedbacks has the effect of making endogenous the inflows of suspended solids from surface runoff and nutrients from surface and ground water (hence, these are no longer shaded). Management interventions based on recognition of causal linkages between nutrients, suspended solids and seagrass loss result in the formation of balancing feedback loops, labelled in Figure 20 as B2, B3, and B4, which reduce the inflows of nutrients and suspended solids to levels designated as acceptable. An important point is that the management feedback structure is fraught with delays. Delays in perceptions, recognition, decision-making, and implementation mean that the balancing feedbacks from management intervention will not go into effect until the ecosystem has been significantly degraded.

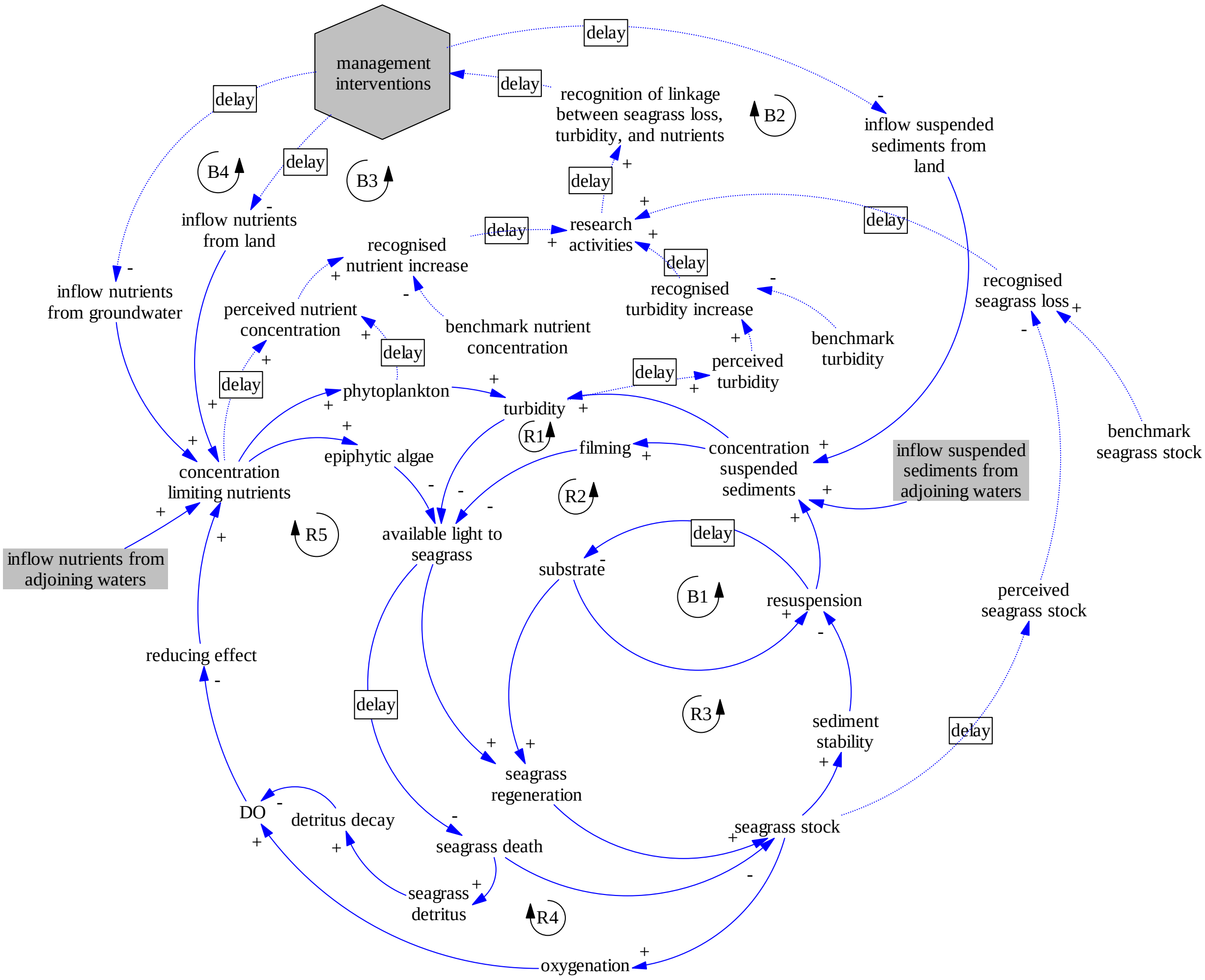

Figure 20. Postulated information structure of management recognition and response. Management causal linkages are indicated with dotted lines.

The first set of delays to consider are the delays in the perception of nutrient concentrations, suspended solids, and seagrass loss. These delays are related to the frequency of ecosystem monitoring and data processing. A second set of delays lies between recognition of environmental problems and initiation of research or investigative activities. In Figure 19 “research activities” represents the sum of research and investigative activities motivated by concerns about seagrass loss, and elevated turbidity and nutrient concentrations. A third tier delay is indicated between research activities and recognition of the linkage between seagrass loss, suspended solids, and nutrients. This delay subsumes the amounts of time required to conclude research projects, communicate findings, and reach consensus. As recognition and acceptance of the linkage grows, pressure will increase to initiate management interventions (indicated by shaded hexagon). The delay between recognition of the linkage and management interventions subsumes decision-making, planning, and consensus building. The final set of delays in the management feedback structure accounts for time lags in implementation of mitigative actions, potentially including infrastructure development, changes in landuse policies, public education, etc.

Figure 20 implies that delays embedded in the human response and management structure can allow ecosystem degradation and seagrass loss to reach significant proportions, potentially overshooting its capacity to regenerate. The diagram suggests that delays in the management structure are key foci for improving the environmental management of the Westernport ecosystem. Other important considerations within the management structure are the desired levels of nutrients, suspended solids, and degree of seagrass area.

10.7. Western Port embayment references: research themes

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10.8. Projects/activities (past and present) relating to Western Port marine environment

The following pages provide more details about recent, current and some proposed research activity in Western Port. In most cases only limited information about the project was available.

Project Ballast Water - Hastings

Interviewee	RC5
Objectives	trial ballast water DSS
Why	decreasing the likely introduction of marine pest
Participants	Victorian Department of Sustainability and Environment Victorian EPA AQIS
Location	
Timing	Start: 2000/1 - End: Dec 2002
Approach	EPA provided a scientific basis for the DSS.
Outputs	DSS Report - Theresa Hatch, Vicki Barnby EPA, Dec 2002. Exotics in WP - (Port Baseline Survey)
Outcomes	

Interviewee	RC12
Objectives	Minimise likelihood of marine pest introductions
Why	
Participants	Victorian EPA TOLL Ports
Location	
Timing	Start: - End:
Approach	
Outputs	
Outcomes	Still being used by TOLL.

Project Bay Load Model

Interviewee	RC4
Objectives	Predict loads exported to Western Port from freshwater
Why	for DSE who needed nutrient management plans across the state as part of the regional catchment strategies. Under the Regional river health strategy.
Participants	Victorian Department of Sustainability and Environment Victorian Department of Primary Industries Melbourne Water CRCCH Port Philip and Western Port Catchment Management Authority
Location	Bass River Western Pt
Timing	Start: - End: June 2003
Approach	For sediment, nitrogen and phosphorus -estimate theoretical generation rates from different land uses -uses 14 subcatchments -water quality information
Outputs	Bay load spreadsheet -report -> due June?
Outcomes	-Feed to NAP planning for DSE ->nutrient management plans -Melbourne water (link with sediments) -> actions for management

Interviewee	RM7
Objectives	Develop screening level model for identifying hot spots and establishing basis for prioritising either remedial action or further investigation
Why	Developed a "Bay Load" model for Agencies, based upon similar work undertaken for Port Phillip Bay (known as PPB Filter).
Participants	Victorian Department of Sustainability and Environment Melbourne Water Victorian EPA

	Port Philip and Western Port Catchment Management Authority
Location	Western Pt
Timing	Start: - End:
Approach	The rectangular grid based model is coded in Excel. It uses % component landuse runoff coefficients to calculate loads for nutrients and sediment for 9 subcatchment. Model is calibrated using data from water quality monitoring.
Outputs	Loads model, and aggregation of landuse data for catchments. The screening level model which has been developed can be used to identify types of things a dynamic catchment model would need.
Outcomes	The landuse data is not adding up - sediment budget not closing. At various points across the catchment it matches the Sednet Model developed by CSIRO, and at others does not. Trying to improve the mixes for landuse.

Project Benthic flora in intertidal mud areas

Interviewee	RC11
Objectives	
Why	
Participants	Parks Victoria Range of Universities
Location	
Timing	Start: - End:
Approach	
Outputs	
Outcomes	

Project Bunyip Creek / Main drain

Interviewee	RC4
Objectives	Stabilise this asset minimise erosion, decrease sediment, increase ecological quality
Why	This is an asset of Melbourne Water, needing management.
Participants	Melbourne Water
Location	
Timing	
Approach	upper Bunyip geomorphology
Outputs	Report - improvement works strategy, available from Melbourne Water. Bunyip main drain Report on improvement works plan
Outcomes	bed and bank stabilization

Project Cardinia Planning

Interviewee	RC15
Objectives	Develop tools and incentives for use in planning
Why	To manage biodiversity, water quality, erosion control, salinity, and land management
Participants	Cardinia Shire Council
Location	
Timing	Start: - End:
Approach	-catchment target / focus e.g. fencing of native vegetation, weed control tradable rights (sites of significance identified in planning documents), rate rebates (for nature covenants), $50 for attending a land management course (landcare courses e.g. soils, farm planning, chemical use) - support to education centre - other incentives – weed grants and tree grants
Outputs	nothing written
Outcomes	

Project Coastal Vegetation monitoring program

Interviewee RC1
Objectives
Why statutory requirement
Participants Victorian Department of Sustainability and Environment
Location
Timing Start: - End:
Approach
Outputs
Outcomes

Project Developing monitoring protocols

Interviewee RC11
Objectives VP use and other's use
Why
Participants Parks Victoria
Location
Timing Start: - End:
Approach
Outputs
Outcomes

Project Fish barriers

Interviewee RC4
Objectives Removal of fish barriers
Why Allow movement of native fish
Participants
Location
Timing
Approach
Outputs
Outcomes

Project Flora and Fauna studies

Interviewee RC13
Objectives usually targeted to an area or issue
Why -basis for management plans
-community communication
Participants Mornington Peninsula Shire Council
Location Western Pt
Timing Start: - End:
Approach
Outputs Weed strategy
Outcomes

Project Flora and fauna study of Platypus Creek

Interviewee RC4
Objectives
Why
Participants Melbourne Water
Location
Timing Start: - End:
Approach
Outputs

Outcomes

Project French Island Marine Vegetation

Interviewee RC1
Objectives update marine vegetation
Why
Participants Victorian Department of Sustainability and Environment
Parks Victoria
Victorian Department of Primary Industries
Location French Island
Timing Start: - End:
Approach fly over
Outputs maps, digital photos
Outcomes

Project Ghost shrimp

Interviewee RC6
Objectives impacts of bait pumping.
Why
Participants LaTrobe University
Location
Timing Start: - End:
Approach
Outputs Contact Fiona Bird
Outcomes

Project Hastings Landuse planning study

Interviewee RM9
Objectives Prepare structure plan for future development of Hastings Port Industrial area following an evaluation of land use and related development issues associated with planning.
Why Provide supportive information for strategic planning.
Participants
Location
Timing Start: 8/7/1993 - End: 8/12/1994
Approach Focused on identifying landuse and provisions for coordinated infrastructure development.
Outputs Draft Structure Plan was exhibited, with submissions received prior to preparation of final plan, which was approved by the Westernport Regional Planning and Coordination Committee in December 1994. Then endorsed by Minister for Planning 1996.
Outcomes Hastings Port Industrial Area - Land Use Structure Plan. No investment by Government needed to facilitated development in the short term.

Project Invertebrates in saltmarsh habitat

Interviewee RC11
Objectives
Why
Participants Parks Victoria
Range of Universities
Location
Timing Start: - End:
Approach
Outputs
Outcomes

Project Lang Lang - erosion projects

Interviewee	RC4
Objectives	stabilisation and decrease erosion
Why	
Participants	Melbourne Water
Location	
Timing	Start: - End:
Approach	
Outputs	
Outcomes	

Project Le Naturaliste in Western Port Commemorative Seminar

Interviewee	RM9
Objectives	In commemorating the French exploration in 1802, prepared a seminar that examined the history and the environment to draw out a vision for the future.
Why	Used the 200 year commemoration as a vehicle for sustainable development
Participants	
Location	various in WP bay
Timing	Start: 13/4/2002 - End: 14/4/2002
Approach	Series of papers
Outputs	
Outcomes	

Project Marine Park Areas

Interviewee	RC11
Objectives	Environmental conditions of assets
Why	For management of MP areas ->monitoring and management actions
Participants	Parks Victoria MAFRI
Location	various in WP bay
Timing	Start: - End:
Approach	Mapping and field monitoring to establish condition
Outputs	VicParks reports will be done
Outcomes	

Project Merricks Creek study

Interviewee	RC4
Objectives	
Why	
Participants	Melbourne Water
Location	
Timing	Start: - End:
Approach	flows into sandy segment of the bay - water quality monitoring
Outputs	
Outcomes	(blue green) algae blooms have occurred - therefore high nitrogen. Probably associated with viticulture, farming, urban land uses in catchment.

Project Morphometrics of seagrass - indicator development

Interviewee	RC1
Objectives	Can seagrass morphometrics be used as an indicator of ecosystem health

Why
Participants Melbourne Water
Victorian EPA
Location
Timing Start: - End:
Approach
Outputs journal articles
Outcomes

Project Mornington Social systems

Interviewee RC13
Objectives Social welfare research
Why for land management impacts on environmental management
Participants Mornington Peninsula Shire Council
Location Western Pt
Timing Start: - End:
Approach
Outputs recreation plans
Outcomes

Project Native Vegetation Plan

Interviewee RC15
Objectives Map native vegetation in Urban growth corridor for future management
Why
Participants Cardinia Shire Council
Location
Timing Start: soon - End:
Approach
Outputs
Outcomes

Interviewee RC14
Objectives
Why
Participants Mornington Peninsula Shire Council
Casey Shire Council
Cardinia Shire Council
Location Western Pt
Timing Start: - End:
Approach Mapping of coastal vegetation, not aquatic
1:2500 scale
ecological vegetation classification
Outputs output will be available
Outcomes

Project Oil Spill Response

Interviewee RC12
Objectives
Why
Participants MAFRI
Marine Safety Victoria
TOLL Ports
Western Port Region Dispersant Use Committee
Location
Timing Start: - End:
Approach
Outputs Lit. Review. May 2002 (Electronic from Dick Cox)
Outcomes

Project Rutherford Inlet Study

Interviewee RC10
Objectives Better management of property frontages on bay
Why
Participants Casey Shire Council
Western Port Catchment Implementation Committee
Location
Timing Start: - End:
Approach looked at properties and action needed.
looking now at trade-offs to get foreshore land.
Outputs
Outcomes

Interviewee RC14
Objectives pt 1 ecological study
pt2 strategic planning
Why
Participants PPK
Casey Shire Council
Location
Timing Start: - End:
Approach
Outputs there will be output available from Ian Stevenson
Outcomes

Project Salinity study - Urban growth

Interviewee RC15
Objectives salinity study of urban growth corridor
Why
Participants Cardinia Shire Council
Location
Timing Start: - End: 2002
Approach
Outputs Report from Sue Harris, Cardinia Shire Council

Project Seagrass monitoring

Interviewee RC6
Objectives Detect changes
Why
Participants Victorian EPA
Western Port Seagrass Partnership
Location

Timing Start: - End:
Approach
Outputs See Doug Newton for reports
Outcomes

Interviewee RC5
Objectives mapping - detects changes
Why -part of SEPP requirements to achieve 5% target recovery and maintenance
Participants Victorian Department of Sustainability and Environment
Victorian Department of Primary Industries
Western Port Seagrass Partnership
MAFRI
Location
Timing 1985,1995,1997
Approach -mapping
-physiological response - Stuart Campbell (JCU)
-current involvement of EPA: longer term monitoring, and audit of SEPP (DSE) achieving target, and replanting via Jason's project
Outputs Andy Stephens report - 1996 report (trends and changes- from library). 1997 fact sheet
MAFRI mapping 2001: Marine habitat database (DSE). Several journal articles by Campbell (e.g. morphometrics) and Doug Bulthuis late 1970s early 1980s
Outcomes -replanting to replace lost seagrass. EPA consider no seagrass loss acceptable when setting licenses.

Project Seagrass replanting

Interviewee RC6
Objectives Different techniques for re-establishing
Why Seagrass recovery
Participants Victorian EPA
Western Port Seagrass Partnership
Location
Timing Start: mid 2001 - End: Dec 2002
Approach - transplant seedlings from areas to new areas at various depths and monitor establishment and ongoing survival
Outputs - final report - a couple of weeks for edited version
Nic Wimbush will email draft
Outcomes - success rates good - establishment good but, smothered by sediments and this has had a significant effect.
- More funding need to attempt this project on a larger scale.
- sediment is the biggest factor affecting the survival of the seagrass
-how does sediment move around the bay?
-identify quiescent patches -> target for replanting

Project Seagrass tissue culture

Interviewee RC6
Objectives Tissue culture of seagrass
Why culture rather than transplanting
Participants Monash University
Location
Timing Start: 2002 - End: might continue
Approach -tissue culture
-genetic diversity
NHT funded - genetic fitness related to survival? ESSO
Outputs No reports yet -> but some data reports (from John Hamill)
Outcomes - population dynamics - genetic diversity - not good / clear results

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Project Seagrass transplant Project

Interviewee RC2
Objectives - test propagation methods
- develop criteria for identifying areas for transplanting seagrass
Why respond to seagrass recovery opportunities in WP
Participants Victorian EPA
Western Port Seagrass Partnership
Location various in WP bay
Timing Start: Jan 2002 - End: Dec 2002
Approach - transfer seagrass replants to selected areas and monitor survival
-field observations of sediment movement and stability
- NHT funded
- linked with Monash artificial propagation project
Outputs Report to be printed next week - available from website
Outcomes Linking seagrass recovery to environmental dynamics (e.g. substrate stability)

Project Seagrass workshop

Interviewee RC6
Objectives See background paper provided
Why See background paper
Also see background paper for participants
Participants Western Port Seagrass Partnership
Location
Timing Start: March 2001
Approach Workshop to develop conceptual model of seagrass dynamics, based upon current scientific knowledge
Outputs -executive summary of report (we have hardcopy)
-conceptual model (Coastal CRC has a copy)
-individual papers?? (J. Swan and Peter Attiwill?)
-background paper
-outcomes report
Outcomes

Project Sediment sources

Interviewee RC4
Objectives Identify sources and loads of sediments into Western Port Bay.
Why recommended by SEPP
Participants Melbourne Water
Victorian EPA
CSIRO Land and Water
Location East Arm
Timing Start: 2000 - End: 2003
Approach
Outputs 4 CSIRO reports available from CSIRO website.
Outcomes Provide a logical basis for placing sediment traps
Should there be action for Western Port - what kind?

Project Sediments - TBT

Interviewee RC5
Objectives Has there been any change in TBT concentrations in last 10 years
Why 1988 <-TBT use on small vessels banned
Participants Queensland EPA
Location
Timing Start: Sampling start - End: 2002
Approach - Sediment and biota - levels TBT
- compared with Late 1980s

	- 1992: imposex in gastropods in WP
Outputs	- Vic EPA report, 1980's, Helen Daly and Gus Fabris, available from EPA library city -EPA 1992 Simon Foles -> Journal articles (EPA library).
Outcomes	-link to management actions regulating TBT - confirming effectiveness of TBT ban - variable results - some decline in some areas -some areas TBT seems to still be in use: need for more action

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Project Septic tanks

Interviewee	RC14
Objectives	Manage old septic systems to minimise impact on water quality.
Why	
Participants	Mornington Peninsula Shire Council
Location	
Timing	Start: proposed - End:
Approach	Upper catchment focus because all coastal villages being sewered now). Will examine water quality.
Outputs	
Outcomes	

Project *Spartina* mapping

Interviewee	RC11
Objectives	monitoring and species identification of Spartina.
Why	
Participants	Parks Victoria Range of Universities
Location	
Timing	Start: - End:
Approach	
Outputs	
Outcomes	

Project Stormwater planning

Interviewee	RC14
Objectives	Stormwater plans for: building, and for subdivisions - to manage sediment, litter etc
Why	
Participants	Casey Shire Council
Location	Western Pt
Timing	Start: - End:
Approach	Pilot projects going. Using existing research
Outputs	Building and construction plan: May 2003 Subdivisions - only at project brief stage. Stormwater management plan - website (all LG's have them) (identifies some threats and values)
Outcomes	

Project Stream frontage program

Interviewee	RC4
Objectives	Protect and rehabilitate riparian vegetation
Why	
Participants	Melbourne Water
Location	
Timing	Start: - End:

Approach Fencing and replanting
Outputs
Outcomes

Project Stream Management - Western Port catchment

Interviewee RC2
Objectives Spatial asset of landuse, water quality, bay activities
Why Cma needed knowledge
Participants Victorian EPA
Port Philip and Western Port Catchment Management Authority
Location
Timing Start: 1999 - End:
Approach
Outputs hardcopy report
Outcomes

Project Stream water quality

Interviewee RC13
Objectives -to respond to concern / issues i.e. investigate
Why
Participants Mornington Peninsula Shire Council
Location Western Pt
Timing Start: - End:
Approach spot investigations
Outputs generally not public - but available if asked for
Outcomes Identify pollutants and some sources -> qualitative loads to bay

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Project Terrestrial remnant vegetation

Interviewee RC13
Objectives
Why
Participants Mornington Peninsula Shire Council
Location Western Pt
Timing Start: - End:
Approach Mapping
Outputs
Outcomes

Project The Western Port catchment

Interviewee RC2
Objectives stream condition
Why establish community understanding of land management and stream management
Participants Landcare
RMIT
Location
Timing Start: - End:
Approach
Outputs -Series of reports
-index of stream condition
-biocides
available RMIT library (internal student reports).
Outcomes community understanding

Project Tooradin Planning

Interviewee RC14
Objectives Develop planning tools for coastal village of Tooradin
Why
Participants Mornington Peninsula Shire Council
Location Tooradin / Koo-Wee-Rup
Timing Start: - End:
Approach
Outputs
Outcomes

Project Unsealed roads

Interviewee RC10
Objectives What are the impacts of runoff from unsealed roads.
Why
Participants Casey Shire Council
Western Port Catchment Implementation Committee
Location
Timing Start: - End:
Approach
Outputs
Outcomes

Interviewee RC14
Objectives
Why Manage run-off from unsealed roads in Western Port Catchment
Participants Mornington Peninsula Shire Council
Location Western Pt
Timing Start: July 2003 - End: 2004
Approach Looking at coastal villages and catchment (e.g. Hastings)
Outputs project brief stage due at end of May
Outcomes

Interviewee RC15
Objectives Which methods of management causes least sediment runoff to water courses
Why
Participants Mornington Peninsula Shire Council
Casey Shire Council
Cardinia Shire Council
Location
Timing Start: mid 2003 - End: mid 2004
Approach Trial different methods: road types, sediment traps
Water quality testing
Seeking funding from Victorian Stormwater Action Program.
Outputs developing brief now.
Outcomes

Project Water Quality monitoring in WP EPA

Interviewee RC5
Objectives Long term trend analyses of WQ
Why
Participants Victorian EPA
MAFRI
Location various in WP bay
Timing Start: 1986 (+70s earlier) - End: on going
Approach -monthly monitoring of:
-phys-chem indicators
-chlorophyll a measured.
-no bacto monitoring now - low concentrations in the past
-no sediments now - previously toxicants and metals
- prior to 1986, was mostly shore-based sampling done by MAFRI.
Outputs -trends report - Western Port
- #3 Draft, 15 years (Di Rose)
- Toxicants in Sediments - Draft report MAFRI (Di Rose)
- no marine data -> DSE warehouse, but data is available upon request
- Report :Western port water quality: Long-term trends in nutrient status and clarity, 1984-2001
- EPA State of the environment report
Outcomes -Compliance with SEPP
-prosecutions / enforcements
-license setting and compliance

Project Water quality monitoring program

Interviewee RC4
Objectives
Why
Participants Melbourne Water, Water Ecoscience
Location
Timing Start: 1997 - End: on going
Approach Fish, macro invertebrates, instream physical form, flow monitoring.
Monthly monitoring of 72 sites in Port Phillip and Western Port Catchment
Data from 16 sites goes to DSE data warehouse
Outputs DSE data warehouse - access via website
-reports and data summaries - available from EPA, DSE.
-fish database - NRE
Outcomes

Project Waterwatch

Interviewee RC15
Objectives Water quality information - supplements EPA and Melbourne water data.
Why
Participants Victorian EPA
Landcare
Cardinia Shire Council
Location
Timing Start: 3 years duration - End:
Approach Freshwater focus
-protocols
-smallest areas
Outputs Waterwatch coordinator - Michelle Dixon
Outcomes

Project Weeds in Western Port Catchment

Interviewee RM19
Objectives Assessment of weeds: threat to indigenous coastal woodlands, dunes and cliff vegetation on Coastal reserve land
Why for local Committees of Management.
Participants Victorian Department of Sustainability and Environment
Location
Timing Start: - End:
Approach Site evaluations.
Detailed knowledge in some specific site, and broad involvement in most areas over the last eight years.
Outputs
Outcomes advice to committees re grant applications for eradication or control projects.
Input to Management Plans, guidance to groups on flora and fauna studies

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Project Western Port Biosphere

Interviewee RC13
Objectives live sustainability - applying ESD - direct on ESD Building understanding and knowledge of the principles, individuals, groups and companies
Why Forum for information and knowledge exchange
-not so much about decision making (-> bureaucracy) value of UNESCO model
Participants Mornington Peninsula Shire Council
Western Port Biosphere Group
Location Western Pt bay entire
Timing Start: December 2002 - End: 10 years
Approach - environmental schools program - partnership with department of learning and employment.
Outputs -reporting on success of biosphere reserves
-brochure
-nomination CD on website
Outcomes UNESCO facilitates communication between biosphere region

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Project Western Port Hydrography

Interviewee RC12
Objectives hydrographic surveys for dredging
Why
Participants TOLL Ports
Location
Timing Start: - End:
Approach 6 monthly survey
Outputs
Outcomes

Project Western Port Land Use

Interviewee RM19
Objectives Land use data collection and mapping, 1974 for the Environmental Conservation Council
Why
Participants Victorian Department of Sustainability and Environment
Location
Timing Start: 1974 - End:
Approach Aerial photo and ground inspection methods.
Outputs

Outcomes Input into the ECC reports.

Project	Western Port Saltmarsh & Mangrove Monitoring Program
Interviewee	RC1
Objectives	Assess the state / condition of saltmarsh and mangrove habitats, identify land uses correlated with condition
Why	Responsibility under SEPP to monitor marine vegetation
Participants	Victorian Department of Sustainability and Environment Australian Catholic University Dept. of Infrastructure
Location	Quail Island Tooradin / Koo-Wee-Rup Rhyll North French Island
Timing	Start: 1999 - End: ongoing
Approach	- vegetation distribution dynamics (mangrove and saltmarsh), in relation to environmental variables. - historical comparison of changes - relate to changes in landuse in catchment.
Outputs	Literature review of mangrove and coastal vegetation studies of WP Saltmarsh & mangrove standard operating manual Saltmarsh and Mangrove monitoring - progress reports
Outcomes	Used for Western Port Baseline Study of marine vegetation - being developed now

Project	Yallock Creek study
Interviewee	RC4
Objectives	
Why	
Participants	Melbourne Water Deakin University
Location	
Timing	
Approach	
Outputs	
Outcomes	High in Phosphorus

10.9. Potential gaps

Gaps identified during construction of conceptual models

Hydrodynamics Gaps

- Flow rates, direction and nutrient content of groundwater is unknown for much of the bay.
- Updated flow rates for catchment surface waterways needed.
- Transpiration rates for saltmarshes and seagrasses.
- Up to date Bathymetry is needed, especially as the intertidal flats and channels of Western Port are constantly changing.
- Hydrodynamics is well known at the large scale for each basin but is not well known at the smaller scale.
- Effects of wind on hydrology (sediment resuspension) needs to be examined. May need to question the location of sites collecting meteorology wind data as it may not be indicative of actual conditions on the bay.
- Some question about published exchange rates / residence times – re-evaluate?

Nutrient Gaps

- Presence / concentrations of other elements for growth, e.g. Si, Fe, other trace elements?
- Carbon data is limited.
- Need temporal data for nutrient inputs into bay (are episodic events (bursts) more important than constant flows).
- Need to know bioavailability of incoming nutrients, dissolved versus particulate, etc. Bio-useable data limited.
- Need to use consistent units when measuring nutrient levels.
- Nutrient, sediment and other contaminant levels of stormwater inputs is unknown.
- Contribution (quantified values) of nutrients from erosion of coastal sediments is unknown.
- Nutrient exchange into Western Port from Bass Strait are unknown. I.e. Need a nutrient budget for Western Port.
- Nutrient levels in the water column of Rhyll basin and Western Entrance are unknown.
- Atmospheric inputs of nutrients into the bay are unknown – what percentage are bioavailable?
- Need better primary production data for phytoplankton.
- Status and productivity of epiphytes, macroalgae and microphytobenthos are unknown within basins and across Western Port.
- Has macroalgae filled the gaps created by the loss of seagrass?
- Has seagrass detritus contributed to the nutrient budgets across Western Port?
- Seagrass production rates needed from more locations.
- Productivity of saltmarshes.
- Productivity of pelagic and subtidal benthic fauna is unknown (though good data on some fish production).
- Consumption and waste rates for different fauna is unknown.
- Transport of organic matter through the food web is unknown.
- Suspended sediments and nutrient correlation is not resolved bay wide. What is the relationship between nutrient concentrations and sediments?
- Source of nutrients is not well known (catchment derived, from increased biological activity or increased amounts of organic matter?).
- Concentrations of nutrients in the sediment needed for all basins.
- Transport of nutrient via sediments is unknown.
- Basin level knowledge of nutrient levels is low, variable or absent.
- Are nutrients derived from the mixing of porewater or resulting from the breakdown of organic materials in the water column?
- The rate of absorption / desorption and its importance in regulating phosphorus is unknown.
- Rates / amounts of remineralisation, benthic fluxes, ammonification, inorganic phosphate fluxes, nitrogen gas fluxes, nitrogen fixation, denitrification, nitrification and the biomass of microbes important in these processes are unknown.
- A nutrient budget for all basins needs to be revisited / done so that a entire bay budget can be done.

- More nutrient monitoring sites needed.
- Little is known about phosphorus dynamics.
- Limited porewater data and benthic standing stocks – important to understand the importance of resuspension in contributing nutrients to the water column.

Sediment Gaps
- Little or no information on catchment input sediment size.
- More accurate and quantitative data needed for coastal erosion and coastal sediment drift for all basins.
- Bay wide quantitative data needed on sediment export/import (need specific data for all basins).
- Atmospheric inputs of sediments into the bay are unknown.
- Need deposition rates of different sediment types/sizes in different hydrological regimes.
- Need to know the rate of sediment deposition/resuspension in saltmarshes, seagrass beds and mangroves. The efficiency of seagrass binding has not been quantified.
- Need to know the movements of sediments at the smaller scale.
- Quantitative data needed for the effects of shipping/boating on sediment resuspension/ erosion (i.e. effects of propellers, wash, anchors).
- Bay wide sediment budget is unknown – are sediments being exported (imported?) to Bass Strait; how much?
- Role of bioturbation in benthic sediment mixing unknown for Western Entrance and Lower North Arm basin.
- More turbidity monitoring sites needed – data needed for Western Entrance and Rhyll basin.
- The nature of sediment accumulation/erosion of intertidal flats is not clear, especially in the Upper North Arm.
- Is the bay able to flush the 'oversupply' of sediments?
- How do different sediments affect water quality – light penetration, productivity?
- Are there any contaminants bound to sediments that are released into the bay?
- What is the time scale for meeting equilibrium of load versus flushing and resuspension?
- Relationship between sediments and biophysical processes (e.g. seagrass health – effects of sediment on smothering (types of smothering), mortality rates, light penetration).

Other
- What is the potential for pest introduction into Western Port via aquaculture and shipping?
- No quantitative, consistent and comprehensive data on the change in environmental conditions/health of Western Port over time – e.g. is macroalgae replacing seagrass?

How long will it take after management of catchment before benefits are seen within the bay?

Gaps previously identified in other reports

Western Port issues, research and management (Chiffings and Johnstone, 2000)
- Sediment, nutrient and toxicant loads – we need to know their origins, distribution, impacts and long-term fates.
- What is the relationship between seagrass and commercial fisheries?
- What is the relative importance of key processes impacting on seagrass (e.g. what effect will changes in nutrient levels have versus changes in sediment levels).

Western Port Perspective (PPK, 2000)
- Better level and coordination of water quality monitoring need for basins, whole bay and catchment.

The Western Port Marine Environment (EPA, 1996)
- No recent investigations have been conducted on the physical condition of Western Port.
- No data collected on sediments or sedimentation within embayments or at the mouths of creeks, rivers or drains.
- Smaller scale current characteristics are poorly understood, particularly flow on mudflats.
- Few measurements of currents outside the main shipping channels.
- EPA metal detection sites are not in high depositional areas. Lack of data on metal concentrations.

- No recent data on biocide concentrations in waters, sediments or biota.
- Lack of continuity of catchment inputs monitoring.
- Relatively few sites monitoring catchment inputs.
- Need to implement the recommendation of the Victorian Water Quality Monitoring Network to add a number of monitoring sites to the lower reaches of inputs to Western Port.
- No monitoring of contaminant input from catchments.
- Lack of data on plankton biomass, productivity and composition (particularly recent data).
- The status of zooplankton communities are unknown.
- Current distribution of salt marshes and mangroves.
- No data on whether fish etc. populations have increased with the observed increase in seagrass cover.
- No recent investigations into the current status of soft sediment beds and there associated infaunal species.
- The current status of invertebrate species, particularly the opisthobranch molluscs *Platydoris galbana* and *Rhodope* sp. of the San Remo Marine Community (listed under schedule 2 of the Flora and Fauna Guarantee Act 1988) are unknown. The status of this community was due for review by Department of Conservation and Natural Resources in 1997.

<u>Western Port Seagrass Seminar – March 2001 (Background Paper)</u>

- What are the minimum habitat requirements for seagrasses and what further information do we need to collect to characterise habitat requirements?
- What do we need to know about seagrass physiology and their response to propagation and transplantation?
- Are revegetation strategies (Seddon and Cheshire, 1999) supported?
- What information do we need to know about the state of restoration ecology that is applicable?
- Is the current 'condition' of Western Port environment sufficient to attempt transplantation?
- What areas are most suitable for revegetation and what areas should revegetation not be attempted?
- No data available on nutrient concentrations of sediments.

<u>Policy impact assessment – Protecting the waters of Western Port and Catchment (EPA, 2001)</u>

- Only a limited number of streams in the catchment are monitored.

10.10. Multiple Objective Decision Support Systems

MODSS and MCA Methodologies

There are many techniques that can be described as MCA and MODSS. Figure 21 lists attributes of the various techniques. The techniques suggested within an adaptive management framework all fall in the highlighted area. These techniques share the same basic building blocks, these being options, criteria and ranking methods (RAC, 1992).

In natural resource and land-use management, the options (also be called alternatives or scenarios) are the proposed land-use or land management practices. In previous studies these have included options to preserve groundwater quality and depth in Far North Queensland, including tree planting, restricting water allocations and greater use of efficient irrigation practices (Robinson *et al*., 1999). In the Burnett MODSS study in Southern Queensland (Eisner *et al*., 2000), the options related to potential water infrastructure planning (dam sites) in the Burnett catchment, where additional options included alternative spillway heights for the same site. In contrast, Dalal *et al.* (1999) used a multiple criteria approach to explore the suitability of sustainability indicators for the wheat industry. In this application, the decision criteria weer defined in terms of desirable attributes of indicators (e.g. measurable, community acceptance, timeliness and ease of interpretation). In this sense, the SMART filter now being used by community groups to define management action targets in the NAPSWQ provide decision criteria that can be incorporated into a MCA.

MODSS Software Applications

In this section a number of recently developed MODSS designed specifically for natural resource and land-use management will be discussed with regards to their possible application to farm forestry decision-making. These are Facilitator (DNR *et al*., 1999), DEFINITE (Janssen *et al*., 2001) and JavaAHP (Zhu and Dale, 2001).

Facilitator

The MODSS software application Facilitator (DNR *et al*., 1999) was developed jointly by the Queensland Department of Natural Resource and Mines, the Agricultural Research Service of the United States Department of Agriculture and Netstorm Pty Ltd, Toowong, Brisbane. This tool was developed to fulfil a need to provide a transparent decision framework to integrate multiple objectives, multiple stakeholders and varied data sources and bodies of knowledge (Lawrence *et al*., 2000).

Facilitator MODSS is a generic MCA tool. It was developed using algorithms and aggregation techniques from a prototype decision-support system (P-DSS) which had been developed by the USDA Agricultural Research Service in Tucson, Arizona (Lane *et al*., 1991, Yakowitz *et al*., 1992). The weighting algorithm is the same as the extreme value method and the aggregation is a weighted summation.

Facilitator is limited by the weighting techniques it provides. The Range of Values or the extreme value method provides a range of results. These ranges are often wide and can be difficult to interpret (see Eisner *et al*., 2000). It is argued that this variation in results reflects the uncertainty of the outcomes (Eisner *et al*., 2000). This problem is likely to be somewhat alleviated in the release of Facilitator Version 1.3 in 2002, which is expected to include the Rank Order Centroid method.

Facilitator can be downloaded from the web free of charge, from the site http://facilitator.netstorm.net.au/. Facilitator is specifically aimed at groups or individuals engaged in natural resource planning with limited funding. Facilitator has a simple user interface for ease of take-up (see Eisner and Jeffreys, 2001). Facilitator is written in platform-independent Java and can be run on any operating system that supports Java. Facilitator reports in Hyper text Mark-up Language (html), therefore the reports can be viewed using any Internet browser software.

Definite

Definite (Janssen, 1991, Janssen *et al.*, 2001) is a high-end multi-objective decision-support tool. It is a modular program with much functionality. The problem definition module includes the ability to construct hierarchies and to evaluate the options by direct assessment or by pairwise comparison, as well as checks for dominance (when one option is outperformed against every criterion by other options), and also correlation analysis on the criteria. The multi-criteria analysis module includes many aggregation and weighting techniques (most of those detailed early in this chapter). Definite includes a cost-benefit analysis module as well as a sensitivity analysis module. Definite is designed to run on the Microsoft Windows operating system and uses other Microsoft products extensively for importing and exporting analyses and reporting analyses. The high level of functionality has both costs and benefits. The user interface is cluttered and complicated to follow and use. This is a tool for researchers and policy workers, not community groups.

Definite is a commercial product and the current cost is A$2500 to A$5000 depending on the license type. This precludes it from most catchment management and other community-based groups engaged in natural resource planning and landholders.

JavaAHP

JavaAHP (Zhu and Dale, 2001) again is a relatively simple tool. The problem definition part of the tool builds hierarchy trees as described by Saaty (1980). This offers a different approach to the matrix or effects table to that applied by Definite and Facilitator. There are benefits to both approaches and it appears largely down to the personal choice of the decision-maker. The weighting techniques available in JavaAHP are the AHP (Saaty, 1980) and SMARTER (Edwards and Barron, 1994), and the aggregation technique is the weighted summation method. The user interface is relatively simple and easy to use.

JavaAHP is run solely over the Internet and is not available for download. It can only be run when the user is connected to the JavaAHP web site. All analyses are also saved on to the web site's host server. The analyses are password protected and therefore can be made available to chosen stakeholders or other decision-makers, thus allowing easy access to current analyses. Mounting and running JavaAHP on the Internet has it's pros and cons: no specialised software is required on the user's computer; JavaAHP runs using Internet browsing software and it is currently freely available. JavaAHP can only be used if the user has an Internet connection. Whilst care has obviously been taken to maximise processing speed and data transfer speed, many people – especially those concerned with natural resource and land-use management – often reside in rural and regional areas and have poor or no access to the Internet. JavaAHP can be found at http://www.chris.tag.csiro.au/JavaAHP/.

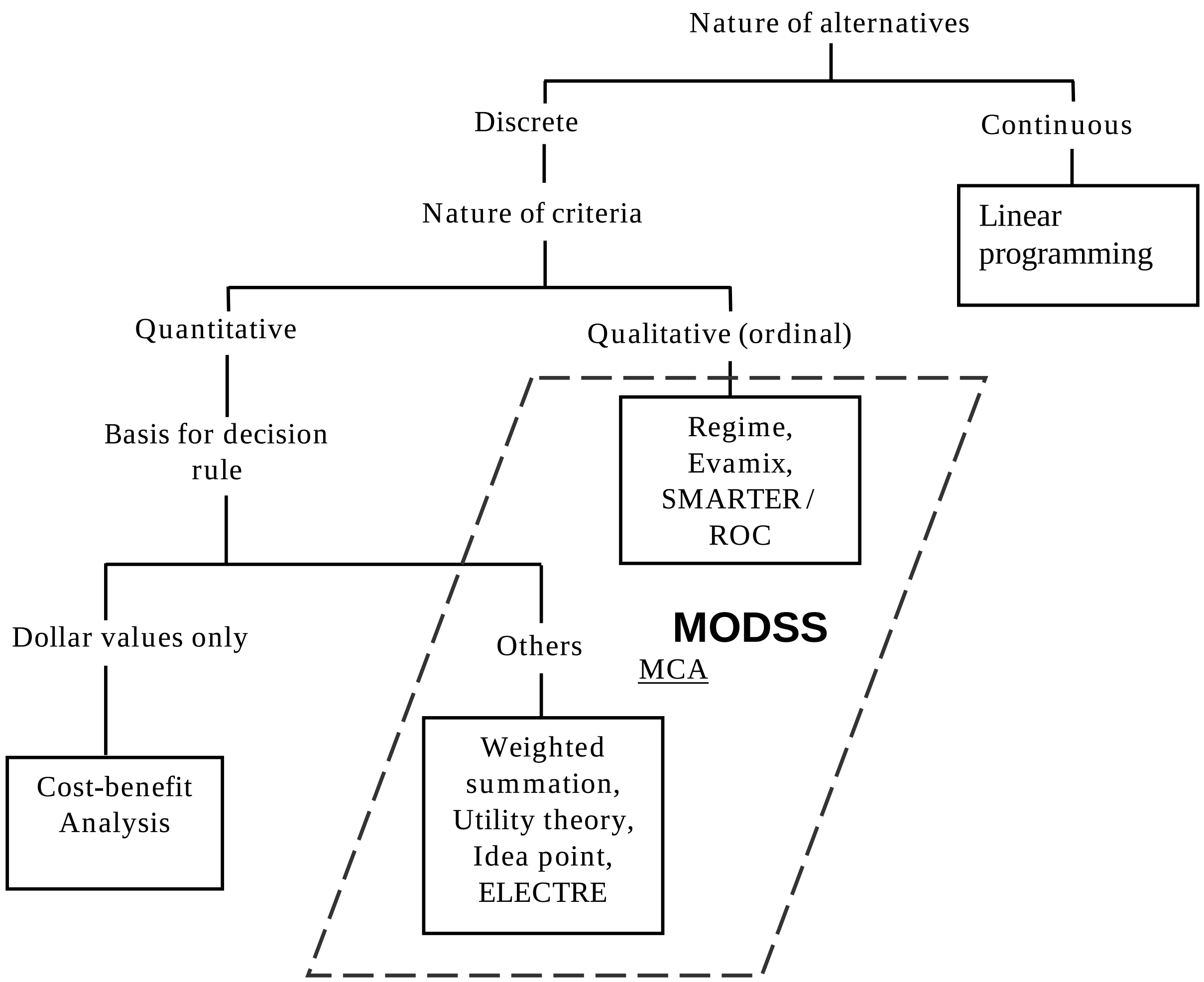

Figure 21. Schematic classification of multi-criteria analysis methods.

10.11. Example agreement for participants in management committees

The following are agreements that can be signed by all participants to the process. In particular they seek a mature approach to negotiation and interaction minimising bullying and coercion. Point 3 below is critical for those involved in the development of agreed science gaps and priorities

1. Members are appointed for their skills and abilities within the area of interest or their specified role within an organisation and membership resides with the individual rather than any nominating organisation. Thus, alternates are not preferred.
2. Members may be obliged to seek the views of their sponsoring organisation in formulating their own views on issues as a member of committees as decided by the committee.
3. Ideally, the decisions of the groups and committees will be made through a process leading to consensus. Discussions about issues on which there is not agreement may be deferred, within time constraints. Those dissenting from the majority are required to detail the reasons for their objections and suggest methods by which their concerns can be addressed and accommodated. Those in the majority are obligated to respond to the objections and offer options that seek convergence of ideas. Following the process, the issue may be resolved by a vote called at discretion of the Chair if consensus cannot be achieved or referred to an independent body such as a citizen jury.
4. Conflicts of interest may arise from time to time. Each member shall disclose to the committee actual and potential conflicts of interest, which may exist from time to time and might reasonably be thought to exist between the person, his or her agency affiliation and the items under discussion. At the request of the chair and/or the majority of other members, reasonable steps must be taken to remove the conflict of interest.

Individual statement for acceptance of committee membership

1. I am prepared to act in the best interest of the .... rather than as an advocate for any particular organisation or interest group, and I am prepared to exercise tact and discretion when dealing with sensitive issues.

2. I recognise that I must have stakeholder confidence and authority and I am prepared to consult closely with stakeholders on matters relating to the scope of my involvement

3. I will endeavour to put forward my views clearly and concisely, and I am prepared to participate constructively to assist the committee to reach and agreed decision considering all the relevant facts.

4. I will not pursue any personal agenda or self-interest, and I undertake to participate in discussion in an objective and impartial manner.