Department of Primary Industries
Office of Water

NSW Cold Water Pollution Strategy

Report on the implementation of stage one

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Executive summary

The Cold Water Pollution Strategy was adopted by the New South Wales Government in July 2004. The strategy aims to reduce the significant effect that major dams have on the ecology of many of the large rivers across New South Wales and is designed to progress in five year stages of planning, implementation and evaluation of outcomes. This report describes progress on the strategy, evaluates its economic benefits and sets objectives for subsequent work to reduce or mitigate the impacts of cold water pollution.

Outcomes achieved in the first five years of the strategy include major infrastructure works at Jindabyne and Tallowa Dams, investigations at both Keepit and Burrendong dams, integration of cold water pollution conditions in State Water works approvals and the identification of high priority dams for possible action in stage 2 of the strategy.

Outcomes not achieved include the completion of works at Keepit and Burrendong dams; investigations on the other identified high priority dams (Blowering, Copeton and Wyangala); the installation of temperature monitoring equipment to aid in the development of improved operating protocols, and the implementation of the revised protocols.

The key causes of delays in meeting these outcomes were the need to coordinate cold water mitigation investigations and works with State Water's Dam Safety Upgrade Program and the lack of funding for cold water pollution modelling and temperature monitoring equipment. The development of improved operating protocols has also proved more complex than anticipated.

It is proposed that the outcomes not achieved in stage 1 be carried over to stage 2 of the strategy. Several additional initiatives are also recommended for stage 2.

1 Background

1.1 Benefits of addressing cold water pollution

Good water quality is one of the fundamental requirements of aquatic ecosystem diversity, productivity and health. Suitable water temperature regimes, in particular, are critical for aquatic ecosystem health. In recent years, governments have made large investments in returning water to the environment, restoring aquatic habitat and reducing barriers to fish passage. The full ecological benefits of these efforts will not be realised if the water released from dams continues to be too cold for native fish and other aquatic organisms to survive and breed.

Cold water pollution (temperature depression), is an artificial decrease in the temperature of water in a natural river. Cold water pollution commonly occurs downstream of large dams due to thermal stratification within the dam, coupled with the release of the lower cold water layer through outlets located towards the base of the wall. The water released from the dam is commonly 10°C colder than natural, and can be up to 17°C colder. Cold water releases from NSW dams have always been an ecological issue, with known effects on ecological processes downstream of dams evident as soon as the dams are filled. Cold water pollution becomes more pronounced when dams contain more than 10 metres of water and is most significant when they are full. The highly developed irrigation industry of the Murray-Darling Basin means that releases from dams is related to irrigation demand. Demand can rapidly change, based on rainfall events, interstate water trading or crop mix water requirements. Large releases may occur independent of dam levels, but cold water pollution is likely to be less of a problem when dam levels are low and releases small.

In New South Wales, cold water pollution is thought to affect around 2000 km of rivers. Longitudinal profiles of river temperatures indicate that water temperature, for example, in the Murrumbidgee, may not recover for the length of the river (Lugg *pers.comm*). No detailed analysis of the total distance of NSW rivers affected by cold water pollution has ever been conducted, but cursory analysis based on available data indicate that 2000 km is a realistic figure. Cold water pollution is not limited to New South Wales. It is a global problem, anywhere large dams have been constructed and water is released from valves at the base of the dam wall. There is a well recognised problem in Victoria, with Hume Dam having well documented cold water effects downstream in the Murray River (Sherman *et al*. 2007).

South-eastern Australian rivers are particularly likely to be affected for three main reasons:

- Dams in the Murray-Darling Basin and south-east Australia are large and deep and are managed to store sufficient water to be useful in the driest conditions
- Murray-Darling Basin dams are generally on the main river and release stored water to the river channel. Dams elsewhere divert water away from the river channel rather than release it to the river channel
- River fisheries in North America and Europe are typically based on Salmonids, such as trout and salmon, cold water species which spawn in winter. Australian native fish tend to spawn in spring and summer in warmer temperatures.

Cold water pollution occurs during the warmer months (spring through to autumn) and is most pronounced in mid-summer when the stratification is most pronounced and large volumes of water are being released for downstream use. The cold water pollution effect can be detected for hundreds of kilometres downstream of many dams.

The impacts of cold water pollution range over a wide spectrum of organisms including fish and macroinvertebrates and are well known (Astles *et al*. 2003, Sherman 2000). The effect on native fish spawning and recruitment is of particular concern and is the best documented impact. The life-cycles of fish are finely tuned to natural daily and seasonal variations in temperature. Large volumes of cold water, lowering the overall temperature of water downstream from a dam, disturb these ecological adaptations. Fast-start performance of golden perch have been found to be affected by cold water, such as that released from dams. This affects competitive behaviour for resources and ability for native warm water fish to escape from predators (Lyon *et al*. 2007). Many species of native fish have been almost eliminated from significant sections of rivers, impacting heavily on both river health and recreational and commercial fishing.

Fish have reasonably well-defined temperature thresholds for the initiation of breeding events. If water temperature fails to reach the relevant threshold fish will not breed despite the fact that other parameters (e.g. day, length, and river flow) may be suitable. Laboratory experiments replicating the effects of Burrendong Dam showed that juvenile silver perch and Murray cod were both profoundly affected by colder water with much lower survival and growth rates over only a 30-day period.

Freshwater catfish are now extremely rare in western rivers where they used to be abundant in the 1960s. Their absence from the Murray River between Hume Dam and Yarrawonga weir and from the Murrumbidgee River between Burrinjuck Dam and Wagga Wagga, when they are otherwise abundant further downstream, is almost certainly due to cold water releases from both dams.

Other research has indicated that cold water pollution eliminates native fish species from the affected rivers. For example, the construction and operation of Dartmouth Dam on the Mitta Mitta River completely eliminated Murray cod, trout cod and Macquarie perch within a few years.

On the basis of available scientific evidence, it is reasonable to conclude that cold water pollution is one of the more serious degrading processes operating in the main rivers of the Murray-Darling Basin as well as some coastal rivers and is probably one of the key factors behind the reduction in abundance and range of native freshwater fish species. Available evidence suggests that cold water pollution reduces the growth and survival of native fish, reduces spawning opportunities, delays egg hatching and promotes invasion by alien species.

The Sustainable Rivers Audit initiated by the Murray-Darling Basin Commission includes an ‘expectedness’ measure, which compares the number of native fish species expected at a site (taking into account fish habitat preferences, altitude, habitat type etc) with the numbers actually caught. The data indicate that the reaches of the main western rivers downstream of large impoundments are generally missing 50 per cent or more of the expected number of native species (generally between 10 to 15 species missing).

Of course this decline in diversity is not wholly attributable to cold water pollution. Other contributing factors include alien species, fish passage barriers (weirs, road crossings), decline in riparian health, desnagging, fishing, sedimentation and disease as well as hydrologic changes and decline in habitat quality. It is interesting to note, that current drought conditions appear to be benefitting many fish populations. Reasons for this are various, including low breeding of floodplain spawning carp, but more importantly, cold water pollution may be less of an issue as dams and discharge rates are at low levels. Nevertheless, research indicates that a substantial increase in the number of native species is certainly possible if one or more of the limiting factors can be eliminated or significantly reduced and cold water pollution is viewed as being one of the most important factors and one that can be more easily addressed.

It is reasonable to assume that addressing cold water pollution will result in the return of native fish to reaches of rivers where they are currently absent. Indeed it is likely that five to seven species could return in many cases. Although some are small-bodied species with little economic value, they often occur in large numbers and play a critical role in aquatic food webs.

Raising water temperatures offers a high probability of inducing significant beneficial response within aquatic ecosystems: higher productivity at all trophic levels; a greater number of native fish breeding events; more successful breeding events; and greater diversity of aquatic invertebrates, fish and other cold-blooded animals such as turtles and frogs. Stocking with hatchery raised fish may be needed to initiate the recovery of local fish populations if fish from adjoining populations are unable to migrate into the affected area or if numbers are so low that natural recruitment cannot be relied upon. These improvements are not likely to be immediate. Some benefits may become apparent within the first 12 months. For example, it is likely that a highly migratory and highly fecund species such as golden perch would migrate upstream and breed in the first spring/summer period following the commissioning of a new multi-level offtake. Increased numbers of ‘young at year’ would be apparent the following year.

However, many fish species (e.g. Macquarie perch, river blackfish, purple-spotted gudgeon) are at such low levels that even if the few remaining individuals responded immediately, it would take several years at least for populations to re-establish and re-populate throughout the river channel. The full benefits may not be apparent for ten years or more.

Recovery could be speeded up in some instances by stocking hatchery reared fish. However, stocking is not a substitute for addressing cold water pollution for several reasons. Indeed stocking fingerlings into rivers affected by cold water pollution is pointless as the habitat is unsuitable and the fingerlings die. This option is only possible for a small number of species with recreational angling value. The majority of species are not stocked at present and indeed, the scientific and technical expertise to breed most species in captivity does not yet exist. Cold water pollution is an ecosystem wide problem. Stocking rivers with fish where cold water pollution has not allowed algal or invertebrate food sources to grow, would be pointless.

Increasing the productivity and abundance of important native fish species such as Murray cod, trout cod, silver perch and golden perch is likely to have significant longer term benefits to the recreational fishing industry by increasing angler satisfaction. Cold water pollution also has an adverse impact upon the suitability of inland rivers for recreational use, most notably swimming, as the water is frequently uncomfortably cold. Addressing cold water pollution will help improve the recreational and tourism value of inland rivers, with substantial social and economic benefits to the communities living along those rivers.

Cold water pollution, while being a common feature of dams everywhere, is not well addressed everywhere. While it is obvious that the ecological effects of cold water pollution are highly degrading and that there are numerous options for addressing the problem (Sherman 2000), active management is not common.

It is important that options to mitigate cold water pollution are tested or modelled before construction; many of the options are relatively expensive and cheaper options may be available. Due to the individual nature of cold water pollution in the large dams in NSW, good feasibility studies prior to construction are required to ensure that the option for mitigation is successful under all conditions for each dam. Each dam needs individual investigation as costs and benefits of mitigation vary.

Sherman (2000) outlined the major options for addressing cold water pollution by NSW dams, with multi-level offtakes and suspended curtains showing the most promise. Surface mounted impellors and compressed air bubblers are less attractive as long term solutions due to ongoing energy consumption and accompanying greenhouse gas implications.

1.2 New South Wales cold water pollution strategy

The protection of water sources and their associated ecosystems is one of the key objectives of the *Water Management Act 2000* (the Act).

The State Water Management Outcomes Plan (SWMOP)[1] developed under the Act and gazetted in 2002, contained a target which required water managers in NSW, to address cold water pollution.

> *Target 26: Dams responsible for cold water pollution identified, a priority listing prepared, and action initiated to ensure that the temperature regime below these dams is kept within the 20th to 80th natural percentile range for each month (or within bounds determined by site specific investigations), by ensuring:*
>
> > *Target 26a Structural modification of at least two priority dams*
> >
> > *Target 26b. Improved operational protocols established for priority dams with existing temperature management infrastructure*

Subsequently, a study funded by the NSW Environmental Trust (Preece 2004) identified a total of 23 dams for action, out of a total of 3,000 dams and weirs assessed in NSW, with nine dams identified as highest priority in the short-term (Table 1).

Table 1. Structures likely to cause severe cold water pollution (taken from Preece 2004)

Rank	Name	Owner
1	Blowering	SW
2	Hume	MDBC
3	Copeton	SW
4	Burrinjuck	SW
5	Burrendong	SW
6	Wyangala	SW
7	Keepit	SW
7	Khancoban	SH
9	Pindari	SW

a. SW = State Water; MDBC=Murray-Darling Basin Commission; SH = Snowy Hydro Ltd.

These high priority dams were identified based primarily on depth of intake for release and size of discharge, which are the most critical factors in the degree of temperature depression (Preece 2004).

Other dams estimated to cause moderate cold water pollution effects numbered 14: Glenbawn, Lostock, Glennies Creek, Carcoar, Toonumbar (State Water dams), Tallowa, Cataract, Warragamba, Cordeaux, Fitzroy Falls (SCA), Jindabyne, Eucumbene (Snowy Hydro), Cochrane, (Eraring Energy) and Googong (ActewAGL).

Four dams were associated with less severe cold water impacts and were a lower priority for action: Windamere, Split Rock and Chaffey (State Water dams) and Talbingo (Snowy Hydro).

[1] Note that the SWMOP expired in 2007.

Preece (2004), together with additional information, was used to develop the *NSW cold water pollution strategy*. Figure 1 shows the 18 dams identified for investigation and possible action over the 25 year life of the strategy. The strategy did not include any actions for Hume Dam, the operations of which are controlled by the Murray-Darling Basin Authority.

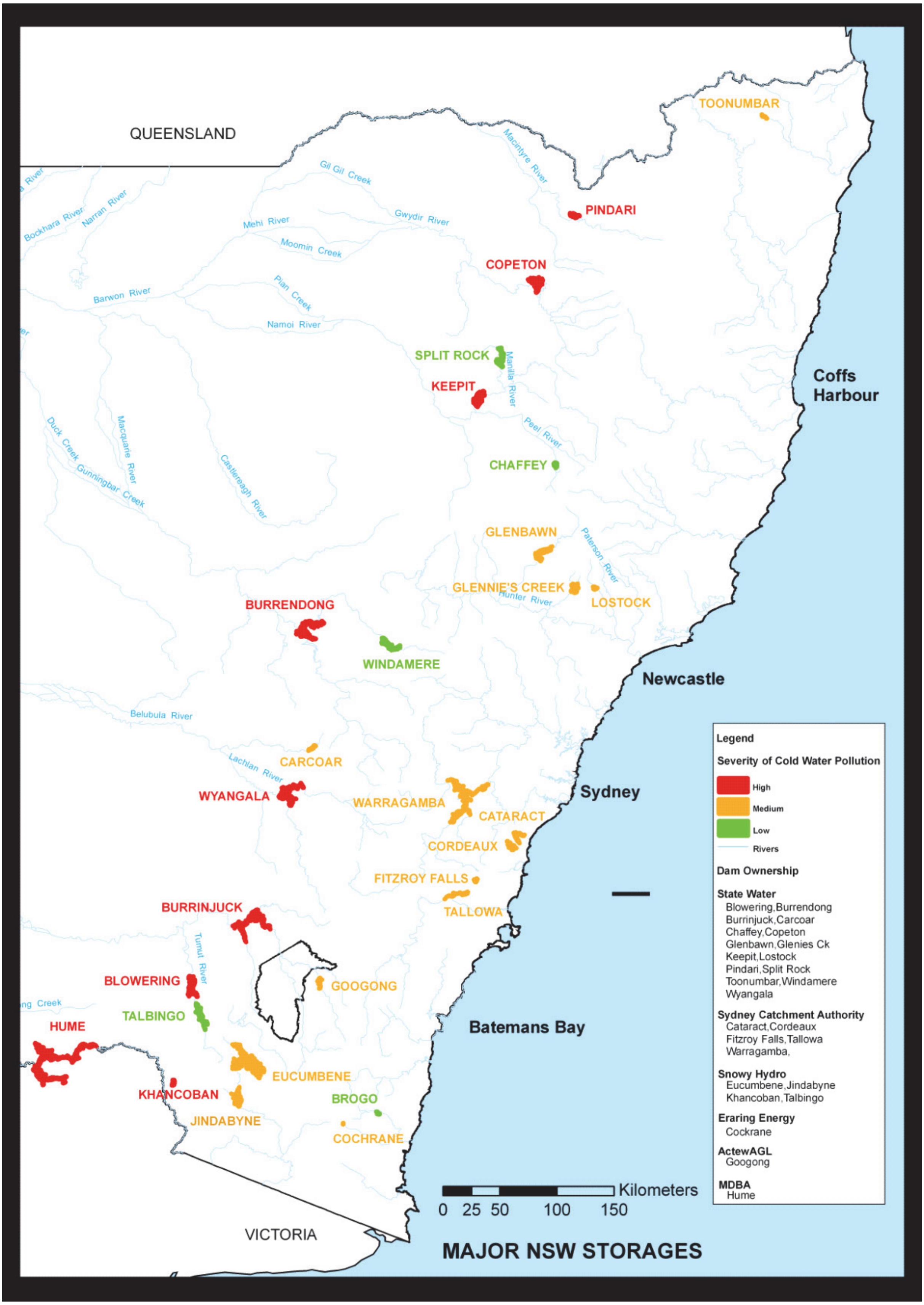

Figure 1. NSW dams with significant cold water potential, updated from Preece (2004)

The NSW Government adopted the Cold Water Pollution Strategy in 2004. The strategy was developed in response to the State Water Management Outcomes Plan (SWMOP) and in recognition that cold water pollution is the second most significant impact arising from the operation of the State's dams (the primary issue being flow regulation). The strategy noted that unless cold water pollution was addressed, the improvements expected in river health as a result of water sharing plans may not be realised.

The strategy outlined a number of actions that need to be taken to address cold water pollution. The actions were to be addressed in stages, with each stage operating over a five year period. The initial stage comprised commencing improvements at priority dams, coordinating actions already in train and establishing the regulatory and governance structure for the strategy. The outcomes of stage 1 of the strategy are outlined in section 2.

2 Key outcomes required for stage 1

2.1 Upgrading dam infrastructure and operational protocols

Stage 1 of the Cold Water Pollution Strategy required the implementation of cold water mitigation actions including capital works by dam operators and the negotiation and agreement on the target priority dams to be investigated for cold water mitigation in subsequent stages of the strategy. Specifically, the strategy required:

- Full scale trial and verification of the use of low-cost engineering solutions (submerged curtain or impellors) to mitigate the impacts of cold water releases from Burrendong Dam on the Macquarie River
- Implementation of cold water mitigation works currently proposed as part of scheduled upgrade works for Keepit Dam
- Implementation of temperature control and fish passage works currently proposed at Tallowa Dam by the Sydney Catchment Authority
- Implementation of temperature control works that are currently proposed at Jindabyne Dam; and
- Implementation of improved operating protocols (including monitoring) and structural modifications recommended by the NSW Environmental Trust Project for the priority dams that already had selective off-take capability (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock and Chaffey)

2.2 Governance and legislative framework

2.2.1 Governance framework outlined by the strategy

The Cold Water Pollution Strategy required that the Water CEOs have responsibility for implementation of the strategy.

2.2.2 Legislative framework

The strategy required that minor amendments be made to the *Water Management Act 2000*, to enable the minister to specify the dams where investigation and works must be taken over a nominated timeframe and to specify the ongoing operating protocols for the nominated works once they have been implemented.

As a consequence of these changes, it was agreed that it would be appropriate to amend the *Protection of the Environment Operations (General) Regulation* so that its licensing requirements would not apply to cold water releases from any dam holding a water supply work approval under the *Water Management Act 2000* (noting that the discharge of a liquid to a water body where the liquid is more than two degrees hotter or colder than the receiving waters is classified as a discharge of thermal waste under the Regulation).

2.3 Monitoring

The Cold Water Pollution Strategy proposed that within the first three years, monitoring equipment is installed at those State Water Dams with existing selective off-take capabilities to aid operating protocol development.

3 Progress on stage 1

3.1 Upgrading dam infrastructure and operational protocols

3.1.1 Trial and verification of low cost solutions at Burrendong Dam

In 2004, GHD were engaged by State Water to investigate options for a multi-level offtake withdrawal at Burrendong Dam (Appendix 1). A range of options to improve release temperatures were investigated including surface mounted impellors combined with a draft tube, floating curtains, floating offtakes and various multi-level offtake designs.

In parallel, State Water engaged Manly Hydraulics Laboratory to undertake a physical 3D model study of a floating curtain around the intake tower. The model demonstrated the feasibility of the curtain system to redirect the upper layers of warmer water into the intake tower. Further refinement of the curtain model was undertaken in 2005/06 to test a less rigid arrangement which could withstand wave action in the storage.

In June 2007, via the Commonwealth funded NSW River Environmental Restoration Program, State Water was able to engage Connell Wagner to investigate the thermodynamic nature of Burrendong storage and determine the potential temperature performance and ecological outcomes that the curtain option may provide. Results indicated that the curtain, when situated at the top of the water column will provide significant improvements in release temperatures.

The next step is to develop a detailed concept design for the curtain to resolve outstanding operation and maintenance issues, flexibility to adjust withdrawal depth to allow for algal management and allow State Water to understand the potential impact of the floating curtain on the dam itself. These investigations will occur in 2009/10. The outcome of this last study will allow State Water to decide on a preferred cold water pollution mitigation option for Burrendong Dam.

3.1.2 Implementation of works at Keepit Dam

In 2003, as part of the Keepit Dam Upgrade Project, State Water undertook a range of investigations exploring the potential options to mitigate cold water pollution at the dam. These investigations included engaging the Department of Commerce to develop engineering solutions and Manly Hydraulics Laboratory to undertake some intensive data collection and data analysis to understand the thermodynamic behaviour of the storage and model the potential improvements offered by the mitigation options.

Based on the outcomes of the above studies, State Water completed a multi-criteria assessment on the suite of potential mitigation options and selected three shortlisted options for further investigations. In 2005, the Department of Commerce were again engaged to develop concept designs for the shortlisted options, to identify capital, operation and maintenance costs and to establish the performance of each option in terms of environmental outcomes, reliability, safety and functionality.

In 2007/08, Manly Hydraulics Laboratory was engaged by State Water to refine the thermodynamic modelling to gain a better understanding of the potential temperature performance and ecological outcomes of a multi-level offtake, especially at medium to high discharges.

The studies and investigations found that the level of environmental performance was similar for all three multi-level offtake options. Construction, operational functionality and cost were therefore used by State Water to select the automatic louvre shutter as the preferred cold water pollution mitigation option at Keepit Dam.

State Water concluded that the automatic louvre shutter system has competitive capital, operational and maintenance costs, is a trusted design, will provide flexibility and will dramatically improve the release temperatures during fish breeding windows and mitigate cold water pollution in the Namoi River (for up to 100km), for the majority of the time.

Construction of the multi-level offtake at Keepit Dam is scheduled to commence in 2011 as part of the Keepit Dam Upgrade Project.

3.1.3 Completion of works at Tallowa Dam

Tallowa Dam was constructed with low level outlets that released water from 21 metres below the full supply level (FSL). Strong thermal stratification of the lake saw releases from the dam being up to 11^{o}C colder than at other downstream sites. Water was low in oxygen with high concentrations of iron and manganese.

In 2005 the Sydney Catchment Authority reviewed several options for mitigating the cold water impacts of releases from Tallowa Dam. Options included selective withdrawal systems including multi-level offtakes, floating intakes and curtains. Artificial destratification was also evaluated.

Long term options were also being evaluated for the dam as part of the NSW Government's Metropolitan Water Plan. In light of potential changes to the dam, artificial destratification was identified as a proven cost-effective option that could be used pending a final decision about any new works at the dam.

3.1.3.1 Artificial destratification

Compressed air bubbling was chosen as an interim measure to mitigate the cold water impacts while environmental flow release works were being designed and constructed. A compressor and diffuser system was commissioned and installed in October 2005 at a cost of approximately $400,000. The system generated a plume of air bubbles upstream from the dam wall which entrained water from the bottom layers of the lake.

Immediately prior to commissioning, temperature results from a thermistor chain near the dam wall indicated the lake as clearly stratified. Following commissioning vertical mixing of the reservoir was visible in December 2005 and by January 2006 the water column temperature was nearly uniform. The average January temperature at the depth of the dam outlets was 12.6^{o}C. In January 2006 the temperature at this depth was 21.9^{o}C. Large sections of the lake were found to be destratified by this system. Downstream releases approached 25^{o}C.

The river habitat downstream of the dam has experienced a notable improvement due to the release of warmer water together with improved oxygen content and lower iron and manganese concentrations. Fish are also more plentiful downstream of the dam wall.

Destratification has continued from October to May each year. Power consumption has cost $60,000 per year resulting in up to 750 tonnes of carbon dioxide being produced. The system was decommissioned in May 2009 when the environmental flow release works were completed.

3.1.3.2 Environmental flow release works and fishway

In March 2007 the NSW Government committed to provide new environmental flows and fish passage at Tallowa Dam. In January 2008 a $26.2 million contract was let for works to achieve these goals including a new gate in the dam crest and a fish lift to allow upstream fish movement.

Now complete, the works ensure that releases of water from the dam come from at or near the surface of the lake. A new surface water drawoff facility provides water to the fishlift from a new concrete inlet chamber attached to the upstream face of the dam. It can access water to 5.25 metres below full supply level. An overshot gate has been constructed within the crest of the dam and can release water down to three metres below full supply level. The overshot gate also provides downstream fish passage.

A monitoring program for the new environmental flows and fishway has commenced and includes the evaluation of water quality and fish communities.

3.1.4 Completion of works at Jindabyne Dam

Snowy Hydro is required under the Snowy Water Licence to construct an outlet at Jindabyne Dam capable of releasing water from above the thermocline. The outlet was to be of sufficient size to enable a flow rate of up to five gigalitres a day, with provision for flushing flows up to 20 gigalitres a day to be delivered through the gated spillway. Snowy Hydro completed temperature control works at Jindabyne Dam as part of a larger capital works program in 2006. The outlet works include an intake tower with trash racks, water quality baulks and adjustable shutters and a thermistor string on the face of the intake tower adjacent to the trash racks to confirm the presence/absence of a thermocline at the intake. Waters travel via a 360metre long concrete lined tunnel and are discharged through submerged discharge valve (SDV) (0-220 megalitres a day); mini-hydro generator (95 -170 megalitres a day); 1.2 metre diameter cone valve (300 to 1,380 megalitres a day) and 1.9 metre diameter cone valve (650 to 3,450 megalitres a day. These outlet structures are operated either individually or in combinations to provide flow rates up to five gigalitres a day consistent with the daily volume targets notified to Snowy Hydro by the Water Administration Ministerial Corporation."

3.1.5 Improved operating protocols at dams with multi-level offtakes

In 2006/07 State Water engaged a water quality scientist from the former Department of Water and Energy (now the NSW Office of Water) to develop preliminary drafts of cold water pollution operating protocols for Pindari, Chaffey, Split Rock and Windamere dams. These drafts provided a technical overview of cold water pollution data and dam operations, characterised stratification and described the downstream impacts. The operating procedure component, while it captured key decision making aspects, needed further drafting for day-to-day use by dam operators. Concurrently, State Water produced draft protocols for Glenbawn Dam and Glennies Creek Dam that followed more of a decision-based flowchart and dam operators at these locations have utilised the draft protocols.

In comparing both styles of draft protocols in 2007/08, State Water decided that it would be worthwhile assembling all of the technical literature information behind the Pindari, Chaffey, Split Rock and Windamere protocols into a technical companion document to State Water's protocols. The remaining protocol components then underwent further drafting in 2008/09 in response to the compliance requirements that emerged from the water supply works approvals issued by the former Department of Water and Energy.

As noted in Section 3.2.2., the *Guidelines for Managing Cold Water Releases from High Priority Dams* was designed, in part, to assist the development of effective dam operating protocols. As the guideline was developed, State Water made further adjustments to the draft protocols to reflect the guideline's requirements. In addition to the advice contained in the guideline, seasonal operating considerations were identified by the Department of Primary Industries to reduce the temperature release impacts on fish spawning.

In 2008/2009, the former Department of Water and Energy's corporate licensing branch commenced the rollout of water supply works approvals with conditions to implement operating protocols in line with the guideline. During this time, State Water has taken the opportunity to road test the protocols and to explore the full ramifications of operating protocol implementation. This has confirmed the need for State Water and NSW Office of Water (formerly the Department of Water and Energy) to collaborate to improve the monitoring network and data needs to meet the guideline.

The full extent of implementation costs also needs to be determined by State Water once these matters have been addressed. The potential of using a pilot approach at one dam to confirm specific data requirements and reporting has also been discussed as an option in 2008/09. The meetings between State Water and the NSW Office of Water in 2009/10 to develop their Memorandum of Understanding will be utilised to work through data management roles, responsibilities and expectations. State Water is also working with other agencies to incorporate other aspects of river operations such as seasonal fish spawning requirements, algal management as well as a mutual understanding of dam operating constraints that may override the ability to mitigate cold water pollution at critical times.

Through another linked initiative, State Water has been documenting the current status of its storage water quality monitoring with a view to developing a strategic water quality program to address its compliance and business needs, including its environment management plan. Three major factors generated the impetus in 2009 to systematically review and improve State Water's water quality monitoring policy, procedures and resourcing. These were its new organisational structure, the works approvals conditions for cold water pollution and the need to quantify water quality monitoring costs for State Water's next IPART pricing submission. Cold water pollution monitoring requirements will form one component of State Water's overall monitoring program and strategic program development will occur from 2009/10.

As part of documenting the current status of monitoring activities, issues with State Water's monitoring methods, instrumentation management and in data management systems were identified through an internal review. Because these matters have ramifications on State Water's operating protocol implementation, they will need to be addressed through the strategic water quality program development as a high priority requirement.

While good progress has been made on the development of the operating protocols, the collective impact of all of the matters noted above means that State Water will need to carefully manage and resource the shift from draft protocols to implementation in the coming years. State Water has recently highlighted that it may not be able to meet the requirements of the guideline in the short term due to dam constraints and gaps in the monitoring network capability. It is proposed that State Water and the NSW Office of Water will work under a memorandum of understanding to address this issue.

3.2 Activities of the Interagency Group for Cold Water Pollution

With the abolition of the Water CEOs Group, responsibility for implementing the strategy became the responsibility of the Senior Officers Group on Water. The Senior Officers Group on Water has undertaken the role of the Water CEOs, as identified in the strategy since this time. An Interagency Group manages the implementation of the strategy on a day to day basis and reports back to the Senior Officers Group on Water.

The NSW Office of Water is required to coordinate the state's response to the strategy.The Interagency Group was originally convened under direction of .the minister for Infrastructure, Planning and Natural Resources.

The interagency group's terms of reference (Appendix 2) governs its operation, defining its role, responsibilities and reporting requirements.

The interagency group has met on average quarterly to coordinate and evaluate progress on the strategy. Outcomes of the interagency group meetings have been reported to the Water CEOs and more recently to the Senior Officers Group on Water on Water. Interagency group meetings act as a forum for information exchange between operators and Government agencies, ensuring critical review of operation implications of proposals. Meetings have addressed issues such as discussion of reports by operators on projects, developing works approval conditions for priority dams, and identifying priority dams for stage 2 of the strategy.

The interagency group has made significant progress in facilitating the implementation of stage 1 of the strategy. The following sections outline the key achievements of the interagency group in progressing stage 1 of the strategy and beyond.

3.2.1 Matrix to establish priority dams for Stage 2 of the Cold Water Pollution Strategy.

The interagency group developed an evaluation matrix to set priorities for stage 2 of the Cold Water Pollution Strategy (Appendix 3). Six criteria were used to complete the prioritisation, including:

- Size of problem – derived from Preece (2004)
- Conservation and environmental values
- Practicality and opportunities
- Effectiveness of works
- Community factors
- Cost of preferred options.

Using this system, the highest scoring storages were Blowering, Copeton and Wyangala dams and the Interagency Group therefore recommended these to the Water CEOs for priority action in stage 2

(2010 – 2015). The recommendations were tabled and endorsed at the Water CEO Meeting of 23 August 2006 (Appendix 3).

3.2.2 Guideline for managing cold water releases

The Interagency Group identified a substantial gap in understanding the best way to evaluate and mitigate the impacts of cold water pollution. To address this gap, the interagency group developed the *Guideline for Managing Cold Water Releases from High Priority Dams* to:

- Provide guidance to dam operators 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 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
- Provide guidance to operators on performance monitoring benchmarks.

The draft guideline (Appendix 4) was endorsed by the Water CEOs at their meeting of 24 August 2007.

Snowy Hydro and Sydney Catchment Authority endorsement was sought by the interagency group. Snowy Hydro gave a qualified endorsement due to concerns driven by the particular and relatively unusual circumstances that Snowy Hydro faces with its water operations. Snowy Hydro is currently still working through the practical application of the guidelines and will provide more detailed commentary of their thoughts and concerns in the near future.

3.2.3 Matrix of requirements for works approval conditions

Draft works approval conditions were developed by the interagency group to assist the Office of Water in developing works approvals for dam operators under the *Water Management Act 2000*, particularly for State Water. The matrix for conditions required for each of the priority dams (Appendix 5) was endorsed by the Water CEOs at their meeting of 24 August 2007.

The interagency group has been consulted by the Office of Water and has advised on the development of works approval conditions as they have been developed. Works approvals that have been issued to date are listed in section 3.3.

3.2.4 Improved temperature monitoring facilities

Monitoring of water temperature around dams is required to allow:

- the development of temperature target curves based on knowledge of natural river temperature regimes
- operators to determine the effectiveness of temperature management actions in regards to mimicking natural temperature variation through time
- regulators to measure compliance with works approval
- the effectiveness of the strategy to be assessed.

Water temperature normally increases as a river flows downstream. This natural temperature rise depends on quantity of flowing water, the substrate and rate of flow. Dark coloured bedrock or sand beds will have quite different effects on temperature increase. Water flowing quickly will generally increase in temperature less over a given distance than slow flowing water. Ambient air temperature will also affect water temperature. Temperature stratification in very slow moving rivers further complicates river temperatures as do storms or spates that can decrease water temperatures by as much as 10 degrees Celsius within short time periods. Development of rivers, such as releases from sewage treatment works may elevate natural in stream temperatures. But the biggest impact is that of major storage dams, with stratification of standing waters creating strong thermoclines. Release from the bottom of dams may cause significant and extended temperature depression downstream.

Establishing the extent of a dam's impacts on water temperature require a reliable understanding of natural water temperature. This allows validation of the best option for dealing with the impacts and the ongoing management of the releases and evaluation of the results of operational changes.

In New South Wales, much major storage that contribute cold water pollution downstream do not have any temperature monitoring equipment upstream and very few rivers have equipment to monitor recovery of water temperature downstream to identify the impact to aquatic communities. The interagency group has produced an unpublished report (Hardwick *et al*. in prep) that identifies the most basic monitoring needs. The funding applications listed below have included the costs from that report.

- New South Wales Treasury under the Community Service Obligation program
- Federal Government program: Caring for our Country
- Federal Government Bureau of Meteorology funding
- State Government hydrometric upgrade program

At present, funding for the monitoring infrastructure and its ongoing maintenance and data collection has not been achieved.

Once funding is available, each high priority dam will need to be investigated separately. The Office of Water and State Water are discussing two pilot projects aimed at developing cold water pollution protocols. These will help to road test and set operating protocols for multi-level off-take structures, based on available temperature data both upstream and downstream of the dam.

3.3 Changes to the legislative framework - Amendment of the *Water Management Act 2000* and management of cold water pollution on works approvals

In NSW, the primary mechanism for the management of cold water pollution is the *Water Management Act 2000* (the Act). As recommended by the cold water pollution strategy, amendments have been made to the Act to ensure effective management of cold water pollution in NSW. These amendments are detailed in the *Water Management Amendment Bill 2005.* The amendments enable cold water pollution mitigation measures to be implemented and enforced via the water management works approvals issued for each storage.

Specifically, Section 100 (3) has been inserted into the Act. Section 100 (3) is:

(3) Without limiting the types of conditions relating to the protection of the environment that the Minister may impose under this section on a water management work approval, those conditions may include conditions relating to 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 to the program from the Minister*
>
> *(c) the implementation of the program*
>
> *(d) the monitoring and reporting on actions taken to implement the program and the impact of those actions on the environment*
>
> *(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.*

Conditions for water management works approvals are developed by the NSW Office of Water. The Interagency Group has a role in ensuring the draft conditions are consistent with the objectives and priorities of the cold water pollution strategy.

Works approvals, including cold water pollution works approval conditions have been finalised between the NSW Office of Water and State Water for the:

- Gwydir Water Source, including Copeton Dam
- Hunter Water Source, including Glenbawn Dam and Glennies Creek Dam
- Namoi Water Source, including Keepit Dam and Split Rock Dam
- Paterson Water Source, including Lostock Dam
- Lachlan Water Source, including Wyangala Dam.

It is recognised that the interagency group needs to monitor the implementation and application of works approval conditions as they relate to cold water and monitoring, budget and operating constraints.

4 Assessing the economic benefits and costs of addressing cold water pollution

4.1 Economic analysis

The interagency group was requested by the Senior Officers Group on Water to provide an assessment of the costs of stage 1 and stage 2 of the cold water pollution strategy. An economic analysis was undertaken to assess the benefits and costs of stage 1 and stage 2 of actions under the Cold Water Pollution Strategy (Hill 2009 – Appendix 6).

The economic analysis compared the Cold Water Pollution Strategy scenario with a base case scenario. Under the base case scenario no capital works were incurred. There were no changes in operational procedures and maintenance costs, and monitoring was not undertaken.

Under the Cold Water Pollution Strategy scenario, investigation costs, capital costs, operation and maintenance costs and monitoring costs were incurred. The benefits were identified as an increase in one native species of fish in rivers affected by cold water pollution in NSW. This assumption was based on studies where cold water pollution has had an impact and on expert knowledge (NSW Trade and Investment) of fish spawning requirements. (Lugg Industry and Investment, NSW September 2009).

As noted in section 1, research has indicated that cold water pollution eliminates native fish species from the affected rivers. Research at Burrendong Dam (Lugg 2009) with paired warm and cold water channels demonstrated high rates of mortality for silver perch when exposed to cold water for only 30 days compared to those living in warm water. The only other species tested (Murray cod) were less affected.

Increasing the temperature of the discharge water so that the minimum spawning thresholds are reached on an annual basis will allow populations to re-establish (Lugg 2009) although stocking with hatchery raised fish may be needed initially to restore populations in the affected areas. Since native fish stocking is already widely practiced, this is not treated as an additional cost.

It is reasonable to assume that addressing cold water pollution would result in the return of at least one species of native fish to reaches of rivers where they are currently absent and it is quite likely that five to seven species could return in many cases. (Lugg 2009 personal communication)

4.1.1 Cold water pollution strategy stage 1 costs

This section addresses the costs of the works actually undertaken in stage 1 over the period 2004-2009. The works not completed in this period, but were part of the proposed works in stage 1, are carried over into stage 2 and costed. The five year stage 1 analysis assessed the costs actually incurred in the five years of the stage 1 cold water pollution strategy. It does not include ongoing costs incurred beyond 2009.

The costs documented in this section exclude the costs of projects initially listed under stage 1 but not actually implemented, such as the capital costs for Burrendong Dam and investigation and capital costs for Keepit Dam (State Water 13/10/09) and the operating protocols and operational costs for the six dams (Chaffey, Glenbawn, Glennies Creek, Pindari, Split Rock and Windamere). The following table outlines costs incurred in the stage 1 analysis.

Table 2 Summary of costs included in stage 1 analysis

Dams	Input to economic analysis
Tallowa*	$ 8 million capital costs $400000 aerator cost $60000 power cost Monitoring cost of $13750 incurred annually for 5 years
Jindabyne**	$8.9 million capital cost Operating, maintenance and monitoring costs of 2.75%* of capital costs i.e. $244,750 per annum
Burrendong***	Investigation costs of $283,000
Keepit ***	Investigation costs of $130,000
Glenbawn***	$200,000 capital cost Assumed that monitoring costs of $20000 and capital costs of monitoring equipment of $20000 were incurred annually*.
Glennies Creek***	$22,000 capital costs Assumed that monitoring costs of $20,000 and capital costs of monitoring equipment of $20,000 were incurred annually.*
Chaffey***	No works or monitoring undertaken or planned in stage 1**
Pindari***	No works or monitoring undertaken or planned in stage 1**
Split Rock***	No works or monitoring undertaken or planned in stage 1** No works undertaken or planned in stage 1**
Windamere***	No works or monitoring undertaken or planned in stage 1** No works undertaken or planned in stage 1**

Sources;*Sydney Catchment Authority, **Snowy Hydro, ***State Water

The analysis assumes that the operation and maintenance costs incurred in stages 1 and 2 are over and above those incurred in the base case.

Based on the information in the above table, the following table shows the annual costs under stage 1 by cost category. The total cost of stage 1 was estimated at $19.4 million, with capital expenditure being the significant cost estimated at $17.5 million.

Table 3 Summary of annual costs by cost category for stage 1

Cost category	20004/05	2005/06	2006/07	2007/08	2008/09	total
investigation	0	90,045	139,811	120,515	62,629	413,000
capital	4,850,000	4,450,000	222,000	4,000,000	4,000,000	17,522,000
operating and maintenance	0	304,750	306,970	306,970	266,970	1,185,660
monitoring	13,750	13,750	93,750	93,750	93,750	308,750
total	**4,863,750**	**4,858,545**	**762,531**	**4,521,235**	**4,423,349**	**19,429,410**

The costs incurred for each dam in stage 1 are shown in the following table.

Table 4 Summary of total costs by dam for stage 1

Dam	$
Tallowa	8,668,750
Jindabyne	9,879,000
Burrendong	283,000
Keepit	130,000
Glenbawn, Glennies Creek structural modifications	468,660
total	**19,429,410**

4.1.2 Cold water pollution strategy stage 2 costs

Several actions in stage 1, while substantially progressed, were not fully completed. This section is based on the recommendation that the uncompleted actions from stage 1 are carried over into the stage 2 analysis. The specific actions to be further progressed in stage 2 are:

- Construction of a multi-level offtake at Keepit Dam and develop operating protocols
- Finalise the investigation into the suspended curtain at Burrendong Dam including the assessment of operation and maintenance implications. Develop a program for construction and draft operating protocols
- Installation of monitoring infrastructure for dams in stage 2
- Finalise operating protocols for those dams that already had selective off-take capability (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock and Chaffey dams)
- Investigate and implement cold water pollution mitigation works in two priority dams, proposed as Copeton on the Gwydir River and Wyangala on the Lachlan River

- Develop a monitoring, evaluation, and reporting (MER) strategy, including commitment to funding installation, data collection and maintenance of monitoring equipment and dedicated human resources to develop temperature growth models for the priority dams. Without such a strategy, the effectiveness and performance of the implementation of cold water pollution mitigation works cannot be assessed.

Stage 2 economic analysis looked at expenditure for the five years of stage 2, being from 2009-2014. The following proposed costs were included in the analysis.

Table 5 Summary of proposed costs included in stage 2 analyses

Project	Investigation Costs ($)	Construction Costs ($)	O&M Costs ($)*	Monitoring Costs** ($)
Operating protocols for Chaffey, Glenbawn, Glennies Creek, Pindari, Split Rock and Windamere	200,000			$50,000 per structure per annum
Keepit	205,000	5,000,000	1% of capital	$50,000 per annum
Burrendong	200,000	4,500,000	1% of capital	$50,000 per annum
Copeton	250,000	15,000,000	1% of capital	$50,000 per annum
Wyangala	100,000	5,000,000	1% of capital	$50,000 per annum

Source: State Water 13/10/09

* estimated by State Water 13/10/09

** Estimated by State Water; Includes infrastructure, monitoring and reporting costs

The estimated total cost for stage 2 is $32.7 million. The bulk of the expenditure is capital costs of $29.5 million and scheduled to be incurred in the last three years of stage 2.

Table 6 Summary of annual costs by cost category for stage 2

Cost category	2009/10	2010/11	2011/12	2012/13	2013/14	Total
Investigation	218333	368333	68333	100000	0	755,000
Capital	0	0	7,500,000	7,000,000	15,000,000	29,500,000
Operating and maintenance	0	0	45,000	290,000	290,000	625,000
monitoring	0	0	50,000	200,000	150,000	400,000
Operating protocols*	200,000	300,000	300,000	300,000	300,000	1,400,000
total	**418,333**	**668,333**	**7,963,333**	**7,890,000**	**15,740,000**	**32,680,000**

* included drafting and implementation of operating protocols for Chaffey, Glenbawn, Glennies Creek, Pindari Split Rock and Windamere.

Source: State Water

The costs incurred by dam in stage 2 are shown in the following table.

Table 7. Summary of total costs for stage 2 by dam

stage 2 costs	$
Operating Protocols for Chaffey, Glenbawn, Glennies Creek, Pindari, Split Rock and Windamere	1,400,000
Keepit	5,490,000
Burrendong	4,890,000
Copeton	15,650,000
Wyangala	5,250,000
total	**32,680,000**

Summary of costs for stage 1 and stage 2

The following table summarises the costs incurred under stage 1 and stage 2 of the cold water pollution strategy

Table 8. Total costs for stage 1 and stage 2

stage	$
stage 1	19,429,410
stage 2	32,680,000

4.1.3 Benefits for stages 1 and 2

Benefits of the Cold Water Pollution Strategy were identified as

- Residual benefits of capital
- Environmental benefits, valued in terms of increases in fish species.

The calculation of residual value of capital works was included in each five year analysis. The capital works were assumed to have a life of 50 years, with the resulting value calculated on a straight line depreciation basis (NSW Treasury 2007). Note that capital expenditure was spread across the five year period of stage 1 and again separately over the five year period for stage 2. The very short timeframe of the analysis therefore has returned high residual values.

Table 9. Residual value of capital stage 1

Dam	Residual value $
Tallowa	7,200,000
Jindabyne	8,010,000
Glenbawn , Glennies	199,800
Total	**15,409,800**

Table 10. Residual value of capital stage 2

Dam	Residual value $
Keepit	4,050,000
Burrendong	4,050,000
Copeton	13,500,000
Wyangala	4,500,000
Total	**26,100,000**

Other benefits

The benefits of stage 1 and stage 2 of the Cold Water Pollution Strategy were conservatively estimated as an overall increase of two species of native fish in eight rivers in NSW as a direct result of the cold water pollution strategy, although the benefits, as stated above, are likely to be higher. The value estimated for this benefit was based on a choice modelling study (Morrison and Bennett 2004), which provided an indication of the order of magnitude that NSW households were willing to pay to achieve a variety of environmental benefits, of which fish species was one benefit quantified.

The statewide study established values held by the public for improved river health from boatable to fishable and swimmable, and improvement in riverside vegetation increases in waterbirds and other fauna. The study also established monetary values held by the public for changes in native fish species numbers.

The values established in the Morrison and Bennett study could be applied to the stage 1 and stage 2 benefits using what is termed 'benefit transfer'. 'Benefit transfer refers to the extrapolation of non-market value estimate generated at a source site to a second target site.' (Morrison and Bennett 2004) While this method does not establish accurate values, it does provide an order of magnitude for determining the benefits derived from the cold water pollution strategy.

This economic analysis assumed that the implementation of stage 1 of the Cold Water Pollution Strategy would result in an increase of two native species in four rivers affected by cold water pollution in stage 1 in New South Wales. The analysis assumed that the implementation of stage 2 of the Cold Water Pollution Strategy would result in an increase of two native species in a further four rivers. Based on response rates of the choice modelling studies (Bennett and Morrison unpublished, and Morrison and Bennett 2004), and the expectation that a percentage of non-respondents could also hold similar values to respondents, a conservative lower bound estimate and an upper bound estimate were calculated for benefits.

The assessment estimated a value of $5 million and an upper bound of $8 million for an increase in one fish species, which, when extrapolated to an increase in two fish species in eight rivers, results in an estimated value of $84 million to $128 million held by NSW households.

Summary

The analysis was based on costs as provided by Sydney Catchment Authority, Snowy Hydro and State Water, and incorporated the interagency group request to show the actual costs of stage 1 and stage 2 separately. The costs can be added to identify the total cost of stage 1 and stage 2. An economic analysis showing discounted costs over time is included in the detailed economic analysis report (Hill 2009)

The estimated benefits focussed on household willingness to pay for an increase in native fish species in the associated rivers of the project.

A number of other benefits could have been included, such as willingness to pay for changes in water quality, aesthetic riverine habitat improvements or recreation values. Inclusion of these benefits would be expected to increase the benefits of the cold water pollution strategy.

The Cold Water Pollution Strategy has other unquantified benefits, such as supporting the capital works of fish passage and river management works. Therefore the current analysis is indicative of a high return on capital invested in the strategy.

However the benefits as calculated indicated that the public values improvements in water quality as measured by increases in fish species.

4.2 Economic analysis of stage 1 over 30 years

The economic costs of stage 1 were calculated over a 30 year period at a seven per cent discount rate (NSW Treasury guidelines 2007). The costs included:

- investigation costs
- capital works costs
- ongoing operating and maintenance costs of capital works
- ongoing monitoring of water quality and temperature

Benefits for stage 1 were conservatively calculated as an increase of two species of native fish in four rivers in NSW as a direct result of the cold water pollution strategy, although the benefits, as stated above, are likely to be higher. The value estimated for this benefit was based on a comprehensive choice modelling study (Morrison and Bennett 2004), which provided an indication of the order of magnitude that NSW households were willing to pay, as a once off payment, to achieve a variety of environmental benefits, of which fish species was one benefit quantified. The estimates were based on a conservative response rate in the choice modelling study (Bennett and Morrison 2001). An estimated upper bound level of benefit was also calculated, based on anticipated values held by survey non respondents.

The total benefits and costs, discounted benefits and costs, net present values and benefit-cost ratios are shown in the following table. A positive net present value of $15 million to $33 million and a benefit-cost ratio greater than one indicate that the Cold Water Pollution Strategy stage 1 can be expected to return positive economic benefits. Other benefits, such as recreation benefits due to improved water quality and aquatic habitat benefits were not quantified. Their inclusion would result in a higher benefit-cost ratio.

Table 11. Summary of economic benefits and costs of cold water pollution stage 1 over 30 years

stage 1	$ Lower bound	$ Upper bound
Total benefits	49,218,000	70,543,900
Total costs	33,626,750	33,626,750
Net benefits	15,591,250	36,917,150
Present value (PV)		
PV benefits	35,485,600	53,793,600
PV costs	20,393,600	20,393,600
Net present value	15,092,000	33,400,000
Benefit cost ratio	1.74	2.64

Note: data rounded

4.2.1 Sensitivity analysis

Sensitivity analysis addresses the uncertainty surrounding the data and scenarios being evaluated. The values of key variables in the analysis are changed to assess the significance of assumptions on the final outcomes of this study.

The key variables in this study were considered to be monitoring costs, discount rates, changes in capital replacement costs, residual values and the dollar value of willingness to pay. These are shown in Table 12 together with their impacts on net present values and the benefit–cost ratios of the identified changes. These individual changes were calculated on the lower bound of the benefit–cost ratio. They generally had small impacts on the net present value. The extent of impact was similar on the upper bound of the benefit-cost ratio.

Halving the dollar value of willingness to pay had the greatest impact, reducing the benefit–cost ratio to 0.89 from 1.74. Changing the discount rate to four per cent reduced the benefit–cost ratio by 0.11, and changing the discount rate to 10 per cent increased the benefit-cost ratio by 0.08.

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Table 12. Summary of sensitivity analysis of key variables on the lower bound of the benefit-cost ratio (BCR)

Variable	Change in variable	Net present value ($)	BCR	Change from analysis BCR= 1.74
Monitoring costs	where estimated at $40,000 were halved to $20,000	15,516,000	1.78	0.04
Discount rate 4%	–	15,416,500	1.63	-0.11
Discount rate 7%	–	15,092,000	**1.74**	0.00
Discount rate 10%	–	14,524,000	1.82	0.08
Capital replacement costs	changed from 25% to 15**%	15,587,000	1.78	0.04
Capital replacement costs	changed from 25% to 35%***	14,597,000	1.70	-0.04
Residual value of capital *	$0 value after 30 years	14,192,000	1.70	-0.04
Willingness to pay benefits	half of the average value of benefits calculated	(2,201,000)	0.89	-0.85

Life of capital was estimated as 50 years.

Note capital expenditure already incurred so sensitivity analysis was not conducted on changes in capital expenditure, only on capital replacement costs.

** Note that Tallowa replacement capital was calculated at 30% Source Sydney Catchment Authority

4.2.2 Threshold analysis

Threshold analysis can be used to indicate the minimum level of benefits such that the net present value of benefits would equal the net present value of costs and the benefit-cost ratio would equal one. The threshold analysis indicated key variables that could change the lower bound benefit-cost ratio to equal one, for example:

- an increase of only five species of native fish, or
- a decrease in the average value held by the public from $5.02 per household to $2.85 per household, or
- a decline in household values in the southern coastal catchment areas from $7.93 to $2.45 per increase of one species of native fish.

The choice modelling and benefit transfer approach does not provide an absolutely accurate dollar value. However, it is a useful tool for decision making for natural resource management, as it can provide quantification of benefits as inputs to the benefit-cost analysis. This methodology in turn can clearly indicate economic viability.

4.3 Discussion

The economic analysis was based on a conservative estimate of benefits. The economic analysis indicated that the stage 1 of the Cold Water Pollution Strategy over 30 years was economically viable with a robust benefit-cost ratio and significant positive net present value.

The estimated benefits focussed on household willingness to pay for an increase in native fish species in the associated rivers of the project.

Inclusion of other benefits would be expected to increase the benefits of the Cold Water Pollution Strategy and increase both the net present value and benefit-cost ratio.

5 Actions for stage 2 and beyond

5.1 Actions carried over from stage 1

Several actions in stage 1, while substantially progressed, were not fully completed. It is recommended that the uncompleted actions be carried over into stage 2. The specific actions recommended to be further progressed in stage 2 are:

1. Subject to approval of capital funding, construct a multi-level offtake at Keepit Dam and develop operating protocols

2. Finalise the investigation into the suspended curtain at Burrendong Dam including the assessment of operation and maintenance considerations. Determine the preferred cold water pollution mitigation option, gain Interagency Group endorsement and seek funding approval. Develop a program for construction and draft operating protocols

3. Develop a monitoring program including progressing installation of required monitoring infrastructure

4. Scope, cost and implement a pilot program to test operating protocols

5. Finalise operating protocols for those dams that already had selective off-take capability (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock and Chaffey Dams)

6. Investigate two other priority dams. Three high priority dams were identified for investigation in stage 2 and endorsed by the Water CEOs. They are Blowering in the Murrumbidgee catchment, Copeton on the Gwydir River and Wyangala on the Lachlan River. Two of these will be chosen by State Water for investigations in the next 5 years of the strategy.

5.2 New activities for stage 2

The Cold Water Pollution Strategy was required to be managed in 5 year stages. The Interagency Group has developed a number of new recommendations to be progressed in stage 2, in addition to those actions carried over from stage 1. These new projects have been considered against the following drivers:

1. The need to progress implementation of the strategy

2. The need to undertake actions that are both cost effective and achievable

3. The needs to ensure key projects (e.g. appropriate monitoring) are progressed.

The following key initiatives have been recommended by the Interagency Group for action in stage 2 of the cold water pollution strategy:

- Develop a monitoring, evaluation, and reporting (MER) strategy. This will require commitment to funding installation, data collection and maintenance of monitoring equipment and dedicated human resources to develop temperature growth models for the priority dams. Without such a strategy, the effectiveness and performance of the implementation of cold water pollution mitigation works cannot be assessed. This is important, given the significant expenditure by Government on actions to mitigate cold water pollution. The interagency group are well placed to collaborate to develop an MER strategy. As outlined in the Cold Water Pollution Strategy the outcomes of the MER strategy may be reported in either the Office of Water Annual Report or the NSW State of the Environment Report.

- Develop an economic template to standardise the economic approach to benefits and costs of the mitigation in terms of real and environmental change. By continually developing environmental analysis techniques and applying them in economic analyses throughout stage 2 and subsequent stages, the interagency group will be better able to cost and attribute value to any cold water pollution investigations and works.

- Develop the Cold Water Pollution Strategy into a program to be rolled out over the next 5 to 20 year period. This will provide adequate time for forward planning, to manage costs and monitoring programs in line with continued and reviewed NRC targets. It will enable funding certainty and a well designed program of infrastructure development and monitoring for improvement.

6 Conclusions

The NSW Government has made significant progress in implementing the cold water pollution strategy. Major achievements have included:

- completion of works at two major dams
- investigation of upgrades at two others
- legislative amendments to the Water Management Act 2000 to formalise the regulation of cold water pollution
- completion of guidelines for the monitoring and assessment of cold water pollution outcomes
- a governance structure that includes regulators, operators, and natural resource management agencies to guide implementation.

A summary of progress against stage 1 is provided in Table 13 below.

Further, the value for money assessment of stage 1 of the cold water pollution mitigation has been estimated to have a benefit-cost ratio of greater than 1.96. Planned dam upgrades to address cold water pollution have been included with other scheduled work as required for dam safety or to address other issues, presenting opportunities for cost savings.

Table 13. Summary of progress of stage 1

Outcome	Action	Status		
		Completed	**On track**	**Notes**
Regulatory framework	Legislative amendments	Yes	-	POEO Regulation and WMA amended to clarify primary role of the latter.
Evaluation of lower-cost options	Burrendong Dam trials	No	Yes	Modelling trials of options complete. Detailed concept design to be further investigated.
Cold water pollution mitigation works	Burrendong Dam	No	Yes	Depends on finalisation of investigations and safety upgrade scheduling
	Keepit Dam	No	Yes	Option development and evaluation complete. Preferred option chosen.
	Tallowa Dam	Yes	-	New works commenced operation in July 2009.
	Jindabyne Dam	Yes	-	Releases have been minimal due to ongoing severe drought
Other structural modifications	6 dams with existing selective offtake capabilities	No	No	Most proposals rejected due to cost and/or operational constraints
Dam operations	Management guidelines	Yes	-	Guideline and matrix of work approval conditions complete
	Work approvals	Partially	Yes	cold water pollution conditions included in work approvals for 7 dams
	Develop and implement revised operating protocols	No	Yes	Operating protocols in preparation
Temperature monitoring	Install temperature monitoring stations	No	No	Funding not yet available
Preparation for next stage	Identify priority dams	Yes	-	Dams identified and endorsed by Water CEOs.
	Investigations conducted	No	No	Funding not yet available.

Although there has been significant progress made within the first five years of the Cold Water Pollution Strategy there have also been some challenges associated with its implementation. These include:

- The complex nature of cold water pollution mitigation – although the issue of cold water pollution has been identified for a number of years, the technology surrounding the potential mitigation of the issue is still evolving. From modelling and defining the actual impact, to developing suitable engineering and operational solutions to reduce this impact. The time taken to undertake investigations, develop suitable designs and move towards construction has taken much longer than originally anticipated hence the carryover of Keepit and Burrendong Dam capital works into stage 2 of the strategy. Implementing operating protocols for dams with existing multi-level offtake capabilities – program planning to address changes in operating protocols needs to occur across the various policy, monitoring and dam operation roles in State Water, particularly given the recent organisation restructure. Lack of monitoring infrastructure and communication and data sharing arrangements have also hindered progress.

  While the protocol drafting has progressed during stage 1, there are factors that require further clarification and program planning to enable State Water to proceed to integrating and using the protocols in its dam operations. These include an incomplete monitoring network, the complex nature of the interaction between cold water pollution, dam management constraints associated with manipulating these towers and the interaction between cold water pollution mitigation and other environmental factors (i.e. algae, water delivery requirements and thermal shock considerations). State Water plans to pilot operating protocols in Glennies Creek Dam using the *Guideline for Managing Cold Water Releases from High Priority Dams* to assess its ability to meet the Guideline in view of the above-mentioned constraints.

- Funding constraints –there have been inadequate funds to date to undertake all activities under stage 1 of the strategy. Due to the current cost sharing arrangements and Independent Pricing and Regulatory Tribunal Determination, budget and funding allocations for cold water pollution will continue be considered as part of the budget process in the context of government priorities

  If budget funding is requested because State Water is not operating at full cost recovery or the Independent Pricing and Regulatory Tribunal (IPART) does not allocate the full cost to users, this would be considered as part of the budget process in the context of government priorities. It needs to be noted that lack of funding has been a major barrier to implementation of some activities in stage 1. This is unlikely to change for stage 2.

The interagency group has acknowledged these challenges and has developed the activities for stage 2 to allow for the realistic resolution of the above mentioned issues allowing the staged rollout of cold water pollution mitigation measures in a cost-effective manner.

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Appendices

Appendix 1. State Water Cold Water Pollution Mitigation Project

Sub Project 3 Modification of Intake Structures at Selective Withdrawal Dams – Engineering Options Report prepared by GHD (updated 2009)

Dam	Option	Details	Cost	Status Current 30/12/08 ⇩	Comments / Prompts
Chaffey	Current Arrangements with Improvements	None recommended	Not Applicable	Not Applicable	Not Applicable
		Modify existing trash racks to provide half rack half baulk to increase selectability of withdrawal layer	$25,582	None Modified Work will not be undertaken	Trash racks designed for 50% blockage thus modification does not provide factor of safety. Dams with HEPS now have additional finer screen on rack effectively providing about 30% blockage (does not apply to Chaffey and Split Rock) Thermodynamics of withdrawal layer negates any impacted suggested improvement would make
	Replace Racks Recommended Option	Shutter modules	$525,625	Work will not be undertaken	Estimated costs provided by GHD appear significantly under estimated based on work undertaken and Keepit estimates. Positive cost benefit ratio could not be defined thus unable to justify cost especially as would generate only a small improvement via the improved operating protocols
Glenbawn	Current Arrangements with Improvements	Provide additional Storage slots for 2 trashracks (only one provided)	Not estimated by GHD	Storage Rack installed on deck to similar design of Chaffey Dam	Work Complete approx $5,000
		Modify Crane to enable east west travel	$67,000	Work Complete	Works complete at $195,000 plus project management costs. Substantially under estimated by GHD

Dam	Option	Details	Cost	Status Current 30/12/08 ⇩	Comments / Prompts
		Modify existing trashracks to provide half rack half baulk to increase selectability of withdrawal layer	$45,018	None Modified Work will not be undertaken	Trashracks designed for 50% blockage thus modification does not provide factor of safety. Dams with HEPS now have additional finer screen on rack effectively providing about 30% blockage (does not apply to Chaffey and Split Rock) Thermodynamics of withdrawal layer negates any impacted suggested improvement would make
	Replace Racks Recommended Option	Split gate modules	$711,177	Work will not be undertaken	Estimated costs provided by GHD appear significantly under estimated based on work undertaken and Keepit estimates. Positive cost benefit ratio could not be defined thus unable to justify cost especially as would generate only a small improvement via the improved operating protocols
Glennies Creek	Current Arrangements with Improvements	Investigate option of providing access bridge to tower	Not estimated by GHD	Work will not be undertaken	Unable to justify cost at >$5,000,000 in 2002/03
		Investigate option of providing windscreen around tower deck	$75,000	Work will not be undertaken	Design of tower/deck etc not capable of handling extra wind loading caused by windbreak
		Investigate option of providing separate town water supply offtake	Not estimated by GHD	Work will not be undertaken	Not possible to modify intake arrangements for TWS
		Redesign and modify existing trashracks to mitigate vibration	Not estimated by GHD	Work Complete Trashracks modified by installing additional horizontal stiffeners	Work Complete at approx cost of $19000. Trashracks not tested yet because of low discharge rates due to drought

Dam	Option	Details	Cost	Status Current 30/12/08 ⇩	Comments / Prompts
		Provide 2 speed operation and incorporate self centring facility to crane	$20,000	Work Complete 2 speed operation installed i.e. fast speed	Work complete at approx $3000 Note 2 speed operation provided but not enabled when crane installed
		Modify existing trashracks to provide half rack half baulk to increase selectability of withdrawal layer	$109,080	None Modified Work will not be undertaken	Trashracks designed for 50% blockage thus modification does not provide factor of safety. Dams with HEPS now have additional finer screen on rack effectively providing about 30% blockage (does not apply to Chaffey and Split Rock) Thermodynamics of withdrawal layer negates any impacted suggested improvement would make
	Replace Racks Recommended Option	Full sliding gate modules	$1,567,555	Work will not be undertaken	Estimated costs provided by GHD appear significantly under estimated based on work undertaken and Keepit estimates. Positive cost benefit ratio could not be defined thus unable to justify cost especially as would generate only a small improvement via the improved operating protocols
Pindari	Current Arrangements with Improvements	Provide Self-Centring Mechanism to overhead crane (inc 2 speed etc see p25 report)	$20,000	Not required	Traverse (east west) travel is slow speed. Only small distance to travel thus no need to speed up. North South and hoist operations already 2 speed. North south has auto slow function for limit of travel

Dam	Option	Details	Cost	Status Current 30/12/08 ⇩	Comments / Prompts
		Increase North South travel of crane to enable racks to be lowered to barge	Not estimated by GHD	Not required	Despite the bridge to tower being long and narrow it is safer to remove racks and baulks by the bridge than over water by barge
		Install trolley and frame system to store trashracks on dam crest	Not estimated by GHD	Work will not be undertaken	Bridge out to intake tower is long & narrow The racks are 3m in height & weigh 2.7t. Trolley and frame system would be unstable no safe way to turn baulk on side with current crane
		Modify existing trashracks to provide half rack half baulk to increase selectability of withdrawal layer	$71,607	None Modified Work will not be undertaken	Trashracks designed for 50% blockage thus modification does not provide factor of safety. Dams with HEPS now have additional finer screen on rack effectively providing about 30% blockage (does not apply to Chaffey and Split Rock) Thermodynamics of withdrawal layer negates any impacted suggested improvement would make
	Replace Racks Recommended Option	Split gate modules	$781,1868	Work will not be undertaken	Estimated costs provided by GHD appear significantly under estimated based on work undertaken and Keepit estimates. Positive cost benefit ratio could not be defined thus unable to justify cost especially as would generate only a small improvement via the improved operating protocols

Dam	Option	Details	Cost	Status Current 30/12/08 ⇩	Comments / Prompts
Split Rock	Current Arrangements with Improvements	Provide slow speed on crane for east west travel i.e. 2 speed self centring facility (see p26 report)	$20,000	Not required	Traverse (east west) travel is slow speed. Only small distance to travel thus no need to speed up. North South and hoist operations already 2 speed. Have installed a remote control hand piece, which makes control of the racks and baulks better.
		Install trolley and frame system to store trashracks on dam crest	Not estimated by GHD	Work will not be undertaken	Bridge out to intake tower is narrow The racks are 3m in height & weigh 2.1t. Trolley and frame system would be unstable no safe way to turn baulk on side with current crane
		Modify existing trashracks to provide half rack half baulk to increase selectability of withdrawal layer	$109,080	None Modified Work will not be undertaken	Trashracks designed for 50% blockage thus modification does not provide factor of safety. Dams with HEPS now have additional finer screen on rack effectively providing about 30% blockage (does not apply to Chaffey and Split Rock) Thermodynamics of withdrawal layer negates any impacted suggested improvement would make
	Replace Racks Recommended Option	Split gate modules	$1,511,745	Work will not be undertaken	Estimated costs provided by GHD appear significantly under estimated based on work undertaken and Keepit estimates. Positive cost benefit ratio could not be defined thus unable to justify cost especially as would generate only a small improvement via the improved operating protocols

Dam	Option	Details	Cost	Status Current 30/12/08 ⇩	Comments / Prompts
Windamere	Current Arrangements with Improvements	None recommended	Not Applicable	Not Applicable	Not Applicable
		Modify existing trashracks to provide half rack half baulk to increase selectability of withdrawal layer	$47,734	None Modified Work will not be undertaken	Trashracks designed for 50% blockage thus modification does not provide factor of safety. Dams with HEPS now have additional finer screen on rack effectively providing about 30% blockage (does not apply to Chaffey and Split Rock) Thermodynamics of withdrawal layer negates any impacted suggested improvement would make
	Modify Trashracks Recommended Option	Full sliding gate modules	$786,861	Work will not be undertaken	Estimated costs provided by GHD appear significantly under estimated based on work undertaken and Keepit estimates. Positive cost benefit ratio could not be defined thus unable to justify cost especially as would generate only a small improvement via the improved operating protocols

Appendix 2. Cold Water Pollution Interagency Group terms of reference

Cold Water Pollution Interagency Group

Formed in Response to CM 98/04 and following correspondence Y04/1590

Terms of Reference

Generally:

Provide a forum to achieve a coordinated, whole-of-government response to the cold water pollution issue.

Specifically:

- Coordinate communication of progress of Cold Water Pollution Strategy to stakeholders.
- Monitor implementation of actions identified as part of stage 1 and outcomes achieved which include:
    1. Trial and verification of low cost solutions at Burrendong.
    2. Implementation of works at Keepit.
    3. Implementation of works at Tallowa.
    4. Implementation of works at Jindabyne.
    5. Implementation of improved operating protocols at 6 dams.
    6. Implementation of structural modifications at 6 dams.
- Develop performance criteria and targets for releases from dams.
- Coordinate review of strategy at end of stage 1 and report outcomes to Cabinet (via Water CEO's and Minister for Natural Resources).
- In consultation with dam owners, determine which dams are to be investigated in each subsequent 5 year stage of the strategy.
- Identify critical issues and set parameters for each detailed investigation.
- Consider outcomes of each detailed investigation and in consultation with dam owners, agree on recommendations for the most suitable option for each dam.
- Regularly report to Water CEO's on progress.
- Prepare reports and present recommendations to Cabinet (via Water CEOs and Minister for Natural Resources) regarding options, priorities and timeframes for priority dams over 20-25 years in 5 year stages.

Appendix 3. Prioritisation process for dams for cold water pollution mitigation

Six criteria thought important for prioritising dams for mitigation of cold water pollution impacts were developed. These criteria are:-

Size of problem – derived mostly from Preece (2004) desktop assessment of dams. Both volume of water released and the height of the dam (and, therefore, the depth of release structures) were considered. Other information on the extent of impact (temperature difference from natural and extent downstream) was also used.

Conservation and environmental values – includes significant aquatic habitats and wetlands, threatened species and communities and other environmental values, where known. Values considered affected by cold water were a focus.

Practicality and opportunities – covers factors that may assist in constructing works to mitigate cold water impacts, such as upgrades necessary to improve dam safety, as well as factors that may hinder such works, such as requiring inter-jurisdictional agreement.

Effectiveness of works – covers factors that may cause difficulties for cold water mitigation, such as short retention time in the dam or cold water inputs from upstream dams. It is otherwise assumed that mitigation will be effective.

Community factors – some of these will be positive, such as a community desire to have changes made because it improves recreational opportunities; sometimes the community will be neutral but interested (and so need to be kept informed); and other times they may have negative perceptions that need to be managed.

Cost of preferred option – the preferred option may be minor works or changes in operating protocols (total cost < $1 million, rated L); use of a thermal curtain or retro-fitting sliding shutters (total cost in the range of $1-5 million, rated M); or complete new release structures may need to be constructed (total cost > $5 million, and probably around $20-30 million, rated H).

Preece’s desktop assessment was also used to provide a list of dams thought to cause severe and moderate cold water impacts, with the addition of Windamere Dam (Macquarie system), where bulk water transfers downstream to Burrendong Dam cause a temporarily greater impact.

Each dam in the list was then assessed as high (H), medium (M) or low (L) against each criterion, based on information provided by members of the interagency group. There were some uncertainties – these are shown by a ‘?’ after the H, M or L.

To derive the priority score, the agreed status (H, M or L) was scored for each criterion. Criteria were regarded as evenly weighted. The scoring went as follows:-

For the first 5 criteria (size of problem, conservation and environmental values, practicality and opportunities, effectiveness of works and community factors) – H = 5, M = 3, L =1

For the cost of preferred option criterion (where a high cost is a worse option than a low cost) – H = 1, M = 3, L = 5

The scores were then added to derive a priority score, with the highest score indicating the highest priority dam.

Of the dams that cause high cold water impacts (Blowering to Khancoban in the table below), the priorities for action are:-

Blowering Dam (Murrumbidgee system)

Copeton Dam (Gwydir system)

Wyangala Dam (Lachlan system, curtain option) had an equal score with Copeton Dam but the higher cost (new offtake) option scored slightly lowe

Populated matrix of dams, criteria, priorities and prioritisation scores

Dams	Size of problem (from Preece 2004)	Conservation & environmental values	Practicality & opportunities	Effectiveness of works	Community factors	Cost of preferred option	Priority score
Blowering Murrumbidgee /Tumut	H - 13 to 16°C and 300km (Buchan & Keenan undated), 10°C max and 8°C average & 400km (Lugg)	H – significant habitats and wetlands; 7 threatened aquatic species and communities; Murray cod (matter for National Environmental Significance under the Commonwealth EPBC Act)	H – under investigation for safety upgrade (completed by 2015)	H	M - valuable trout fishery in Tumut river. Not likely to be impacted, may even benefit from cold water pollution mitigation but perceptions may be negative. Swimming too cold at Tumut.	M (curtain) – H (new offtake)	**26** (curtain option) **24** (new offtake option)
Hume Murray	H - 5°C (Walker 1979), 5 to 7°C (Ryan et al 2001), 4°C vs surface, 3.2°C average and 5.5°C peak vs Kiewa (Lugg)	H – significant habitats and wetlands; 7 threatened aquatic species and communities; Murray cod (matter for National Environmental Significance under the Commonwealth EPBC Act)	L – preliminary investigations; requires co-ordinated action through MDBC; money granted for infrastructure improvements	L - Cold water from Dartmouth and Khancoban makes mitigation more difficult; capability for very large releases required	M	H – new offtake	**16**
Copeton Gwydir	H - Up to 13.7°C & 265km (Schalk undated)	H – significant habitats; 5 threatened aquatic species and communities; Murray cod (matter for National Environmental Significance under the Commonwealth EPBC Act)	M – under investigation for safety upgrade (completed by 2015)	H	M – white-water rafting affected by cold	H – new offtake	**22**
Burrinjuck Murrumbidgee	H - 7 to 8°C (Buchan & Keenan undated); cold water impacts unlikely to reach Tumut junction	M – significant habitats; 7 threatened aquatic species and communities; stream degraded; Murray cod (matter for National Environmental Significance under the Commonwealth EPBC Act)	L - no upgrades scheduled	M - some potential for mitigation with existing infrastructure (revised protocols for operation of 3 level release structure being developed)	L	L - nothing planned	**18**
Wyangala Lachlan	H - 7°C @35km downstream & 170km (Burton 2000), 13.8°C vs surface & 9.9°C vs natural surrogate &200km (Lugg)	H – significant wetlands; National Park; 7 threatened aquatic species and communities; Murray cod (matter for National Environmental Significance under the Commonwealth EPBC Act); other iconic species	M – under investigation for safety upgrade (completed by 2015)	H	L	M (curtain) – H (new offtake)	**22** (curtain option) **20** (new offtake option)
Khancoban Murray/ Swampy Plain River	H - 7.2°C (Lugg)	M – approx. 100km downstream to Lake Hume; highly altered flow regime; some riverine wetlands; 3 threatened fish species; Murray cod (matter for National Environmental Significance under the Commonwealth EPBC Act)	L – Government agreed indemnity to 2012	L – Receives cold water from other Snowy dams; limited opportunity to warm water as storage relatively small, therefore short retention time; have to be mitigated at feed dams?	M – part of iconic system (but lower profile than Eucumbene)	H – new offtake	**13**

The following dams were considered to have the potential to cause only moderate cold water impacts and/or had a lack of information on some criteria and were therefore not scored for priority. Works are proposed at Cataract and Cordeaux to provide for environmental flows, as part of the Metro Water Strategy before the end of 2009. Cold water pollution mitigation work at other dams in this group is not a high priority at this stage.

Dams	Size of problem	Conservation & environmental values	Practicality & opportunities	Effectiveness of works	Community factors	Cost of preferred option
Cataract Nepean	L – M	M* – approx. 10km section downstream to water off-take weir (Broughtons Pass); flow regime highly altered (M-H downstream of weir)	H – environmental releases planned and infrastructure changes necessary (by 2009)	H	H – considerable community interest in river system	M
Warragamba Hawkesbury-Nepean	L – M	M – river degraded due to pollution and altered flow regime; Grayling fish species may be present (matter for National Environmental Significance under the Commonwealth EPBC Act)	M – environmental releases to be determined by 2015 with initial consideration by 2009.	H	H – considerable community interest in river system	H
Lostock Hunter/ Patterson	L – M (spills approx 75% of year)	M – modified flow regime; rural area; some iconic species recorded downstream	L – no upgrades planned	M – aeration found not to be effective	L – tourist area	H – new offtake
Carcoar Lachlan/ Belubula	M	M – modified flow regime; rural area	L – no upgrades planned	M - aeration found not to be effective	L	H – new offtake
Cordeaux Nepean	L – M	M* – approx. 20km section downstream to water off-take weir (Pheasants Nest); flow regime highly altered (M-H downstream of weir)	H – environmental releases planned and infrastructure changes necessary (by 2009)	H – requires protocols for operation of multi-level offtake	H – considerable community interest in river system	M
Toonumbar Richmond	L – M (spills approx 90% of year)	M – upper parts of river in quite good condition; National Parks around dam, but rural downstream	M – could have a sliding sleeve installed, like at Brogo	M	L – bass fishing; popular recreational area; National Park	L
Cochrane Bega	M	M – river heavily silted, patchy native riparian vegetation	L?	L – short retention time	L?	M?
Eucumbene Snowy/ Eucumbene	L – no releases made	L - <30km downstream to Lake Jindabyne	L – no environmental releases planned; Government agreed indemnity until 2012	M	H – part of iconic scheme	H?
Googong Murrumbidgee	M	L - <30km downstream to Lake Burley Griffin; urban and rural impacts	H – already has multi-level offtake?	H?	M – recreation and fishing	L
Fitzroy Falls Shoalhaven/ Yarrunga Creek	M	M – approx. 17km downstream to Tallowa; National Park	M?	M – short retention time; water mostly pumped in?; no major stratification	M - Aesthetic values/ National Park; Hydro-electric; part Sydney drinking water supply	M?
Windamere Macquarie/ Cudgegong	M - 25km but up to 80km during bulk water transfers (Burton 2001)	M?	M- revised protocols for operation of offtake under development	M – bulk water transfers entrain water from whole dam, mitigation difficult	L	M?

* Priority still under negotiation within the Cold Water Pollution Interagency Group;

Appendix 4. Guidelines for managing cold water releases from high priority dams

Introduction

Cold water pollution (thermal pollution occurs downstream of most large dams in NSW due to 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 impacts at high priority dams where it is technically and economically feasible to do so.

This guideline is 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 two 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
- It makes no mention of the natural temperature regime
- For most large dams, most of the time, 100 per cent 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**.

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:

- undertaking an investigation of the environmental impact of cold water releases and the options for mitigation of that impact
- preparing a program to mitigate the impact of cold water releases and the obtaining of approval of the program from the minister
- implementing the program

- monitoring and reporting on actions taken to implement the program and the impact of those actions on the environment
- carrying out new works or the making of alterations to existing works, or both
- operation method 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^{th} percentile and < 20^{th} percentile..

The State Water Management Outcomes Plan (SWMOP) similarly defines the target for water temperature (Target 26) as between the 20^{th} to 80^{th} natural percentile range for each month (or within bounds determined by site specific investigations). Note that this introduces a temporal element ('for each month') recognising that water temperature varies significantly throughout the year.

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:

1. Summer suppression
2. Winter elevation
3. Annual amplitude reduction
4. Seasonal displacement
5. Impact upon diel variation (ie 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°C. More usually it is around 8 to 12°C.
- The winter elevation effect is most usually in the range of 2 to 4°C with a maximum of around 9°C.
- The magnitude of the annual amplitude reduction varies from about 4°C to more than 10°C.
- Seasonal displacement can be up to 13 weeks later.
- Impacts are 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 impacts 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 °C.
- Water temperature in most lowland rivers typically varies from about 5 to 10 °C in the depths of winter to 20 to 30 °C at the height of summer. It changes by about 4 °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°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°C on average per week (i.e. 4 °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 (that is, 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 two 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:

- 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).

- 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:

1. During the ‘bedding in phase’ following the completion of new infrastructure or the adoption of a new operating protocol for existing infrastructure to provide feedback and help refine the settings required to get outlet temperature observations closely mimicking predicted-natural temperature observations.

2. 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} percentiles of all the monthly observations

        ii. the 5^{th} and 95^{th} percentiles

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

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

        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 10 km 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

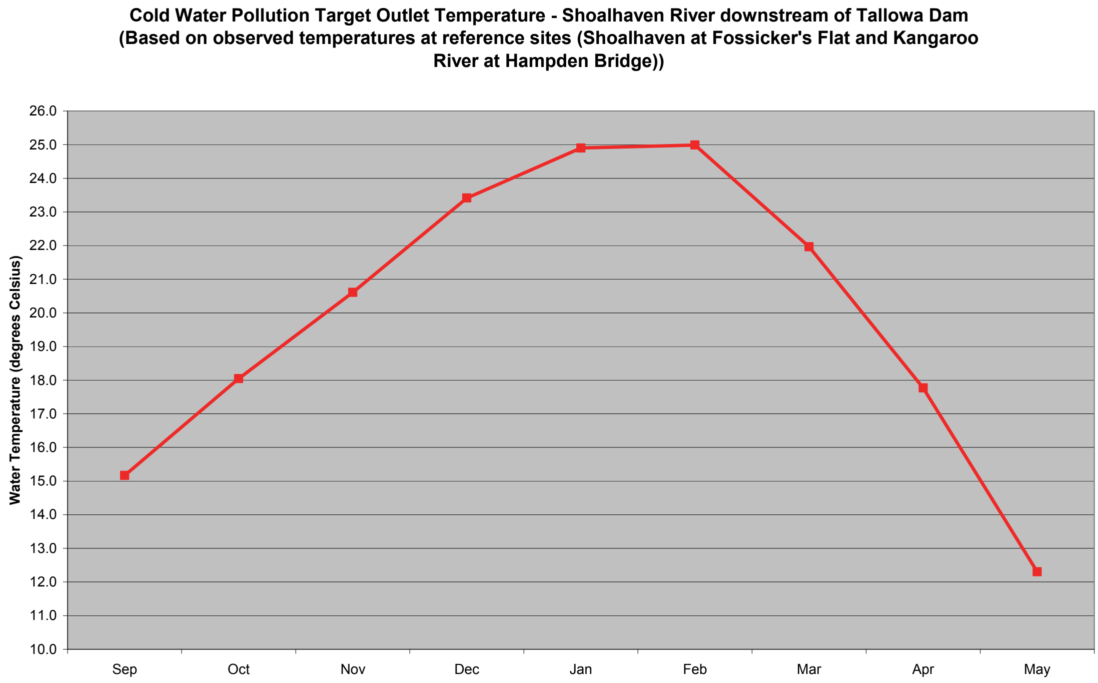
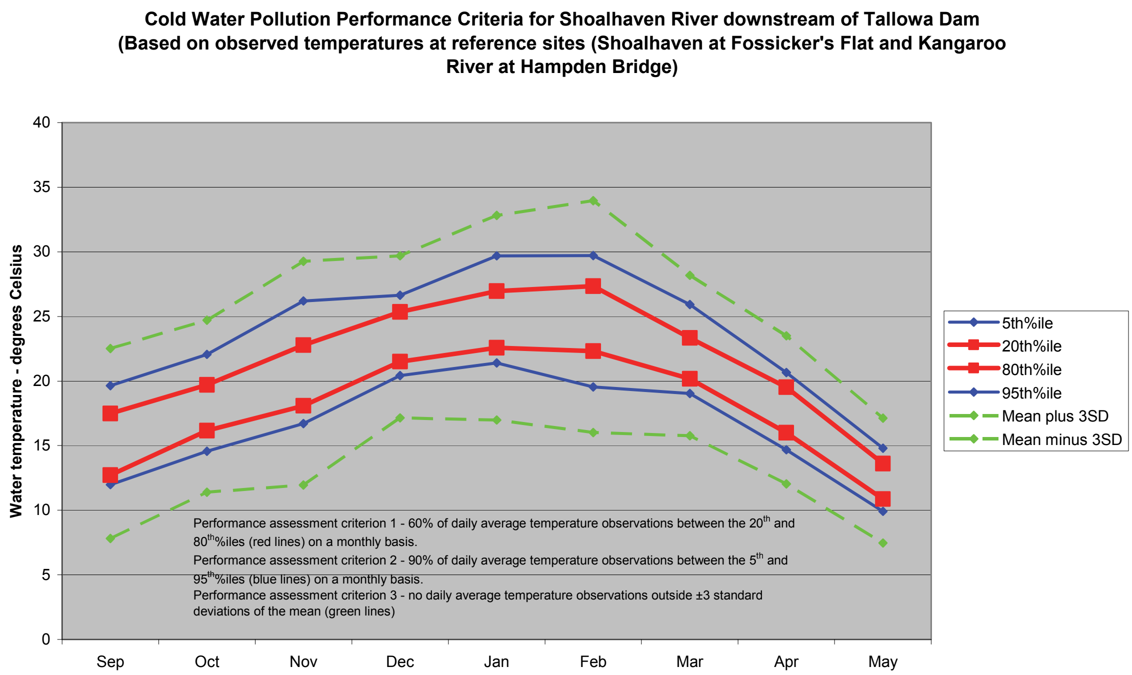


Figure 2



Appendix 5. Matrix of requirements for works approval conditions relating to cold water pollution for New South Wales storages

Note: This table only relates to those dams that will be approved under the Water Management Act. It does not include dams owned and operated by Snowy Hydro.

		Stage 1 dams 2004 - 2009									Stage 2 dams 2010-15			Potential stage 3 or 4 dams 2016 =>										
Relevant Section of Water Management Act	**Suggested Condition**	**Burrendong**	**Keepit**	**Tallowa**	**Pindari**	**Glenbawn**	**Glennies**	**Windamere**	**Split Rock**	**Chaffey**	**Blowering**	**Copeton**	**Wyangala**	**Brogo**	**Burrinjuck**	**Cataract**	**Warragamba**	**Cordeaux**	**Cochrane**	**Googong**	**Tantangara**	**Carcoar**	**Lostock**	**Toonumbar**
100(3)(a) Investigations, recommendations, options, design and cost	I. The licence holder is to undertake investigations of options and costs for the mitigation of cold water pollution.										R	R	R											
100(3)(b) Preferred options/ministerial approval	II. The licence holder is to develop options including a recommended preferred option for ministerial consideration for the mitigation of cold water pollution by 200x.	R	R								R	R	R											
100(3)(c) Implement program	III. Subject to approval by the minister, the licence holder is to develop and implement a program for the construction of works for the mitigation of cold water pollution.	R	R								R	R	R											
100(3)(d) Monitor/report on program	IV. The licence holder will provide within 3 months of the end of each financial year or annually on an agreed date, a report to Office of Water detailing its performance against the approved program.	R	R								R	R	R											

		Stage 1 dams 2004 - 2009									Stage 2 dams 2010-15			Potential stage 3 or 4 dams 2016 =>										
Relevant Section of Water Management Act	**Suggested Condition**	**Burrendong**	**Keepit**	**Tallowa**	**Pindari**	**Glenbawn**	**Glennies**	**Windamere**	**Split Rock**	**Chaffey**	**Blowering**	**Copeton**	**Wyangala**	**Brogo**	**Burrinjuck**	**Cataract**	**Warragamba**	**Cordeaux**	**Cochrane**	**Googong**	**Tantangara**	**Carcoar**	**Lostock**	**Toonumbar**
100(3)(e) Construct new works	V. The licence holder will undertake construction of works to address cold water pollution consistently with the approved program by 200x.	R	R								R	R	R											
100(3)(f) Operate monitor report and review	VI. The licence holder is to prepare and submit an approved operating protocol for the management of cold water pollution by 200x in accordance with the Guideline for Managing Cold Water Releases for High Priority Dams issued by NSW Office of Water on DATE.	R	R	R	R	R	R	R	R	R	R	R	R	R	R					R	R			
	VII. The licence holder is to use its best endeavours to operate the dam according to the Operating Protocol.	R	R	R	R	R	R	R	R	R	R	R	R	R	R					R	R			
	VIII. The licence holder is to use its best endeavours to operate the dam to minimize cold water pollution. (Note that this is an alternative to condition VII to be used for low risk dams that do not have temperature management infrastructure in place or planned.)															R	R	R	R			R	R	R

		Stage 1 dams 2004 - 2009									Stage 2 dams 2010-15			Potential stage 3 or 4 dams 2016 =>										
Relevant Section of Water Management Act	**Suggested Condition**	**Burrendong**	**Keepit**	**Tallowa**	**Pindari**	**Glenbawn**	**Glennies**	**Windamere**	**Split Rock**	**Chaffey**	**Blowering**	**Copeton**	**Wyangala**	**Brogo**	**Burrinjuck**	**Cataract**	**Warragamba**	**Cordeaux**	**Cochrane**	**Googong**	**Tantangara**	**Carcoar**	**Lostock**	**Toonumbar**
	IX. The licence holder will provide within 3 months of the end of each year or annually on an agreed date a report to Office of Water detailing its performance against the protocol, including instances of and reasons for departure from the operating protocol, outcomes achieved (in accordance with the Guideline for Managing Cold Water Releases for High Priority Dams issued by Office of Water on DATE) and proposals for improvement in performance	R	R	R	R	R	R	R	R	R	R	R	R	R	R					R	R			
	X. The licence holder is to implement a water temperature monitoring program by 2000x in accordance with the Environmental Performance Guideline for Cold Water Releases for High Priority Dams issued by NSW Office of Water on DATE. Data must be archived and stored for future use	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Key R = Required

(yellow)	Endorsed priority dams for infrastructure works during first five year stage of Government's Cold Water Pollution Strategy (2004 – 2009)
(blue)	Endorsed priority dams for structural modifications to existing multi-level outlets and implementation of operating protocols during first five year stage of Government's Cold Water Pollution Strategy (2004 – 2009)
(grey)	Endorsed priority dams for infrastructure works during second five year stage of Government's Cold Water Pollution Strategy (2010 – 2015)
(white)	Dams that are identified as potential cold water pollution risks that could potentially be addressed in third or fourth stages of Government's Cold Water Pollution Strategy (2016 –)

Appendix 6. Value for money economic analysis for NSW Cold Water Pollution Strategy - stage 1

Executive summary

Cold water pollution occurs when large dams and weirs release cold water from deep in the storage into downstream rivers. In some cases this cold water can be up to 12 degrees cooler than the water downstream in the river. Of 3,000 dams and weirs in NSW, eight cause severe cold water pollution, fourteen cause medium impacts and four causes less severe impact (Preece 2004, Sherman 2000).

These dam releases adversely affect fish survival. Cold water pollution contributes to reducing the range and abundance of native freshwater fish through reducing fish growth and survival. Fish breeding can be compromised with changes in seasonal temperatures. Low temperatures can affect zooplankton, a major food source for young fish. A lack of seasonal temperature ranges can reduce the number of macro invertebrate species in the summer period.

These studies estimated that controlling cold water impacts from the high and moderate priority dams would improve temperature conditions for more than 2,400 km of river length, representing 80 per cent of the 3,000 km affected by cold water pollution in NSW.

The NSW Office of Water, in partnership with other key agencies is implementing the Cold Water Pollution Strategy to improve NSW river health. These improvements in river health are expected to assist in the recovery of native fish populations and aquatic biodiversity.

Stage 1 of the Cold Water Pollution Strategy included investment in: temperature control works at Tallowa, Jindabyne, Glenbawn and Glennies Creek Dams. Stage 2 includes improved operating protocols and structural modifications at Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock and Chaffey Dams as well as capital works at Burrendong and Keepit Dams. Stage 2 of the strategy includes a review of stage 1 and recommendations for an ongoing investment in prioritising further dam modifications and operation over a 25 year period in five year stages.

The economic analysis of stage 1 of the NSW Cold Water Pollution strategy indicates that the economic benefits of the strategy are greater than the economic costs incurred in the capital works, investigation costs and ongoing operation, maintenance and monitoring costs. Benefits were valued as the NSW household willingness to pay for an increase in native fish species in NSW Rivers. The benefit-cost ratio ranges from 1.74 to 2.64 and the net present value over 30 years was estimated at $15 million to $33 million. The sensitivity analysis indicated that the benefit-cost ratio was robust.

The study did not evaluate total economic benefits. With a benefit-cost ratio of greater than one, it clearly identified that benefits were greater than costs.

These results indicate that continuation of the program can be expected to result in further significant benefits to communities across NSW.

Background

Cold water pollution refers to unseasonably cold water (colder than the natural river temperature) being released into rivers from dams during the warmer months of the year. This occurs when dams can only release water from the colder bottom layer rather than the warmer upper layer of stored water.

The impacts of cold water pollution include:

- reduced stream temperatures, 8-12 degrees Celsius lower than natural temperatures, in spring and autumn
- reduced annual ranges of temperature in river water
- delayed peaks in the temperatures of river water during summer (Preece 2004)

Cold water pollution contributes to reducing the range and abundance of native freshwater fish through reducing fish growth and survival. Fish breeding can be compromised with changes in seasonal temperatures. Low temperatures can affect zooplankton, a major food source for young fish. A lack of seasonal temperature ranges can reduce the number of macro invertebrate species in the summer period (Astles et al 2003).

Cold water pollution is most pronounced in inland rivers during the summer because large volumes of water are released from storages for the irrigation season – December to February. Cold water pollution may increase mortality in native fish, such as silver perch, that spawn and hatch in early to mid-summer.

Experimental studies by Astles et al (2003) with juvenile silver perch showed that exposure to cold water pollution may have significant impacts on survival. In this study juvenile silver perch exposed to cold water began to die after 6-8 days; after 25 days less than 50 per cent of the starting population was alive.

The study by Preece (2004) provided a basis for the interagency group on cold water pollution to identify priorities for investigation and subsequent actions of the cold water pollution strategy

The following eight dams in NSW are considered to cause severe cold water pollution (Preece 2004) and are listed as high priority for action (first 7 are State Water dams; the 8th is a Snowy Hydro dam):

- Blowering
- Copeton
- Burrinjuck
- Burrendong
- Wyangala
- Keepit
- Pindari
- Khancoban.

The following 14 dams are listed as causing moderate cold water pollution impacts:

- Glenbawn, Lostock, Glennies Creek, Carcoar, Toonumbar (State Water dams)
- Tallowa, Cataract, Warragamba, Cordeaux, Fitzroy Falls (SCA)
- Jindabyne, Eucumbene (Snowy Hydro)
- Cochrane, (Eraring Energy)
- Googong (ActewAGL).

Four dams were associated with low cold water pollution impacts and were a lower priority for action:

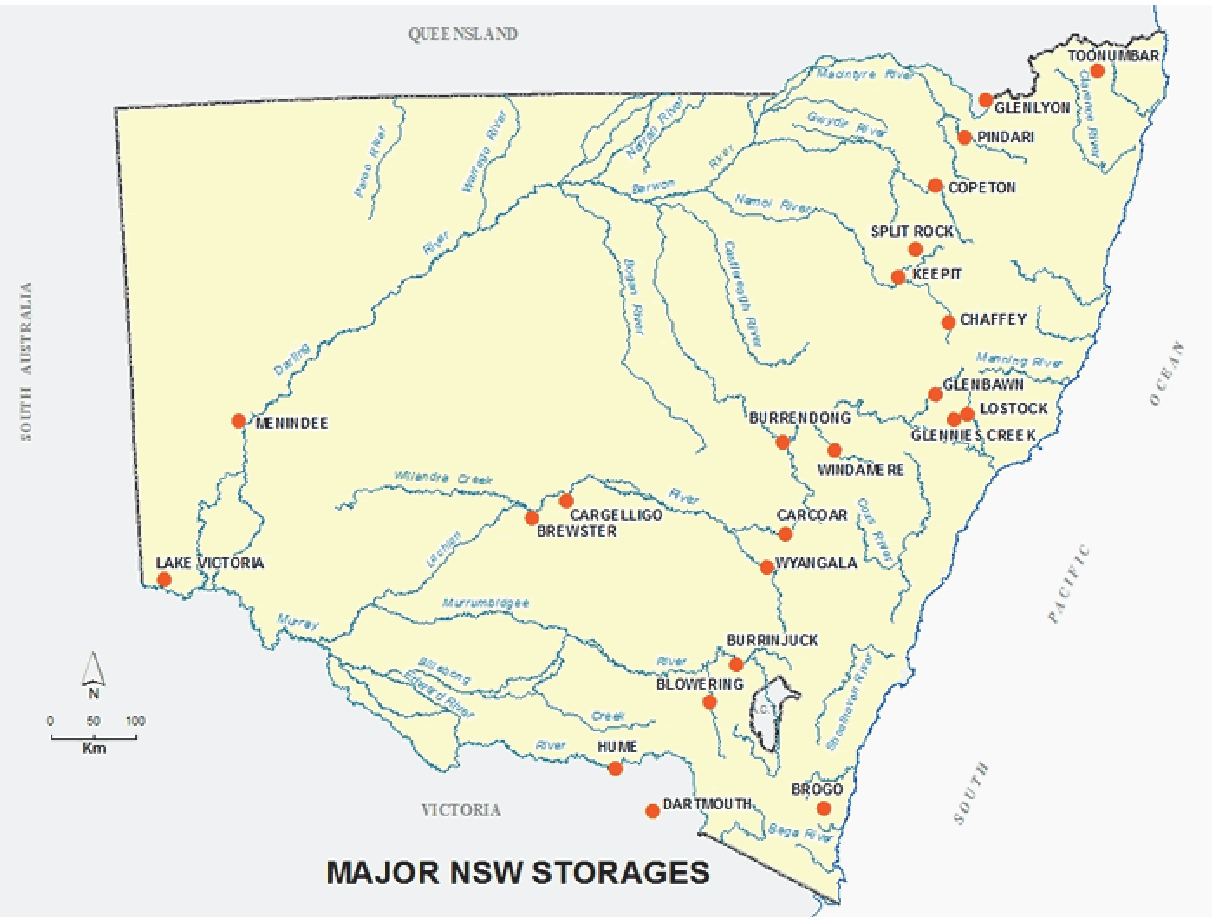
- Windamere, Split Rock and Chaffey (State Water dams) with existing infrastructure so require changed operating practices
- Talbingo (Snowy Hydro)

This report outlines the economic analysis of stage 1 of the cold water pollution strategy. It addresses the study objective, the economic methodology and the economic results of the analysis. The last section outlines the implications of the economic results.

Difficulties arose in isolating the economic impacts of the specific cold water pollution works, as the capital works were integrated with other works, such as dam upgrades and fish passage works. The benefits of the Cold Water Pollution Strategy are intertwined, as it supports and is supported by other policies. These policies include expenditure on improving riverine/aquatic systems to meet Catchment Management Authority Cap targets and the Natural Resource Commission's State Targets for Natural Resource Management. Rectifying cold water pollution is a first order driver in improving aquatic condition and is an essential precursor to achieving the full benefits of other river improvements

The policy issue of interaction with cold water pollution measures and effectiveness of other policies that link in with cold water pollution abeyance expenditure also supports the outcomes and intentions of environmental flows (including Commonwealth buybacks) and impacts on habitat.

Figure 2 Major water storages in NSW



Source: NSW Office of Water

Overview of cold water pollution strategy

The NSW Office of Water in partnership with other key agencies is implementing the Cold Water Pollution Strategy to improve NSW river health. These improvements in river health are expected to assist in the recovery of native fish populations and aquatic biodiversity.

The Cold Water Pollution Strategy was initiated by the New South Wales Government in July 2004. This strategy, to reduce the significant effect that major dams have on the ecology of many of the large rivers across New South Wales, is designed to progress in five year stages to allow for planning and sequential infrastructure implementation. Many outcomes have been achieved in the first five years of the strategy. These include major infrastructure works at Jindabyne and Tallowa Dams, investigations at both Keepit and Burrendong dams, integration of cold water pollution conditions in State Water works approvals and identification of high priority dams for investigation in stage 2 of the strategy.

Raising water temperatures offers a high probability of inducing significant beneficial response within aquatic ecosystems – higher productivity at all trophic levels, a greater number of native fish breeding events, more successful breeding events, and greater diversity of aquatic invertebrates, fish and other cold-blooded animals such as turtles and frogs.

This strategy consists of two stages. Stage 1 of the Cold Water Pollution Strategy required the implementation of cold water mitigation actions including capital works by dam operators and the negotiation and agreement on the target priority dams to be investigated for cold water mitigation in subsequent stages of the strategy. The progress of stage 1 is summarised in the following section.

Stage 2 of the Cold Water Pollution Strategy is to: identify, review and report on the outcomes of stage 1; develop options, priorities and timeframe for cold water pollution mitigation works at priority dams over 20-25 years.

The objective of the economic assessment in this report is to:

- Assess the economic viability of stage 1 of the cold water pollution strategy.

A following economic report will address the economic analysis of stage 2 of the Cold Water Pollution Strategy with its objective to;

- Support the application for funding for stage 2 of the cold water pollution strategy; this is to include a demonstration of value for money of the proposed cold water pollution mitigation measures.

Current status of stage 1

The Cold Water Pollution Interagency Group (CWP Interagency Group) Draft Terms of Reference 30/11/07) nominates priority actions. The current status of stage 1 of the Cold Water Pollution Strategy is listed in the following table. Some projects have now been completed while others are in the investigation phases. Relevant capital works are expected to start in 2011 for Keepit Dam and 2012 for Burrendong Dam.

Table 14 Status of stage 1 components of Cold Water Pollution Strategy June 2009

Stage 1 –Action	Status as at June 2009	Planned progress
Implementation of temperature control and fish passage works at Tallowa by SCA	Completed 2009	-
Implementation of temperature control works at Jindabyne	Completed 2006	-
Trial and verification of low cost engineering solutions at Burrendong Dam on Macquarie River	Modelling complete. Detailed concept design now planned.	Capital work anticipated to start in 2012
Implementation of mitigation works at Keepit (Namoi)	Investigation work completed for Keepit	Capital works for Keepit anticipated to start in 2011
Implementation of improved operating protocols and 6 dams (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock, Chaffey)	Water supply works approvals with cold water pollution mitigation conditions requiring operating protocols issued by OFFICE OF WATER: Hunter, 1 Jan 09 – Glenbawn Dam, Glennies Creek Dam Namoi, 1 Jul 08 – Split Rock	While State Water has drafted operating protocols, there is a need to cost out all implementation requirements for each dam, including data management, compliance reporting and staff capacity building costs as per the new State Water organisation arrangements. .
Implementation of structural modifications at 6 dams (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock, Chaffey)	Glenbawn and Glennies Creek completed. Modifications at other dams assessed as not required. No further work planned.	

Source Sydney Catchment Authority, Snowy Hydro, State Water, CWP Interagency Group July 2009

Economic analysis of stage 1 over 30 years

The economic analysis addressed the costs and benefits of works actually implemented to reduce cold water pollution in stage 1 of the Cold Water Pollution Strategy (CWP Interagency Group) Draft Terms of Reference 30/11/07):

- Implementation of temperature control and fish passage works at Tallowa Dam on the Shoalhaven River by Sydney Catchment Authority(SCA)
- Implementation of temperature control works at Jindabyne Dam on the Snowy River
- Investigation into low cost engineering solutions at Burrendong Dam on the Macquarie River
- Investigation into mitigation works at Keepit Dam on the Namoi River
- Implementation of structural modifications at Glenbawn (Hunter River) and Glennies Creek dams.

Issues and assumptions

The economic analysis examined:

- The base case of doing nothing, i.e. no change in the pre-strategy management of water releases, or capital works.
- The change from the base case to that of the implementation of stage 1 of the cold water pollution in terms of economic costs and benefits.

In the cold water pollution economic analysis, the assessment of specific costs and benefits became complex. In several cases the capital works to mitigate cold water pollution impacts were integrated with other major capital works, (e.g. fish passage provision and/or dam safety), and the specific costs relating to combined capital, operating and maintenance were estimated.

The cost input data were provided by relevant agencies in the Cold Water Pollution Interagency Group. Where data were not available, estimated data were approved by the interagency group. This arose in the instances where the capital works for cold water pollution mitigation were part of broader capital works programs for dams. The benefits of the works were also linked to the outcomes of other projects and policies for improvement of riverine natural resources.

The implementation of stage 1 is not uniform and has experienced various delays. While some capital works were completed or underway, other costs incurred to date were mostly investigation costs. Implementation has also been tied to the capital works programs of dam safety priorities and fish passage works together with the preference to integrate cold water pollution works with these other capital works investigations, both in timeframe and construction.

The benefits of the stage 1 in mitigating cold water pollution in terms of fish habitat are interlinked to the capital works on fish passage. Cold water pollution works together with fish passage works will maximise the outcomes and benefits of both programs.

Economic impacts

A benefit-cost framework was applied in assessing the economic efficiency of the proposed cold water pollution strategy.

Although costs were readily determined, establishing a monetary value for benefits such as changes in fish species was not as straightforward. This was largely due to the uncertainty surrounding the quantified change in the number of species directly attributable to the cold water pollution strategy.

The possible impacts of the Cold Water Pollution Strategy considered included:

- Length downstream from dams of reduced water temperatures
- Improved aquatic habitat through regulation of cold water entering downstream from dams
- Changes in fish populations downstream from dams due to warmer water temperatures
- Changes in fish species (specifically increases in native fish species) [2]
- Changes in opportunities for recreational fishing and swimming
- Cost of supplying fish (numbers and/ or species) from farmed supplies
- Avoided future losses of numbers of fish and their species

[2] The CWP strategy may also impact negatively on introduced species such as trout and associated recreational fishing of trout.

- Avoided future decline in aquatic habitat
- Avoided future impacts on horticulture from cold water in irrigation

In the process of quantifying environmental benefits, the following benefits and methodologies were considered:

- 'Downstream water temperature and distance of water temperatures impacts' from the source could be used as a proxy for benefits
- The benefits or recreational fishing or other activities, such as swimming as an indicator of the benefits of avoided cold water pollution (calculated using the travel cost method)
- Willingness to pay (stated preference technique) for a range of environmental benefits associated with cold water pollution mitigation, such as improved river health, changes in fish species and populations, and changes in riverine and aquatic habitats (Hill 1994, Morrison and Bennett 2004, Adamowicz 2004).

Scenarios

The following section outlines the costs and benefits that were quantified in the analysis of stage 1 of the cold water pollution strategy.

The base case was considered where there was no Cold Water Pollution Strategy in place. Cold water would continue to be released from dams. Fish species and their numbers would continue to decline. Some species of native fish could continue to be absent from highly impacted reaches. The Cold Water Pollution Strategy was assessed relative to the base case.

Scenario 1 represented implementation of the cold water pollution strategy. As a result of the strategy, water temperatures would increase downstream of specific dams. The numbers of native fish and their species would increase.

The analysis quantified the benefits and costs over 30 years, applying a discount rate of 7 per cent (NSW Treasury 2007). The sensitivity analysis addressed the main variables in the assessment, as well as discount rates of four per cent and 10 per cent. The economic efficiency of stage 1 was identified by determining the net present value and the benefit-cost ratio. A positive net present value and a benefit–cost ratio greater than one would indicate that the Cold Water Pollution Strategy could be expected to return positive economic benefits. This study did not identify the distribution of these benefits.

The capital costs of major works were assumed to be undertaken and completed within a year, unless otherwise stated. A lag for the impacts on fish was considered. However the methodology ultimately applied to value the benefits was independent of lag effects.

Economic costs

The following section outlines the costs applied in the economic analysis. The data was provided by the relevant authority responsible for the dam and works. Where the relevant data and level of detail were not readily available, informed opinion provided the input costs. The tables also provide comment/details of the costs.

The costs assessed were;

- Investigation costs
- Capital costs of works
- Ongoing operating and maintenance costs of capital works
- Ongoing monitoring of water quality and temperature.

Implementation of temperature control and fish passage works at Tallowa by SCA

The capital works upgrade at Tallowa Dam included a fishway as well as temperature control works. The costs applied in this analysis were based on an estimated breakdown of temperature control costs.

Table 15 Tallowa Dam cold water pollution costs

Cost category	Details and data provided	Input to economic analysis
Capital costs	Estimated that $8 million as the component related to cold water pollution mitigation. This is part of the $24 million (in 2006 prices) for the Fishway and Multi level offtake (MLO) Capital replacement costs of 30% total $2 million incurred in years 15 and 25 Aerator at cost of $400,000 in year 1	$8 million for capital works Capital replacement costs of $600,000 incurred in years 15 and 25 Aerator at cost of $400,000 in year 1
Operating and maintenance costs	Costs incurred for fish passage as well as cold water pollution.	Aerator operation and maintenance costs of $60, 000 Other operation and maintenance costs assumed to be 0.5% of capital costs
Monitoring costs	Monitoring samples measure a range of parameters.	Monitoring costs totalled $13750 annually , based on • $9000 for operational and maintenance related to flow and temperature for 5 sites with auto samplers (2 inflow sites, 1 within the lake, 2 downstream sites) • $4750 being half of monitoring for macro invertebrates costs (half of $9500) on an average annually for 1 site.

Source: Tony Paull, Sydney Catchment Authority, input from DECCW staff

Implementation of temperature control works at Jindabyne

The works were completed in 2006 as part of a larger capital works upgrade.

Table 16 Jindabyne cold water pollution works costs

Cost category	Details	Input to economic analysis
Capital costs	$8.9 million of the $90 million spent at Jindabyne was attributed to mitigation of cold water pollution	$8.9 million
Operating and maintenance costs and monitoring costs	2.75% of capital costs	2.75%* of capital costs i.e. $244,750 pa

Source: Andrew Nolan Snowy Hydro

* Note that the monitoring costs were not separated from operating and maintenance costs.

Trial and verification of low cost engineering solutions at Burrendong Dam on Macquarie River

The project is currently incurring investigation costs with planned capital works starting in 2012.

Table 17 Burrendong Dam costs of Cold Water Pollution Strategy for stage 1

Cost category	Details	Input to economic analysis
investigation	$283,000 Cumulative cost of option development, engineering concept design, physical modelling and ecological modelling.	$283,000 incurred over 4 years

Source State Water Corporation July 2009. At this stage, construction to be included as part of Burrendong Dam Safety Upgrade Project.

Implementation of mitigation works at Keepit Dam (Namoi)

Cold water pollution mitigation works at Keepit Dam are planned to start in 2011 as part of the Keepit dam safety upgrade project.

Table 18 Implementation costs of mitigation works at Keepit (Namoi)

Cost category	Details	Input to economic analysis
Investigation	$130,000 Cumulative cost of option development, engineering concept design and ecological modelling	$130,000 over 3 years.

Source State Water Corporation July 2009. .

Implementation of improved operating protocols at six dams (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock, Chaffey)

Under stage 1 operating protocols were to be investigated for six dams as listed. These operating protocols are expected to have an impact on downstream water temperatures.

Table 19 Implementation costs of improved operating protocols at six dams (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock, Chaffey)

Cost category	Details	Input to economic analysis
Operating protocols drafting	Currently being written	0

Source State Water July 2009

Implementation of structural modifications at six dams (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock, Chaffey)

The current status of capital works and expenditure is outlined in the following table for six dams in New South Wales.

Table 20 Implementation costs of structural modifications at six dams (Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock, Chaffey)

Dams	Modifications undertaken	Cost ($)	Input to economic analysis
Glenbawn	Storage rack installation and crane modifications	200,000	$200,000 capital costs plus capital replacement cost of 25% incurred in years 15 and 25 In the absence of detailed costs, the economic analysis assumed that monitoring costs of $20000 and capital costs of monitoring equipment of $20000 were incurred annually*.
Glennies Creek	Trashrack modification and crane modifications	22,000	$22,000 capital costs plus capital replacement cost of 25% incurred in years 15 and 25 In the absence of detailed costs, the economic analysis assumed that monitoring costs of $20,000 and capital costs of monitoring equipment of $20,000 were incurred annually.*
Chaffey	No works undertaken or planned in stage 1**	0	0
Pindari	No works undertaken or planned in stage 1**	0	0
Split Rock	No works undertaken or planned in stage 1**	0	0
Windamere	No works undertaken or planned in stage 1**	0	0
Total Cost		**222,000**	

Source: State Water July 2009 * Costs estimated by NSW Office of Water and approved by State Water

Summary of costs

The costs for 30 years of stage 1 of the strategy, as calculated for the economic analysis, are summarised in the following table. The total cost calculated for stage 1 was $34 million. Capital expenditure, as expected, was the greatest cost at $23 million. Operating and maintenance costs were $7 million. The cost of monitoring during stage 1 was approximately $2.6 million ($87000 per annum), based on the assumption that the same level of monitoring would be maintained over that period. This data could provide considerable benefits as input for planned capital works and broader resource management knowledge.

Table 21 Summary of costs for stage 1 of the Cold Water Pollution Strategy over 30 years

Stage 1 costs	($)
Capital costs	23,227,500
Operating and maintenance	7,333,750
Monitoring	2,652,500
Other	413,000
Total	**33,626,750**

Economic benefits

A wide range of economic benefits were identified from the Cold Water Pollution Strategy including:

- Improved aquatic habitat through regulation of cold water entering downstream from dams
- Improved numbers of fish downstream
- Changes in fish species downstream
- Avoided future losses of numbers and species of fish
- Avoided future decline in aquatic habitat
- Residual value of capital

To quantify these benefits the following methodologies were considered:

- The avoided costs of growing out and stocking rivers of specific fish (alternative cost method)
- Expenditure by recreational anglers (travel cost method)
- Knowledge that aquatic habitat is supporting native fish (existence values, and bequest values; contingent valuation or choice modelling methodology).

Given the scope and timeframe of the study, the economic analysis applied data from a major choice modelling study in estimating benefits.

Estimated value of increases in the number of species of native fish

The significant expected benefit of the Cold Water Pollution Strategy is positive changes to numbers of native fish and their species downstream from the dams implementing works in stage 1.

The following evaluation of the economic benefits of stage 1 of the Cold Water Pollution Strategy was based on the comprehensive choice modelling study by Morrison and Bennett (2004) that established values for native fish species. Choice modelling assesses the respondents' willingness to pay for the outcomes of resource management.

Morrison and Bennett identified that respondents held different values for environmental benefits according to the location of the benefit and the location of the respondent. The values applied were based on their pooled model, which was generated to identify systematic differences in value estimates due to catchment or sampling differences.

Using the choice modelling methodology, the New South Wales wide study established values held by the public for improved river health from boatable to fishable and swimmable, improvement in riverside vegetation increases in waterbirds and other fauna. The study also established monetary values held by the public for changes in native fish species numbers.

The values established in the Morrison and Bennett study could be applied to the stage 1 benefits using what is termed, benefit transfer. 'Benefit transfer' refers to the extrapolation of non market value estimate generated at a source site to a second target site' (Morrison and Bennett 2004). Although this method does not establish accurate values, it does provide an order of magnitude for determining the benefits derived from the cold water pollution strategy.

This economic analysis assumed that the implementation of stage 1 of the Cold Water Pollution Strategy would result in an increase of two native species in four rivers affected by cold water pollution in stage 1 in New South Wales. Applying the Morrison and Bennett (2004) methodology and results, an estimated value held by NSW households for the increase of one native species was calculated. The analysis assumed:

- a total number of households in NSW of 2,665,448 (Australian Bureau of Statistics estimate for 2009)
- A response rate of 39.6 per cent of households holding a dollar value (Morrison and Bennett 2004),
- A weighted average dollar value of $5.02 per increase of one species of native fish based on June 2009 dollar values. This figure was based on the estimated number of households in southern coastal, northern coastal, southern inland and northern inland regions (Morrison and Bennett 2004, Bennett and Morrison unpublished) multiplied by the values held by respondents for the environmental good within and out of catchment for each catchment category. This dollar value is a once-off payment by households.

Note that this is a conservative estimation of values held by NSW households. Bennett and Morrison (unpublished) addressed the expectation that the values held by non-respondents would be greater than the zero-willingness-to-pay value applied in their study. Applying an upper bound figure based on the assumption that another third of non-respondents held values similar to respondents, the benefit value of an increase of one native species would increase from $5 million to $8 million. Under this assumption, an increase of eight species would be valued at a total of $64 million. Equation 1 outlines the general assessment of benefits for the change in fish species.

Equation 1 Willingness to pay for an increase of one native fish species

average value per household	x	survey participation rate	x	number of NSW households	=	dollar value per increase in 1 native fish species

Summary of benefits

The benefits quantified in this study are outlined in the following tables. Based on an estimated value of $5.02 per household respondent, the benefits calculated for an increase of one native fish species were $5 million as a lower bound and $8 million as an upper bound. The benefits for an increase of eight native fish species were $42 million as a lower bound and $64 million as an upper bound.

Table 22 Summary of values held for increases in native fish species in NSW

Willingness to pay	$ Lower bound	$ Upper bound
Average value per household*	$ 5.02	$ 5.02
Dollar value per 1 native fish species**	$ 5,296,155	$ 7,961,886
Dollar value per 2 native species in each of 4 rivers	**$** 42,369,240	**$** 63,695,088

*2009 values and rounded to two decimal places.

** held by NSW households

The above calculations of estimated benefits imply a greater degree of accuracy than can be expected based on the input data. The data presented in the results section are rounded.

The residual value of capital was calculated as straight line depreciation with capital estimated to have a life of 50 years (NSW Treasury 2007). In this study the total residual value of $6.8 million was 14 per cent of lower bound total benefits and 10 per cent of upper bound total benefits.

Table 23 Summary of residual values for stage 1 over 30 years

Dam	Residual value $
Burrendong	0
Glenbawn, Glennies	88,800
Jindabyne	3,560,000
Keepit	0
Tallowa	3,200,000
Total	**6,848,800**

Results of Stage 1 Economic analysis over 30 years

The assessment of economic benefits and costs is summarised in the following table. Under the conservative assumptions applied in the analysis, the net present benefits are positive and the benefit-cost ratios are greater that one. This indicates that under the assumptions applied in this analysis the Cold Water Pollution Strategy stage 1 is economically viable. The net present value over 30 years was $15 million and the benefit-cost ratio was 1.74. Applying the upper bound benefits showed a net present value of $33 million and a benefit-cost ratio of 2.64.

Table 24 Summary of economic benefits and costs of stage 1 Cold Water Pollution Strategy over 30 years

	lower bound $	**upper bound $**
Total benefits	49,218,000	70,543,900
Total costs	33,626,750	33,626,750
Net benefits	**15,591,250**	**36,917,150**
Present value benefits	35,485,600	53,793,600
Present value costs	20,393,600	20,393,600
Net present value	**15,092,000**	**33,400,000**
Benefit cost ratio	1.74	2.64

Note: data rounded

Sensitivity analysis

Sensitivity analysis addresses the uncertainty surrounding the data and scenarios being evaluated. The values of key variables in the analysis are changed to assess the significance of assumptions on the final outcomes of this study.

The key variables in this study are outlined in the following table, together with the impact on the lower bound net present value and the benefit-cost ratio of the identified changes. Halving the dollar value of willingness to pay had the greatest impact, reducing the benefit–cost ratio to 0.89 from 1.74. Changing the discount rate to four per cent reduced the benefit–cost ratio by 0.11, and changing the discount rate to 10 per cent increased the benefit-cost ratio by 0.08.

Table 25 Summary of sensitivity analysis of key variables

Variable	Change in variable	Net present value ($)	BCR	change from BCR= 1.74
Monitoring costs	where estimated at $40,000 were halved to $20,000	$ 15,516,000	1.78	0.04
Discount rate 4%		$ 15,416,500	1.63	-0.11
Discount rate 7%		**$ 15,092,000**	**1.74**	0.00
Discount rate 10%		$ 14,524,000	1.82	0.08
Capital replacement costs	changed from 25% to 15**%	$ 15,587,000	1.78	0.04
Capital replacement costs	changed from 25% to 35%***	$ 14,597,000	1.70	-0.04
Residual value of capital *	$0 value after 30 years	$ 14,192,000	1.70	-0.04
Willingness to pay benefits	half of the average value of benefits calculated	$ (2,201,000)	0.89	-0.85

Life of capital was estimated as 50 years.

Note capital expenditure already incurred so sensitivity analysis was not conducted on changes in capital expenditure, only on capital replacement costs.

** Note that Tallowa replacement capital was calculated at 30% Source Sydney Catchment Authority

Threshold analysis

Threshold analysis can be used to indicate the minimum level of benefits such that the net present value of benefits would equal the net present value of costs and the benefit–cost ratio would equal one. The threshold analysis indicated key variables that could change the lower bound benefit–cost ratio to equal one, for example:

- an increase of only five species of native fish
- a decrease in the average value held by the public from $5.02 per household to $2.85 per household
- a decline in household values in the southern coastal catchment areas from $7.93 to $2.45 per increase of one species of native fish.

Discussion

The economic analysis was based on a conservative estimate of benefits. The economic analysis indicated that the stage 1 of the Cold Water Pollution Strategy was economically viable with a robust benefit-cost ratio and significant positive net present value.

The estimated benefits focussed on household willingness to pay for a possible increase in native fish species in the rivers associated with the project.

The study did not evaluate total economic benefits. A number of other benefits could have been included, such as willingness to pay for changes in water quality, aesthetic riverine habitat improvements or recreation values. Inclusion of these benefits would be expected to increase the benefits of the Cold Water Pollution Strategy and increase both the net present value and benefit-cost ratio. These results indicate that continuation of the strategy can be expected to result in further significant benefits to communities across NSW.

The strategy has other unquantified benefits, such as supporting the capital works of fish passage and river management works. Therefore the current analysis is indicative of a high return on capital invested in the strategy. The benefits as estimated indicated that the public values improvements in water quality as measured by increases in the numbers of species of native fish.

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Addendum

Cold water pollution strategy stage 1 - State Water updates December 2010

A number of actions to be performed by State Water in stage 1 of the Cold Water Pollution Strategy remained incomplete when the stage 1 report was presented to the NRE CEO Cluster group in November 2009. Since that time State Water has actively sought to complete those tasks. This short report provides an update of State Water actions in the year since the stage 1 report was finalised.

Stage 1 of the Cold Water Pollution Strategy outcomes not achieved in stage 1 of the Cold Water Pollution Strategy to November 2009 included:

- completion of works at Keepit and Burrendong dams
- investigations on the other identified high priority dams (Blowering, Copeton and Wyangala)
- installation of temperature monitoring equipment to aid in the development of improved operating protocols and
- the implementation of the revised protocols.

During 2010, State Water advises that much progress has been made.

Burrendong Dam: the concept design was completed this year

AMOG Consulting (AMOG) was contracted by State Water Corporation (State Water) to undertake the concept development of a floating curtain system for Burrendong Dam in NSW. The State Water Corporation Burrendong Dam Conceptual Design of Floating Curtain System stage 2a Structural Assessment of Curtain System and Intake Tower report was finalised in August 2010.

This project formed part of the NSW Rivers Environmental Restoration Programme (RERP) subprogram called 'better delivery of environmental water' and State Water's environmental program. The floating curtain concept was designed to mitigate cold water pollution in the Macquarie river which receives out-take waters from the Dam. This report presents the structural assessment findings for the floating curtain system and intake tower.

The assessment of the intake tower indicates that the tower support columns and cylindrical walls have adequate capacity to account for the additional loading from the floating curtain. The tower roof is likely to require additional strengthening to account for the additional live loading.

Strengthening using carbon fibre reinforced strips would be adequate and is estimated as in the order of $50,000 to $100,000. However more work is required to further develop the floating curtain concept and progress to detailed design, recommendations are listed in report.

Copeton Dam: Multi-level Off-take

State Water advises that Copeton will require activities for a multi-level offtake

Keepit Dam: Construction of the Multi-level offtake at Keepit Dam

This was scheduled to commence in 2011 as part of the Keepit Dam Upgrade Project. State Water advised that the design for the raising of the embankment and MLO has already started however works are not expected to commence until 14/15.

Wyangala Dam

State Water advises that Wyangala will have the thermistor chain installed during 2010. The interagency group will work with State Water to improve water monitoring around the dams.

Blowering Dam

State Water advises that Blowering Dam has had a thermistor chain installed during 2010.

Pindari, Glenbawn, Glennies Creek, Windamere, Split Rock and Chaffey

Structural modifications were investigated for these dams, but all were found to have minimal benefit, not able to be undertaken on storages or cost to high.

Draft protocols have been prepared for Glennies Creek, Glenbawn, Split Rock, Pindari, Windamere and Chaffey. Trials on procedures were undertaken at Glennies Creek in the 2009/10 irrigation season. (The interagency group has provided feedback to the protocols. NSW Office of Water is to provide temperature curves to further develop the protocols)

State Water advises that their obligations under the Algal strategy (RACC Plan) require the release of flows from below the algal bloom. Meeting cold water pollution targets implies releasing water from the upper parts of the water column. These opposing requirements means cold water pollution targets cannot be met in storages experiencing an algal bloom.

Other operational protocols

Only one High priority dam has a multi-level off-take, making protocols irrelevant until some structures are retro fitted to the dams of concern.

Development of a monitoring program

State Water advises that this has been completed as part of the Strategic Water Quality Monitoring Program (SKM contract).