CSIRO

CSIRO LAND and WATER

The Western Port sediment study

By P.J. Wallbrink, G.J. Hancock, J.M. Olley, A. Hughes, I.P. Prosser, D. Hunt, G. Rooney, R. Coleman and J. Stevenson

Melbourne Water

EPA VICTORIA

Consultancy Report
CSIRO Land and Water, March 2003

CSIRO LAND and WATER

The Western Port sediment study

By P.J. Wallbrink, G.J. Hancock, J.M. Olley, A. Hughes, I.P. Prosser, D. Hunt, G. Rooney, R. Coleman and J. Stevenson

Melbourne Water

EPA VICTORIA

Consultancy Report
CSIRO Land and Water, March 2003

Front cover:
Photograph from Lang Lang beach looking south west across mudflats towards French Island.

This report should be referenced as:

Wallbrink, P.J., Hancock, G.J., Olley, J.M., Hughes, A., Prosser I. P, Hunt, D., Rooney, G., Coleman, R. Stevenson, J. (2003). The Western Port sediment study, CSIRO Consultancy report, 2003.

General overview:

This report summarises the findings of a three year study to determine rates of accumulation and redistribution of sediment within Western Port, as well as contributions to this sediment from its catchment sources. The delivery of sediment to Western Port has changed since European arrival. Large scale clearing, draining of the Koo Wee Rup swamp, and construction of channels across the swamp has led to an increase in catchment erosion and an increase in the efficiency of sediment delivery to the marine environment.

The study has found that persistent high turbidities arise from the daily reworking and resuspension of fine sediment by tidal, wind and wave action. Data from sediment cores indicates that a large proportion of sediment delivered to the North Arm is being transported clockwise around the embayment. Consequently, sediment delivered to the northern region has the ability to affect water quality and seagrass habitat of eastern and southern regions by the creation of a zone of turbid water during transport, and by increasing the extent of mud deposition in the Corinella and Rhyll segments.

The dominant catchment source of the fine sediment is subsoil from channel and gully erosion of the Bunyip and Lang Lang River systems. Erosion from the clay banks to the north west of the Lang Lang jetty also appears to be an important local source of fine sediment. The contribution of the Bass River is relatively minor, contributing less than 10% to the fine sediments in the southern (Rhyll) segment of Western Port.

Sediments from catchment erosion will continue to be a problem for Western Port if rehabilitation and stabilization programs are not undertaken. The timeframe for recovery is probably in the order of decades and is a function of i) the effectiveness of rehabilitation efforts to reduce sediment influxes from the tributary catchments and the clay banks, ii) the residence times of sediment in the tributary channels and iii) flushing rates of sediments from the bay.

The Western Port sediment study

Table of Contents

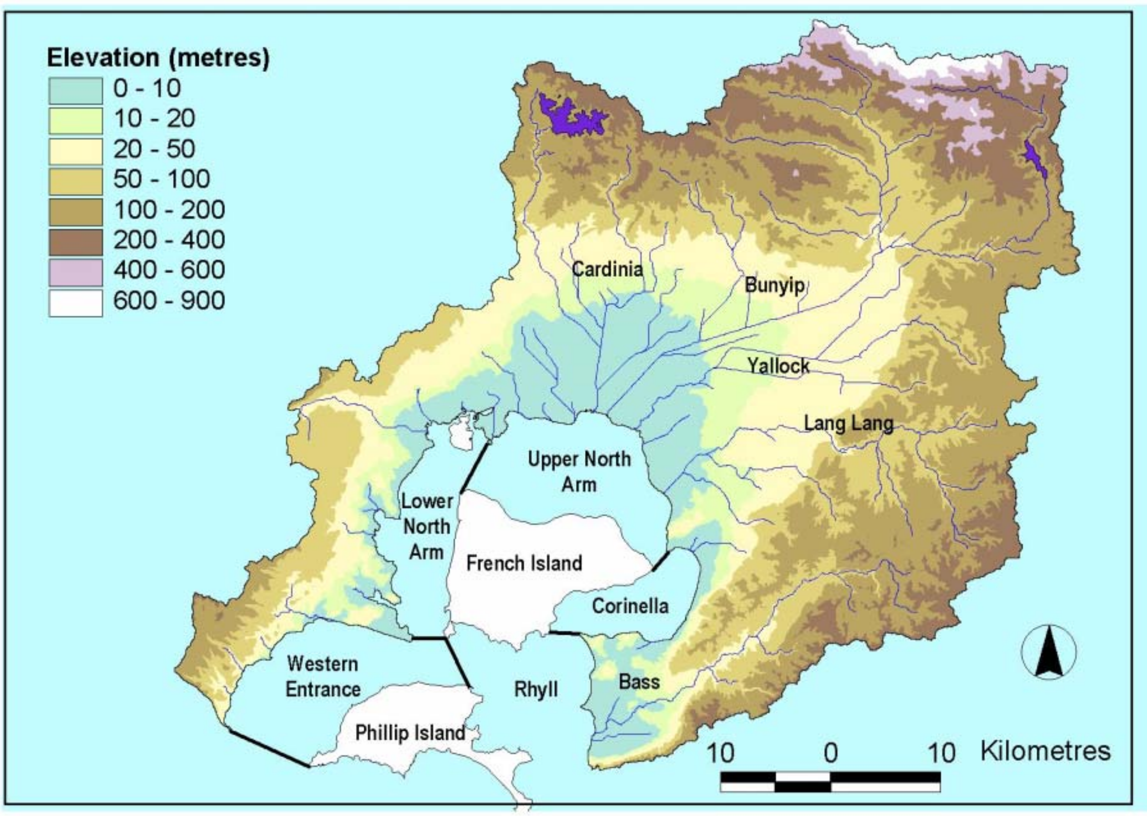

Figure 1: The segments of Western Port and major tributaries of its catchment. Note: elevation data not available for French and Phillip Island.

Introduction

This report summarises the outcomes of a three year study assessing three key sediment related themes in Western Port i) sediment accumulation in the Bay, ii) sediment redistribution in the Bay, and iii) sources of sediment to the Bay. The project was undertaken by CSIRO Land and Water, Melbourne Water and EPA Victoria. A map of the catchment showing the major tributaries, elevations and segments of the embayment are given in Figure 1. Here we provide a summary and integration of the major findings of the study. This is supported by four appendices:

Appendix A: Literature review pertaining to behavior and sources of sediment within the Western Port marine and catchment environments, published as Wallbrink, P.J. and Hancock, G., CSIRO Land and Water Technical Report 12/03, 2003.
http://www.clw.csiro.au/publications/technical2003/tr12-03.pdf

Appendix B: Technical report on sediment accumulation and redistribution in the bay, published as Hancock et al., CSIRO Land and Water Technical Report 47/01, 2001.
http://www.clw.csiro.au/publications/technical2001/tr47-01.pdf

Appendix C: Technical report pertaining to construction of suspended sediment and bedload budgets for the Western Port catchment, published as Hughes et al., CSIRO Land and Water Technical Report 4/03, 2003.
http://www.clw.csiro.au/publications/technical2003/tr4-03.pdf

Appendix D: Technical report pertaining to a tracer assessment of sediment sources to Western Port, published as Wallbrink et al., CSIRO Land and Water Technical Report 8/03, 2003.
http://www.clw.csiro.au/publications/technical2003/tr8-03.pdf

The Western Port marine environment

The marine environment of Western Port is highly dynamic. Deposited muds and sands are subject to dispersal and entrainment by tides, waves and wind forces. Sediment mixing has occurred to at least 18 cm in the eastern arm of the embayment, and 12-24 cm in the north arm. The distribution of sediment within the bay was mapped extensively in 1975 (Marsden et al., 1977) and also in 2001, (Hancock et al., 2001: Appendix B). A comparison of the <4 µm sediment size class in the intervening period shows that significant redistribution over the 26 year period has occurred (Figure 2).

What we found:

- Fine-sediment transport in Western Port is a dynamic process of resuspension and deposition driven by wind and tidal currents.
- Fine-grained sediment is being focused in eastern and southern deposition zones as a result of clockwise redistribution. Sediment appears to have been lost from the north, above French Island, accumulating in the east (Corinella) and south (Rhyll) segments. This process appears to have resulted in significant changes to the composition of North Arm sediment over the last 25 years.
- This north-south transport of fine-grained sediment is a potential cause of the persistent turbidity in the northern and eastern regions.

There has been substantial fine-sediment removal from the northern arm, above French Island and offshore from Bunyip and Cardinia Creeks. This has been matched by a significant accumulation of material in the south bay near Churchill flats, and also to the east of Phillip Island near Corinella. This is consistent with the transport of sediment in a clockwise direction around French Island (Figure 3).

Evidence supporting the clockwise redistribution of fine sediment comes from ^{210}Pb and ^{137}Cs inventories reported in Hancock et al. (2001: Appendix B). The ^{210}Pb and ^{137}Cs values increase from the north through to the east and south of French Island, reflecting the transport and focusing of fine-grained mud. The transport process appears to be driven by a series of re-suspension and deposition events on a time scale of <1 day (determined using water column measurements of ^{234}Th (Hancock et al., 2001: Appendix B). This is consistent with a tidally-driven process. Obvious symptoms of this sediment entrainment and transport process are high and persistent turbidities within the bay, particularly in the shallow northern and eastern zones.

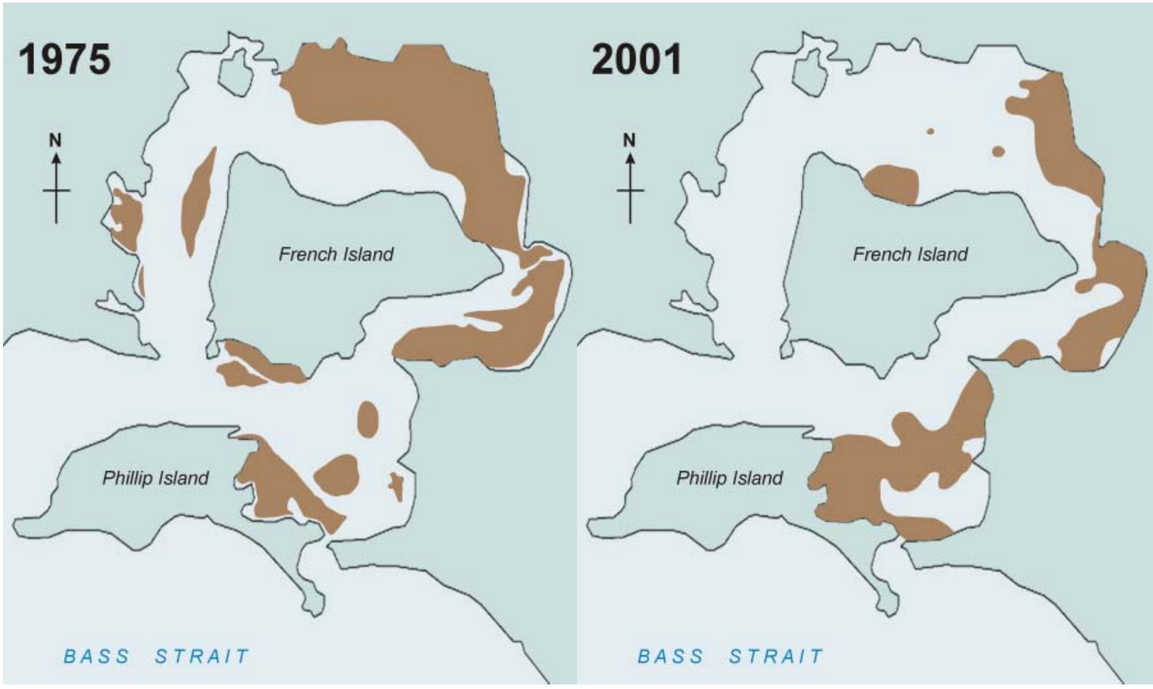

Figure 2: Redistribution of <4 μm mud, as measured by Marsden et al., (1977) '1975 map' and Hancock et al. (2001) '2001 map'.

A large proportion of fine-grained sediment entering the bay is accumulating in the eastern (Corinella) and the south-east (Rhyll) segments. The clockwise redistribution of fine material is resulting in the northern arm core material becoming sandier in texture compared to the southern and eastern cores (Figure 3). Based on accumulation rates and sediment-core studies the fine-grained sediment load in these segments is calculated to be between 70-100 kt yr^{-1} (Hancock et al., 2001: Appendix B). Due to the likelihood of mixing in the upper sediment layer, the sediment accumulation rates determined from the sediment cores are an upper limit, and are constrained to be less than 0.5 cm/yr. Sediment loads predicted by SedNet modelling (Hughes et al., 2003: Appendix C) suggest the mean accumulation rate in the north is much less than 0.5 cm/yr, possibly being as low as 0.1 cm yr.

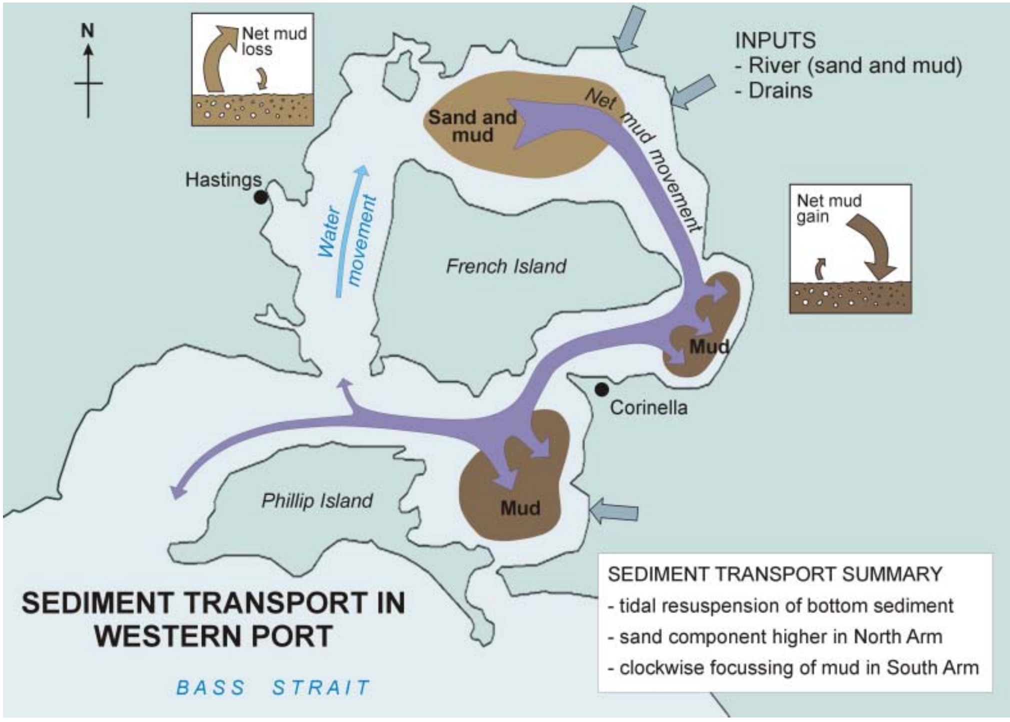

Figure 3: Summary of sediment redistribution in Western Port (from Hancock et al., 2001; Appendix B).

Implications of the research, actions for the future:

The cause of persistent high turbidities in the north and eastern segments is shown to result from daily wind and tidal-driven re-suspension, rather than continual sediment inputs from the tributary catchments.

The re-suspension and transport processes occurring in Western Port also show that sediment delivered to the North Arm has the ability to affect seagrass habitat in the eastern and southern regions by the generation of persistent turbidity, and by the rapid accumulation of fine sediment in the Corinella and Rhyll segments. Turbidity generated by re-suspension may have been exacerbated by the recent decline of the seagrass beds, and may continue to retard their re-colonisation. If this is the case, re-establishing North Arm seagrass beds is a priority to improve seagrass survival elsewhere.

The sediment accumulation rate in the North Arm is not well defined. The clockwise transport of mud indicates that not all sediment being delivered to the North Arm remains in that region. Two sedimentation scenarios are proposed for the North Arm; i) sediment will continue to accumulate at rates up to 0.5 cm/yr, ii) an equilibrium has been attained between the sediment storage redistribution (transport) such that net accumulation is approaching zero. If seagrass planting is to go ahead in the North Arm, the reality of either of these scenarios will affect the choice of seagrass species, and its location.

Unknowns and future research

- The causal link between turbidity and seagrass growth/decline needs to be well known.
- The dynamics of sediment accumulation in the North Arm needs clarification.
- A marine sediment budget needs to be constructed. This report has provided constraints on terrestrial inputs and identified internal transport pathways, but the rate of sediment movement within the embayment and material export to the ocean is unknown.
- A hydrodynamic model for the bay should be constructed. This will enable the terms of the sediment budget to be translated into a working, dynamic model of sediment redistribution, and will aid seagrass planting.

Catchment sediment inputs to the marine environment

The major potential sources of fine grained sediment to Western Port were investigated and characterised. These were the five tributary catchments (Cardinia, Bunyip, Yallock Lang Lang and Bass), clay banks to the north of Lang Lang jetty, cliffs to the south of Lang Lang jetty, and unsealed roads.

What we found:

- The Bunyip and the Lang Lang Rivers are the major catchment contributors of fine grained sediment to Western Port.
- Subsoil erosion from channels and gullies is the dominant sediment source in all the tributary catchments.
- The majority of sediment bound P is also from subsoil erosion. The largest tributary contribution of sediment–P is the Lang Lang followed by the Bunyip.
- Geochemical tracing has shown that the clay banks to the north-east of the Lang Lang River outlet are an important source of fine-grained sediment to the North Arm.
- The Bass River contributes <10 % to fine sediment in the south (Rhyll) segment.

Two independent methods were used to estimate their contributions. The first was SedNet (a GIS-based geomorphic model) which calculated fine suspended and bedload sediment loads for each of the tributary catchments (Hughes et al., 2003: Appendix C). The loads were derived by summation of modelled erosion from the soil surface, stream banks, and gullies on a river link by link basis (Prosser et al., 2001).

The model accounts for upstream and downstream inputs to each link, and includes storage. Results for suspended-sediment material are given in Table 1. They show that most of the material is delivered from the northern catchments, in particular the Bunyip and the Lang Lang Rivers. Highest yields of suspendable sediment (ie. the suspended sediment load as a function of catchment area) were from the Lang Lang followed by the Bass, although the total load from the latter was not high. The lowest yield arises from Cardinia and Yallock Creeks (Figure 4).

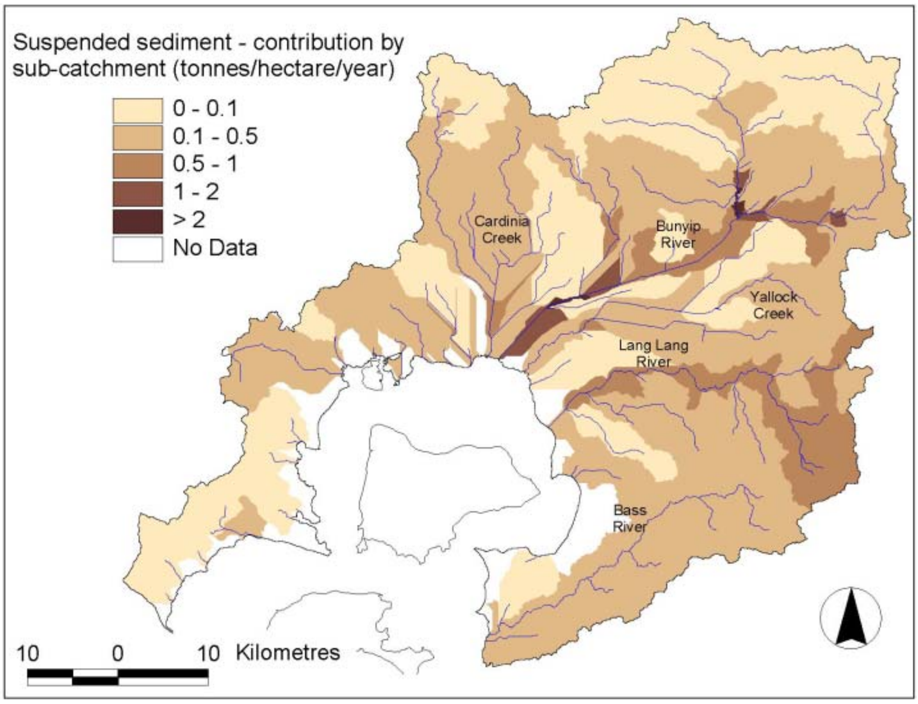

Figure 4: SedNet derivation of tributary sediment yields (from Hughes et al., 2003: Appendix C).

Table 1: Total suspended sediment export for the main Western Port watersheds as calculated by SedNet

Watershed	Area	Total suspended sediment export	Rank by load	Suspended sediment yield per unit area	Rank by yield
	(km^2)	($kt\ y^{-1}$)		($t\ ha^{-1}\ y^{-1}$)	
Bass River	266	8	3	0.30	2
Bunyip River	890	22	1	0.25	3
Cardinia Creek	398	6	5	0.15	5
Lang Lang River	423	20	2	0.47	1
Yallock Creek	286	6	4	0.21	4

The second method utilised a suite of major and minor elements (Wallbrink et al., 2003: Appendix D). Here the relative contributions from the different sources were determined by matching their elemental compositions to fine-grained (<4 µm) sediment deposited in the northern and southern regions of Western Port. Results from this method are given in Table 2. The tracer-based method agrees with the SedNet model in identifying the Bunyip and Lang Lang Rivers as major sources of sediment, but also points to the clay banks to the north-east of the Lang Lang River in addition to Cardinia Creek as significant sources. SedNet modelling did not consider erosion from the clay banks. The tracers agree with SedNet in estimating the contribution from the Bass catchment to be small (<10% of fine sediment in the Rhyll segment).

Table 2: Tracer derived contributions from each source to deposited, 4 μm sediment in the North and South Bays. Due to the clockwise transport of sediment the Bass River was not considered to be a source of sediment to the North Arm. Absolute uncertainties are ±5%, and only values above 10% are likely to be significant.

Source	**North Arm%**
Lang Lang cliffs – shoreline to south of Lang Lang jetty	0
Clay banks – shoreline to north of Lang Lang jetty	32
Cardinia River	21
Bunyip River	27
Yallock Creek	0
Lang Lang River	18
Unsealed Roads	2
	Rhyll segment
North Arm sediment	>90%
Bass River	<10%

Differences in predicted contributions from the two methods arise due to: a) particle-size differences (the tracers focus on <4 μm material, whereas SedNet calculates a result for all suspendable size classes); b) sediment-source considerations, ie. SedNet only models tributary inputs; c) the time-frame over which the methods apply; tracers probably reflect contemporary sediment input (last decade or two), whereas SedNet estimates are averaged over the last 100 years.

Both SedNet and fallout radionuclides show that subsoil eroded from gullies and channel banks is the most important source of sediment in all the major tributary catchments, making up more than 80% of sediment eroded from the Western Port catchment. Erosion of topsoil was most significant in the Bass catchment accounting for 21% of deposited sediments in the Bass River (Figure 5). However, this erosion source is minor when the total sediment flux to Western Port is considered.

Loads of phosphorus to Western Port are estimated using SedNet sediment loads and phosphorus concentrations measured on catchment soils and sediments (Table 3). The estimates are for fine suspended sediment as this is the size range for which we have phosphorus data. The data show the Lang Lang River is the largest contributor of fine sediment-bound phosphorus with approximately equal contributions from Bass and Bunyip Rivers. This ranking is different to the sediment load rankings which show Bunyip as the highest contributor, and comes about due to the lower sediment-phoshorus levels in the Bunyip compared to the other tributaries.

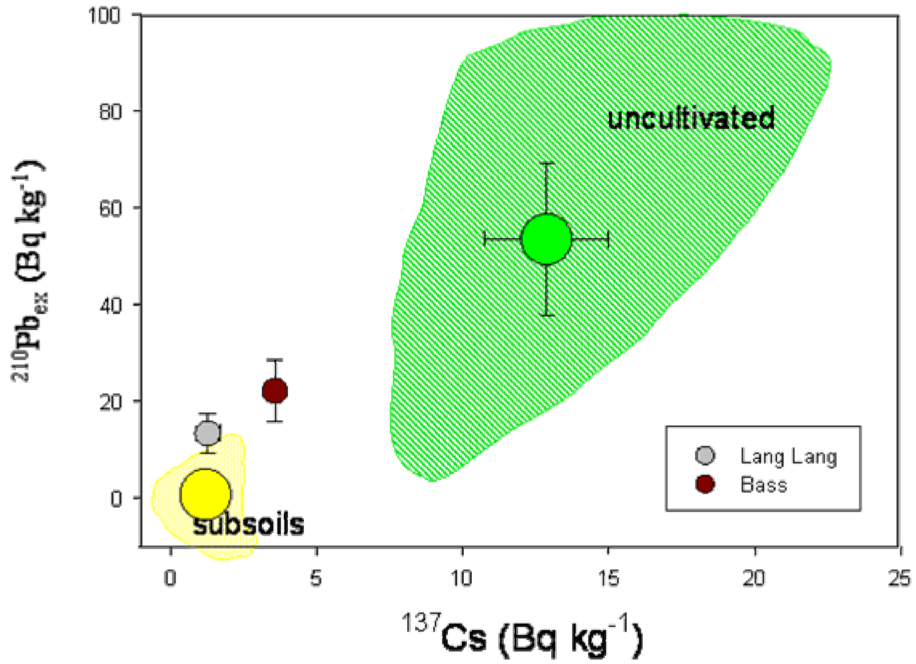

Figure 5: Mean fallout radionuclide concentrations of recently deposited sediments from the Bass and Lang Lang Rivers as well as the means and fields of the erosion sources from which they are derived (from Wallbrink et a, 2003: Appendix D).

Table 3: Estimated phosphorus loads from the tributary catchments of Western Port.

Tributary	Area	Annual fine sediment load *	Phosphorus	Annual fine sediment-phosphorus load	Rank
	(km^2)	($kt\ y^{-1}$)	($mg\ g^{-1}$)	($t\ y^{-1}$)	
Bass River	266	8	2.01	16.08_{17}	3
Bunyip River	890	22	0.74	16.28_{19}	2
Cardinia Creek	398	6	1.22	1.68_{30}	5
Lang Lang River	423	20	1.31	26.2_{3}	1
Yallock Creek	286	6	1.27	7.62_{18}	4

Implications of the research, actions for the future

The general agreement between the tracing techniques and SedNet modelling on major catchment sources and erosion processes provides a basis to assess sediment sources in order of importance, and to identify remedial action most likely to have maximum effect (Table 4). The actions listed are based on the current catchment management resource literature.

Table 4: Action plan for reducing sediment and nutrient delivery to Western Port (based on a summary and ranking of sediment sources from SedNet modeling, geochemistry and radionuclide tracing, physical measurements and available information from the literature).

Source	Status	Erosion source	Erosion process	Remediation action: short term	Remediation action: long term
Clay Banks	Major	Shoreline erosion	Slumping/wave attack	Stabilisation	Re-establishment of mangroves if appropriate
Bunyip River	Major	Subsoil	Bank erosion Gully erosion Ratio 68:32[a]	Stabilise banks	Reconnect channel to floodplains: Re-establish and manage riparian corridors
Lang Lang River	Major	Subsoil	Bank erosion Gully erosion Ratio 39:61	Stabilise gullies	Re-establish and manage riparian corridors
Cardinia Creek	Major[b]	Subsoil	Bank erosion Gully erosion Ratio 75:25	Stabilise banks	Reconnect channel to floodplains: Re-establish and manage riparian corridors
Bass River	Minor	Subsoil	Bank erosion Gully erosion Ratio 80:20	Stabilise banks	Re-establish and manage riparian corridors
Unsealed roads	Minor	Surface	mechanical action/Surface washoff	Improve roadside drainage to buffers	Establish buffers around runoff drains
Yallock Creek	Minor	Subsoil	Bank erosion Gully erosion Ratio 54:46	Stabilise gullies	Reconnect channel to floodplains: Re-establish and manage riparian corridors
Bass River	Minor	Surface soil	Sheet and rill erosion	Investigate land uses	Improved land management and re-establishment of riparian corridors
Lang Lang Cliffs	Minor	subsoil	Mechanical failure wave attack	Natural	

[a] Ratio between bank erosion yield and gully erosion yield within that tributary catchment derived from Tables 2 and 3 in Appendix C.
[b] Status derived from the geochemistry data, although on basis of SedNet this is probably the least important of the major sources.

Unknowns and future research:

- There appears to be a source of sediment bound phosphorus in the Bass catchment that is not supported by catchment erosion (outlined in Appendix D; Wallbrink et al, 2003). This is probably either initially dissolved in form or of organic nature. Likely sources are unsewered townships, or agriculture (e.g. fertilizer in runoff and livestock waste).
- The residence time of sediments in the tributary channels is unknown. This information is required to determine the timeframe over which benefits from remedial catchment action will arise. This recovery time is linked to another unknown, the rate of sediment export from Western Port to the ocean.
- Monitoring of major rivers for suspended solids and major nutrients should either continue (where underway) or commence immediately (in ungauged tributaries) so that the impacts of catchment rehabilitation works can be quantified.

Bibliography:

Prosser, I.P, Rustomji, P., Young W., Moran, C.J. and Hughes, A.O. (2001a) Assessment of River Sediment Budgets for the National Land and Water Resources Audit. CSIRO Land and Water Technical Report 15/01, CSIRO Land and Water, Canberra, 2001.

http://www.clw.csiro.au/publications/technical2001/tr15-01.pdf

Lovett, S. and Price, P. (eds) 1999 Riparian Land Management Technical Guidelines Volume one: Principles of Sound Management, Land and Water Australia, Canberra.

First National Conference on Stream Management in Australia Proceedings, 19-23 February 1996, Merrijig, Victoria, Volume I.

Second Australian Stream Management Conference Proceedings: the challenge of rehabilitating Australia's streams, 8-11 February 1999, Adelaide, South Australia, volumes I and II.

Third Australian Stream management Conference Proceedings: the value of healthy streams, 27-29 August 2001, Brisbane, Queensland, volumes 1 and II.