SOURCE WATER MANAGEMENT- DEEP RESERVOIR CIRCULATION

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7th Annual WIOA NSW Water Industry Operations Conference and Exhibition
Exhibition Park in Canberra (EPIC),
9 to 11 April, 2013

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ABSTRACT

There is no better way to manage our scarce and therefore valuable water resource than to manage it in the reservoir to improve its quality so that more expensive treatment costs can be reduced. This is known as Source Water Management minimising risk to the owners and operators.

Early research (Elliott 1997) concluded if the temperature gradient in a water storage dam was uniform, reservoirs would not turn over improving the general quality of the water (Morgan et al). Uniform water temperatures throughout the column allowed deep vertical jet penetration inhibiting the growth of algae, the warmer temperatures deeper in the dam eliminated cold water pollution from releases downstream. Forcing the oxygen rich top water layer to the bottom of a water reservoir improved the oxygen concentration of the entire water body, the oxygen in the water at these lower levels oxidized the soluble iron and manganese, these and other elements came out of solution and dropped to the dam floor. Good management of our scarce water resource and by improving the quality of these water bodies, treatment costs can be drastically reduced. PAC costs can also be reduced. The removal of Fe and Mn will reduce the cost in the water treatment plant.

1.0 INTRODUCTION

There is an ever increasing pressure to provide safe, clean drinking water. Cost minimisation and rationalisation of authorities, means there is a need to reduce the cost of water treatment and improve the environment through a reduction in process, and management of the resource at the same time as improving and growing the revenue base. Water managers have been driven by the need to TREAT water with better technology and improved process; however the significant savings in improving the raw water supply have largely been overlooked. Authorities in all diverse climates are realising that artificial 'top to bottom' circulation has both short term and long term measurable benefits in the water treatment process. 'Source water management', provides reduced final water treatment costs while improving the aquatic environment.

The trend by water authorities to maximise the available water, increase the water quality and minimise the cost of treatment and storage, has driven the change and a reevaluation of previous technology and to look for alternatives to *'Source Water Management'*.

2.0 RESERVOIR DESTRATIFICATION

Artificial destratification involves mixing the water body to dissipate thermal layers, the benefits are:

- Autumn turnover is eliminated
- Water drawn off is of more uniform quality and therefore potentially easier to treat.
- Blue Green Algae is controlled and the use of chemicals or PAC eliminated.
- Metals such as manganese (Mn) and Iron (Fe) are oxidized out of the water.

- Fish habitat in the reservoir is improved.
- Cold water with low DO released from the lower levels of a dam, which can upset fish migration patterns downstream (Mobley et al, 1995, Greene et al, 1997), is minimised.
- Ecological balance of a degraded storage is restored.

Adaptations of mechanical impellers were made previously where little was known of flow rate requirements, jet velocities, optimum location and direction and operating protocols. Bubble plume systems have been used in Australia and overseas. Compressed air destratification systems consume high energy (about 50-100 kW in a typical medium size dam). However, McAuliffe and Rosich (1990) reported that bubble plume systems have had limited success in reducing undesirable algal species in a little over 50% of cases, and have reduced manganese, iron or sulphides in only 69% of cases. Blackman, (2001) reported that only 53% of compressed air systems were successful to some extent and only 11% of dam managers reported that they were fully satisfied with the success of the system in their dam. Many bubble plume installations stand idle since their ability to solve the problem has not been realised, and operating costs are high. Thus the only viable alternative was seen to be expensive treatment of the poor quality raw water at the treatment plant.

3.0 A DESTRATIFICATION AERATION DEVELOPMENT DEEP RESERVOIR CIRCULATION

This technology uses a low energy (4-8 kW) mechanical circulation system that efficiently and effectively moves water through the thermocline; i.e. the thermal barrier between surface water and bottom water thereby artificially destratifying the whole of the storage.

Unlike traditional aeration systems that attempt to raise anoxic bottom water from the hypolimnion, loaded with dissolved metals, such as reduced iron (Fe) and manganese (Mn) as well as nutrients, to mix with the water high in dissolved oxygen (DO) at the surface, the surface mounted circulation system moves DO saturated surface water to the bottom region where high biological oxygen demand and high chemical oxygen demand occur. By removing the surface layer and directing flow to the hypolimnetic bottom layers the: (i) rate of transfer of oxygen at the surface interface is increased, (ii) nett DO distribution throughout the whole storage is maximized, and (iii) nutrients (which feed algal blooms) are not brought to the surface and made available for algal growth at the euphotic zone.

Top-down circulation is desirable in the control of Cyanobacteria or Blue Green Algae. The surface layer, is sucked in and discharged where sunlight cannot penetrate. The algae are thereby light-limited, transported through turbulent flow, and subject to an instantaneous pressure change. This creates an environment that is unfavorable for the cell growth and the life cycle of Cyanobacteria is disrupted, along with the oxidization of available phosphorous and the change in Phosphorous: Nitrogen ratio.

3.1 Energy Requirement

The small model, is powered by a 1.5 KW electric motor and is capable of destratifying a storage volume of up to approx 5,00 ML, the larger with a 5.5 KW motor will destratify a storage of approximately 18,500 ML.

Outstanding results in larger reservoirs of over 30,500 ML have been achieved and opportunity now exists to solve problems in very large storages greater than 100,000 ML.

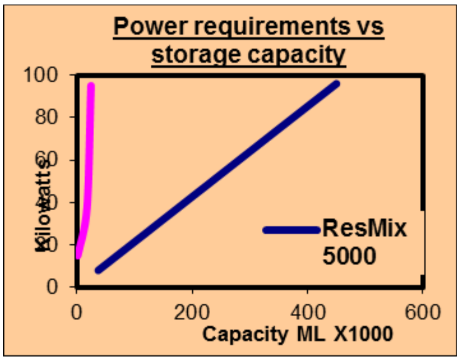

Figure 1: ***Power requirements of: ResMix 5000, and compressor driven Bubble Plume destratification methods, versus storage capacity. Bubble Plume data compiled from actual installations (BLACKMAN 2001)***

The reason for the dramatic difference in energy requirements is the exploitation of the principles of hydraulics and fluid dynamics in the liquid phase and the elimination of the inefficiency of air compression.

A preliminary design and scoping study (Elliott 2012) compared operating costs of artificial destratification methods proposed for Nambucca on the NSW north coast and is summarised in Table 1. This study compared deep circulation with rising bubble plume, and demonstrated that the method had the potential to use only 10% of the power of compressed air systems.

Table 1: ***Cost comparison of the Deep Circulation with air diffuser for Nambucca (2013)***

		ResMix 3000	Typical Air Diffuser
No of units		1	1
Power	kW	1.5 Maximum (0.8 Average)	45 (Continuous)
Flow	m^3/s	2	10
Efficiency	m^3/s per kW	1.33	0.25
Location		Pontoon	Dam floor
Draft Tube		Yes	No
Power cost	annual	$1,752 (Continuous)	$50,000 **(½ Time)

The completed design of the compressed air system incorporates a 45kW compressor and will have a high energy demand;. By contrast surface circulation uses a 1.5 kW motor. The annual saving in electricity usage of $50,000 with the conservative assumption of the compressor system operating for only 12 hours. There is a significant economic benefit in utilising the system. And the operating cost and all of life cost is very much less than that for the bubble plume system. (Spain 2013)

3.2 Horizontal distribution of dissolved oxygen

Warm, oxygen-rich surface water pumped downwards will mix to some extent with lower DO water near the bottom of the jet.

It will then find its neutral buoyancy level and flow radially outwards as an intrusive gravity current, thereby transferring DO horizontally.

3.3 Iron and Manganese

The most recently completed large installation for ACTEW Water was designed and installed to overcome high soluble manganese concentration. A system was installed at Googong Reservoir, volume of 124,500 ML and currently draws approximately 16 kW of electrical power. A bubble plume system was not considered as achieving satisfactory raw water quality results were not achievable without very large amounts of power.

A ResMix 3000, (Figure 2) unit was installed by CS Energy in Swanbank Dam, to remove the problem of manganese build-up in the power plant cooling tower. McAlpine (pers comm, 2000.) reported a 5% increase in plant efficiency and removal of the risks to staff from toxic Blue Green Algae contact.

Figure 2: ***ResMix 3000 installation at the CS Energy Swanbank power station reservoir***

3.4 Algal Control

Report on the installation of a ResMix 3000 in the Timor Dam (2,000 ML) in central NSW indicates successful Blue Green Algal control Tighe (2000).

Blue green algal counts, which had been historically high, are now continually low, Figure 3 below. *Since the WEARS system was installed there have been no significant blue green algal blooms, and Cyanobacteria has been held at near zero counts since 1999, apart from an identified 'wash-in' event (Tighe 2001),* However within a few days the count was again near zero due to the impact of the ResMix system. A significant saving also realised by eliminating or minimizing the use of powdered activated carbon (PAC).

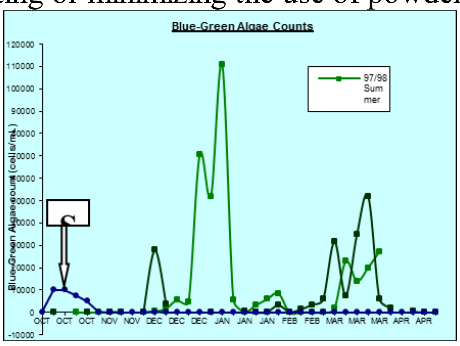

Figure 3: ***Blue green algal counts in Timor Dam, for summer periods between1997-2000.***

4.0 DECISION STRATEGY

In Toowoomba, on Queensland's Darling Downs, regular algal blooms at the city's three water supply dams resulted in the Toowoomba City Council reassessing its strategies and ability to deal effectively with an organic contamination event. Toowoomba's water supply is sourced from an aquifer under the city and surface water storages. The surface storages, Lakes Cooby, Perseverance and Cressbrook, provide up to 85% of requirements.

When a storage reaches algal alert level-three (the highest alert level), the storage is taken off line and an alternative supply is selected. If other storages are simultaneously in alert level conditions, a decision is made to take water from the lowest risk storage and to treat it using chlorine. Design and installation of the traditional type destratification system, using bubble plume technology, was estimated to cost $200,000 per storage in 2000. An alternative technique would be to install a PAC facility.

Council's decision to install the *ResMix system* was influenced by the long-term benefits of destratification and the energy savings associated with that system. It was not just a case of avoiding one or two BGA contamination events, but a case of eliminating the incidences of BGA outbreaks (Dinsey 2002).

4.1 Description of the work

In May 2001, the Council accepted a proposal submitted for the design, manufacture, and installation and commissioning of low-energy mechanical systems for Lake Cooby and Lake Perseverance. The impellers rotate at a constant, relatively low speed, depending on flow requirement. To achieve the anticipated design flow rates of between 10,000 and 15,000 liters per second, the installations comprise two units attached by a walkway, with the two contra-rotating impellers.

Council adopted this strategy, instead of the PAC dosing plant at Mt Kynoch or a compressor type system, for several reasons. These included:

- Much lower power requirements of the *WEARS* reservoir systems resulting in about only 8-10% of the operating costs in terms of electrical energy;
- An ability to use the systems in larger, deeper water storages;
- Control of algal toxins and other water quality problems at the source rather than by treatment of downstream contaminated water at the PAC dosing plant;
- Water supplied to consumers between the water storages and the water treatment plant does not have to be treated independently.

The dissolved oxygen gradients and temperature gradients for Cooby and Perseverance Dams respectively, clearly demonstrate the effect of the system in breaking the thermal and chemical strata. Figures 4, 5, 6 and 7 below, The system was installed late in 2001 in each of these dams.

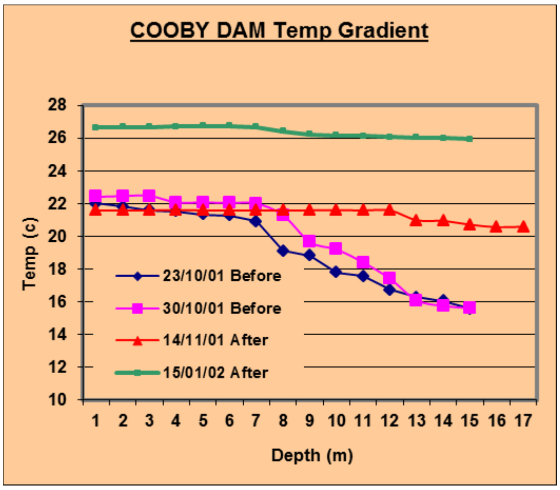

Figure 4: ***Temperature gradient before and after a WEARS Close Coupled SMDI-5 system was installed at Cooby Dam***

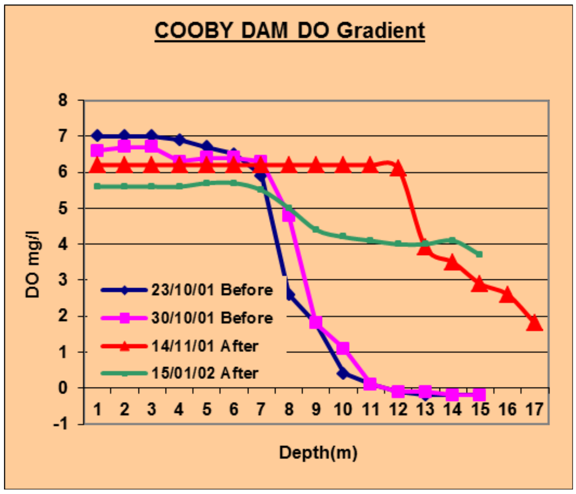

Figure 5: ***Dissolved oxygen gradient before and after a WEARS Close Coupled SMDI-5 system was installed at Cooby Dam***

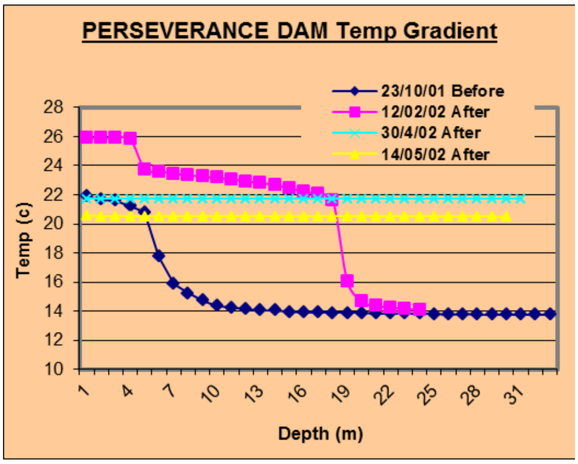

Figure 6: ***Temperature gradient before and after a WEARS Close Coupled SMDI-5 system was installed at Perseverance Dam***

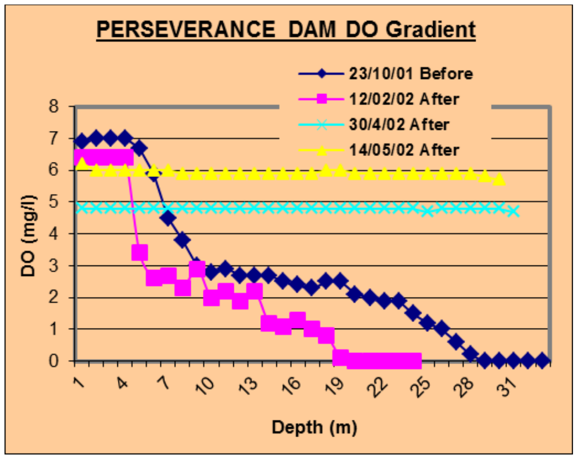

Figure 7: ***Dissolved oxygen gradient before and after a WEARS Close Coupled SMDI-5 system was installed at Perseverance Dam***

This system has been operational since 2001 at the time of writing nearly 13 years, to the satisfaction of the authority.

4.2 Most recent

In 2012, ACTEW Water evaluated solutions for the Cotter Dam Expansion and decided to install ResMix systems for deep water circulation. The Cotter Dam had a Solar Powered ResMix system operating for several years to minimise manganese concentrations and address issues of poor water quality previous to and after the fires of 2003.

Immediately after the fires, there was an increase in the turbidity and associated iron and manganese in the water flowing into the three Cotter River reservoirs. (ACTEW Web). The ResMix system operating at 1 kW on PV Solar fully mixed the top 13m of the reservoir enabling oxidisation of metal ions naturally leached from surrounding soil and runoff in a reducing low oxygen environment.

From this and the success at Googong Dam (2006-recent), WEARS have been engaged to design, construct, install and commission the ResMix system for the Enlarged Cotter. The new dam will have a capacity of 78,000 ML, nearly 20 times its current size, and the new reservoir will increase the ACT Water storage capacity by 35%.

Deep circulation of the reservoir was seen as an important measure to reduce or eliminate the effects of reservoir inversion (turnover), minimise soluble metal ions, such as: manganese (Mn) and Iron (Fe), and increase the depth of dissolved oxygen to protect native fish species. The enlarged Cotter at full service level is approximately 80m and the effective depth of circulation is such to eliminate the potential for lake turnover and the consequence of distributing low DO water and soluble metals through the water column.

5.0 CONCLUSIONS

Water management authorities are becoming increasingly more aware that the WEARS surface circulation system is the most economic operational tool available to deal with problems associated with water storages such as: autumn turnover, metals in solution, eutrophication, Blue Green Algal blooms, all of which contribute to problems of taste, odour and quality, along with downstream cold water pollution or downstream cold water discharge, general raw water quality and reservoir ecological health. Problems that have traditionally been expensive to overcome in terms of ongoing costs and capital expense are now available to both large and small reservoir management authorities.

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