Figure 1: *The Canning River looking upstream from Kent Street Weir*

The story so far

In River Science 13 we explained how artificial oxygenation worked and in River Science 14 we talked about previous oxygenation trials on the Canning River. Since then, a full-scale oxygenation plant treating 2 km of river has been installed on the Canning River over the summer of 1999/2000. The installation of this plant, which was funded by the Coast and Clean Seas and Swan-Canning Cleanup Programs, represented a progression from the testing of oxygenation, to its application as a remediation technique for the Canning River upstream of Kent Street Weir. An open tender process was used to select a contractor to design, build and operate the plant, in contrast to the initial trials which were conducted in collaboration with research partners.

Oxygenated area extended

The oxygenated area stretched from Kent Street Weir to Greenfield Street footbridge, a length of two kilometres (see Figure 2). The oxygenation plants were located at Bacon St, Wilson, and Camsell Way, Ferndale.

Two instead of one

The oxygenation system consisted of two oxygenation plants as shown in Figure 2, each of which treated approximately one kilometre of river. The existing oxygenation plant at Bacon Street was enhanced and re-used. Modifications included the addition of an automatic control system and an extra distribution pipe to distribute oxygenated water down to Kent Street Weir.

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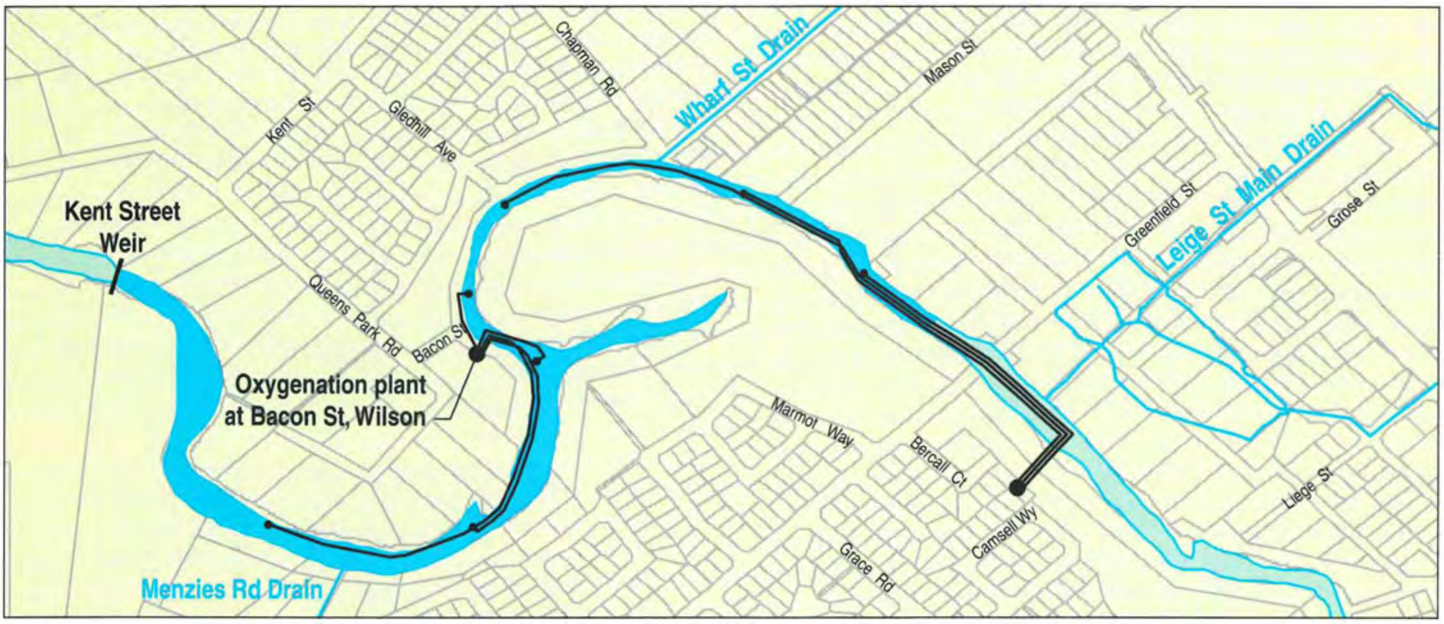
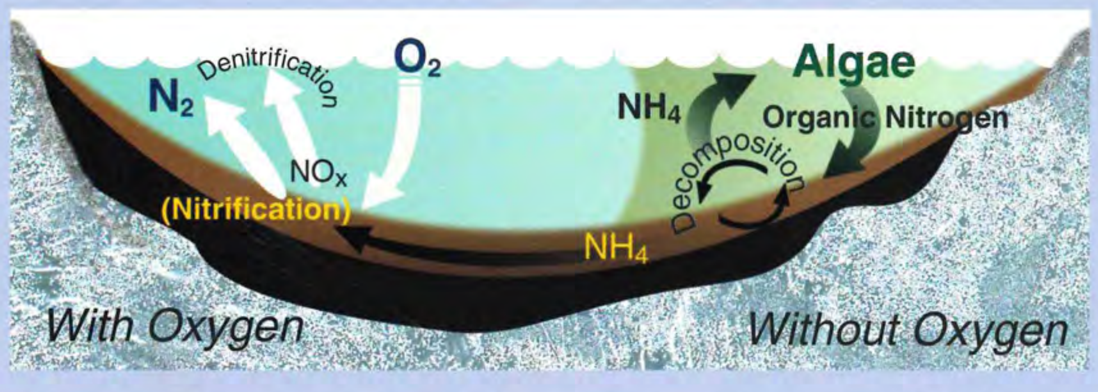
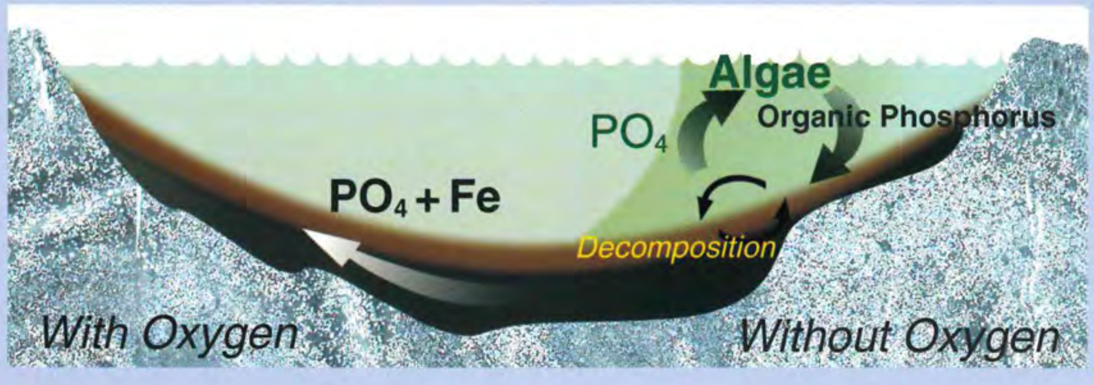


Figure 2: *Location of oxygenated area showing location of plants and layout of diffuser pipes*

How oxygenation affects nutrient cycling



An important pathway by which nitrogen is removed from the aquatic system is via the different but complementary processes of nitrification and denitrification. Nitrification (a process that requires oxygen) converts the ammonium to nitrate. Denitrification, for which oxygen is not essential, then converts the nitrate to nitrogen gas.



In the presence of oxygen, soluble phosphates rapidly bind with other minerals, typically iron oxide, and are then no longer available to plants. When oxygen is not present, iron oxides become more soluble, and the bound phosphorus also enters solution.

Figure 3: *One of the two oxygenation plants used in the 1999/2000 project. Left: water pump in foreground with control panels and oxygen vessel behind. Right: Distribution pipes in foreground with oxygen dissolver and oxygen vessel in background*

A new oxygenation plant was installed at Camsell Way on the grounds of an existing Water Corporation pump station. The excavation of a 70 m trench from the river to the plant was required to lay the pipes connecting the oxygenation plant to the river. Due to the close proximity of the new plant to houses, soundproofing was used to reduce noise levels to a minimum. The installation of the new plant began on 6 January 2000 and was completed on 15 February 2000.

The oxygenation trial lasted from 17 October 1999 to 15 May 2000

The Bacon Street oxygenation plant (used in the 1998/99 trial) began operation on 17 October 1999, and oxygenated 1.3 km of river. The new oxygenation plant at Camsell Way was completed on 15 February 2000. From this date until the end of treatment on 15 May 2000, the total length of river oxygenated was two kilometres.

The oxygenation plant at Bacon Street operated reliably during the six months of operation, and after some fine tuning the new oxygenation plant also operated reliably. Approximately 90% of the oxygen injected into the water by the plant remained dissolved after being returned to the river.

From record heat to record rainfall, an extreme summer

While the oxygenation plant was being installed, Perth experienced its hottest December on record, with an average maximum temperature of 32.4°C. On 15 January 2000 the weather changed dramatically, with 13 mm rainfall followed by a downpour of 75 mm on 22–23 January 2000. Rainfall of 102 mm was recorded for the month compared to the average of nine millimetres, making January 2000 the wettest January on record. In seven days 2700 ML flowed through the oxygenated area, which had a volume of 80 ML. After this extreme turn-around, the weather was typical of late summer with only sparse rainfall occurring.

Dissolved oxygen concentrations in the oxygenated area dropped following the rainfall but rapidly increased as the oxygenation plant replenished dissolved oxygen concentrations. Large rainfall events often cause extended periods of low dissolved oxygen concentrations, but monitoring during the 1998/1999 trial showed that the oxygenation plant would generally return dissolved oxygen concentrations to 5 mg/L within one day of the rain event. Nutrient concentrations associated with this rainfall peaked on 18 January in the oxygenated area, confirming that it is often the first rainfall that transports the highest concentrations of nutrients

Figure 4: BOC Gases contractors installing dissolved oxygen probes for the automatic control system

Figure 5: Water flowing over the Kent Street Weir at the beginning of the oxygenation season

into the river, rather than the largest rainfall event. The January rainfall events resulted in elevated nutrient concentrations, but these dissipated within one to two weeks and did not seem to detrimentally affect water quality for the remainder of the treatment period.

Dissolved oxygen levels in the treatment area were higher than the rest of the river

During the summer dissolved oxygen concentrations in a fairly stagnant water body such as the Canning River tend to be higher at the surface, where there is contact with the atmosphere. However, dissolved oxygen concentrations are generally low close to the bottom, especially if there is stratification or plentiful decaying organic matter. Therefore it is important that the oxygenation plant returns oxygenated water to the bottom of the river.

In the oxygenated area median bottom dissolved oxygen concentrations were 5.7 mg/L compared to 2.9 mg/L in the control area. This represents a 190% increase in dissolved oxygen concentrations. At the surface, median dissolved oxygen concentrations were 130% higher in the oxygenated area. These increases are significant because:

- They show that the oxygenation plants were effective at increasing dissolved oxygen concentrations, especially on the bottom;
- Dissolved oxygen concentrations were raised from a marginal level for some aquatic fauna to being sufficient to support aquatic life. Dissolved oxygen concentrations less than three milligrams per litre are generally accepted as being detrimental to the health of a river system (references cited in McLusky, 1989 and Kennish, 1990).

Aquatic fauna were more common in oxygenated areas

A preliminary survey of aquatic fauna, conducted by researchers from University of Western Australia and Curtin University during the 1999/2000 oxygenation period, found that there were higher densities of fish, freshwater prawns and benthic (bottom dwelling) invertebrates in the oxygenated area than at the control sites. This shows that oxygenation can have a positive effect on aquatic fauna in oxygen-poor environments.

Nitrogen and phosphorus concentrations in the Canning above Kent Street Weir were lower than previous years

Nitrogen and phosphorus concentrations in the oxygenated and control areas over the 1999/2000 oxygenation period were both much lower than in the years preceding the commencement of the oxygenation trials (see Table 1). Median ammonium concentrations in bottom water of the oxygenated area were 38 times lower than those recorded in the corresponding period of 1995/1996, and median filterable reactive phosphorus (i.e. phosphorus available to plants) concentrations in the bottom water of the oxygenated area were 12 times lower than those recorded in the corresponding period of 1995/1996. The results represent a drastic improvement in water quality and a large reduction in the amount of nutrients available to fuel phytoplankton blooms.

Nitrogen concentrations in both the oxygenated and control areas of the Canning River during the period of oxygenation were often too low to adversely affect the ecosystem. Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Table 1: *Median bottom nutrient levels for the oxygenated and control areas of the Canning River*

Area	Year	NH_3N	NO_x	TN	FRP	TP
Control	1999/2000	0.08	0.02*	0.92	0.06*	0.13*
Oxygenated	1999/2000	0.05	0.05*	0.82	0.04*	0.09*
Control	1998/1999	0.115*	0.02	0.83	0.07	0.15
Oxygenated	1998/1999	0.022*	0.02	1.00	0.10	0.21
Limited oxygenation[1]	*1997/1998*	*0.43*	*0.03*	*1.45*	*0.15*	*0.43*
Pre oxygenation[1]	*1996/1997*	*0.32*	*0.01*	*1.2*	*0.08*	*0.43*
Pre oxygenation[1]	*1995/1996*	*1.9*	*0.01*	*2.6*	*0.38*	*1.1*

* Denotes where there was a significant difference (90% confidence) between the median nutrient concentrations in the oxygenated and control areas.

[1] *Data collected from same site as present oxygenated area.*

Figure 6: *Menzies Road drain where it enters the Canning River*

(ANZECC/ARMCANZ, 2000) suggest 1.2 mg/L for total nitrogen and 0.15 mg/L for nitrate as levels at which there is a low risk of adverse environmental impacts occurring. There are no guidelines for ammonium. Median bottom water total nitrogen and nitrate concentrations in oxygenated and control areas for both 1999/2000 and 1998/1999 oxygenation periods were below these concentrations, indicating that for more than 50% of the time, bottom water nitrogen concentrations were a low risk to water quality (see Table 1).

Previous trials and microbiological studies have shown that oxygenation does affect nitrogen concentrations. This year, despite the low median values recorded in the oxygenated area, it proved difficult to separate the effect that the oxygenation had on nitrogen concentrations from other factors that affect nitrogen concentrations. The fact that nutrient concentrations in the oxygenated and control areas were generally low relative to historical data may have made it more difficult to establish differences between concentrations in the oxygenated and control areas. Other factors that made interpretation of results more difficult include the staged commencement of oxygenation, the extreme weather conditions experienced and the inherent variability between the oxygenated and control sites.

Median phosphorus concentrations in the bottom waters of both the oxygenated and control areas of the 1999/2000 treatment period were slightly greater than the low risk guideline (see Table 1). The low risk guidelines for phosphorus concentrations are 0.065 mg/L for total phosphorus and 0.04 mg/L for filterable reactive phosphorus. A comparison of phosphorus concentrations between oxygenated and control areas showed that phosphorus levels were significantly lower in the oxygenated section. There is the possibility that some PhosLock™ clay (a modified clay designed to bind phosphorus which was also being trialed in the Canning River at that time) entered the oxygenated area and may have contributed to this result.

Determining the full extent of oxygenation on nutrient concentrations requires experiments and monitoring targeted specifically towards this goal. In 1999/2000 the main objective was to get the new plant installed and ensure that it was properly oxygenating the designated treatment area. A focus of the next oxygenation period will be optimising the monitoring program to better capture the effect of oxygenation on nutrient concentrations.

We still need to work on reducing nutrient concentrations

The historically low nutrient concentrations recorded for the past two years are good news for the river, and it is probably no coincidence that over this period there have been no extended algal blooms. But this is no reason to become complacent about nitrogen and phosphorus concentrations. From 1995 to 1998 nutrient concentrations were much higher than over the past two years (see Table 1). Although oxygenation does help to reduce stores of nitrogen and carbon in the river sediments, high nutrient concentrations could easily return if dissolved oxygen concentrations reduce for extended periods of time.

The most important reason for continued effort is that more nitrogen and phosphorus are `continually entering the Canning River from drains and groundwater seepage. Until these sources of nutrients are reduced to the point where the natural cycling processes of the river can deal with them, continued efforts to reduce nutrient concentrations will be necessary. The Swan-Canning Cleanup Program has many initiatives which aim to reduce the amount of nutrients that are entering our rivers. For more information, please refer to the Swan-Canning Cleanup Action Plan.

Figure 7: Water quality sampling for the oxygenation project

Blue green cyanobacterial bloom flushed out by rainfall

The extremely hot weather during December provided the ideal conditions for a phytoplankton bloom to develop. Phytoplankton cell densities increased rapidly near Kent Street weir in late December from 3000 cells/mL on 21 December 1999 to 35 000 cells/mL on 4 January 2000. By 11 January the bloom had spread up the river to Bacon Street and Nicholson Road bridge. Phytoplankton densities at Kent Street Weir were 92 000 cells/mL, of which 77 000 cells/mL were cyanobacteria, mainly *Anabaena Spiroides*. This cell density was higher than the recommended maximum level for direct contact of 20 000 cells/mL (ARMCANZ, 1992). This bloom was totally distinct from the later *Microcystis Aeruginosa* bloom on the Swan River.

Heavy rainfall on 21 January ended the bloom by flushing it over the Kent Street Weir. Due to the bloom being diluted by the much larger volume of the lower Canning River and the estuarine conditions below the Weir, the bloom did not persist. By 25 January total phytoplankton cell densities were 2000 cells/mL at Kent Street Weir. This is considered a moderate amount of cells and is quite normal for summer. There were no other phytoplankton blooms in the Canning River over the 1999/2000 summer.

More information on phytoplankton blooms in the Canning River can be found in River Science Issue 4.

Summer ended with clear water and plentiful oxygen

At the start of March 2000 water clarity in both the oxygenated and control areas rose dramatically. Water clarity is measured with a Secchi disk, a white disk that is slowly lowered into the water. The depth at which it can no longer be seen is the Secchi depth, which is typically around one metre in the Canning River. The highest water clarity measured during the 1999/2000 summer was a Secchi depth of 3.2 m, which was measured in the oxygenated area. This reading indicates low phytoplankton densities and also shows that the oxygenation process does not stir up particles from the sediment, which can result in nutrients being added to the water column.

In March and April 2000 there were nine consecutive weeks where the biochemical oxygen demand (BOD) concentrations in the oxygenated area were below the detection limit of the test used to measure it. BOD is a measure of the organic matter present in the water that can be decomposed by biological processes. This is a very positive result because it indicates that decomposing organic matter is being efficiently recycled in the ecosystem. When dissolved oxygen concentrations are very low the recycling process is inefficient, so organic matter builds up and provides a potential source of nutrients that could fuel future phytoplankton blooms.

Future goals in the Canning River oxygenation project

Future work on the Canning River oxygenation project will concentrate on:

- Targeting monitoring to gather more data on the impact of oxygenation on nutrient concentrations.
- Optimising the automatic control and data recording systems installed in February 2000. This will improve the efficiency of the oxygenation plant by reducing gas and electricity consumption, and will provide better information on dissolved oxygen concentrations in the river.

Acknowledgments

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For more information

More information on the Canning River oxygenation project and the Swan-Canning Cleanup Program is available from the Swan River Trust.

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