Potential for Thermal Shock in the Murray-Darling Basin
A Scoping Study for the Murray-Darling Basin Commission

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Executive Summary

While there is some evidence that cold water releases from dams cause significant biological impacts in the Murray-Darling Basin (MDB), there is limited information on the significance of rapid changes in water temperature. Anecdotal evidence indicates that unnaturally large and sudden changes in water temperature below instream structures may be of sufficient magnitude to cause thermal shock in aquatic biota. The Murray-Darling Basin Commission (MDBC) has commissioned this study to scope the significance of the issue within the regulated rivers and streams of the MDB.

This desktop study was undertaken in two steps; (i) a review of scientific and other information on the physical conditions and biological consequences of thermal shock and (ii) a review and assessment of structures with significant thermal shock potential in MDB. Current understanding of the mechanisms and impacts of rapid temperature change were summarised from available literature. This information was then used to develop conceptual models of the causes of sudden temperature change and the consequential biological impacts as a basis to assess the potential thermal shock of dams within each State of the MDB.

There are two key physical processes that lead to sudden temperature change in waters below dams and weirs. Structures may have a direct effect on downstream water temperature by releasing water with markedly different temperature to that occurring naturally in river and streams. This mechanism (termed the source effect) depends largely on the stratification behaviour of the storage and the depth from which water is released. The second mechanism of sudden temperature change is referred to as a regulation effect and is associated with changes to the hydrological patterns of downstream rivers. Changes to the volume of water in rivers below dams affects the rate at which water heats and cools in response to natural diurnal heat flux.

Large and rapid changes in water temperature can potentially impact all aquatic and semi-aquatic biota, particularly those with less well developed thermo-regulatory capacities. However, the majority of literature on biological impacts of sudden temperature change has concentrated on fish. The susceptibility of a fish to temperature shock is dependant on the species, age of the fish, body size, acclimation history, time of the year, time of the day and instream habitat composition. It appears that most fish are capable of making long-term acclimation adjustment to slow temperature change, however rapid temperature changes can lead to severe impacts. Indirect mortality may result from behavioural changes which make fish more susceptible to predators. Direct mortality may result from extreme temperature fluctuations while death of more sensitive life stages may occur at smaller fluctuations.

Major challenges to this study were the lack of relevant information on thermal tolerances of local species and the limited number of dams in the MDB where temperature is continuously monitored. As a consequence, the approach taken in this desktop study was to assess potential for thermal shock based on the characteristics of physical infrastructure and general release information. Existing databases were interrogated to determine the structures most likely to possess thermal shock potential. Structures with high thermal shock potential were shortlisted based on screening criteria which

included: height of the structure; type of outlet works; primary purpose of the dam; size and pattern of releases; and other relevant physical characteristics where recorded.

This classification was cross-referenced with other sources of readily available information to compile a shortlist of 102 candidate structures in the MDB with potential for sudden temperature change. Of these, 29 structures were deemed to have a high potential to cause abrupt temporal changes in temperature. The majority of structures were located in New South Wales (19), while six were identified in Queensland, and two in each of the Australian Capital Territory and Victoria.

This study found that source-driven sudden temperature change is likely below dams that are deep enough to thermally stratify during warmer months and capable of rapid changes in release depth either by multi-level intake structures or via alternating spillway and deep-intake releases. This is relevant to irrigation dams and some of the town water supply dams that are capable of rapid changes in releases depth. Localised regulation effects may occur below any dam that ceases or reduces flow after a period of artificially high flow. Sudden temperature change may occur at distance from large dams due to a sudden shift between cold dam releases and warm water tributary inflows. Hydropower dams with fluctuating release volumes also have a high potential to effect rapid temperature change.

- A number of recommendations to address the issue have been made. These fall into two categories; (i) precautionary measures to mitigate potential impacts of rapid temperature change and (ii) research priorities to address the significant knowledge gaps identified in this study. There appears to be scope for more environmentally considerate release strategies to reduce the potential of thermal shock pending further work to better define the significance of the issue. These strategies include:
- gradual (or stepwise) changes in release height when switching between different intakes;
- . gradual (or stepwise) changes in release volume;
- . protocols to optimise release and selective withdrawal management within given constraints; .
- adaptive management utilising real-time data to fine tune release operations; and
- . conducting outlet maintenance at times when thermal stratification in storages is less pronounced.

A number of research priorities are also suggested. The thermal shock sensitivity of most of the freshwater fish in the Murray-Darling Basin is largely undetermined. More comprehensive information on the biological impacts of the rate of change and absolute temperature change is required. The importance of habitat immediately downstream from large dams is largely undetermined in Australia. Instream habitat (including woody debris) provides shelter from velocity and can also provide shelter from the effects of temperature. Similarly, the provision of an escape route for biota and/or offstream habitat may provide options of refuge from temperature fluctuations. The collection of continuous temperature data and targeted biological response information can provide the basis for a quantitative risk assessment that could be used to verify the ecological impact of thermal shock in the context of broader ecological disturbance associated with the impact of dams in general. Targeted physical and biological research investigations can provide sufficient guidelines to water management authorities for minimising the risk of thermal shock on native freshwater fish and allow adaptive management with specific targets.