REVIEW OF THE

LOWER VASSE RIVER CLEANUP PROGRAM

2005

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Summary

The Lower Vasse River Cleanup Program is a successful approach to managing water quality problems through integrating technical, ecological and social factors. A large amount of on-ground activity has been completed, resulting in direct benefits to the river and several important learnings for waterway management. The overall aim of the Cleanup Program is to improve the ecological health of the Lower Vasse River. This has been achieved to a degree with obvious improvement in terms of habitat function through revegetation activities, however measurable changes in overall health including water quality and instream ecological improvements will take longer to measure. The Program is has met most of the original short term objectives, with the only shortfall being improved management of flows. Progress is being made towards the long term objectives and continued monitoring and maintenance works will be important in ensuring that this continues. A summary of Program objectives and the associated works, outcomes and recommendations is provided in Table 3.

Following completion of the major project activities the Cleanup Program has received several important awards in recognition of its success. In 2001 GeoCatch and the Shire of Busselton received an award from the Keep Busselton Beautiful Council for the revegetation works. The Cleanup Program was awarded the Living Streams Award and the Rivercare Award at the WA Landcare Awards in 2003. The program was also a finalist in the Bush, Land and Waterways Category of the 2003 WA Environment Awards and the 2004 National Landcare Awards. The Stormwater project received a WA Coastal Award in 2002 in the category of Outstanding Coastal Project.

This review has been completed to provide an assessment of the activities of the Cleanup Program to date and to assist in identifying future actions that will protect and build on the investment that has been made to date. The outcomes of this review will be used as a basis for community input to the future directions of the Cleanup Program. A summary of activities, outcomes and recommendations for the Cleanup Program is provided in Table 1. While specific recommendations are given for all elements of the Program, the priority areas for action are considered to be:

- continued partnerships to assess appropriate sediment remediation options;
- maintenance of revegetated areas in terms of weed control;
- continued revegetation with emergent and submerged plants;
- formalise agreed management of water flows through the river to maximise flushing;
- management of the feral goldfish population;
- identifying and addressing point source problems in particular septic tank leachate; and
- ongoing monitoring and evaluation to measure progress towards long term objectives.

Table 1. Comparison of objectives, outcomes and recommendations for the Lower Vasse River Cleanup Program

Short term objectives	Projects and specific objectives	Outcomes	Recommendations
To remove or treat the nutrient rich organic ooze currently accumulating in the deeper pools.	*Oxygenation* To determine whether it was physically possible to oxygenate large sections of the river (480m). To investigate the impact of the oxygen plume on the water quality of the Lower Vasse River.	Oxygenation increased oxygen levels in the river and there was some evidence of improved habitat conditions for aquatic organisms. The trial started after the onset of a major algal bloom. There was no significant effect on nutrient concentrations or phytoplankton density.	**STR1.** Use of a temporary in situ data logger to investigate diurnal fluctuations in oxygen levels would provide useful information for future use of oxygenation or aeration and Phoslock^{TM}. **STR2.** Continue investigations into future sediment remediation options in partnership with the Department of Environment.
	Dredging To create deep pools to reduce water temperature. To trial removal of the sediments to assess the logistics and the risks involved.	3000m^3 of organic sludge was removed during March 2001, creating deeper areas in the river with cooler temperatures in bottom waters. If the problem of disposal of the material could be overcome, dredging has the potential to be a viable option for removing nutrient-rich sediment and creating a deeper, cooler river system.	**STR3.** Undertake a bathymetric survey of the Vasse River to determine depth and to monitor any future changes. **STR4.** Continue to seek viable options for disposal of sediment from dredging activities, particularly marketable disposal options.
	Phoslock Trials To determine whether PhoslockTM could reduced dissolved phosphorus levels in the water column; and To determine if reduced levels of dissolved phosphorus trials had an impact on algal blooms.	Trials of Phoslock^{TM} completed in 2001, 2001-02 and 2003-04 resulted in demonstrated water quality improvements with reduced levels of dissolved phosphorus.	**STR5.** Undertake sediment core sampling to investigate remaining active Phoslock^{TM}.
To reshape the bed and banks along a 2 km length of the Lower Vasse River. To revegetate approximately 10ha of river foreshore with native plants.	*Reshaping and Revegetation* Increase shading of the river to reduce water temperatures and hence the risk of algal blooms; Promote the re-establishment of native fauna by providing a source of organic debris and habitat and providing protection from predators; Fill in existing 'deadwater' sections of the river which accumulate floating debris during low water flow; and Re-establish some natural foreshore meanders and fringing vegetation into the modified river channel, which has been straightened and widened in the past.	Reshaping in the river has included construction of terraces and an island which will provide additional areas of shading and habitat. Dredging has created deeper, cooler areas in the river. The dredging project has created deeper cooler areas in the river. 2,200 metres of foreshore was successfully revegetated along a 1,845 metre length of river, between April 2001 and December 2002. 30,000 seedlings of over 50 species were planted. Revegetation areas range from 2 to 8 metres wide, with a total area of approximately 10ha.	**RRE1.** Undertake weed control and additional plantings as follows: Isaac Street Reserve: – Fairlawn St drain to Bensted St drain: Extensive weed control and replanting is needed for the whole area. Heavy mulching is recommended to prevent weed invasion. Maintenance will need to be done to ensure the same problem does not happen again. The reed raft needs to be removed, as the bottom has fallen out and there are no plants left. – Bensted St drain to corner: This are has less weed invasion, although spraying and hand weeding is required throughout. Planting on banks is generally sufficient, with only small areas needing infill planting. The corner property has almost no plants remaining and the property owner should be consulted prior to replanting to ensure plants are considered acceptable here. – Throughout the reserve, emergent sedges should be planted on the lower banks, including *Schoenoplectus vallidus*, *Baumea articulata* and *Eleocharis acuta*.

			Southern Drive: – Revegetation has been very successful with adequate survival. Some hand weeding and spraying for annual weeds is needed in Spring, in conjunction with heavy mulching to prevent reinvasion. – Emergent sedges should be planted on the lower banks throughout, including *Schoenoplectus vallidus*, *Baumea articulata* and *Eleocharis acuta*. Causeway to Butter Factory: – Revegetation has been very successful with adequate survival. Some hand weeding and spraying for annual weeds is needed in Spring, in conjunction with heavy mulching to prevent reinvasion. – A small area either side of the footbridge was planted with very low species, which have been unsuccessful and should be replaced with *Baumea juncea*. – Emergent sedges should be planted on the lower banks throughout, including *Schoenoplectus vallidus*, *Baumea articulata* and *Eleocharis acuta*. – Plant understorey of *Lepidospermum gladiatum* (sword sedge) beneath Peppermints near Peel Terrace. – Poison remaining willow trees on southern bank near wetlands. **RRE2.** Develop landscape and revegetation plan for the northern river bank in Breeden Park and seek endorsement from community and Shire.
	Macrophyte Establishment Study A literature / knowledge search and review to explore the range of available species, their characteristics and potential suitablility; Identification of likely species for planting; Develop planting requirements for a limited number of trial species Small scale planting and monitoring to see how the plants behave Identification of issues involved in larger scale plantings.	*Vallisinaria americana* found to grow well, would become established in Vasse River easily, but population may expand rapidly. *Myriophyllum papillosum* unsuccessful, mainly due to epiphyte growth *Potamogeton crispus* unsuccessful, not attributed to epiphyte growth, apparently adversely affected by phytoplankton bloom. Trails continuing with additional species and parallel laboratory investigations. Macrophytes identified as having significant potential to improve water quality and habitat.	**RRE6.** Continue research partnership with Murdoch University to implement macrophyte establishment.
To create a series of river pools and riffles zones along a 5km section of the River.	Not achieved.	The river environment in this area resembles a lake system, because most flow is diverted. Would be feasible in upper reach of Lower Vasse River for habitat benefits but would have limited water quality outcomes.	**RCM4.** Seek opportunities for fencing and rehabilitation of river sections upstream of the main project area, linking with implementation of the Vasse River Action Plan.

To re-establish the water flow to support riverine and aquatic ecosystems.	*Reinstating Flows* Oxygenate the water. Provide improved conditions for microbial action. Reduce water temperatures and hence the risk of algal blooms. Promote the re-establishment of native fauna.	Flow management has not been formalised as initially planned. The diversion drain valve was broken in 2001, so was effectively partially open all year. It was fixed in early 2002 and closed. Water levels were very high in town throughout 2002 and the valve was left closed. Some earthworks at Ford Rd were undertaken in early 2003 to improve drainage and the valve opened. It has remained open since then.	**RRE3.** Formalised management agreement to allow maximum flows through the Lower Vasse River. Flow control structures to be managed by the Shire of Busselton in accordance with advice from the Lower Vasse River Technical Panel, taking into account the following factors: – All relevant structures influencing flow including the diversion drain valve, the Butter Factory check boards, the New River drop boards and the Vasse Floodgates; – Allow for maximum flows to be released into Lower Vasse River from the Vasse Diversion Drain, following diversion of flows from the first major rainfall event which typically has very poor water quality; – Liaise with Department of Conservation and Land Management Busselton Office in managing weeds and drainage at Ford Road to ensure water does not back up at this point. Typha control should be sensitive to nesting seasons and undertaken in late winter – spring. If required, earthworks should be undertaken in late summer when water levels are lowest. A weed management plan for this area should include replacement of Typha with native, non-invasive species. – Installation of a gauge board to allow monitoring of water levels. – Formal records of the management of structures should be kept to allow reliable assessment of water quality and water levels with regard to flow conditions. – Investigate need for replacing the Butter Factory check boards. – Investigate feasibility of enlargement of the diversion drain valve to allow for greater flushing of the Lower Vasse River.
To encourage the re-introduction of native aquatic plants and native fish populations.	*Fish Population Study* Undertake a comprehensive fish faunal survey of the Lower Vasse River. Educate local volunteers in the identification of native and introduced fishes. Formulate an eradication program of introduced fishes. Provide recommendations achieving establishment of appropriate native fish species.	Fish survey completed and report published (Morgan and Beatty, 2004). Fish population of LVR included 6 native species but is dominated by the feral mosquitofish and contains a feral goldfish population. Goldfish population may be relatively new and may increase rapidly in near future. Goldfish population is likely to contribute to algal blooms through feeding behaviour and stimulation of algae in passage through digestive system of goldfish.	**RRE4.** As recommended by Morgan and Beatty (2004), implement an ongoing goldfish eradication program with associated research objectives. Maintain research partnership with Murdoch University.
To raise the awareness of communities of the South West Region of the need to actively		The project has raised the profile of river restoration in the region and provided inspiration for several new projects by local landholders and community groups. It has also increased knowledge of appropriate techniques and	**CCI1.** Continue good communication of project outcomes. **CCI2.** Present findings of review and proposed recommendations to community to allow input to future activities.

manage our waterways.		provides a high profile demonstration site.	**CCI3.** CCI3. Provide opportunities for community feedback about the project.
To reduce nutrient sources to the Vasse River from the catchment.	*Busselton Stormwater Management* To treat the stormwater from commercial and urban areas prior to discharge into the River.	Best management practices (BMPs) were installed on stormwater drainage lines at 24 sites including interceptor devices and separators, vegetated detention, vegetated swale drains, gross pollutant and litter traps and Upgrades and alterations to the drainage network. Clean Drains awareness campaign raises awareness of schools and general community of protecting stormwater from pollution.	**UCM1.** Investigate innovative stormwater treatment options appropriate for Busselton. An Expression of Interest for a project to undertake stormwater management planning in the Shires of Busselton, Capel and Augusta-Margaret River has been submitted for inclusion in the South West Catchments Council's Regional Investment Plan. **UCM2.** Provide training opportunities for local government staff to improve maintenance operations for the stormwater system . Seek training through implementation of the Department of Environment's Stormwater Management Manual when completed. **UCM3.** Undertake an industry survey, similar to that done in the Swan-Canning catchment, to determine risk posed by activities in the industrial and commercial areas and to assess the potential benefits of Cleaner Production Training. Possible partnership with Curtin University's Centre for Cleaner Production. An Expression of Interest for a regional project to progress Cleaner Production has been submitted for inclusion in the South West Catchments Council's Regional Investment Plan. **UCM4.** Continue water quality monitoring in urban drains in partnership with local schools and Ribbons of Blue. **UCM5.** Support rehabilitation of natural wetland systems to enhance their ability to cope with pollution loads from urban areas. **UCM6.** Investigate potential risk of export of accumulated nutrients and sediments in detention basins to be exported to the river and options for managing this. **UCM7.** Continue Clean Drains awareness campaign through Ribbons of Blue and seek feedback from Ribbons of Blue Coordinators regarding potential improvements for this campaign. **UCM8.** Investigate potential point sources of nutrients to the Lower Vasse River and Vasse-Wonnerup Wetlands from unsewered areas and develop actions to intercept or treat these sources. **UCM9.** Promote 'catchment friendly gardens' to urban households to improve water quality in runoff from these areas.
	Vasse River Action Plan To work with landholders in the rural catchment to manage stock access, improve riparian vegetation and reduce nutrient inputs to the Vasse River.	Fencing of 60% of the river reduces direct inputs of nutrients and organic material from animal wastes where stock have previously had uncontrolled access to the river.	**RCM1.** Continue routine monitoring by Department of Environment at two sites on the Lower Vasse River and site 610017 on Vasse Diversion Drain to facilitate assessment of long-term trends in water quality. **RCM2.** Provide continued support for Vasse River Action Plan, DairyCatch and Nutrient Smart projects to achieve nutrient reduction in the rural catchment. **RCM3.** Seek opportunities for fencing and rehabilitation of river

			sections upstream of the main project area.
To implement a monitoring and evaluation program that will enable the community to track improvements with water quality, success of habitat establishment, and health of aquatic plants and fish populations.		Monitoring of Program success continues through: Aquatic macroinvertebrate monitoring Routine water quality monitoring by Department of Environment Photo-point monitoring of revegetation	**RRE5.** Undertake Macroinvertebrate monitoring during Spring 2005 for comparison to results from 2001. Analysis of results should focus on changes in invertebrate communities with regard to changes in habitat at various sites. Involve Ribbons of Blue in this monitoring where possible. **WQ1.** Continue long-term water quality monitoring by Department of Environment. **WQ2.** Seek assistance from DoE to estimate relative nutrient contributions to the Lower Vasse River from different sources. **RRE9.** Continue photo-point monitoring of revegetation.
Other	Use of reed rafts to create additional shading and habitat; and Feral duck capture and relocation.	Reed raft installed in Isaac St reserve area. Rapid growth of rushes commenced after installation. Use of raft for breeding by waterbirds. Feral duck capture successful but trap stolen.	**RRE7.** Installation of more reed rafts in project area, subject to design improvements. **RRE8.** Provide assistance to local wildlife group FAWNA to develop and implement a plan for capture and relocation of feral ducks from the Vasse River. There is also a need to investigate and manage the source of feral ducks, as new individuals keep appearing on the scene.

Long term objectives	**Outcomes**
To restore the ecological values (eg. fringing vegetation, native fish) and functions (eg. water flow, nutrient stripping, flood control) of the Lower Vasse River.	Native riparian vegetation has been successfully established in the project area, and continues to contribute to improved ecological functions in the river including shading, habitat and nutrient stripping. Water flows will continue to be managed in the long term. The overall monitoring and evaluation program described above will provide long term information.
To provide a high profile, practical example of integrated and coordinated river restoration within the South West Region.	The project successfully demonstrates both practical river restoration techniques, and an integrated partnership approach with strong input from the local community. The project has provided case studies used by the Department of Environment in terms of community involvement, Aboriginal liaison, sediment removal and river reshaping.
To ensure that the Lower Vasse River meets the Australian Water Quality Guidelines for protecting aquatic ecosystems.	Insufficient time has passed to assess this objective. Long term water quality monitoring by WRC will assess progress toward this objective.

Introduction

1.1 The Lower Vasse River Cleanup Program

The Lower Vasse River flows through the centre of Busselton into the internationally significant Vasse-Wonnerup Wetland System. It is highly modified and has become very degraded with serious algal blooms occurring during the warmer months. The visual impact, nuisance odours and health risks associated with algal blooms are of great concern to the community and waterways managers. In response to the problem, the Geographe Catchment Council (GeoCatch), the Department of Environment (DoE) and the Shire of Busselton developed the Lower Vasse River Cleanup Program.

Commencing in 1999, the Program aims to improve the ecological health of the Lower Vasse River and to provide a practical demonstration for integrating and coordinating technical, ecological and community input into river rehabilitation. A multidisciplinary team - the Lower Vasse River Technical Panel - was formed with technical, ecological and community liaison expertise to determine and oversee activities undertaken through the Program.

The long term objectives of the Cleanup Program are:

- To restore the ecological values (eg. fringing vegetation, native fish) and functions (eg. water flow, nutrient stripping, flood control) of the Lower Vasse River.
- To provide a high profile, practical example of integrated and coordinated river restoration within the south-west region.
- To ensure that the Lower Vasse River meets the Australian Water Quality Guidelines for protecting aquatic ecosystems.

The short term objectives of the Cleanup Program, to be achieved within three years, were:

- To reshape the bed and banks along a 2km length of the Lower Vasse River;
- To remove or treat the nutrient rich organic ooze currently accumulating in the deeper pools;
- To create a series of river pools and riffle zones along a 5km section of the River;
- To revegetate approximately 10ha of river foreshore with native plants;
- To re-establish the water flow to support riverine and aquatic ecosystems;
- To encourage the re-introduction of native aquatic plants and native fish populations;
- To raise the awareness of communities of the South West Region of the need to actively manage our waterways;
- To implement a monitoring and evaluation program that will enable the community to track improvements in water quality, success of habitat establishment, and health of aquatic plants and fish populations;
- To treat the stormwater from commercial and urban areas prior to discharge into the River; and
- To work with landholders in the rural catchment to manage stock access, improve riparian vegetation and reduce nutrient inputs to the Vasse River.

From the outset, it was recognised that there would be no single solution to the problems of the Lower Vasse River. Instead, a number of projects were developed covering four main components as follows:

- sediment treatment and removal;

- restoring river ecology;
- rural catchment management; and
- urban catchment management.

Extensive community consultation and communications are also an important part of planning and implementation of the Cleanup Program, as is ongoing routine water quality monitoring.

1.2 Purpose of the Review

An extensive amount of work has been undertaken from 1999 to 2004 through the Lower Vasse River Cleanup Program. In order to assess progress towards the objectives and to determine appropriate future activities, GeoCatch requested a review of the Cleanup Program.

This review document describes the activities that have been undertaken as part of the Lower Vasse River Cleanup Program, provides an assessment of the outcomes for each activity, and provides recommendations for future activities. Each component of the program is assessed and a summary table of activities, outcomes and recommendations is provided in the final section.

2 Sediment Treatment and Removal

2.1 Background

Additional inputs of sediment and organic material from the catchment, combined with reduced flushing of the system, have led to the accumulation of a thick layer of rich organic sludge on the riverbed. More than two metres of fine organic sediment has accumulated in some areas of the Lower Vasse River. This sediment is a significant internal source of nutrients. When oxygen is low or when sediment is disturbed by wind, nutrients are released into the water where they are available to algae. In some parts, sediment accumulation made the river less than half a metre deep during summer and conditions rapidly become very warm. The algae thrive in the nutrient rich water, especially when it is warm and there is plenty of sunlight.

An investigation into the feasibility of remediating anoxic, nutrient rich sediments in the Lower Vasse River was carried out in 1999 by Sinclair Knight Merz (SKM). Results of the study showed that the accumulated of sediment was flocculent with a very fine particle size and low density. The investigation also revealed that the sediments were high in nitrogen and phosphorus and had acid forming potential. All other chemical parameters, including heavy metals, were below guideline criteria.

As part of the Lower Vasse River Cleanup Program, trials to treat and remove the sediment have been undertaken including:

- oxygenation of the river
- dredging of a section of river to remove the sediments; and
- the use of the modified clay Phoslock^{TM}.

The use of flocculating clay to and straw bales were also trialed to determine any effect in improving water quality.

2.2 Oxygenation

The information presented here has been extracted from White (1999). Sediments in the Lower Vasse River have been identified as a substantial internal source of nutrients to the river, contributing to algal blooms. Nutrients are rapidly released from sediments under conditions of very low oxygen. Oxygenation is commonly used to treat domestic and industrial effluent, and continues to be a standard treatment for the reduction of odour, biological oxygen demand and nitrogen.

A trial of oxygenation was undertaken in the Lower Vasse River during the summer of 1998/99 with the following aims:

- To determine whether it was physically possible to oxygenate large sections of the river (480m).
- To investigate the impact of the oxygen plume on the water quality of the Lower Vasse River.

The trial was successful in that oxygen levels in the river were increased, and operation of the plant ran smoothly. There was some evidence of improved habitat conditions for aquatic organisms by providing higher oxygen levels. The monitoring program was considered to be insufficient to thoroughly assess the effects of oxygenation on water quality. Unfortunately the trial started after the onset of a major algal bloom. No significant reduction in nutrient levels was indicated, and there was no impact on the density and composition of the phytoplankton population which was already present.

White (1999) recommended further research into the potential application of oxygenation as a management option for the Lower Vasse River, with a longer period of oxygenation prior to the onset of an algal bloom. The report also suggested that there may be benefit in trialing oxygenation in combination with other remediation techniques such as Phoslock™. The Shire of Busselton has suggested investigating aeration as a cheaper alternative to oxygenation.

Prior to undertaking further trials however, more information on diurnal fluctuations in oxygen levels in the river is needed to help determine the benefits of future treatments using oxygenation or aeration and/or Phoslock™. If existing oxygen levels are adequate, oxygenation or aeration may not be of great benefit. Daytime oxygen data for the Lower Vasse River indicates acceptable levels throughout the project area in both surface and bottom waters during the day. This is probably due to oxygen production from photosynthesis by algae during the day. However little is known about oxygen levels at night, when photosynthesis is absent. This may be when low oxygen levels occur, driving nutrient release from sediments.

2.3 Dredging

Removal of all the nutrient rich sediments from the Lower Vasse River may not guarantee the prevention of algal blooms. This is because nutrient levels in groundwater and surface waters from the catchment are sufficiently high to cause a bloom on their own. In addition, logistically the removal of all the sediment is expected to be prohibitively expensive. More research would be needed to justify extensive dredging.

The main objective of the sediment removal trial was to create deep pools to reduce water temperature. High water temperature is one of the key factors that promotes phytoplankton growth and hence increases the risk of algal blooms occurring. The creation of deep pools in conjunction with the establishment of overhanging trees that will shade the river aim to achieve cooler water temperatures and reduce the likelihood of algal blooms.

A secondary objective of the sediment removal trial was to assess the logistics, costs and the risks of this activity. The project provided some useful learning outcomes.

Approximately 3,000 cubic metres of sediment was dredged from the river during March 2001. The organic sludge was pumped from the river to an evaporation dam in the light industrial area. After the sediments were left to settle overnight, excess water was drawn from the surface of the dam. This water was pumped back to the river via a stormwater basin and drain that were treated with Phoslock™. A filtration curtain was used at the end of the drain as a final treatment to remove fine sediments from the water column.

Prior to the trial the following were identified as risks associated with sediment removal:

- potential for acidification of sediments when exposed to air;
- impacts on benthic flora and fauna;
- odour generation from exposing anoxic sediments to air; and
- the input of nutrient rich water and high BOD of return waters into the Lower Vasse River.

Intensive monitoring provided good information for management of these issues during trial, and none of these potential negative impacts eventuated. There was an interesting outcome regarding acidification of sediments.

Additional analyses to determine the acid forming potential of the sediments was undertaken in March 2000 by Alan Tingay and Associates. Results confirmed that the material had significant acid generating potential when exposed to air. The recommendation was therefore to dose the dredge product with lime. Based on the laboratory results, it was estimated that 90 tonnes of lime would be needed. As this seemed excessive, a decision was made to closely monitor the pH of the dredge material, and to dose with lime as required if the pH measured less than 6. To prevent the leaching of potentially acidic material into the groundwater below the dam, the dam was lined with a fine grained lime product. Drains carrying return waters ware also lined with lime. Water quality monitoring was undertaken to assess nutrient, pH and oxygen levels in the dredged material and in return waters.

Intensive monitoring of the pH of dredged material and return waters found levels ranging from 6.35 to 9.58, generally increasing as the trial progressed. Increasing levels may be related to the lime dosing of the dam and drains. No acidification was observed in the evaporation dam as the material dried.

Nutrient levels in return waters were extremely high throughout monitoring, with average concentrations of 1.5mg/L total phosphorus and 11.2mg/L total nitrogen. The Phoslock^{TM} applied to the detention basin appeared to have little effect on phosphorus concentrations. This may have been due to insufficient contact time with water as it flowed through the basin, or insufficient amounts Phoslock^{TM} to deal with such high concentrations. These very high levels of nutrients resulted in a dense algal bloom in the river at the outflow point however this bloom was contained within the filtration curtain. Nutrient concentrations outside the filtration curtain were consistent with background levels.

Oxygen levels in dredged material were very low at around 6% saturation, however aeration resulting from pumping from the pond increased oxygen levels to around 80%. Dissolved oxygen remained at around 80% saturation on return to the river.

Routine water quality monitoring indicates that water quality (in terms of total nitrogen and total phosphorus concentrations) was significantly better in the summer of 2001/02, following dredging, than in other years. However, this cannot be attributed conclusively to dredging. Other factors that may have contributed were increased flushing due to the Diversion Drain valve being open all year and the effects of the Phoslock^{TM} trial.

The major problem with the dredging project was disposal of the dredged material. During project planning Malatesta Greenwaste Pty Ltd indicated that, once the dredge spoil was dried sufficiently to be transferred into a truck, they would take the material to their Bunbury depot and combine it with sand and other greenwaste to produce a slow release fertiliser. Some material was excavated from the dam by Malatesta however it was found to be unsuitable for this purpose because it was too fine. The material was instead used by the Shire of Busselton in rehabilitation of a gravel pit in Chapman Hill.

The dredging resulted in the removal of a substantial amount of nutrient rich sediment, and created a deeper river channel. Physical profile data has been obtained for the dredged area through the Phoslock^{TM} monitoring program. This data indicates that the depth in the dredged area has increased from less than 0.5m during summer to greater than 1.3m in parts. The increased depth has been maintained since dredging. The deeper bottom waters have cooler temperatures than surface waters. Cooler temperatures potentially provide less favourable conditions for algal blooms, and may be more suitable for native fish and other aquatic life. This is an important outcome and was the key objective of the trial. The increased depth will also have reduced sediment disturbance by wind, which has potential to cause nutrient release. Recently, shallow summer water levels due to leakage of the Butter Factory check boards have been a problem.

2.4 Phoslock™Trials

Phoslock™ is an innovative modified clay, developed by CSIRO in collaboration with the Water and Rivers Commission (now Department of Environment) designed to reduce the release of phosphorus from sediments in waterways. It acts to permanently bind filterable reactive phosphorus (FRP), which is the type available to algae. It is effective over a pH range of 5-10. By limiting the amount of phosphorus we wanted to see whether a blue-green algal bloom could be either prevented or shifted to a less harmful phytoplankton group.

Due to the experimental nature of the material at the time of trial it was manufactured as a slurry and dispersed through the water so that it would settle on the bottom in a very thin layer. By applying it this way it was discovered that the clay settled very quickly and in doing so removed dissolved phosphorus from the water overlying the sediment. During subsequent applications we tried to applied the Phoslock™ so as to remove the phosphorus from the water as or before a bloom developed and also tested whether a bloom could be stopped by an application. The clay is applied as slurry from a small boat. As it drops down through the water column it binds FRP. It then settles on the riverbed and acts as a reactive layer, intercepting any FRP that may be released by the sediment.

As part of the Cleanup Program, three trials using the modified clay product Phoslock™ were conducted in the Lower Vasse River by the Department of Environment and CSIRO (Water and Rivers Commission, 2003).

The first trial was in March 2001. At this time, a severe bloom of blue-green algae was established in the river. After Phoslock™ was applied, the levels of FRP were reduced by 95%. However the algal bloom continued. Algae are able to take up more nutrients than are required and store these for later use, and this may have sustained the algal bloom after Phoslock™ was applied. Another reason may have been efficient recycling of phosphorus within the bloom.

A second trial was undertaken during the summer of 2001-02, with an initial application made in October, before an algal bloom had established. Further applications were made in December and January. Levels of FRP were reduced by up to 86% in this trial. Although a mixed bloom of green and blue-green algae occurred in January, the density of the algal bloom was 80% lower in the treated area compared with the untreated area. This trial has shown that reduced FRP caused by Phoslock™ can limit the growth of harmful algal blooms.

A third trial was undertaken in 2003-04. Unfortunately due to delays in mixing the clay, the trial commenced after an algal bloom occurred. The bloom sustained itself for the whole summer. The little FRP that was not locked up in the algal bloom was removed by the application of Phoslock™. Concentrations of FRP were reduced from 0.22mg/L to 0.005mg/L following application and remained below this for the rest of the season. Another problem for this trial was the late and incorrect installation of the Butter Factory check boards, which led to very low water levels.

The main benefit of the Phoslock™ applications has been the permanent removal of phosphorus that had accumulated in sediments, to the extent that nutrient concentrations in the water column were reduced. By so doing algal growth was limited for some time in the order of weeks to months.

The trials have also highlighted some constraints on the use of Phoslock™ to create nutrient limitation:

- It can't be used in reaction to a bloom event – P limitation has to be maintained throughout the algal growth season. Once excess nutrients are incorporated into algal biomass it is difficult it is too late to strip out the P. Experience has shown algal blooms can occur and persist despite low concentrations of dissolved nutrients in the water column because they rapidly cycle the P from dying to growing cells.
- Keeping phosphorus concentrations low over the duration of the summer growing season is difficult to do, if all other factors are conducive to algal growth and nutrient pollution from external sources continues

- Algae and nutrients may be transported into a waterway from adjoining reaches of the waterway or drains. Nutrient limitation alone cannot effectively deal with this situation, and if conditions in the treated waterway are conducive to growth, the algae may use excess nutrients stored in their cells to multiply and reach bloom concentrations.
- Future applications of Phoslock™ will depend on the availability of funding and of a commercial supply.

Ideally, as sources of phosphorus are removed, and river ecology and catchment management improve, the required frequency of Phoslock™ applications to reduce phosphorus efflux from sediments will diminish. The investigation, and if possible, removal of potential point sources of pollution of the Lower Vasse River identified by the Department of Environment (2004) should be a fundamental element of any sediment treatment or removal strategy, regardless of the use of Phoslock™. The removal of sources of nutrient pollution would enhance the impacts of Phoslock™ applications by sustaining nutrient limitation, which in turn will reduce algal growth, decreasing the required rates and frequency of Phoslock™ application.

More information on diurnal fluctuations in oxygen levels in the river would be useful in assessing the need for future Phoslock™ applications and potential combination with oxygenation or aeration treatment.

2.5 Flocculating Clay Trial

In-river remediation techniques trialed by the Department of Environment, such as oxygenation and Phoslock™, have aimed to control cyanobacterial blooms primarily through creating nutrient limitation. However there are several limitations of trying to control algal growth solely through nutrient limitation: it can’t be used reactively; maintaining nutrient limitation to the extent that a bloom will not occur over the duration of the summer growing season is difficult to do, if all other factors are conducive to algal growth; and algae may be transported into a waterway from adjoining reaches of the waterway or drains.

Flocculating clays may provide a complimentary approach in certain situations to the techniques developed for nutrient limitation. The flocculating action of the clay doesn’t directly kill the algal cells; it merely makes them settle. The depth and clarity of the water are important factors in determining how effectively algae are removed from the photic zone. Algal cells trapped in the river silt may also be more susceptible to attack from bacteria.

Two different flocculating clays have been trialed on the Vasse River. In April 2000 a mixture of poly aluminium chloride and clay was applied to the Lower Vasse River in a joint project between WRC and CSIRO. Observations showed some flocculation did occur, although the appearance of the river was not improved overall and some milky scum did develop at the surface.

On 28 February 2002, an experimental clay developed by CSIRO was applied to an algal bloom contained within a sediment curtain on the Vasse River. Approximately 1000L of clay slurry was applied to an area of ca.10m diameter. The trial was monitored by CSIRO and results showed a visual improvement in the appearance of the treated area and a substantial decline in surface chlorophyll compared to ambient conditions. However, monitoring only continued for one day. Further trials of this flocculent have not been conducted in the Vasse River due to the difficulties in scaling up this technique, and due to the fact that the Lower Vasse River is shallower than desired for this treatment to be fully effective.

2.6 Straw Bale Trial

There has been anecdotal evidence suggesting bales of straw can be useful in managing algal blooms in farm dams. Bales of straw were placed in the Vasse River upstream of the Causeway bridge in April 2000 to trial this method. No effects on water quality were observed as a result of the straw bales being present.

2.7 Sediment treatment and removal - recommendations

STR1. Use of a temporary in situ data logger to investigate diurnal fluctuations in oxygen levels would provide useful information for future use of oxygenation or aeration and PhoslockTM.

STR2. Continue investigations into future sediment remediation options in partnership with the Department of Environment.

STR3. Undertake a bathymetric survey of the Vasse River to determine depth and to monitor any future changes.

STR4. Continue to seek viable options for disposal of sediment from dredging activities, particularly marketable disposal options.

STR5. Undertake sediment core sampling to investigate remaining active Phoslock^{TM}.

3 Restoring River Ecology

3.1 Background

The river form has been greatly modified in the project area. Major clearing of the fringing foreshore vegetation has occurred on the Lower Vasse River since European occupation, as part of past activities to 'beautify' the river and allow access to the river's edge for recreation purposes. In town this was replaced largely with lawn foreshores and deciduous trees. The river channel has been significantly widened and flow volumes have been substantially reduced.

Past changes to the river's natural form have impaired the natural ecological functions of the river. It does not provide the diverse habitat needed by many of our native animals, both on the land and in the water. Lawn requires fertilisers that make their way to the river. Lawn cuttings and leaves from deciduous trees contribute excess organic matter to the river. This material decomposes to become part of the organic sludge on the riverbed.

It was identified that improving water quality and sustaining this improvement long term was best achieved by restoring the natural ecological functions of the river environment. This is a major aim of the Cleanup Program and a major project was initiated to reshape and revegetate the Lower Vasse River. The objectives of this project were:

- Increase shading of the river to reduce water temperatures and hence the risk of algal blooms; and
- Promote the re-establishment of native fauna by providing a source of natural organic debris and habitat.
- Fill in existing 'deadwater' sections of the river which accumulate floating debris during low water flow; and
- Re-establish some natural foreshore meanders and fringing vegetation into the modified river channel, which has been straightened and widened in the past.

In addition to reshaping and revegetation, the Cleanup Program is addressing ecological improvement through:

- reinstating flow in the river through improved management of the diversion drain valve;
- investigation of fish populations in partnership with Murdoch University;
- research into the establishment of aquatic macrophytes in partnership with Murdoch University;
- monitoring of aquatic macroinvertebrate monitoring;
- use of reed rafts to create additional shading and habitat; and
- feral duck capture and relocation.

3.2 Revegetation

About 50,000 native plants of over 30 species were established through revegetation activities. Revegetation has clearly been successful, with vigorous growth and obvious improvements in habitat with many waterbirds nesting in the new vegetation. Most species grew successfully. There were problems with establishing some rushes and sedges on the waterline where water birds pulled seedlings out. This was particularly a problem with coots plucking out emergent plants, such as *Baumea articulata* and *Eleocharis acuta,* which had significant plant losses. In the case of *E. acuta* wire netting placed over new plants to protect them was successful.

The retention of some open parkland areas and creation of areas with only low vegetation has maintained some access to the river and views. Historically, the Lower Vasse River has been a focal point for the community for a variety of recreational activities including regional festivals. The revegetation project has found a balance between maintaining social values and establishing fringing vegetation that will benefit the river in the long term.

Photo points are used to monitor the progress of revegetation, which has clearly been successful. In addition to vigorous growth, there are obvious improvements in habitat with many waterbirds nesting in the new vegetation.

3.2.1 Weed Control

Dense kikuyu growth on the banks had to be controlled for successful revegetation. This was achieved mainly by scalping back lawns from the foreshore using an excavator or treating the lawn in steep areas using glyphosate herbicide. Roundup Biactive was used as this does not contain a wetting agent and so is less harmful to frogs. In Stage 2 all lawn areas were sprayed with herbicide prior to scalping and this has resulted in less regrowth of kikuyu but other weed invasion has still been a problem. Edging of revegetated areas was needed to control lawn invasion and to provide a mowing edge. For Stage 1 a limestone trench edge was created 0.5m deep and filled with limestone rubble. For Stage 2 a similar trench was created and filled with limestone road base with a limestone pathway 1.0m wide created above this. This allowed good access along the river in this more popular area. At Isaac St Reserve Timber edging was installed using Jarrah sleepers dug half into the ground. The limestone trench and pathways have been more effective than the wooden sleepers.

Ongoing control of grass and other weeds in the revegetated areas is important. In some areas this has gone unchecked and is now a big job. Due to the dense plantings, only very careful hand-spraying or hand–pulling of weeds is possible. As native plants mature they will shade out weeds and less weed control maintenance will be needed. Dense mulching is effective in reducing weed invasion and is needed throughout the project area.

3.2.2 Deciduous Tree Removal

The revegetation project also involved the removal of exotic deciduous trees along the margins of the river that have the potential to drop leaves into the water thus contributing to nutrient and organic load.

Isolated deciduous trees along the foreshore were uprooted and removed with an excavator. An area of dense silver poplar trees upstream of the Causeway was also removed with an excavator. The growth was too dense to poison trees and plant amongst them. These trees had a large number of nests and it was planned to leave those trees that overhung the water for nesting. Unfortunately the logistics of removal did not allow for this because the dense mass of trees had entangled root systems and all trees were removed. The trees were removed during winter and not during breeding season. The nest were mainly cormorant nests, and these birds tend to be opportunistic nesters, so could easily build new nests in the adjacent area of flooded gums (Jim Lane, pers comm). The revegetation in this area has already become well-established and is likely to provide suitable nesting sites in the near future.

An area of willow trees opposite the Butter Factory Museum were poisoned and the dead trees left in place to allow nesting sites to remain while new plants matured. This has worked well and was feasible as the willows were spaced sufficiently to allow planting between them.

3.3 Reshaping Bed and Banks

The banks were reshaped to create areas suitable for revegetation. Reshaping involved creating terraces in front of steep banks, and also the construction of island. The objectives of developing islands and terraces were to:

- Shade the river where it is at its widest to reduce water temperatures and hence the risk of algal blooms;
- Promote the re-establishment of native fauna by providing a source of organic debris and providing protection from predators;
- Fill in existing 'deadwater' sections of the river which accumulate floating debris during low water flow; and
- Re-establish some natural foreshore meanders and fringing vegetation into the modified river channel, which has been straightened and widened in the past.

Western Australia has no previous examples of construction of terraces and islands in rivers, and so these techniques had to be developed. Terraces were created by the infilling of designated sections of the river with a mixture of limestone rocks and sand based fill. Fill was stabilised by the placement of matting over the surface and planting native vegetation. The island was constructed in the same way, filling outwards from the shore and then digging away the land bridge at the end. The increase in water levels and associated flooding potential was assessed by Shire of Busselton's engineers prior to these works, and no additional flood risk has been created.

An Aboriginal site monitor was on site during all earthworks. In addition to monitoring for any items of cultural significance, the monitor tried to relocate any fauna such as frogs and gilgies to avoid harm.

Reshaping of the river bed through dredging has created deeper, cooler sections of river that provide more favourable conditions for aquatic fauna.

3.4 Reinstating Flow

In 1927, the Vasse Diversion Drain was constructed which now accepts 90% of the Vasse River catchment, diverting it away from the Lower Vasse River and the Vasse-Wonnerup Wetlands System and directly into Geographe Bay to the west of the main Busselton township. The construction of the drain allowed the town of Busselton to expand into previously flood prone land.

The source of the Lower Vasse River is now a 900mm flow pipe set in the base of the Vasse Diversion Drain. Flow into the Lower Vasse River is limited to releases from a valve on the pipe and surface runoff from the localised catchment. The Lower Vasse River terminates at a check board structure located near the Butter Factory in the centre of Busselton township. This structure separates the Lower Vasse River from the Vasse-Wonnerup Wetlands System and acts to artificially maintain water levels in the Lower Vasse River during summer. Flow is also influenced by operation of the Vasse Floodgates downstream. Another drop board structure is located between the Vasse River and the New River Wetland opposite the Busselton Shire offices. Boards have not been in place here for about 20 years (Frank Elliot, pers comm).

Diversion of flow and installation of the check boards has greatly reduced the amount of flushing in the Lower Vasse River and the area is now more like a wetland than a river. There is no water flow data collected for the Lower Vasse, however, it can be assumed that flows are very low to non-existent in summer and low in winter. Reinstating flows in the Lower Vasse River was one of the major objectives of the Cleanup Program.

Initial discussions within the multi-disciplinary team identified opening of the valve in summer as one of the key ways to re-instate flow and improve water quality when at its poorest. Discussions with CALM on this management option identified potential impacts of altering the hydrological regime on the Melaleucas (Paperbarks) in the Vasse-Wonnerup Wetlands, downstream of the Lower Vasse River. These paperbarks require a period of low water levels over summer to survive and are currently at their limit of summer/autumn inundation. Observations of flows since commencement of the Program indicate that summer flows in the Vasse Diversion Drain are probably insufficient to allow water through the valve into the Lower Vasse River.

There was also a perception that that the valve needs to be closed in winter during peak rainfall times to direct water through the diversion drain and prevent flooding in Busselton. It was suggested that opening the valve in spring would be the best option for improving water quality in the Lower Vasse River. Advice from the Department of Environment (Rick Bretnall, pers comm) suggests that opening the valve during winter will not contribute to flooding in Busselton.

The environmental objectives of managing the valve at the Vasse Diversion Drain to re-instate a flow in spring were to:

- oxygenate the water;
- provide improved conditions for microbial activity;
- reduce water temperatures and hence the risk of algal blooms; and
- promote the re-establishment of native fauna.

The diversion drain valve was broken in 2001, so was effectively partially open all year. It was fixed in early 2002 and closed. Water levels were very high in town throughout 2002 and the valve was left closed. Some requests from landholders downstream of the valve were made in spring 2002 to open the valve however this was not done due to a possible risk of water backing up in the wetlands upstream of Ford Rd, where there is a large infestation of Typha weed. Some earthworks at Ford Rd were undertaken in early 2003 to improve drainage and the valve opened. It has remained open since then. Management of weeds at Ford Road area and earthworks to improve flow will be important in managing flows to ensure water does not back up at this point. Typha control should be undertaken in late winter – spring and any earthworks in late summer.

It is difficult to analyse water quality data with respect to flows because records have not been kept. This should be done in the future to allow reliable assessment of water quality and water levels with regard to flow conditions. However water quality was very poor over the summer of 2002-03, when the valve had been left closed all year.

Flow management has not been formalised as initially planned and this needs to be addressed in the future. There is still a perception that improved management of flows could increase flushing of the Lower Vasse River and improve water quality. Management should take into account all structures influencing flows in the lower Vasse River: the diversion drain valve, the Butter Factory check boards, the New River drop boards, and the Vasse floodgates. In particular, timely management of the diversion valve and butter factory check boards would be of benefit. Depending on additional advice regarding flooding risk the optimal scenario may be to divert flows from the first major rainfall event, which typically has very poor water quality, then open the valve and remove the check boards to allow maximum flows through the Lower Vasse River for the remainder of the flow season.

3.5 Fish Population Studies

Initial monitoring of fish populations in the Lower Vasse River by Murdoch University in November 2001 involved a basic survey using throw nets. This identified two native fish species, the western hardyhead (*Leptatherina wallacei*) and the Swan River goby (*Pseudogobius olorum*). Large numbers of the introduced mosquitofish (*Gambusia holbrooki*) were also found. No carp or goldfish were found during this survey.

A comprehensive fish faunal survey of the Lower Vasse River was undertaken by Murdoch University's Centre of Fish and Fisheries Research using a grant from Fishcare WA. Morgan and Beatty (2004) provide a detailed report on this survey and the information here has been extracted from this.

An initial survey in December 2003 followed by a major sampling occasion in March 2004 identified the presence of six native fish species including the Swan River goby, western hardyhead, western minnow (*Galaxias occidentalis*), nightfish (*Bostockia porosa*), western pygmy perch (*Edelia vittata*), and sea mullet (*Mugil cephalis*). The estuarine Swan River goby and western hardyhead were most dominant of these. It also identified the introduced mosquitofish and goldfish (*Carassius auratus*), with the mosquitofish dominating in most sections.

91 goldfish were found in the survey ranging in size to over 40cm. Based on age structure, the establishment of goldfish in the Lower Vasse River appears to have been relatively recent and is a major concern for river management. Research has demonstrated that growth rates of some blue-green alga species are increased by passage through goldfish intestines (Kolmakov and Gladyshev, 2003). Goldfish also disturb bottom sediments during feeding and this may lead to release of nutrients and contribute to algal blooms. The current population is likely to expand rapidly and an eradication program is needed to manage this problem.

Researchers were also concerned by restricted flow conditions in the Lower Vasse River which are likely to have contributed to poor water quality, facilitated establishment of the feral species and may be an impediment to movement of native fish.

3.6 Macroinvertebrate Monitoring

Monitoring of aquatic macroinvertebrates is often used to assess the health of waterways and is being used to assess the improvements in aquatic habitat achieved through the Cleanup Program. Sampling was undertaken at five sites during October 2001. Future sampling at these sites will help to determine the whether the vegetation is providing enhanced habitat and if the ecology of the river is changing.

Site 1 is located in the adjacent New River Wetland where healthy native vegetation and varied habitat remains, acting as a reference site. Site 2 is along the lawn foreshore at Breeden Park, where no revegetation is planned. Sites 3 is a revegetated area in front of the Busselton Shire offices, which at the time was very bare with only small seedlings present. Site 4 is a revegetated area on the river bend with some existing native vegetation. Site 5 is just upstream of Strelly St bridge with lawn and some overhanging native species.

Samples were identified to species level and abundance of each species recorded and results are shown in Table 1 below. This sampling event will provide good baseline data for comparison with future sampling to evaluate improvements in aquatic habitat.

In general all sites had species which are indicative of nutrient-enriched waters. The reference site (Site 1) had the highest diversity of species. This site also had several species of Hydrophillidae (water scavenger beetles) that were absent from all other sites. Large numbers of the amphipod *Austrochiltonia subtenuis* were also found at this site, while only 2 were found at site 4 and none at other sites. One species of Trichoptera (caddisfly larvae) was found (*Triplectides australicus*) during sampling, present at all sites but in much larger numbers in the grassy sites (2 and 5), using grass cuttings as cases. Site 3 had the lowest diversity but highest abundance, mainly due to large numbers of the waterboatmen genus *Micronecta*. This site was the most exposed with no shade and this is probably an important factor. *Micronecta* was common at Sites 1, 2, 3 and 4, and is known to respond positively to eutrophication (Davis and Christidis, 1997). The introduced aquatic snail *Physa acuta* was abundant at all sites. Non-biting midge larvae (family Chironomidae) were common at all sites. Chironomids of the genus *Chironomus*, which are common in organically polluted waters (Gooderham and Tsyrlin, 2002), were abundant at sites 1, 3, 4 and 5.

Table 2. Species diversity and abundance in Lower Vasse River, October 2001

Site	Species Diversity	Abundance	Dominant species
1	33	362	Amphipod *Austrochiltonia subtenuis* (102), Waterboatmen *Micronecta sp*. (47); *Chironomus sp*. (45); Snail *Physa acuta* (30).
2	24	270	Snail *Physa acuta* (78); Waterboatmen *Micronecta robustum* (59), *Micronecta sp*. (35).
3	14	443	Waterboatmen *Micronecta sp*. (243), *Agraptocorixa sp*. (61); *Chironumus aff. alternans* (55); Snail *Physa acuta* (48).
4	25	354	Waterboatmen *Micronecta sp*. (167); Snail *Physa acuta* (65); *Chironumus aff. alternans* (32).
5	32	270	*Chironomus aff. alternans* (85); Caddisfly larvae *Triplectides australicus* (43); Waterboatmen *Agraptocorixa sp*. (33); Snail *Physa acuta* (26).

3.7 Macrophyte establishment

Recently GeoCatch and the Department of Environment have negotiated a research partnership with Murdoch University, through the Cleanup Program, to investigate the potential for establishment of submerged aquatic plants (macrophytes) in the system as a means of improving habitat and water quality. This investigation was undertaken as an honours research project during spring and summer 2003-04, and the results described below are taken from the thesis for this work (Novak, 2004).

The three species of submerged plants trialed in this project were *Vallisineria americana*, *Potamogeton crispus* and *Myriophyllum papillosum*. Of these, only *V. americana* grew successfully. Failure of *M. papillosum* was primarily due to an excessive epiphyte load, and death of *P. crispus* was due to phytoplankton blooms. While *V. americana* was successful in this trial, establishing this species in the Lower Vasse River should be approached cautiously because it has potential to grow throughout the river, possibly dominating the entire system.

High nutrient concentrations are a major factor limiting the ability to establish macrophytes due to the effect on epiphyte and phytoplankton growth. Phoslock^{TM} has the potential to reduce nutrient concentrations sufficiently to allow a ‘window of opportunity’ for establishment of macrophytes.

Macrophytes appear to have the potential to limit algal blooms through providing important habitat for grazing organisms which limit growth of phytoplankton. Habitat would also be improved for other native fauna.

Trials using other species and establishment techniques are continuing to further assess the potential for using macrophytes in restoration of the Lower Vasse River. Similar research is being done in the Canning River in Perth, and laboratory trials are also being undertaken to assess tolerance of plants to different nutrient concentrations. Future trials are likely to involve longer term studies of larger scale plantings for those species that can be successfully established.

3.8 Reed Raft

A reed raft island was installed in the Lower Vasse River in summer 2002-03 to provide an initial assessment of this option for providing additional areas of shade and habitat and instream plants. The raft was approximately 1.5 by 2.0 metres, constructed of a frame of PVC pipe inlaid with a plastic mesh base and jute matting. The raft took some time to prepare due to low initial growth rates. Once placed in the river, growth of sedges was rapid and waterbirds began nesting on the reed raft. During the summer of 2004-05 the bottom of the raft collapsed and sank.

With some design improvements, reed rafts have potential to provide additional areas of shade and habitat in a short time frame. There is also potential to harvest rushes and sedges when mature for planting on river banks.

3.9 Feral Duck Relocation

Feral ducks are common along the Lower Vasse River, particularly in Breeden and Rotary Parks. These ducks compete with native species and are also very aggressive. Many people are tempted to feed the feral and native ducks and this contributes more nutrients to the river. Local wildlife group FAWNA has been coordinating removal of feral ducks from the river. The ducks were captured using a trap made from framing and netting, and given to local vineyards. Unfortunately the trap was stolen, somewhat hampering efforts. FAWNA should be supported to try this again if they are keen to assist.

3.10 Restoring River Ecology – Recommendations

RRE1. Undertake weed control and additional plantings as follows:

Isaac Street Reserve:

- Fairlawn St drain to Bensted St drain: Extensive weed control and replanting is needed for the whole area. Heavy mulching is recommended to prevent weed invasion. Maintenance will need to be done to ensure the same problem does not happen again. The reed raft needs to be removed, as the bottom has fallen out and there are no plants left.
- Bensted St drain to corner: This are has less weed invasion, although spraying and hand weeding is required throughout. Planting on banks is generally sufficient, with only small areas needing infill planting. The corner property has almost no plants remaining and the property owner should be consulted prior to replanting to ensure plants are considered acceptable here.
- Throughout the reserve, emergent sedges should be planted on the lower banks, including *Schoenoplectus vallidus, Baumea articulata* and *Eleocharis acuta*.

Southern Drive:

- Revegetation has been very successful with adequate survival. Some hand weeding and spraying for annual weeds is needed in Spring, in conjunction with heavy mulching to prevent reinvasion.
- Emergent sedges should be planted on the lower banks throughout, including *Schoenoplectus vallidus, Baumea articulata* and *Eleocharis acuta*.

Causeway to Butter Factory:

- Revegetation has been very successful with adequate survival. Some hand weeding and spraying for annual weeds is needed in Spring, in conjunction with heavy mulching to prevent reinvasion.
- A small area either side of the footbridge was planted with very low species, which have been unsuccessful and should be replaced with *Baumea juncea.*
- Emergent sedges should be planted on the lower banks throughout, including *Schoenoplectus vallidus, Baumea articulata* and *Eleocharis acuta*.
- Plant understorey of *Lepidospermum gladiatum* (sword sedge) beneath Peppermints near Peel Terrace.

- Poison remaining willow trees on southern bank near wetlands.
- Develop landscape and revegetation plan for the northern river bank in Breeden Park and seek endorsement from community and Shire.

RRE2. Formalised management agreement to allow maximum flows through the Lower Vasse River. Flow control structures to be managed by the Shire of Busselton in accordance with advice from the Lower Vasse River Technical Panel, taking into account the following factors:

- All relevant structures influencing flow including the diversion drain valve, the Butter Factory check boards, the New River drop boards and the Vasse Floodgates;
- Allow for maximum flows to be released into Lower Vasse River from the Vasse Diversion Drain, following diversion of flows from the first major rainfall event which typically has very poor water quality;
- Liaise with Department of Conservation and Land Management Busselton Office in managing weeds and drainage at Ford Road to ensure water does not back up at this point. Typha control should be sensitive to nesting seasons and undertaken in late winter – spring. If required, earthworks should be undertaken in late summer when water levels are lowest. A weed management plan for this area should include replacement of Typha with native, non-invasive species.
- Installation of a gauge board to allow monitoring of water levels.
- Formal records of the management of structures should be kept to allow reliable assessment of water quality and water levels with regard to flow conditions.
- Investigate need for replacing the Butter Factory check boards.
- Investigate feasibility of enlargement of the diversion drain valve to allow for greater flushing of the Lower Vasse River.

RRE3. As recommended by Morgan and Beatty (2004), implement an ongoing goldfish eradication program with associated research objectives. Maintain research partnership with Murdoch University.

RRE4. Undertake Macroinvertebrate monitoring during Spring 2005 for comparison to results from 2001. Analysis of results should focus on changes in invertebrate communities with regard to changes in habitat at various sites. Involve Ribbons of Blue in this monitoring where possible.

RRE5. Continue research partnership with Murdoch University to investigate implement macrophyte establishment.

RRE6. Installation of more reed rafts in project area, subject to design improvements.

RRE7. Provide assistance to local wildlife group FAWNA to develop and implement a plan for capture and relocation of feral ducks from the Vasse River. Investigate and manage the source of feral ducks, as new individuals keep appearing on the scene.

RRE8. Continue photo-point monitoring of revegetation.

4 Rural Catchment Management

4.1 Background

Degraded river systems in the catchment contribute to poor water quality in receiving waterbodies. While much of the Vasse River catchment has been diverted, there is still a significant contribution of inflows from rural areas to the Lower Vasse River through the valve. Clearing and uncontrolled stock access to rivers have had a major impact on fringing or riparian, vegetation. Riparian vegetation is important in maintaining bank stability, intercepting runoff and also for maintaining river ecology. Where stock are allowed free access to rivers, their waste products are readily mobilised and moved downstream, contributing nutrients and organic matter. Poor land management including excessive use of fertilisers can also contribute to poor water quality.

The Vasse River Action Plan was developed in partnership with the Vasse-Wonnerup Land Conservation District Committee (LCDC) to provide information on the state of the Vasse River and to recommend strategic management actions to improve water quality and river ecology. The plan was produced in 2000 and continues to be implemented, with advice and funding provided to landholders to undertake river restoration activities. These activities primarily include fencing, erosion control, weed control and revegetation.

In the rural catchment area, implementation of the Vasse River Action Plan by landholders through the Vasse-Wonnerup Land Conservation District Committee (LCDC) has resulted in fencing of 60% of the river. This reduces direct inputs of nutrients and organic material from animal wastes where stock have previously had uncontrolled access to the river. Work continues to encourage and assist landholders to undertake river restoration project. This project is complemented by the Water Corporation's Environmental Improvement Initiative (EII) and, more recently, the DairyCatch project, which target nutrient reductions in the rural catchment through implementing best management practice.

The Department of Environment routinely monitors water quality in the Vasse Diversion Drain (Site 610014). Recent data analyses by the Department of Environment (2004) classified total nitrogen concentration at this site as moderate for the period 2001-2003, with a median concentration of 1.28 mg/L. No trend in total nitrogen concentrations was detected. Similar analyses were not done for total phosphorus due to inadequacies in data. Annual load estimated of total phosphorus and total nitrogen were extremely variable and strongly related to annual flows.

4.2 Rural Catchment Management – Recommendations

RCM1. Continue routine monitoring by Department of Environment at site 610017 on Vasse Diversion Drain to facilitate assessment of long-term trends in water quality.

RCM2. Provide continued support for Vasse River Action Plan, DairyCatch and Nutrient Smart projects to achieve nutrient reduction in the rural catchment.

RCM3. Seek opportunities for fencing and rehabilitation of river sections upstream of the main project area.

5 Urban Catchment Management

5.1 Background

A large part of the Lower Vasse River catchment comprises urban land uses. Prior to the Cleanup Program, most of the stormwater from commercial, industrial and residential areas drained directly into the Lower Vasse River via stormwater drains without filtration or treatment of any kind.

One of the key strategies of the Lower Vasse River Cleanup Program is to treat the stormwater from urban areas prior to discharge into the River. Under an agreement with the Water and Rivers Commission, the Federal Government's Coasts and Clean Seas program committed $250,000 towards implementing stormwater management in the Lower Vasse River catchment. The Shire of Busselton and GeoCatch have jointly managed the project which has included active improved management of stormwater and raising community awareness of stormwater pollution through the Clean Drains campaign. This project received a WA Coastal Award in 2002 in the category of Outstanding Coastal Project.

The impact on water quality in the Lower Vasse River of septic tank leachate in the urban catchment has not been addressed through the Cleanup Program, however has been identified as a potentially significant source of nutrients in catchment modelling analysis done by the Department of Environment (DoE, 2004). In particular the Vasse River Resort is situated directly on the banks of the river near Strelly St Bridge and is unsewered. Septic tank leachate from this source may be a significant nutrient source which could be directly managed.

5.2 Stormwater Management

Best management practices (BMPs) were installed on stormwater drainage lines at 24 sites. The Water and Rivers Commission's *Manual for Managing Urban Stormwater Quality in Western Australia* formed the basis of planning and design for the upgrade of Busselton's stormwater drainage system. BMPs included interceptor devices and separators to remove oils and grit from stormwater before it enters the river, vegetated detention basins to slow and filter stormwater and allow sediment deposition, vegetated swale drains and gross pollutant and litter traps. Upgrades and alterations to the drainage network were also required.

This project has become a demonstration initiative, providing many learning outcomes that can be shared with others. It has improved the capacity of the Shire of Busselton to manage stormwater throughout the shire, and to make improved recommendations to developers.

The major BMP type implemented was construction of stormwater detention basins. Monitoring of drains and basins was undertaken in 2002 to investigate effectiveness of stormwater detention basins and to determine the levels of pollutants in stormwater.

Monitoring of drains in 2003 aimed to determine levels of pollutants in drains without any BMPs installed with the aim of guiding future management, and to further investigate the effectiveness of Fairlawn St detention basin. Year 11 Biology students from McKillop Catholic College assisted with monitoring since 2003.

Only Fairlawn Street detention basin indicated any nutrient stripping effectiveness, with concentrations of nitrogen, phosphorus and suspended solids generally lower flowing out of the basin than coming in from stormwater pipes. This drain differs from the others in design, with an elongated shape, and also has more in-stream vegetation established. The exception to this was during the first storm event sampled in 2003, where phosphorus concentrations exiting the drain were higher.

This outcome suggests that the desired shape for stormwater treatment basins is a widened drain with minimal storage of water and maximum perennial in-stream vegetation. Redesigning drains may therefore be preferable to building more detention basins in the Busselton area. The most effective systems for improving water quality entering Geographe Bay are probably the wetlands themselves. It may be a more efficient management option to protect and enhance the natural functions of the Busselton wetlands than constructing detention basins.

Although nutrient levels were sometimes elevated during storm event sampling, overall nutrient concentrations were low to moderate for stormwater drains in the Busselton area (Table 2). High nutrient concentrations were generally associated with storm events, however not all storm events resulted in high concentrations in drains.

Table 3. Median and maximum total nitrogen and total phosphorus concentrations in stormwater drains in Busselton and nutrient classification status.

Site	TN Median (mg/L)	TN Maximum (mg/L)	TN status	TP Median (mg/L)	TP maximum (mg/L)	TP status
Petit Cres	1.54	2.6	moderate	0.034	0.042	low
West St	1.60	1.9	moderate	0.088	0.100	low
Ford Rd	0.77	2.5	low	0.088	0.088	low
Causeway Dr	0.66	2.2	low	0.110	0.220	moderate
Bunbury St	1.10	5.1	moderate	0.035	0.150	low
Fairlawn St	1.60	6.6	moderate	0.058	0.550	low
Frederick St	0.76	1.6	low	0.045	0.210	low
Strelly St	0.61	1.5	low	0.070	0.190	low

With regard to other pollutants in the stormwater system, drainage waters contained undetectable or acceptable concentrations for most toxicants including hydrocarbons, pesticides, volatile organic compounds and arsenic. Surfactants were detected in Frederick Street and Strelly Street drains but no guideline is available for this parameter. While hydrocarbons were not detected, a distinct petroleum smell was noted at Fairlawn Street drain on several sampling occasions, which discharges opposite a Caltex service station. Hydrocarbons are very volatile and difficult to monitor, but will continue to be an important parameter for monitoring at this site.

Some heavy metal concentrations were of concern, particularly chromium, copper, lead and zinc (Figure 1). Most drains significantly exceeded the copper guideline of 0.014 mg/L. West Street and Ford Road drains had elevated levels of chromium and lead. All monitored drains all had Zinc levels much higher than the guideline of 0.008 mg/L. Targeting more awareness-raising efforts at businesses may be beneficial in managing this problem.

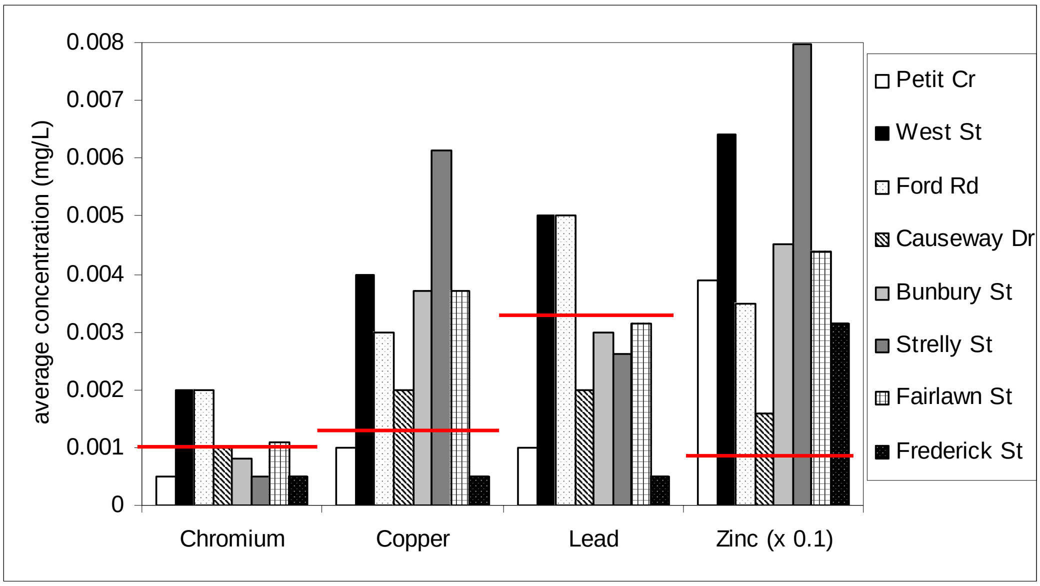


Figure 1. Average heavy metal concentrations found in Busselton stormwater drains in 2002-03. Lines indicate guideline concentrations for protection of aquatic ecosystems (ANZECC, 2000).

5.3 Clean Drains Awareness Campaign

Reducing pollution at its source is an integral part of stormwater management and there are simple measures that the general community can take to protect water quality. Based on a successful project in the neighbouring Leschenault catchment, a Clean Drains campaign is being coordinated through the GeoCatch Ribbons of Blue Program. The aim of the project is to increase student and community awareness about street run-off and household drains that carry a range of pollutants unfiltered into our rivers, wetlands and Geographe Bay. Through the display and distribution of educational materials, greater recognition of the potential impacts of everyday activities is being promoted. Promotional material for the Clean Drains awareness campaign includes T-shirts, stickers, posters, and fridge magnets with the slogans “Don’t let your Bay go down the drain” and “Keep our Bay healthy – take care in the catchment”.

Stormwater information sessions and tours are available to all classes in the catchment. Students learn about the difference between water movement in a naturally vegetated area and an urban area, and about the different types of pollutants carried in stormwater. They also learn about what they can do to help keep stormwater as clean as possible, and visit sites where BMPs have been installed. Students take home the message to their families and friends.

Another way that students are working to increase awareness of stormwater pollution is by painting around stormwater drains. Students paint colourful designs including the words ‘Drains to the Bay’ or ‘Clean Water Only’ around the drain. The bright, eye catching designs draw people’s attention to the stormwater drainage issue and increases the student’s awareness and ownership of the problem.

This campaign has been a successful component of the Ribbons of Blue program and should continue in the long term.

5.4 Urban Catchment Management – Recommendations

UCM1. Investigate innovative stormwater treatment options appropriate for Busselton. An Expression of Interest for a project to undertake stormwater management planning in the Shires of Busselton, Capel and Augusta-Margaret River has been submitted for inclusion in the South West Catchments Council's Regional Investment Plan.

UCM2. Provide training opportunities for local government staff to improve maintenance operations for the stormwater system . Seek training through implementation of the Department of Environment's Stormwater Management Manual when completed.

UCM3. Undertake an industry survey, similar to that done in the Swan-Canning catchment, to determine risk posed by activities in the industrial and commercial areas and to assess the potential benefits of Cleaner Production Training. Possible partnership with Curtin University's Centre for Cleaner Production. An Expression of Interest for a regional project to progress Cleaner Production has been submitted for inclusion in the South West Catchments Council's Regional Investment Plan.

UCM4. Continue water quality monitoring of nutrients and contaminants in urban drains in partnership with local schools and Ribbons of Blue.

UCM5. Support rehabilitation of natural wetland systems to enhance their ability to cope with pollution loads from urban areas.

UCM6. Investigate potential risk of export of accumulated nutrients and sediments in detention basins to be exported to the river and options for managing this.

UCM7. Continue Clean Drains awareness campaign through Ribbons of Blue and seek feedback from Ribbons of Blue Coordinators regarding potential improvements for this campaign.

UCM8. Investigate potential point sources of nutrients to the Lower Vasse River and Vasse-Wonnerup Wetlands from unsewered areas and develop actions to manage these.

UCM9. Promote 'catchment friendly gardens' to urban households to improve water quality in runoff from these areas.

6 Community Involvement and Communication

6.1 Background

Being in the centre of Busselton, the project area has a very high profile. The river and surrounding parklands also have considerable cultural heritage values. It was recognised that the work undertaken to restore river ecology would result in a considerable change to the 'face of the river'. To many people lawn foreshores and deciduous trees are considered very attractive, and views of water vistas highly valued. However, most people did recognise that the river environment was seriously degraded and were in agreement that effort was needed to improve water quality.

Community involvement commenced prior to the formation of plans for proposed works, so that the community could raise issues and have input to the planning process from the very beginning. General concepts were outlined, with experts from Water and Rivers Commission explaining the proposed benefits of works in detail and available for one-on-one discussion to ensure a high level of understanding. Understanding the benefits of the proposed works was essential to the community accepting the Program.

The project area is important to the Aboriginal community. Historically, it has been an important camping and hunting area. The local Aboriginal community has been extensively consulted throughout the project to ensure that these values were respected. The Aboriginal community provided advice on heritage issues and details of how the river used to be, before it became so degraded. Local Aboriginal people have been very supportive of the project and provided a representative to supervise all earthworks.

The community continued to be involved beyond planning, and were very active in helping with the revegetation work. Almost two hundred people helped with planting along the river, including school groups, community volunteers and community groups. Arbor Day in 2001 was a great success with a large and diverse group working together to plant a large area of foreshore. The project has become a communications case study for the Department of Environment.

Community involvement and communication has included:

- Four community planning workshops, with a total of 120 attendees.
- Four consultation meetings with local Nyoongar representatives involving ten people each time.
- Distribution of information update fliers to 50 local residents at different stages in the project.
- Regular local media features to inform the wider community about the project components and progress.
- Five school planting and learning days, with over 150 students involved.
- Eight individual community volunteers assisted in ongoing planting activities along the river.
- Over 50 people attended an Arbor Day planting event in 2001.
- Production and installation of interpretive signage, including an information shelter and 14 trailside plaques to provide information about the project and about river ecology.
- Official launch of the interpretive signage and celebration of the project's success in June 2003, with over 50 attendees.
- Production and distribution of 1000 information booklets and 1000 small pamphlets to outline the Cleanup Program and show the walk trails, providing ongoing educational resources.

- Stormwater quality monitoring in conjunction with McKillop Catholic College Year 11 Biology Students.

Community feedback about the project is also considered an excellent indicator of success, and a great deal of positive feedback has been received. The *Vasse River Visitor's Book* is used to record the observations and opinions of the community, which include comments on the value and success of the new vegetation and improvements in the quality of the water. In 2001 the Keep Busselton Beautiful Committee presented GeoCatch and The Shire with an award for the revegetation project.

Continuing good communication is needed to maintain the profile of the Lower Vasse River Cleanup Program, to provide feedback about the Program's achievements and to seek community input for any further activities and to.

6.2 Community Involvement and Communication – Recommendations

CCI1. Continue good communication of project outcomes.

CCI2. Present findings of review and proposed recommendations to community to allow input to future activities.

CCI3. Provide opportunities for community feedback about the project.

7 Water Quality

7.1 Summary of Water Quality in the Lower Vasse River

The Department of Environment has routinely monitored water quality at two sites in the Lower Vasse River since 1996. This monitoring program provides excellent baseline data and will continue to provide long-term data on the success of the Cleanup Program. Phytoplankton monitoring is included in this monitoring to determine public health risk and to provide an indicator of improved river ecology.

Water quality in the Lower Vasse River is extremely poor. Concentrations of total nitrogen are high to very high and concentrations of total phosphorus are very high. Overall median values in this area were 1.8mg/L total nitrogen and 0.20mg/L total phosphorus over the monitoring period (August 1996 to March 2004). Nutrient concentrations tend to be highest during summer and autumn.

Total phosphorus concentrations appear to be decreasing at the Old Rail Bridge site (VASR2), but increasing at the Strelly St Bridge site (VASR1). No trends are apparent for nitrogen. The lowest median concentration of both TN and TP was observed at the Old Rail Bridge over the summer of 2001-2002. This was the summer following dredging operations and a Phoslock™ trial was also being undertaken. The highest median concentration of both TP and TP was observed at the Strelly St Bridge site over the summer of 2002-2003. This coincides with the diversion drain valve being left shut.

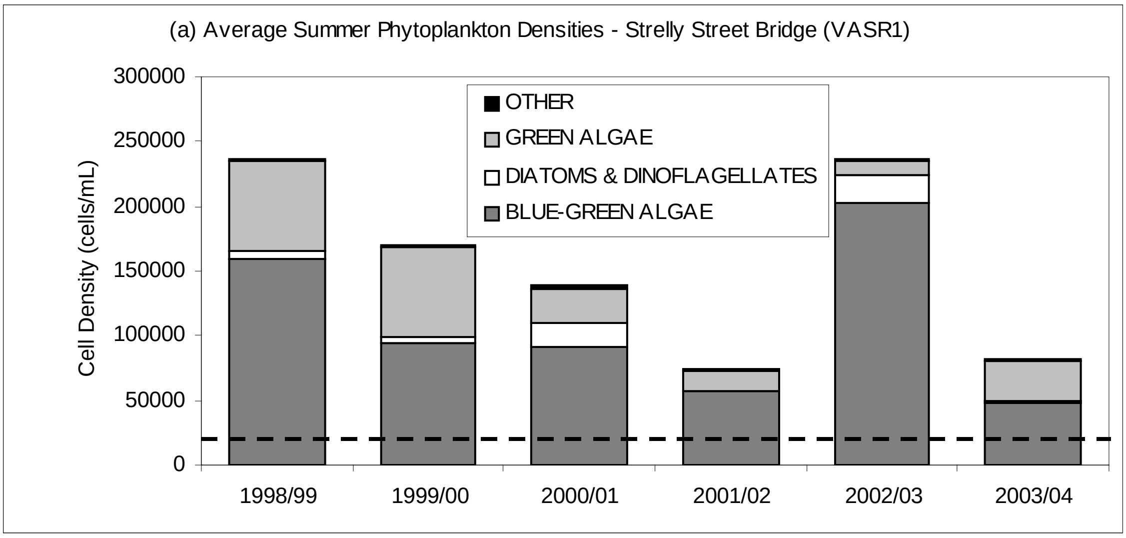
Phytoplankton growth is at extremely high levels in this area of the Lower Vasse River. Chlorophyll concentrations are high to very high, at nearly 20 times the ANZECC (1992) guideline. Phytoplankton monitoring indicates very high densities of phytoplankton during summer and autumn, with blue-green algae (Cyanophyta) and green algae (Chlorophyta) the dominant types present. Blue-green algae are frequently present at densities in excess of 100,000 cells/mL and are often much higher, with maximum reported densities in excess of 500,000 cells/mL. Persistent blooms of potentially toxic blue-green algae have lead to erection of permanent warning signs. Common types of blue-green algae in the Lower Vasse River include species of *Microcystis* and *Anabaena*. The water is very green in colour during summer and autumn, and often large clumps (colonies) of microscopic cells are clearly visible. Despite poor water quality, many waterfowl visit the area apparently not bothered by the algal bloom.

While algal blooms are still common in the Vasse River, there is some indication that they are becoming less severe. In particular, the density of algal blooms has been lower at both sites during the summers of 2001-02 and 2003-04 (Figure 2). Although Phoslock™ was applied during these summers, the lower density was noted in both the treated and control areas. Also of interest is that in between these seasons, the relatively poor season of 2002-03 coincided with the diversion valve being closed throughout the year.

This area remains relatively fresh throughout most of the year, with an average of 0.6 parts per thousand (ppt), but is sometimes brackish (up to 1.8 ppt). Dissolved oxygen concentrations in the Lower Vasse River are generally high, and rarely reach critical levels during the day. No data is available for oxygen levels at night. Very high oxygen levels occur during summer and autumn as a result of photosynthesis by large densities of algae. The open shallow waters are very warm during summer and autumn, with an average of 19°C and maximum temperatures of up to 30°C.

Measurable improvements in the health of the river continue to be monitored through water quality and biological monitoring.

A better understanding of the relative contribution of nutrients from different sources would be valuable in prioritising future works for the Cleanup Program. This would include estimates of contributions from rural and urban surface waters, groundwater and sediments. The use of modelling tools would be useful to achieve this.



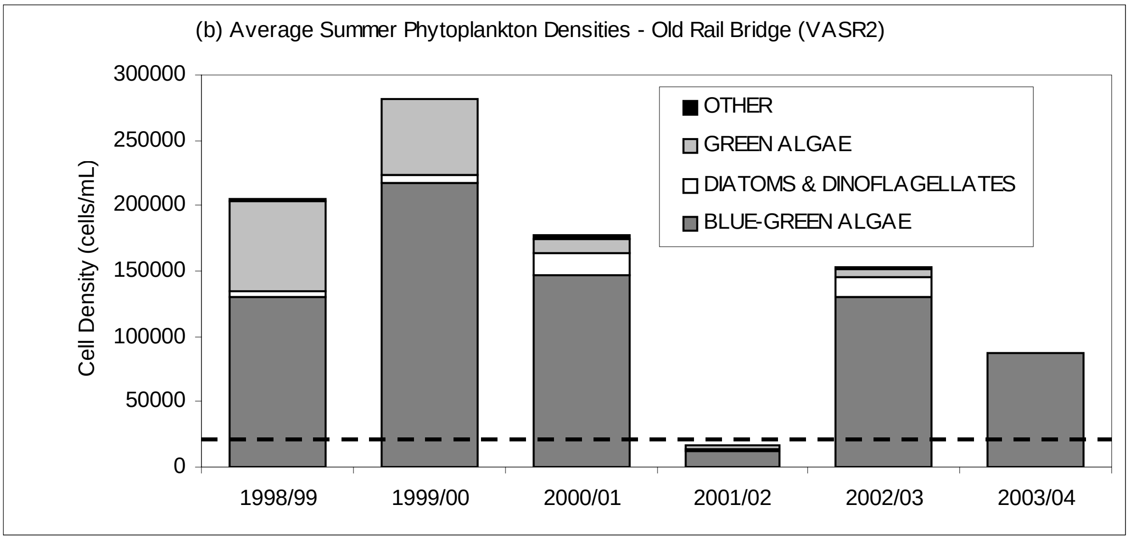


Figure 2. Average summer phytoplankton densities in the Lower Vasse River since 1998. The dashed line indicates the recommended health guideline for recreational activity (20,000 cells per millilitre).

7.2 Water Quality – Recommendations

WQ1. Continue long-term water quality monitoring by Department of Environment.

WQ2. Seek assistance from DoE to estimate relative nutrient contributions to the Lower Vasse River from different sources.

8 References

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