NSW Government
Office of Water

NSW Cold Water Pollution Strategy

Guidelines for managing cold water releases from high priority dams

Leading policy and reform in sustainable water management

Publisher

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The NSW Office of Water manages the policy and regulatory frameworks for the state's surface water and groundwater resources to provide a secure and sustainable water supply for all users. The Office of Water also supports water utilities in the provision of water and sewerage services throughout New South Wales.

NSW Cold Water Pollution Strategy: Guidelines for managing cold water releases from high priority dams

April 2011

ISBN 978 1 74263 155 4

Acknowledgements

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NSW Treasury – Minh Thy Truong, Angelina Bilas

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Introduction

Cold water pollution or thermal pollution occurs downstream of most large dams in NSW due to the release of water derived from deep within the dam to the downstream river channel.

A range of studies and investigations have indicated that cold water pollution has significant adverse impacts upon aquatic organisms and aquatic ecological processes and is a key determinant of river health.

The NSW Government has recognised the importance of the cold water pollution issue and has agreed upon a strategy to investigate, and where possible ameliorate, the impact at high priority dams where it is technically and economically feasible to do so.

These guidelines are to be applied to those high priority dams releasing cold water derived from thermal stratification within the dam where feasibility studies have determined that changes to structures and or operating protocols can technically and economically deliver improved thermal outcomes downstream of large dams.

At some dams, infrastructure for managing cold water pollution already exists and is currently in use. The challenge for these sites is to better manage the infrastructure to optimise the temperature and other water quality outcomes. At other dams, no such infrastructure exists, and new outlet arrangements may be required.

It is the Government's intent to issue Works Approvals to dam owners/operators under the *Water Management Act 2000.* Works Approvals may include requirements (Conditions) to manage cold water releases. The specific requirements will reflect the dam's priority for mitigation measures (as assessed periodically by Government). The potential scope of these conditions is outlined in Section 100 of the Act (see below).

Existing guidelines relating to water pollution cannot be directly applied (see below) and provide little definitive guidance for the construction or modification of infrastructure or the development of operating protocols that may be required to be developed under a Works Approval. Guidelines on the temperature targets to be incorporated into an operating protocol would ensure equity for dam owner/operators and consistency across the state.

These guidelines have been developed to:

- Provide guidance to dam operators who are, or will be responsible for the management of cold water pollution mitigation infrastructure such as multi-level intakes and destratification units to assist them develop appropriate operating protocols for each dam under their control.
- Provide guidance to engineers and designers who are evaluating options and designing new infrastructure to ameliorate cold water pollution regarding the desirable performance standards for such infrastructure.
- Clarify what is and what is not deemed to be cold water pollution to assist the longer term assessment of satisfactory performance of cold water pollution infrastructure.

It is expected that a Works Approval condition may require the dam owner/operator to develop the protocol in a manner consistent with the guidelines. Compliance with the Works Approval would then be assessed on the basis of faithful implementation of the protocol rather than achievement of a specified temperature outcome.

Legislation

Cold water releases from a water supply work are subject to the provisions of the *Protection of the Environment Operations Act 1997*. The making of such releases may be a water pollution offence where the release of water is 2 degrees Celsius colder than the water into which it is discharged as Schedule 3 of the *Protection of the Environment Operations (General) Regulation 1998* includes the following definition of water pollution:

Any thermal waste (being any liquid which, after being used in or in connection with any activity, is more that 2 degrees Celsius hotter or colder than the water into which it is discharged).

Such a definition is of little value to the management of cold water pollution as:

(a) It makes no mention of the natural temperature regime and

(b) For most large dams for most of the time, 100% of the discharge passes through the dam, and so the discharge temperature is the same as that of the receiving waters.

Regardless, the *Protection of the Environment Operations (General) Regulation 1998* (cl.56A) makes an exemption from a water pollution offence if this cold water is discharged from a water supply work pursuant to an approval under the *Water Management Act 2000* **that contains conditions dealing with the cold water releases** (author's emphasis).

The necessary conditions in the approval under section 100(3) of the *Water Management Act 2000* may include any or all of the following matters:

(a) The undertaking of an investigation of the environmental impact of cold water releases and the options for mitigation of that impact

(b) The preparation of a program to mitigate the impact of cold water releases and the obtaining of approval of the program from the Minister

(c) The implementation of the program

(d) The monitoring and reporting on actions taken to implement the program and/or results against temperature target curves

(e) The carrying out of new works or the making of alterations to existing works, or both

(f) The method of operation of water management works.

Objectives and targets

The NSW Water Quality Objectives set out the agreed environmental values and long term goals for NSW surface waters. They were developed in consultation with the community and represent their values for local waterways. In terms of cold water pollution the most relevant values are protection of ecosystems and recreational use.

The Australian and New Zealand Environment Conservation Council (ANZECC) published the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000) (commonly referred to as the ANZECC 2000 guidelines). These guidelines complement the NSW Water Quality Objectives and define the numerical criteria that protect and maintain those values. However, the ANZECC 2000 Guidelines provide little definitive guidance for dealing with water temperature other than to say that "local or regional reference site data (should be) used to derive guideline values" and "where local reference site data is not gathered, apply the default, regional low risk triggers values". The default trigger values are defined as >80%ile and < 20%ile.

The State Water Management Outcomes Plan 2003 (SWMOP) similarly defined the target for water temperature (Target 26) as between the 20th to 80th natural percentile range for each month (or within bounds determined by site specific investigations). Note: the SWMOP is no longer operational.

Nature of temperature impacts

Discharges from large dams are typically colder than natural for approximately half the year and warmer than natural for the other half of the year. The annual temperature range, between the summer peak and winter trough, is typically suppressed compared with natural and the pattern of seasonal variation is typically displaced backwards in time by several weeks. Daily variation (night versus day) is also typically suppressed.

Therefore the impact of cold water releases can be broken down into five components:

(a) Summer suppression

(b) Winter elevation

(c) Annual amplitude reduction

(d) Seasonal displacement

(e) Impact upon diel variation (i.e. variation over a 24 hour period).

Lugg (in press) scoped the cold water pollution situation across the Murray Darling Basin. For dams which were examined in detail, a summary of the extent of these impacts is:

- Dams are typically most strongly stratified in December/January/February and isothermic (uniform temperature at all depths) in June/July/August.
- The maximum magnitude of the summer suppression effect is around 16^{o}C. More usually it is around 8 to 12^{o}C.
- The winter elevation effect is most usually in the range of 2 to 4^{o}C with a maximum of around 9^{o}C.
- The magnitude of the annual amplitude reduction varies from about 4^{o}C to more than 10^{o}C.
- Seasonal displacement can be up to 13 weeks later.
- Impact is greatest immediately downstream of the dam and are ameliorated with distance downstream. Effects may persist for tens or even hundreds of kilometres if large discharges are being made from full or near full dams that are strongly stratified.

These effects need to be considered within the context of natural conditions:

- The diel (24 hour) variation of water temperature in a natural stream can be up to 5^{o}C.
- Water temperature in most lowland rivers typically varies from about 5 to 10^{o}C in the depths of winter to 20 to 30^{o}C at the height of summer. It changes by about 4^{o}C per month on average during the spring and autumn.

Defining temperature management targets

The NSW Government has endorsed the principle of requiring dam operators to “match the temperature of releases from individual dams as closely as possible to the natural temperature regime having regard to the associated costs and benefits”.

Matching the temperature regime on an hourly basis (i.e. mimicking the natural diel variation) is unachievable given the timeframes involved in changing infrastructure settings). However a specific target for the hourly rate of temperature change may be appropriate to guard against “thermal shock”.

Matching the temperature regime on a daily basis is also unwarranted given the natural diel variation of up to 5^{o}C. However using daily time-step data (e.g. mean daily temperature) to assess performance is appropriate.

Matching the temperature regime on a monthly basis appears to be a workable and reasonable compromise between ecological outcomes and manageability. Going to a weekly time-step would increase management costs and is unnecessary given that stream temperatures in natural conditions only increase by about 1^{o}C on average per week (i.e. 4 ^{o}C per month) during spring and autumn, when temperature change is most pronounced. A change of 1^{o}C would be ecologically insignificant under most circumstances.

The winter temperature elevation is generally less of a problem. The water stored in dams in winter is warmer than that naturally flowing in streams due to its greater thermal bulk and buffering capacity. It is also isothermic (i.e. uniform temperature from top to bottom) - so selective withdrawal to mimic predicted natural temperatures is not a practical option.

The volumes released in winter are typically much smaller (often 2 orders of magnitude less than summer releases) due to lack of demand. These small volumes of water will lose heat energy to the atmosphere and equilibrate relatively rapidly. The length of stream affected by temperature elevation in winter is therefore significantly less than that affected by summer suppression.

Therefore, the approach of managing releases to better mimic the background temperature regime should be limited to the spring/summer/autumn period.

Baseline data and monitoring requirements

Local reference data for each dam is needed to provide a benchmark for monitoring. Essentially this is the “expected natural” temperature regime (i.e. variation over a full 12 month period) for the monitoring site downstream of the dam. This could be derived from:

- field measurement before the dam was constructed (pre-dam data).
- measurement of local tributaries flowing into the dam or into the river downstream of the dam or in the river upstream of the influence of stored water (termed “reference sites”). Allowance may need to be made to compensate for elevation, stream length and hydrological differences.

In the absence of either of these kinds of data, synthesized, s data derived from incomplete water temperature records combined with air temperature records could be used.

The “expected natural” temperature regime could be expressed and graphically depicted in terms of mean monthly temperature as well as various monthly percentiles (e.g. 5th, 20th, 80th etc).

With regard to performance monitoring and assessment, temperature needs to be measured at a suitable distance downstream of the dam. If the monitoring site is too close, there may not be enough time for waters from different outlets to mix and equilibrate, leading to false conclusions. If the site is too far from the dam, natural warming or tributary inputs may disguise the temperature impacts. Site selection must take account of local factors, but a location within several kilometres of the dam is a reasonable rule of thumb. With regard to performance monitoring and assessment, generally the site should be upstream of the confluence of major tributaries. Existing gauging stations should be used wherever possible.

Modern data loggers make the task of recording water temperature a simple and straightforward exercise. Given the need to guard against thermal shock, monitoring temperature changes on an hourly basis is appropriate. Hourly data should be converted to daily averages to assess performance against the targets.

Temperature also should be continuously monitored at several “reference sites” (tributaries or the main river upstream of the dam) to enable performance assessment.

Guidelines

The guidelines should be used in two ways:

1. To set monthly targets for dam operators to aim at in their day to day management of the dam infrastructure (e.g. this month we are trying to achieve an outlet temperature of XXoC). These would be derived from averages of pre-dam or tributary temperatures and incorporated into operating protocols as a “target outlet temperature curve”. An example derived for the Shoalhaven River at Tallowa Dam is attached (Figure 1).
2. As a performance assessment tool. Outlet temperature observations (from the temperature monitoring site downstream of the dam) would be compared with the expected-natural temperature observations (from reference sites such as unregulated tributaries) at the end of each month. Historic data should not be used as it could not account for recent weather conditions (i.e. unseasonably hot or cold). An example derived for the Shoalhaven River at Tallowa Dam is attached (Figure 2).

Performance assessment is particularly relevant:

- During the “bedding in phase” following the completion of new infrastructure or the adoption of a new operating protocol for existing infrastructure to provide feed back and help refine the settings required to get outlet temperature observations closely mimicking predicted-natural temperature observations.
- When unseasonably cold weather depresses water temperature below the long term average thereby making it impossible for dam operators to achieve the monthly target. Such an assessment would demonstrate that reasonable steps have been taken to mitigate cold water pollution.

For each dam:

1. A “target outlet temperature curve” should be established.
   (a) The curve should be equivalent to the monthly mean expected natural temperature for the dam site derived from whatever suitable data is available (pre-dam, tributary, upstream and air temperature). Where data from smaller or larger streams that are some distance away from the dam site is used, they should be modified if necessary to compensate for differences in elevation and hydrology.
   (b) The “target outlet temperature curve” should be incorporated into the operating protocol and used to guide the day-to-day operation of the dam outlet infrastructure.
2. Performance of the outlet infrastructure should be assessed on a monthly basis particularly during the initial commissioning or bedding-in stages or following the adoption of a new operating protocol.
   (a) At the end of each month (or other specified period) “Monthly performance assessment limits” should be established for each dam. These would be established from data collected over the previous month(s) from tributary or upstream-of-dam monitoring sites. Hourly data would be most suitable as it would generate 672 to 744 observations per month compared with daily data which would only generate 28 to 31.
   (b) “Monthly performance assessment limits” should be equivalent to:
      i. the 20^{th} and 80^{th}%iles of all the monthly observations
      ii. the 5^{th} and 95^{th}%iles
      iii. plus and minus 3 standard deviations from the mean.

(c) The performance of the outlet infrastructure should be assessed by comparing single daily temperatures (taken at regular periodic intervals) or mean daily temperatures (e.g. from hourly or more frequent sampling) with the “Monthly performance assessment limits”.

(d) Satisfactory performance should initially be defined as:

i. achieving a 60% compliance with the 20^{th} to 80^{th}%ile range,(i.e. would require at least 18 daily observations to be within the range for a 31 day month)

ii. achieving a 90% compliance within the 5^{th} to 95^{th}%ile range, (would require 27 daily observations within the range for a 31 day month) and

iii. no observations outside the range of ±3 standard deviations of the mean.

3. A target rate of change (both increase and decrease) to reduce the risk of thermal shock should be determined. The target should take into account the nature of the local hydrological system and the operational and asset management requirements. This may only need to be monitored whilst changes are being made to outlet arrangements and should be location specific.
4. Temperature management and performance assessment should be limited to the spring/summer/autumn period.
5. Performance assessment should be conducted at a site within several kilometres downstream of the dam but upstream of any confluences with major tributaries and certainly no more than 10km downstream.

Two example graphs showing the monthly target and the performance criteria utilising data from Tallowa Dam on the Shoalhaven River are attached.

References

Lugg, A (in press) The scope of the cold water pollution problem in the Murray Darling Basin, NSW Department of Primary Industries.

Figure 1: Cold water pollution Target Outlet Temperature – Shoalhaven River downstream of Tallowa Dam

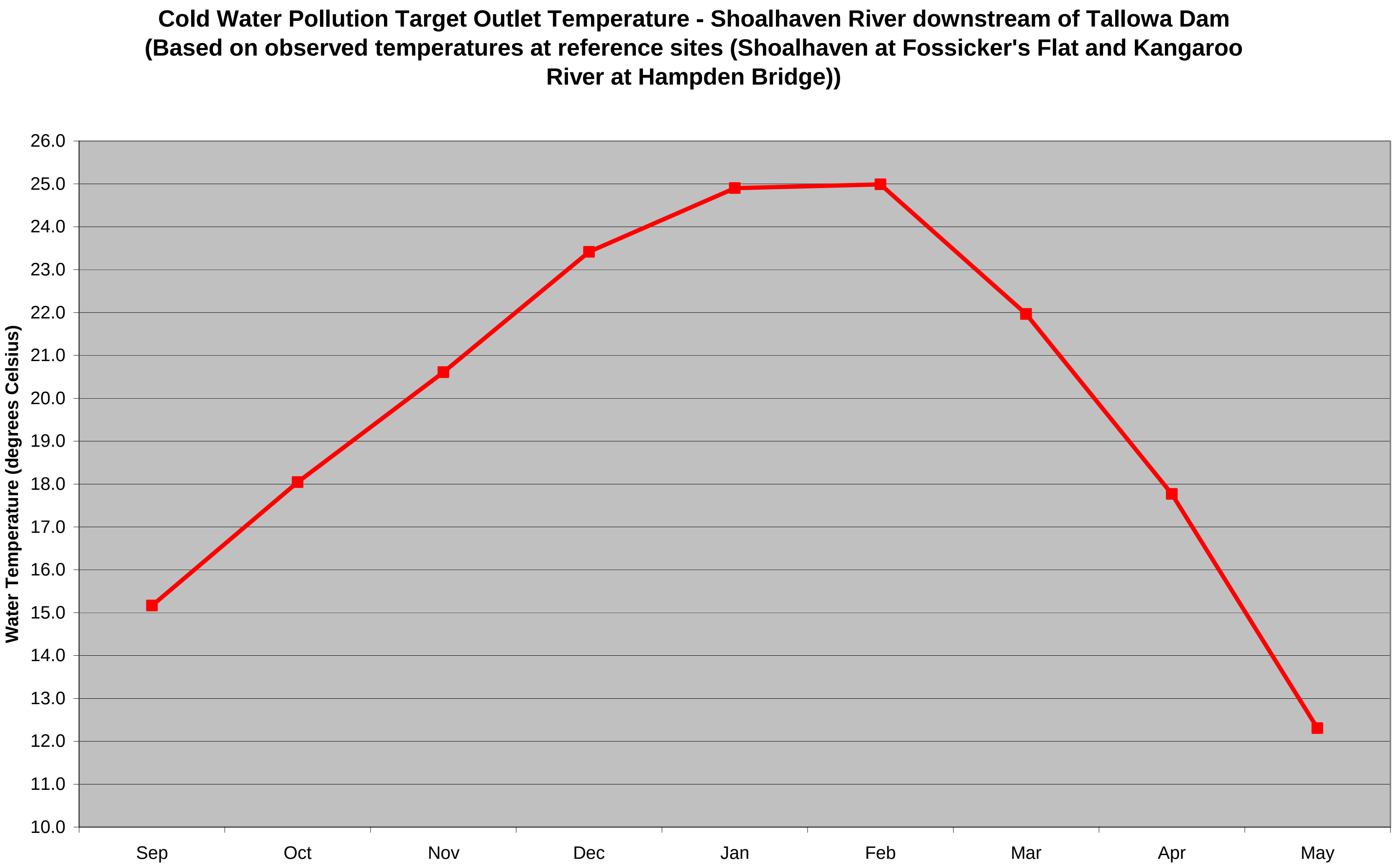

Figure 2: Cold water pollution Performance Criteria for Shoalhaven River downstream of Tallowa Dam