APPENDIX N

RESPONSE TO DPIE – FURTHER INFORMATION REGARDING BIOSECURITY

Response to DPIE

Further Information regarding biosecurity and the Snowy 2.0 project

31/01/20

Executive Summary

On 13 September 2019, Snowy Hydro Limited (SHL) lodged the Snowy 2.0 Main Works Environmental Impact Statement (Main Works EIS) with the Department of Planning, Industry and Environment (DPIE). On 2 October 2019, SHL wrote to the Secretary of the DPIE requesting a general exemption pursuant to s402 of the *Biosecurity Act 2015* (NSW) (Act), from the following provisions of the Act with respect to the operation of Snowy 2.0:

- the general biosecurity duty which applies in relation to biosecurity risks which arise from the potential transfer of Redfin Perch (*Perca fluviatilis*) (redfin) , Climbing Galaxias (*Galaxias brevipinnis*), Eastern Gambusia (*Gambusia holbrooki*) and Epizootic haematopoietic necrosis virus (EHNV); and
- the mandatory measures which apply in relation to redfin and EHNV.

Following a review of the application for exemption and the supporting material in the Main Works EIS, on 15 January 2020 the Department of Primary Industries (DPI - Biosecurity and Food Safety) requested SHL provide further information to support its request for an exemption. The information provided in this report responds to that request. Specifically:

- Details on the proposed offset strategy for aquatic impacts is provided at section 6;
- Further information on risk management at Tantangara Reservoir is provided in section 4.2. SHL has not been able to obtain full access to the study referenced by DPI but note that the study was conceptual only in its approach, utilised a different screen type to that proposed for Snowy 2.0 and did not replicate other key features of the proposed design. To our knowledge, the study is not peer-reviewed or complete. As such, SHL is of the view that this study does not provide any value with regards to predicting the likely efficacy of the screening system proposed at this location;
- Details of Snowy Hydro's investigations over the past two years into all possible options to prevent, eliminate or minimise the biosecurity risk associated with the movement of water from Talbingo to Tantangara Reservoir during the operation of Snowy 2.0, are provided in sections 2 to 4 . This includes engineering and design requirements, potential environmental impacts, costs and an assessment of efficacy for each option; and
- An assessment of the effectiveness and practicability of possible management actions based on the definition of "reasonably practicable" under the Act is provided throughout this report in each relevant section.

This report can also be used to support an application for a permit pursuant to s216 of the *Fisheries Management Act 1994* (NSW), or an exemption under that Act, as noted in DPI's letter of 15 January 2020. SHL welcomes further discussion with DPI on this issue.

Functional Requirements of Snowy 2.0

The Snowy 2.0 2000 MW, 350 GWh utility scale storage project has been declared Critical State Significant Infrastructure by the former Minister for Planning, and recognised as a committed project by the Australian Energy Market Operator (AEMO) in their Integrated System Plan (ISP). This makes Snowy 2.0 the largest committed renewable energy project in Australia.

The National Energy Market (NEM) is experiencing a rapid transition away from thermal generation towards variable renewable energy (VRE). This transition is being driven by two factors; firstly, the lower incremental cost of VRE (as compared to new thermal generation), and, secondly, the zero emissions profile of VRE together with the necessity of combating climate change. The most efficient way to manage the intermittency of VRE, and to maximise its benefits, is through projects which not only "firm" wind and solar power but which also capture and store surplus renewable energy for dispatch during periods of relative scarcity.

Snowy 2.0 is the single most important project that satisfies these criteria. Together with the existing Snowy scheme (4GW), Snowy 2.0 (2GW) represents the best example of an optimal enabling technology for a low carbon and secure future Australian energy system. While the existing Snowy Scheme is already critical to ensuring the reliability and security of the NEM, Snowy 2.0 will be necessary to quite literally 'keep the lights on' and will be called on when other supply sources are experiencing failures, transmission lines are out, or demand is high. SHL has therefore set strict reliability and availability requirements of close to 100% for Snowy 2.0, to ensure that the facility is capable of performing its intended function at all times. Any alterations or additions to the design of Snowy 2.0 that could reduce the reliability, availability or capacity of the station to pump or generate at any given time will reduce the value and function of Snowy 2.0 to the NEM and potentially affect energy system security.

Biosecurity Obligations

In the operation of Snowy 2.0, Snowy Hydro has a general duty under the Act to ensure that, so far as is reasonably practicable, any biosecurity risk arising from its operation is prevented, eliminated or minimised. Section 21 of the Act provides that if it is not reasonably practicable to prevent or eliminate the biosecurity risk, then there is a duty to minimise the biosecurity risk so far as is reasonably practicable. This makes clear that the general duty is not an absolute duty to prevent or eliminate risk, but rather is to be based on an assessment of what is reasonably able to be done taking into account and weighing up in the circumstances of each individual case the matters set out in section 16 of the Act. In addition, Snowy Hydro is subject to the mandatory measures (Mandatory Measures) which apply to redfin and EHNV pursuant to clause 18 of the Biosecurity Regulation 2017 (NSW) (Regulation).

SHL expects that the operation of the Snowy 2.0 project, specifically the transfer of water between Talbingo Reservoir and Tantangara Reservoir during station operation, may pose a biosecurity risk and/or may not comply with the mandatory measures by virtue of the potential transfer of a variety of biota, listed above.

What is the potential biosecurity impact and risk?

Pest fish are known to occur in and around Talbingo Reservoir. It is possible that the operation of Snowy 2.0 may entrain and transfer individuals of these species through the proposed pipeline and pumped hydroelectric station into Tantangara Reservoir.

The likelihood of Tantangara Reservoir and connected tributaries being favourable for redfin and eastern gambusia population establishment is somewhat uncertain. This is primarily due to the outcomes of modelling showing that habitat suitability of streams and waterbodies within the Upper Murrumbidgee catchment was largely unsuitable or marginal (less than 20% chance of survival) for redfin (Baumgartner et al., 2017), the presence of minimal aquatic vegetation and other complex habitat and the large operating range of the reservoir (Cardno, 2019).

A biosecurity impact related to the operation of Snowy 2.0 will only occur if the following series of events occur:

1. Pest fish occur in the vicinity of and are entrained into, the Talbingo intake;
2. A proportion of these fish survive the effects of extreme pressure, high shear stress and avoid being fatally struck by the turbine blades during transport through the Snowy 2.0 tunnels and station;
3. Sufficient numbers of these fish are transferred and survive such that breeding in Tantangara Reservoir is possible;
4. Conditions in Tantangara Reservoir prove favourable for breeding success leading to population establishment; and
5. The population numbers increase to such an extent over such an area that an adverse effect on the economy, the environment or the community occurs.

Whether this series of events will occur cannot be known with certainty until Snowy 2.0 becomes operational. Should this risk eventuate in Tantangara Reservoir, there may be impacts to native fish and/or recreationally important salmonids. A key point is that the aquatic environment of Tantangara Reservoir and the catchment upstream (with the exception of the Tantangara Creek headwaters) are dominated by introduced salmonids and there are no known threatened fish species or Endangered Ecological Communities (EEC's) present within Tantangara Reservoir or immediately upstream (Cardno, 2019).

There are however, threatened species known to occur further upstream in the headwaters of Tantangara Creek (Stocky galaxias), downstream in the Mid-Murrumbidgee River below Tantangara Dam (Macquarie Perch, Trout Cod and Murray Cod) and the catchment of Lake Eucumbene forms part of the Snowy River EEC (Cardno, 2019). As such, the severity of the potential biosecurity impact arising from the potential inadvertent transfer of pest species is different within Tantangara Reservoir, where no threatened species are known to occur and where the aquatic ecology is heavily modified by salmonids, compared to locations outside of Tantangara Reservoir which include areas of habitat for threatened species.

Any consideration of the potential biosecurity impact and risk at locations outside of Tantangara Reservoir must also take into account the fact that threatened species in these areas are currently subject to multiple existing threatening processes, irrespective of Snowy 2.0. If approved and once operational, the risk of Snowy 2.0 contributing any further biosecurity impacts to these species outside of Tantangara Reservoir, is very low due to the mitigation outlined in the Main Works EIS and below.

As such, the residual risk of a biosecurity impact occurring to threatened species due to the operation of Snowy 2.0 is very low. Should this risk eventuate as a result of a failure of the controls proposed for Snowy 2.0, there are a number of actions the State has already identified that could be evaluated to assist with building resilience of threatened species in the catchments upstream and downstream of Tantangara Reservoir.

Investigations to achieve obligations

Acknowledgement of the potential biosecurity risk has led SHL, in conjunction with scientific experts from THA Aquatic (2019), to exhaustively review the available options to prevent, eliminate or minimise the potential biosecurity risk over the past two years. This review has included an assessment of all known technologies to prevent or minimise rates of pest fish entrainment into the Talbingo intake, options to minimise the scale of the potential biosecurity impact by limiting the area (i.e. the number of catchments) where it may occur and investigations into the elimination or reduction of the source fish populations in Talbingo Reservoir. Investigations regarding the potential to prevent or manage the spread of EHNV have also been undertaken.

Prevent

The review concluded that there are no reasonably practicable mitigation measures available that could be incorporated into the design of Snowy 2.0 to fully prevent the biosecurity risk associated with the potential transfer of redfin, other pest fish and/or EHNV between the two reservoirs. This is due to:

- the high cost of construction (Table 1);
- the potential risk that additional complex works pose to the reliability of the Snowy 2.0 station;
- the increased environmental impacts associated with the larger disturbance footprint due to significant volumes of additional blasting and dredging in the reservoirs with consequent impacts at excavated material placement locations;
- significant ongoing operational costs and maintenance requirements;
- human safety and significant non-target species mortality for electrical barriers; and
- uncertain efficacy in light of the unprecedented application of the technologies at this scale.

Eliminate

For reasons outlined in this report, elimination of the biosecurity risk via removal of pest fish populations in Talbingo is also not considered reasonably practicable.

Minimise

When considering how SHL could minimise the potential biosecurity risk posed by Snowy 2.0, consideration was given to measures that could potentially reduce the number of fish transferred to Tantangara Reservoir (Entrainment Reduction) and measures that could reduce the scale of biosecurity impact i.e. minimise the area over which pest fish could potentially establish and cause an impact (Secondary Controls).

There are inherent features of the existing design that will act to minimise fish entrainment at the Talbingo intake such as the depth of the top of intake and the construction of an approach channel (which will remove vegetation and complex habitat from around the intake). Additional options to further minimise the rate of entrainment and transfer of fish are considered unlikely to reduce the numbers of fish potentially transferred down to a level that would materially reduce the risk of redfin population establishment in Tantangara Reservoir and a consequent biosecurity impact, should conditions within the reservoir prove favourable for redfin reproduction.

Considering the low likelihood of efficacy in minimising the scale of the potential biosecurity impact, the costs of all potential options to minimise fish entrainment are disproportionately high (Table 1). These options would also increase the disturbance footprint of construction works, including within Talbingo reservoir which is habitat to Murray Crayfish, listed as vulnerable under the *Fisheries Management Act 1994.* These options are not considered reasonable either alone or in combination due to the low likelihood of any material reduction in the risk of environmental harm or a biosecurity impact.

Table 1: Summary of estimated additional construction costs for options to prevent or reduce entrainment into the Talbingo intake of Snowy 2.0

Type of Structure	Estimated additional procurement and construction cost ($AUD)	Estimated additional Operational and Maintenance Costs ($AUD/year)
Measures to prevent fish transfer		
Fine (0.5mm) screens installed at Talbingo and Tantangara intakes (Submerged Water Intake, Fish-Friendly Screen)	$619,000,000	$4,000,000
Electrical deterrence and fish euthanasia at the Talbingo intake	$535,000,000	$15,000,000
Measures to reduce fish entrainment		
Fixed Flat Panel Bar Racks (20mm spacing) installed at both intakes	$220,000,000	$3,000,000
Light and sound behavioural deterrent (Synchronised Intense Light and Sound, Bio Acoustic Fish Fence) in front of the Talbingo intake	$207,000,000	$1,000,000
Barrier net in front of the Talbingo and Tantangara intakes	$55,000,000	$4,100,000

In comparison, the mitigation measures proposed in the Main Works EIS provide an effective means of minimising the potential biosecurity impact that could occur by limiting the potential range expansion of pest species from Tantangara Reservoir into other catchments to the greatest extent practicable.

The proposed mitigation measures include installing fish barriers on the outlets to Tantangara Reservoir and in the Upper Tantangara Creek catchment at an estimated cost of A$30 million. Screening these outlets using the best available technology in screening systems is expected to significantly reduce the likelihood of pest fish being able to access these areas and therefore minimise the spatial extent of the potential biosecurity risk of Snowy 2.0. These measures represent the most reasonably practical way of minimising the risk to significant aquatic species associated with the operation of Snowy 2.0. As noted within the Main Works EIS and outlined again in this report, SHL has high confidence in being able to avoid spill from Tantangara Dam.

By undertaking these measures, as discussed above, the risk to any threatened species and EECs is dramatically reduced as are any potential impacts to recreationally important salmonid populations in Lake Eucumbene and connected catchments. SHL has committed to offsetting the residual potential impact to recreational fishing that may occur in the Tantangara reservoir catchment.

SHL considers that for the reasons outlined in this report, the measures proposed within the Main Works EIS meet the requirements of the general duty under the Act and also, in light of the critical significance of the Snowy 2.0 project to NSW and the broader NEM, provides sufficient justification for the Secretary to grant an exemption from both the general duty and the mandatory measures pursuant to section 402 of the Act, and to issue a permit or exemption pursuant to s216 of the *Fisheries Management Act 1994*.

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Acronyms

AEMO	Australian Energy Market Operator
AUD	Australian dollars
Biosecurity Act	*Biosecurity Act 2015* (NSW)
Biosecurity Regulation	*Biosecurity Regulation 2017* (NSW)
CFS	Cubic feet per second (1 cfs is equivalent to 0.03cumecs)
CSU	Charles Sturt University
DPI	Department of Primary Industries
DPIE	Department of Planning, Industry and Environment
EEC	Endangered Ecological Community
EHNV	Epizootic haematopoietic necrosis virus
EIS	SHL's Environmental Impact Statement for Main Works
EPA	Environment Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPRI	Electric Power Research Institute
FMA	Fisheries Management Act 1994
FSL	Full Supply Level
GL	Gigalitre (1 GL is equivalent to 1,000,000,000L)
GWh	Gigawatt hour
ISP	Integrated System Plan
M-E Tunnel	Murrumbidgee-Eucumbene Tunnel. A one way tunnel linking Tantangara Reservoir with the Eucumbene Reservoir
MGD	Million Gallons per day
ML	Megalitre (1 ML is equivalent to 1,000,000L)
MOL	Minimum Operating Level
MW	Megawatt
NEM	National Electricity Market
NSW	New South Wales
OEH	Office of Environment and Heritage
PHES	Pumped Hydroelectric Station
ROW	River Outlet Works
SHL	Snowy Hydro Limited
SWL	Snowy Water Licence
USA	United States of America
USD	United States Dollars (as at 15/01/2010 USD$1 is equivalent to AUD$1.45)
VRE	Variable renewable energy

1. Introduction

On 13 September 2019, the Main Works EIS was lodged with DPIE and on 2 October 2019, SHL wrote a letter to the DPIE requesting an exemption from certain obligations under the Act for the operation of Snowy 2.0. Following a review of the application for exemption and the supporting material in the Main Works EIS, the DPI - Biosecurity and Food Safety has requested (via a letter received on the 15th of January 2020) that SHL provide further information regarding the manner in which SHL has sought to prevent, eliminate and minimise as far as is reasonably practicable the biosecurity risk and impacts on aquatic ecology that may be associated with Snowy 2.0.

This report is a response to that letter. It reiterates information previously provided and/or presented to agencies and provides justification for SHL's request for a general exemption pursuant to s402 of the Act, from the following provisions of the Act with respect to the operation of Snowy 2.0:

- the general biosecurity duty which applies in relation to biosecurity risks which arise from Redfin Perch (*Perca fluviatilis*) (redfin), Climbing Galaxias (*Galaxias brevipinnis*), Eastern Gambusia (*Gambusia holbrooki*), and Epizootic haematopoietic necrosis virus (EHNV); and
- the mandatory measures which apply in relation to redfin and EHNV.

This report can also be used to support an application for a permit pursuant to s216 of the *Fisheries Management Act 1994* (NSW), or an exemption under that Act, as noted in DPI's letter of 15 January 2020. SHL welcomes further discussion with DPI on this issue.

Within this introductory section, an overview of the legislative context for these requests is set out in Section 1.1, followed by a description of the assessment approach in Section 0. An overview of redfin and other pest fish ecology is provided in Section 1.3 and key details regarding the importance of the Snowy Scheme and Snowy 2.0 for Australia's current and future electricity needs and the importance of these assets being available and reliable at all times is provided in Section 1.4.

1.1. Legislative Context

SHL has a general duty under the Act to ensure that, so far as is reasonably practicable, any biosecurity risk arising from its operation of Snowy 2.0 is prevented, eliminated or minimised. Section 21 of the Act provides that if it is not reasonably practicable to prevent or eliminate the biosecurity risk, then there is a duty to minimise the biosecurity risk so far as is reasonably practicable. "Reasonably practicable" is defined in Section 16 of the Act as:

> *in relation to the prevention, elimination or minimisation of a biosecurity risk, means that which is, or was at a particular time, reasonably able to be done, taking into account and weighing up all relevant matters including:*
>
> *(a) the biosecurity risk concerned, and*
> *(b) the degree of biosecurity impact that arises, or might arise, from the biosecurity risk, and*
> *(c) what the person concerned knows, or ought reasonably to know, about the biosecurity risk and the ways of preventing, eliminating or minimising the risk, and*
> *(d) the availability and suitability of ways to prevent, eliminate or minimise the biosecurity risk, and*
> *(e) the cost associated with available ways of preventing, eliminating or minimising the risk, including whether the cost is grossly disproportionate to the risk.*

In addition, SHL is subject to the mandatory measures which apply to redfin and EHNV under clause 18 of the Regulation. The mandatory measures prohibit the possession, control, sale or purchase, moving or releasing of redfin and EHNV including their movement or release.

SHL expects that the operation of the Snowy 2.0 project, specifically the transfer of water between Talbingo Reservoir and Tantangara Reservoir during station operation, may pose a biosecurity risk and/or may not comply with the mandatory measures by virtue of the potential transfer of a variety of biota, including:

a) Redfin, which have been observed in Talbingo Reservoir;
b) Climbing galaxias, which have not been observed in Talbingo Reservoir but have been observed in the Yarrangobilly River which feeds Talbingo Reservoir;
c) Eastern gambusia, which have been observed in Talbingo Reservoir; and
d) EHNV, which has not been observed in Talbingo Reservoir but redfin are the primary host.

SHL's proposed approach to meeting the general duty under the Biosecurity Act in terms of what is reasonably practicable, and its justification for the request for an exemption from both the general duty and the mandatory measures, is set out in sections 2, 3 and 4 (with respect to Redfin and other fish) and 5 (with respect to EHNV).

As discussed in the Main Works EIS and earlier correspondence with DPI and DPIE, studies commissioned by SHL and undertaken by fisheries scientists at Charles Sturt University (CSU) indicate that it is likely that some life stages of redfin and other fish may become entrained and survive transport through the pipeline from Talbingo Reservoir to Tantangara Reservoir (Ning et al., 2019). Whether these fish will actually be entrained into the intake and survive transfer between Talbingo Reservoir and Tantangara Reservoir cannot be known with certainty until the Snowy 2.0 project becomes operational. However, Ning et al. (2019) indicate that it is reasonable for SHL to assume that the operation of the Snowy 2.0 project, specifically the transfer of water between Talbingo and Tantangara Reservoirs, may pose a biosecurity risk.

Acknowledgement of the potential biosecurity risk posed by the operation of Snowy 2.0 has led SHL, in conjunction with scientific experts from THA Aquatic (2019), to exhaustively review the available options to prevent, eliminate or minimise the potential biosecurity risk associated with the operation of Snowy 2.0 since the project's inception. This review has included an assessment of all known technologies to prevent or minimise rates of pest fish entrainment into the Talbingo intake of Snowy 2.0, options to minimise the scale of the potential biosecurity impact arising from Snowy 2.0 by limiting the area (i.e. the number of catchments) where it may occur and investigations into elimination of the source redfin population. Investigations regarding the potential to prevent or minimise the spread of EHNV have also been undertaken.

As will be set out in this report, the review concluded that it is not reasonably practicable for SHL to prevent or eliminate the potential biosecurity risk having regard to the matters set out in s16 of the Act and given the absence of suitable mitigation measures that could reasonably be incorporated into the design of Snowy 2.0 to completely prevent the potential transfer of redfin, other pest fish and/or EHNV between the two reservoirs. Importantly however, there are mitigation measures proposed in the Main Works EIS which will:

- minimise entrainment as a result of the depth of the intake and the construction of an approach channel which will remove vegetation and complex habitat from the intake; and
- limit the potential range expansion of pest species from salmonid-dominated Tantangara Reservoir into other catchments. These mitigation measures include installing fish barriers on the outlets to Tantangara Reservoir and in the Upper Tantangara Creek catchment at an estimated cost of A$30 million. Screening these outlets using the best available technology in screening systems is expected to significantly reduce the likelihood of pest fish being able to access these areas and therefore minimise the spatial extent of the potential biosecurity risk of Snowy 2.0.

These measures represent the most reasonably practical way of minimising the risk to significant aquatic species associated with the operation of Snowy 2.0.

1.2. Assessment Approach

Central to the assessment of what reasonably practicable measures could be implemented to prevent, eliminate or minimise the potential biosecurity risks posed by the operation of Snowy 2.0 is the consideration of options for reducing the potential biosecurity impact by managing risk throughout the potential fish transfer risk pathway (i.e. an additive approach).

A biosecurity impact as a result of fish transfer from Talbingo to Tantangara Reservoir during the operation of Snowy 2.0 will only occur if a series of events occur, as follows:

1. Pest fish occur in the vicinity of and are entrained into, the Talbingo intake;
2. A proportion of these fish survive the effects of extreme pressure, high shear stress and avoid being fatally struck by the turbine blades during transport through the Snowy 2.0 tunnels and station;
3. Sufficient numbers of these fish are transferred and survive such that breeding in Tantangara Reservoir is possible;
4. Conditions in Tantangara Reservoir prove favourable for breeding success leading to population establishment; and
5. The population numbers increase to such an extent over such an area that an adverse effect on the economy, the environment or the community occurs.

Whether each of the steps in this pathway are realised and pest fish species, including redfin, climbing galaxias and/or gambusia establish in Tantangara Reservoir cannot be known with certainty until the Snowy 2.0 project becomes operational. In our assessment of options to prevent, eliminate or minimise the potential biosecurity impacts associated with potential fish transfer, SHL has taken a precautionary approach in proposing what it considers the most reasonably practicable means of minimising the potential biosecurity impacts of pest fish transfer and population establishment in Tantangara Reservoir should the full series of events occur.

In considering what is reasonably able to be done to prevent, eliminate or minimise biosecurity risks, section 16(a) of the Act requires consideration of the biosecurity risk concerned. This requires a consideration of the existing risk of inadvertent or deliberate introduction of redfin to Tantangara Reservoir and/or other connected catchments where they are currently absent irrespective of Snowy 2.0. As discussed in more detail in Section 1.3 below, deliberate or inadvertent introductions remain a credible risk as evidenced by the relatively recent introduction of redfin to the upper Lachlan catchment in NSW which was first detected in 2005 (Pearce, 2013).

1.2.1. Pest fish entrainment

The likelihood of entrainment of fish at the proposed Talbingo intake of Snowy 2.0 was assessed in a scientific study by Ning et al. (2019). The qualitative assessment was performed to ascertain if there was a credible likelihood that (a) redfin and gambusia would be present in the proposed intake area; (b) the intake dimensions suit entrainment; (c) the hydraulics of the intake will entrain fish; (d) habitat around the intake would be suitable; and (e) fish are present at the entrainment depth.

Results indicated that the proposed intake will fall within the depth range adult, juvenile and larval redfin have been observed to occupy in reservoirs when reservoir levels are low. Given its depth, it is unlikely that the area in front of the intake would be used for spawning. Given the apparent preference of gambusia for shallow, slow-flowing areas with abundant cover, the area directly in front of the intake would probably not contain desirable conditions for them (Ning et al., 2019).

Based on the reference design for the project, at minimum operating level (MOL), the top of the Talbingo Snowy 2.0 intake will be up to 9m below the water surface and up to 18m at full supply level (FSL), with the base of the intake and the intake channel another 10m below these depths. These depths are close to the maximum depth range that adult (5–10 m depth; juvenile (12–15 m) and larval (13–14 m) redfin have been observed to occupy in reservoirs (Ning at el., 2019) although there are instances of adults being observed at depths greater than this (Thorpe 1977; Imbrock et al. 1996). As part of construction, an approach channel will be excavated in front of the intake to enable the smooth intake and exit of water during operation. All potential fish habitat in this area such as timber or rocky outcrops would be expected to be removed during construction.

SHL, in conjunction with scientific experts from THA Aquatic (2019), have exhaustively reviewed all available technologies that could prevent or minimise the entrainment of fish into the Talbingo intake. Although options exist to either prevent or minimise entrainment, none of these options either alone or in combination are considered reasonably practicable having regard to the considerations of s16 of the Biosecurity Act.

Options considered to prevent fish entrainment are presented in Section 2 while options to minimise are presented in Section 4. A discussion on the potential to eliminate the Talbingo population of redfin or other pest fish, which would have the practical effect of preventing entrainment, is presented in Section 3.

1.2.2. Pest fish survival

Studies commissioned by SHL and undertaken by fisheries scientists at Charles Sturt University (CSU) indicate that factors such as high pressure, shear stress and blade strike during transport through the tunnels and station will lead to the mortality of fish of every life stage tested, however, the studies concluded that on the basis of the experiments and modelling undertaken, it is likely that some redfin and other fish of all life stages may survive transport through the Snowy 2.0 pipeline to Tantangara Reservoir (Ning et al., 2019).

Any measures to alter the design of the Snowy 2.0 tunnels or turbines in an attempt to increase the likelihood of fish mortality during transport such as by increasing the shear stress, would affect the efficiency of the completed station. They would also be unlikely to guarantee mortality of all fish that may be transferred. As such, they are not considered reasonably practical and are not dealt with further in this assessment.

1.2.3. Number of fish transferred

The number of live fish transferred to Tantangara Reservoir will be determined based on the number of fish entrained into the intake at Talbingo Reservoir and the percentage of these that survive transport through the Snowy 2.0 development.

The options investigated to minimise potential entrainment rates (discussed in Section 4) primarily act to reduce the rate of entrainment and transfer of larger more mobile adult fish who would be unable to be entrained through smaller bar racks, would be less likely to pass a barrier net and would be most likely to respond and move away from behavioural stimuli such as sound and light. None of these measures would be expected to be particularly effective at preventing transport of eggs, larvae and juvenile fish.

As noted in Section 1.3 below and discussed further in Section 4.1.7, the ability of populations of redfin to establish from introductions of as little as 11 individuals (Harris, 2013) and the potentially high rates of larvae and juvenile entrainment mean that measures to further reduce the number of adult fish susceptible to entrainment are unlikely to materially reduce the likelihood of sufficient numbers of fish being transferred such that breeding is not technically possible.

Accordingly, implementing additional measures to further minimise the numbers of fish being transferred from Talbingo Reservoir to Tantangara Reservoir is not considered likely to reduce the biosecurity risk.

1.2.4. Likelihood of breeding success

As discussed in Section 1.3 below, the likelihood of Tantangara Reservoir and connected tributaries being favourable for redfin and eastern gambusia population establishment is somewhat uncertain. This is primarily due to the outcomes of modelling showing that habitat suitability of streams and waterbodies within the Upper Murrumbidgee catchment was largely unsuitable or marginal (less than 20% chance of survival) for redfin (Baumgartner et al., 2017), the presence of minimal aquatic vegetation and other complex habitat and the large operating range of the reservoir (Cardno, 2019).

SHL does not believe that there are any additional measures that could be employed to minimise the likelihood of pest fish breeding success in Tantangara Reservoir and this is not dealt with further in this assessment

1.2.5. Biosecurity impact

The potential biosecurity impact arising from inadvertent transfer of pest species and EHNV include impacts to native aquatic species and recreationally important salmonids in the Tantangara Reservoir catchment and in locations downstream including the Murrumbidgee River below Tantangara Dam and Lake Eucumbene and connected catchments via the transfer of water through the Murrumbidgee-Eucumbene tunnel (Cardno, 2019). These potential biosecurity impacts are summarised in Section 6.4 of the Main Works EIS and described in detail within the Aquatic Ecology Assessment for the Main Works EIS (Appendix M.2; Cardno, 2019).

If a population of redfin or other pest fish establish in the Tantangara Reservoir catchment (and for the reasons provided above, it is not certain that this would actually occur given the operating and environmental conditions of Tantangara Reservoir), a biosecurity impact would be expected to occur through impacts to native fish and/or recreationally important salmonids. A key point is that the aquatic environment of Tantangara Reservoir and the catchment upstream (with the exception of the Tantangara Creek headwaters) are dominated by introduced salmonids and there are no known threatened fish species or Endangered Ecological Communities (EEC's) present within Tantangara Reservoir or immediately upstream (Cardno, 2019).

There are however, threatened species known to occur further upstream in the headwaters of Tantangara Creek (Stocky galaxias), downstream in the Mid-Murrumbidgee River below Tantangara Dam (Macquarie Perch , Trout Cod and Murray cod) and the catchment of Lake Eucumbene forms part of the Snowy River EEC (Cardno, 2019).

As such, the severity of the potential biosecurity impact arising from the potential inadvertent transfer of pest species is different within Tantangara Reservoir, where no threatened species are known to occur and where the aquatic ecology is heavily modified by salmonids, compared to locations outside of Tantangara Reservoir which include areas of habitat for threatened species. The degree of biosecurity impact posed by the potential transfer of pest fish from Talbingo Reservoir to Tantangara Reservoir is therefore far less than the potential impact on catchments beyond Tantangara Reservoir. The degree of the biosecurity impact that arises, or might arise, from the biosecurity risk is an express matter for consideration under s16 of the Act in the assessment of what is reasonably practicable pursuant to the general biosecurity duty.

As discussed in Appendix M.2 of the Main Works EIS and in Section 4.2, SHL maintains that the proposal to install fine mesh screens at the outlets to Tantangara Reservoir and create a barrier to upstream fish migration on the upper section of Tantangara Creek represents the most reasonably practical means of minimising the potential biosecurity impact of Snowy 2.0 by limiting the catchment area over which it could occur, including a focus on keeping pest fish out of areas of habitat of known threatened species.

Whilst SHL acknowledges that some impacts to recreationally important salmonids in Tantangara Reservoir could occur if redfin establish in the reservoir (Main Works EIS, Appendix M.2), SHL have proposed offsets (see Section 6) to mitigate these impacts and ensure the recreational value of the reservoir is maintained. The screening system proposed for the outlets of Tantangara Dam will also protect the recreational fishing values of the Mid-Murrumbidgee River and Lake Eucumbene and connected catchments to the greatest extent practicable.

As will be discussed further in Section 6, populations of threatened species present in the catchment connected to Tantangara Reservoir are subject to multiple threatening processes that will continue to remain active irrespective of Snowy 2.0. A number of actions have been identified in various action plans as being necessary to ensure the continued viability of these populations (Commonwealth of Australia, 2018; DPI, 2020). SHL would consider supporting these actions, should the risk of pest fish transfer to the Murrumbidgee River below Tantangara Reservoir or to the Upper Tantangara Creek beyond the proposed barriers eventuate as a result of a failure of the controls proposed for Snowy 2.0. As noted in the Main Work EIS and in this report, SHL consider the likelihood of this occurring to be very low.

1.3. Redfin Ecology

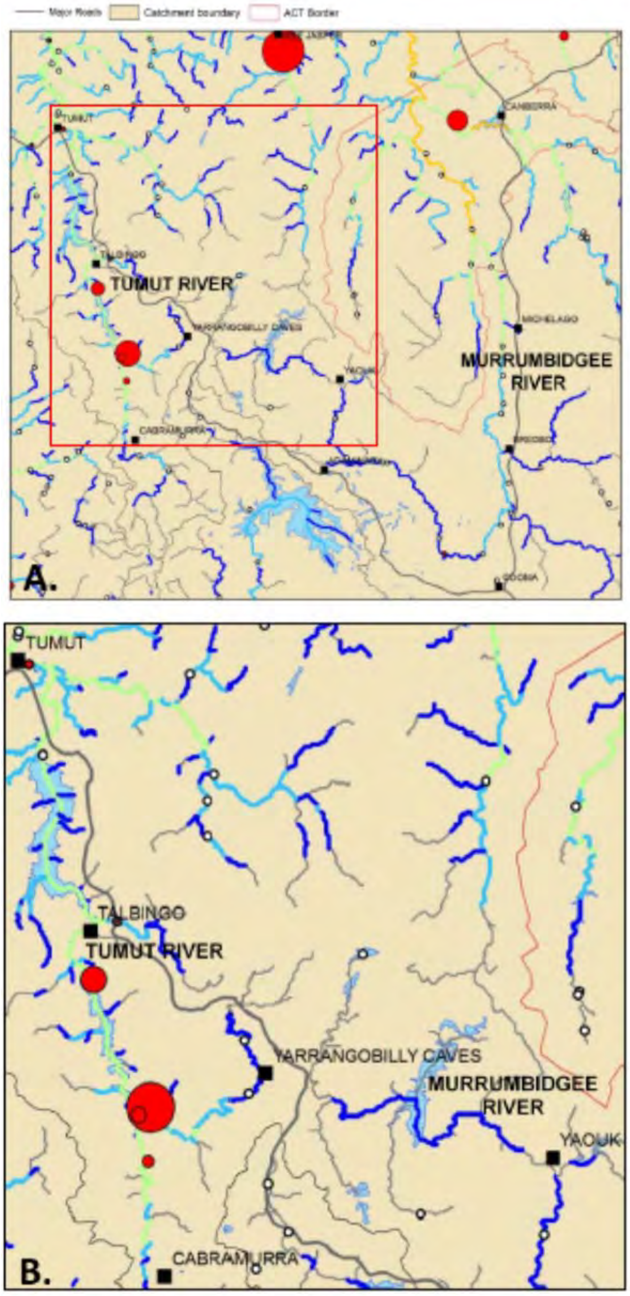
Redfin were introduced to Tasmania in 1862, Victoria in 1868 and NSW in 1888 (Pratt, 1979). Up until fairly recently, redfin were deliberately stocked within waterways throughout NSW due to their popularity as a sport fish and they remain a popular target for recreational fishing, including in locations where they are present in the Snowy Mountains. The deliberate transfer of redfin is now illegal in NSW, although there are indications that illegal and inadvertent translocations continue (Lintermans, 2004). Redfin was declared a Class 1 noxious fish in NSW in 2010. From 1 July 2017 the NSW Government implemented the NSW Biosecurity Legislation. Under this legislation, redfin have been declared a 'notifiable pest species' in NSW under Schedule 1 of the Regulation. This means that redfin are subject to mandatory measures which prohibit the possession, control, sale or purchase, moving or releasing of the species.

The successful spread of redfin throughout NSW and other parts of Australia is considered to be in part, due to their ability to establish populations from the introduction of a relatively small number of individuals. The original introduction of redfin to Tasmania was based on only 11 individuals (Harris, 2013). Lintermans (2004) notes that redfin have been introduced to various waterways via contaminants of fish stocking, their use as live bait by fishermen, escape from outdoor ponds and dams, deliberate legal stocking, deliberate illegal stockings and potentially transfer on commercial fishing gear.

Although the results of the experiments by Ning et al. (2019) indicate that transfer of redfin to Tantangara Reservoir via the Snowy 2.0 tunnels is considered likely, it is not certain that this will result in the establishment of a breeding population in this reservoir. Given previously widespread and active translocation of redfin, it is somewhat surprising that redfin are not already present in the Upper Murrumbidgee catchment. There are reports that attempts were made to introduce redfin to the upper Murrumbidgee as early as the 1870's but they apparently failed (Trueman, unpublished). A historical newspaper report from the early 1900s notes an intent to introduce them to Cowra Creek in the Numeralla River catchment (a tributary of the Murrumbidgee River at Numeralla) (Sydney Morning Herald, 29/5/1908) although none are known to be present there now (Cardno, 2019). Pratt (1979) notes the absence of redfin from upland zones of the Murrumbidgee is likely to be due to its poor swimming ability.

This suggests that the lentic habitat of Tantangara Reservoir may be considered suitable habitat although the large level variations (23m operating range) may affect breeding success as redfin typically spawn and lay egg strings amongst aquatic plants (Lintermans, 2007) which are generally only located in shallow water areas (and are in sparse abundance at Tantangara (Cardno, 2019). Within Tantangara Reservoir, due to the large operating range, these shallow areas may subsequently be exposed to air or drowned out prior to egg hatching. For example, a study on the fish communities of the upper and lower reservoirs of the Muddy Run Pumped-Hydroelectric Station (PHES) found evidence that fish were transported from the lower reservoir to the upper reservoir. However, the results of the study also suggested that the variation in water level of the upper reservoir (up to 15m per week) prevented the successful breeding of selected species of fish in the upper reservoir (Robbins and Mathur, 1976). This study is relevant to the operation of Snowy 2.0 due to the much greater operational range of Tantangara Reservoir (23m) compared with Talbingo Reservoir (9m).

Redfin are considered to prefer lentic environments with abundant vegetation (Weatherly and Lake, 1967; Lintermans, 2007). As noted in Cardno (2019), unlike Talbingo Reservoir, Tantangara Reservoir is largely devoid of aquatic vegetation and other complex habitat. The habitat suitability of the upper Murrumbidgee River catchment was assessed by Baumgartner et al. (2017) using a combination of reservoir temperature data and maximum entropy (MaxEnt) modelling. Whilst the assessment of water temperature data found that reservoir conditions were within the known range of redfin tolerance, the Max Ent modelling showed that habitat suitability of streams and waterbodies within the Upper Murrumbidgee catchment was largely unsuitable (grey lines, Figure 1) or marginal. Marginal habitat is defined as a less than 20% chance of survival (dark blue lines, Figure 1) (Baumgartner et al., 2017).



MaxEnt modelling has been used to predict waters that could support Redfin perch if introduced. Grey areas are unlikely to support; dark blue denotes more marginal habitats (<0.2 chance of survival), pale blue (0.2-0.4), green (0.4-0.6), yellow/orange (0.6-0.8), red (0.8-1.0)

Figure 1: Map of the Snowy Mountains Area indicating (A.) the study area and (B.) showing where redfin have been recorded (red) circles scaled to total catch on a logarithmic scale; small 1 individual; medium 10 individuals, large 1,000 individuals). Sampling locations where no Redfin perch have been caught are denoted as small white circles (Baumgartner et al., 2017 p.15).

1.3.1. Other fish species

As with redfin, the experiments by Ning et al. (2019) showed that adult eastern gambusia could survive experiments with conditions designed to replicate pumping at Snowy 2.0. In the absence of further data, the Main Works EIS assumed that survival of other life stages and for climbing galaxias and other fish present in Talbingo is also possible (Cardno, 2019).

Eastern gambusia show a preference for calm, warm shallow water with abundant vegetation or other cover (Pyke, 2006) and as such, potential entrainment and transfer of this species through Snowy 2.0 was considered by Ning et al. (2019) to be less likely than for redfin. The habitat suitability of Tantangara Reservoir for this species is uncertain, although this species typically shows a preference for much warmer water than that found at Tantangara Reservoir (Pyke, 2006).

Climbing galaxias are an Australian native species with a preference for fast flowing headwater streams (Australian Museum, 2019). They are considered translocated to the Murray Darling Basin (MDB) (Lintermans, 2007). The reproductive ecology of landlocked populations in the MDB is unknown, but it is possible that reservoirs or lakes replace the marine larval stage (Lintermans, 2007). If the few climbing galaxias detected in the Yarrangobilly River catchment form part of a breeding population, it is possible that the fish may spend part of their larval life stage within Talbingo Reservoir where they may be at risk of entrainment into Snowy 2.0. Due to the very low observed abundance of this fish, the risk of entrainment through Snowy 2.0 was assessed as unlikely by Cardno (2019).

1.4. Snowy 2.0 Station Reliability

The Snowy 2.0 2000 MW, 350 GWh utility scale storage project has been declared Critical State Significant Infrastructure by the former Minister for Planning (a CSSI project), and also recognised as a committed project by AEMO in their ISP (AEMO, 2019).

The NEM is experiencing a rapid transition away from thermal generation towards VRE. This transition is being driven by two factors; firstly, the lower incremental cost of VRE (as compared to new thermal generation), and, secondly, the zero emissions profile of VRE together with the necessity of combating climate change. This cost-effectiveness of VRE has led to a significant expansion of wind and solar power and a continuing retirement of existing coal-fired generation capacity. While the growth of VRE is a welcome development, as recognised by the ‘Finkel Review’, it also poses significant risks for the security and reliability of the electricity grid, since a certain amount of dispatchable capacity is required to maintain system security and reliability (that is, an ability to generate on-demand when VRE is unavailable) (Finkel, 2017).

In their 2020 ISP, AEMO predicts a further 30,000 to 47,000 MW (equivalent to 15 to 24 Snowy 2.0 stations) of new large scale VRE will be required to be added to the National Electricity Market (NEM) and that this will in turn require the additional support of up to 21,000 MW of new dispatchable (firm) capacity, and up to 15,000 MW of storage capacity (AEMO, 2019). Without alternatives, gas-fired power stations would be required to provide much or all of this firming capacity, but such gas-fired power plant cannot provide storage, resulting in significant new carbon footprint, increased consumer costs and a wastage of surplus renewable energy.

The most efficient way to manage the intermittency of VRE, and to maximise its benefits, is through projects which not only “firm” wind and solar power but which also capture and store surplus renewable energy for dispatch during periods of relative scarcity. Snowy 2.0 is the single most important project that satisfies these criteria. Together with the existing Snowy scheme (4GW), Snowy 2.0 (2GW) represents the best example of an optimal enabling technology for a low carbon and secure future Australian energy system. In particular, Snowy 2.0 is the only project which has the deep storage capacity to manage the growth of VRE. Further details on the strategic need for Snowy 2.0 are provided in Chapter 3 of Volume 1, and Appendix H of the Main Works EIS.

While the existing Snowy Scheme is already critical to ensuring the reliability and security of the NEM, Snowy 2.0 will be necessary to quite literally ‘keep the lights on’ given the increasing penetration of VRE and will be called on when other supply sources are experiencing failures, transmission lines are out, or demand is high. This is because of its unique combination of functionality (fast start firm dispatchable renewable energy generation, utility scale storage and system services such as Frequency control, voltage control, system strength and inertia contribution services) and its location between the two major load centres in the NEM. AEMO has already recognised the importance of Snowy 2.0 in its ability to maintain a secure future energy system. In the 2020 ISP, AEMO highlighted the challenges associated with the increasing unreliability of ageing coal-fired plant and as well as the insurance value of bringing forward the connection of Snowy 2.0 given the growing risk of premature retirement of existing thermal power stations (AEMO, 2019).

In short, Snowy 2.0 will add critical reserves for keeping the system in balance. As such, design parameters for Snowy 2.0 must focus on ensuring the highest levels of reliability and availability (higher than that of the sources it is designed to back up such as VRE, coal and gas). SHL has therefore set strict reliability and availability requirements of close to 100% for Snowy 2.0, to ensure that the facility is capable of performing its intended function at all times. A recent example of the need for the very highest reliability occurred on 10 February 2017 when NSW was experiencing heatwave conditions and there were unplanned outages at other generating stations. NSW came close to significant power disruptions and almost certainly would have experienced extensive blackouts if the existing Snowy scheme generation was not able to generate. Furthermore, the finely balanced demand and supply conditions experienced in the 2018 and 2019 summers in many parts of the NEM point to the need not only for additional generation capacity, but also to the need for such capacity to have the highest degree of availability.

Any alterations or additions to the design of Snowy 2.0 that could reduce the reliability, availability or capacity of the station to pump or generate at any given time will reduce the system-wide value and function of Snowy 2.0 and is likely to have a negative effect on system security. Any infrastructure, such as screens or other devices that impede the flow of water into or out of the intakes could directly impact the ability of Snowy 2.0 to achieve its stringent design objectives and thereby reduce its utility to the energy system. The incorporation of maintenance-intensive equipment on or around the intakes is also likely to reduce the availability of the station. Such equipment would require outages to perform routine maintenance and would also create the risk of unplanned failures. Any infrastructure which introduces a 'single point of failure', where the entire station is vulnerable to the failure of a single component, is not only sub-optimal engineering practice, but in the case of Snowy 2.0 risks disrupting the power supply to NSW and Victoria and threatening blackouts.

As discussed in more detail below, the only options considered technically possible to prevent the movement of the smallest life stages of the pest species through the Snowy 2.0 intakes from Talbingo Reservoir to Tantangara Reservoir are fine mesh screens and electrical euthanasia. For the fine mesh screens, high levels of redundant equipment would be required on the intake structures to ensure Snowy 2.0 is capable of fulfilling its reliability requirements. This means that additional screens above the nominal flow capacity would be required to prevent a reduction in the volume of water that can be passed through the structure caused by multiple screens being out of service or throttled by blockages. These additional screens would serve to reduce (but not eliminate) the risk of failures or blockages of the screens affecting the ability of the Snowy 2.0 station to pump or generate at a given capacity. As noted above, if such an event were to occur at a time that Snowy 2.0 was required to meet grid requirements, this could have severe consequences. The option of electrical euthanasia would likely represent a single point of failure for the station if correct operation of the electrical array was a condition of station operation.

For potential controls intended to minimise fish transfer from Talbingo reservoir to Tantangara reservoir, a key feature of the design would have to include an acknowledgement that failures of these systems would not lead to restrictions on station operation. This would have the effect of further limiting their potential effectiveness in minimising the entrainment and transfer of pest fish.

Although still high, the reliability requirements for the releases from Tantangara Dam and water transfers through the Murrumbidgee-Eucumbene (M-E) Tunnel are considerably less than those of the Snowy 2.0 tunnel and power station between Talbingo Reservoir and Talbingo Reservoir. Coupled with the lower discharge and single direction flow, this means that SHL have high confidence in being able to operate and maintain the proposed screens at this location to meet water release requirements under the Snowy Water Licence without affecting the reliability or operation of Snowy 2.0 or any of the Scheme's other power assets.

In light of the above, SHL has proposed control measures which prevent, eliminate or minimise the risk of fish transfer in accordance with its duty under the Act, but which also recognise the importance of Snowy 2.0 and which maximise its benefits to the energy system.

2. Options to Prevent the Biosecurity Risk

Given that Ning et al. (2019) indicate that all life stages of fish, including eggs and larvae, may be susceptible to entrainment and could survive transfer, the only options considered technically possible to prevent the movement of the smallest life stages of the pest species through the Snowy 2.0 intakes are very fine mesh screens and electrical euthanasia.

2.1. Fine mesh screens

Screens with mesh fine enough to physically prevent entrainment of eggs and larvae, which have little or no motility and lack the ability to respond to external stimuli, could theoretically be capable of excluding all life stages of fish from being entrained into the Talbingo intake. However, this has never been attempted at a plant even close to the size of Snowy 2.0 or in any bi-directional flow applications (i.e. such as pumped hydro) (EPRI, 2013; THA Aquatic, 2019). A number of screen types and arrangements exist and these were all reviewed for suitability by THA Aquatic (2019).

The requirement for 100% exclusion, coupled with research into the estimated size of redfin eggs and larvae, has determined that the maximum mesh size for exclusion of this species is 0.5mm (THA Aquatic, 2019). This sizing requirement, along with the high discharge, bi-directional flows and large variations in water level that will be inherent in the operation of Snowy 2.0, excludes most of the available fish screening options that are used at water intakes elsewhere across industry. According to THA Aquatic (2019), the largest known installation of 0.5mm fine mesh at a water intake is the Prairie Island Nuclear Power Station which has a maximum capacity of 39.7m^3/s compared with Snowy 2.0's proposed peak capacity of 320m^3/s during pumping and 410m^3/s during electricity generation.

A fundamental issue with all technologies reviewed for the project, is that technologies are typically developed and installed with the aim of *reducing* fish entrainment and consequent mortality of commercially important species (such as salmonids) as opposed to totally preventing the transfer of all fish life stages. In these applications, the loss of a small percentage of individuals due to entrainment and transfer is considered acceptable and this forms the basis for many of the designs (THA Aquatic, 2019).

Considering these constraints, THA Aquatic identified three screening technologies that, based on a high level assessment, warranted further investigation regarding their suitability for Snowy 2.0 to prevent entrainment and transfer of all fish. The proposed technologies were:

- flat-panel wedge-wire screens;
- drum screens; and
- submerged water intake, fish-friendly (SWIFF) screens.

Not all suppliers of these technologies felt that they could manufacture screens to the required specifications for Snowy 2.0. This is primarily due to the large required screen size and the specification that, not only do the screens need to be fabricated to 0.5mm, but all seals and attachment points must also meet the 0.5mm sizing requirement at all times over the life of the equipment. The following screen suppliers were contacted regarding this project:

- Aqseptence Group
- AWMA
- Beaudrey
- Hydrolox
- Ovivo

Of these suppliers, only E. Beaudrey & Cie (Beaudrey) responded to enquiries and felt that screens could be supplied that could meet the requirements of the station such as bi-directional flow, high flow rates, large reservoir level variations and a maximum mesh and seal aperture of 0.5mm. It should be noted that Beaudrey does not have any reference projects with a design criteria of full exclusion. Even then, none of these screen types have ever been used in a bi-directional flow context so significant verification works would be required to ensure that any such structure at the Snowy 2.0 intakes could successfully operate with flow moving in both directions without compromising seals and other equipment or the reliable operation of the Snowy 2.0 station.

All three options would require significant additional civil works within and around the Talbingo and Tantangara Reservoirs including a significant increase in the total volume of excavated rock. One of the main differences between the three options is in the scale of the additional civil works and excavated rock management that would be required.

2.1.1. Managing Bi-directional flow

As noted above, none of the options listed above have been developed for use in a bi-directional flow application so their use in Snowy 2.0 would be considered experimental.

It is important to note that for all screening options, it would not be possible to remove debris that would become impinged on the upstream face of the screens at the Talbingo intake during electricity generation unless identical sized mesh is installed at the intake at Tantangara reservoir, because any debris caught on the upstream face would potentially block the flow of water leading to a station outage or damage to the fine mesh of the screens at Talbingo.

An alternative to ‘dual screening’ that was considered included an arrangement in which the screens at Talbingo Reservoir were bypassed during generation mode by constructing an additional intake and closing and opening gates depending on the mode of operation in order to avoid the need for a fish exclusion structure at Tantangara Reservoir. To achieve this, during generation, the gates of the bypass structure would be required to be open while gates leading to the Talbingo fish exclusion structure would be required to be closed. Transitioning to pump mode would be vice versa. This option is not considered feasible for multiple reasons.

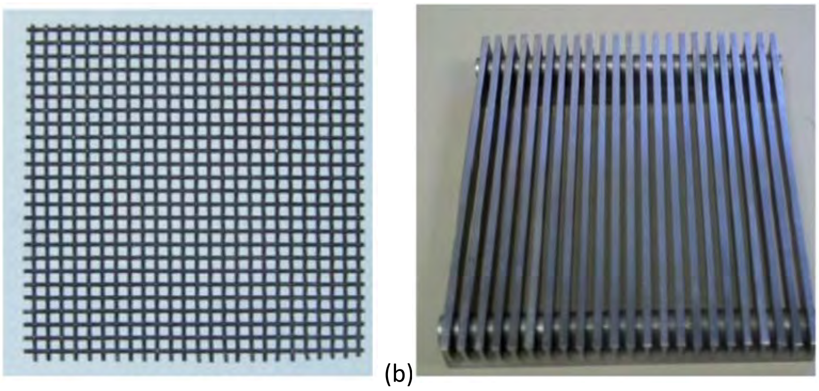
Firstly, the incorporation of an alternating gated facility would prevent the performance objectives of Snowy 2.0 from being achieved. Snowy 2.0 has been designed to be capable of achieving 1000MW in 90 seconds and full station output in 260 seconds. In this concept, the gate to the generating outlet would need to be open prior to generation which is expected to take up to 10 minutes to operate. This alone would prevent Snowy 2.0 from fulfilling its requirements to the grid as explained in Section 1.4.

Secondly, this concept would not be effective due to the fact that the plant has been specified to be capable of performing what is known as 'hydraulic short circuit', which is the act of operating one or more units in the station as a pump (motor) while one or more others are operating as a turbine (generator). The purpose of this is to enable a seamless selection of load points to maximise grid regulation capability. The issue with this in this context is that as some units are pumping sending water uphill, the others would be generating, allowing water back down, resulting in net tunnel movements that would not normally be achievable in singular operation modes. Theoretically, in this operation mode, almost any net tunnel movement could be achieved with potential for frequent switching between downstream and upstream flow, a scenario that would be unable to be managed via a gated system. This would also mean that the tunnel flows in generating mode could be very low enabling fish to swim against them and enter the structure while the generation gates were open. It is also conceivable that fish could move into the intake during periods of low generation or during the station shut down and gate closing sequence. These fish would then be transferred to Tantangara Reservoir when the station switched to pumping mode.

Thirdly, if installed, the gated intakes would represent a single point of failure that could render the entire Snowy 2.0 Station out of service should the gates not open when required or fail to close. As noted in Section 1.4, such a design issue may limit the ability of Snowy 2.0 to generate on demand and if it occurred at a time when supply was constrained, could potentially disrupt the power supply to NSW and Victoria.

2.1.2. SWIFF Screens

SWIFF screens operate fully submerged, meaning both that the size of the infrastructure can be managed and that the complete screening area can be situated below MOL, to ensure it is fully effective under all reservoir levels. Unlike other options, the SWIFF screens investigated are of a woven mesh construction as opposed to wedge wire. Although wedge wire screens can be easier to clean using brushing systems, a study by EPRI (2003) has shown that larvae entrainment is possible through wedge wire at relatively low velocities necessitating a much greater screen area if this type of screen is selected compared to woven wire used in the SWIFF concept below which has a square aperture (Figure 2). For this reason, it was considered that the inherent design of the flat panel and drum screen options would result in an inefficient configuration in terms of surface area that would grossly inflate the size of the equipment, infrastructure and civil excavation relative to the SWIFF option. As a result, it was concluded that the SWIFF screen should be investigated primarily and taken to a concept level of design.



(a) (b)

Figure 2: Comparison of (a) woven and (b) wedge wire screen types (USBR, 2014, p.9)

Subsequently, a concept design was undertaken for the SWIFF screening arrangement. The original concept presented in the letter to DPIE dated 2 October 2019, has subsequently been revised to consider refinements to the design and additional screens required to maintain station reliability and also to present the likely costs associated with civil excavation and excavated material disposal. The concept design considered by SHL includes screens at both the Talbingo and Tantangara Reservoir intakes in order to ensure that blockages do not occur on the upstream face of the Talbingo screens during water transfer from Tantangara to Talbingo Reservoir during electricity generation mode (See Section 2.1.1). Despite the fact that the screens will be located below MOL, significant infrastructure such as gantry cranes and trash raking facilities will be required above MOL and up to and above FSL, to ensure that the screens will be accessible for inspections and maintenance and also to ensure that screens can be cleaned and replaced without risking fish transfer.

To limit the possibility of fish larvae being entrained, the supplier has recommended that approach velocities be limited to 0.26 m/s. The SWIFF drums proposed by Beaudrey would be 15 m in diameter and 13.9 m long. The duty number of SWIFF drums required was based upon the velocity criteria and net open surface area of the screens to pass the required flow rate of the facility. To achieve low approach velocities, the scale and surface area of mechanical structures is significant, along with the civil excavation works required to house them.

Considering the criticality of Snowy 2.0 to the stability of the NEM, SHL undertook a preliminary reliability, availability and maintainability assessment to determine the potential reliability impact to the Snowy 2.0 facility with the incorporation of the fish screening infrastructure. The focus of this effort was to get an appreciation of the potential impact of screen blockages, equipment failure and routine maintenance on the expected availability and reliability of the proposed station and obtain a preliminary estimate of the number of potential additional screens required to ensure that failures or required maintenance activities would not unreasonably affect the reliability of the station.

SHL has operating experience from one existing hydroelectric power station that utilises filters of similar aperture on the cooling water system to that proposed for fish exclusion. The cooling water system on this unit consumes approximately 53 L/s or 0.01% of the capacity of the Snowy 2.0 scheme. This experience has shown that even in the upper catchments of the Snowy Mountains where water quality is typically very good, very high blockage rates can occur potentially leading to frequent station outages and necessitating a high frequency of cleaning and backflushing operations.

Based on this operational experience and other expectations of inspections and maintenance, it is anticipated that frequent outages would be required to maintain the integrity of the screening equipment. At a minimum, this would require regular inspections, cleaning and repair of cylinders and seals, removal of debris and sediment build-up within the chamber and auxiliary equipment repair and replacement. In order to reduce the potential impact of screen blockages and equipment failures and maintenance activities on the pumping and generation availability of Snowy 2.0, additional screens and other measures will be required at each intake (Table 2).

The findings of the preliminary assessment suggested that the original design of the screening plant would grossly impact the certain capacity of Snowy 2.0, and its ability to provide the firming services required for the NEM. Preliminary remediation measures suggest additional redundant screens would be required, the number dependent on the velocity criteria adopted (Table 2). It is important to note that the number of additional screens listed in Table 1 is based on a preliminary reliability assessment that has made assumptions around the proposed design including the identified failure modes of the equipment as well as the failure and repair scenarios anticipated during operation, e.g. screen clogging rates and the operational regime for generation and pumping. Given 0.5mm mesh screens have never been deployed at a facility as large as this or used in a bi-directional flow situation, it is entirely possible that the estimated rates of blockages and the estimated time required to return equipment back to service following maintenance and failures may be higher than estimated which could further jeopardise the performance of the stations and result in having to increase the number of additional screens required and hence further increase the scale of excavation and construction costs.

As discussed in Section 1.4, a failure to include sufficient additional screens to manage blockage rates and the outage times required for routine maintenance and repairs would have severe consequences for the reliability of the Snowy 2.0 station and its ability to meet its design objectives.

Artists impressions of the fish exclusion structures at Tantangara and Talbingo Reservoir are shown in Figure 3 and Figure 4.

Table 2: Key Design Parameters for SWIFF Fish Exclusion Structure

Design Parameters	**Tantangara to Talbingo (Generating Mode)**	**Talbingo to Tantangara (Pumping Mode)**
Design flow Q_d [m^3/s]	378 + 10% = 415.8	297 + 10% = 326.7
Approach velocity [m/s] v	0.26	0.26
Required gross screen area [m^2] $A_g = Q_d/v$	1,600	1,257
Screen surface area [m^2] A_s	668	668
Number of SWIFF drums N_i [No.] A_g/A_s	1,600/668 = 2.39 say 3	1,257/668 = 1.88 say 2
Estimated required redundancy to meet 98.5% availability of Snowy2.0 for operation N_j [No.]	2	2
Total number of SWIFF drums $N_i + N_j$ [No.]	3 + 2 = 5	2 + 2 = 4

Figure 3: Artist impression of Tantangara Reservoir at MOL showing the excavation and concept design of the SWIFF drum structure. The boat just out of the intake channel is 6.7m long.

Figure 4: Artist impression of Talbingo Reservoir at MOL showing the excavation and concept design of the SWIFF drum structure. The boat just out of the intake channel is 6.7m long. The Sydney Opera house is also included to provide an additional indication of scale.

Operating Principle of Beaudrey Drums

The operating steps for pumping water from Talbingo to Tantangara Reservoir through the fish exclusion structure is schematically shown in Figure 5 and Figure 6 and described as follows:

1. Water from Talbingo Reservoir enters the fish exclusion structure through the screened gates of the outer chamber of the enclosure pits in which the submerged SWIFF drums are located. The outer screen prevents coarse debris such as floating submerged logs from entering the outer chamber and damaging the thin aperture skin plate of the drums.

2. Water then flows from the outside of the drums through the 0.5 mm apertures into the drums and exits the inside of the drums through gated outlet slots.
3. From there, the water is conveyed through the transition structure into the tailrace tunnel of the power waterway, pump/turbines, inclined pressure shaft and headrace tunnel to the fish exclusion structure at Tantangara Reservoir.
4. After having passed through the transition structure at Tantangara, water enters the gated outlet slots of the SWIFF drum enclosure pits and exits the drums through the 0.5 m apertures into the outer chambers of the enclosure pits and from there through the enclosure gate slots into Tantangara Reservoir.
5. In generating mode the flow direction is reversed.

The operation of the fish exclusion structure would need to be integrated into the Snowy 2.0 project providing power and communication links to the station's operation and control centre. Spare parts, drum cleaning equipment and other consumables would need to be stored at the intake gate control buildings located at the Talbingo and Tantangara intake gate shafts of the power waterway.

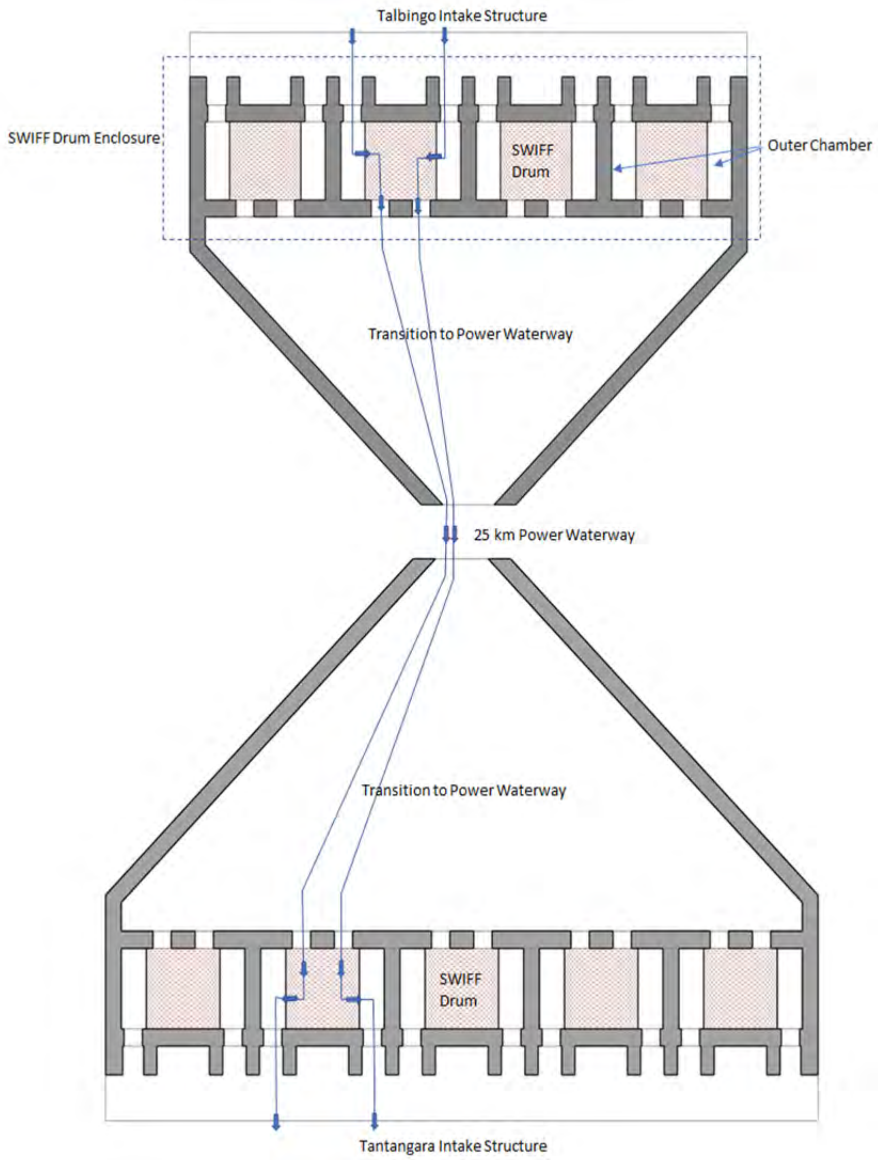
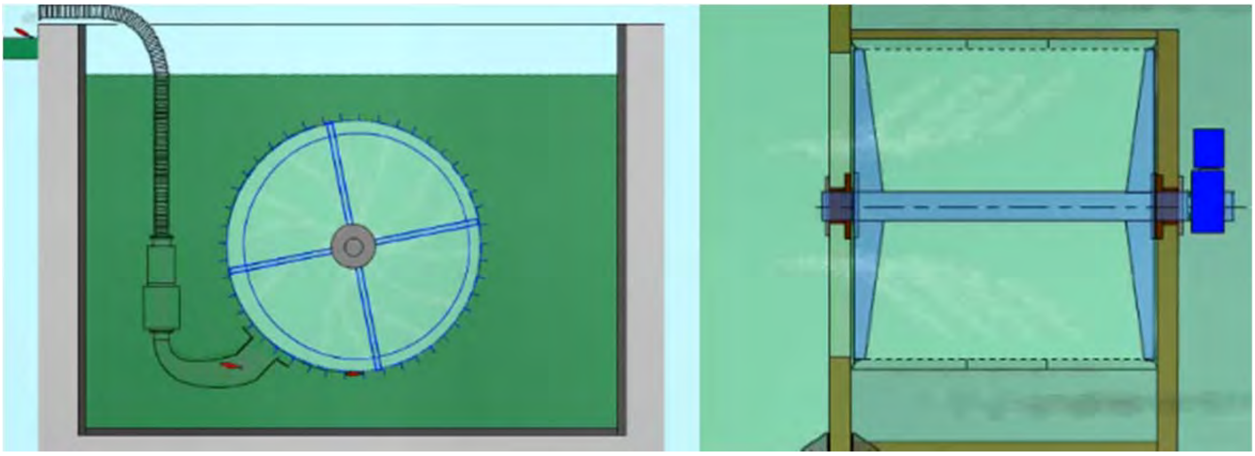


Figure 5: Schematic of flow from Talbingo to Tantangara Intake Structure



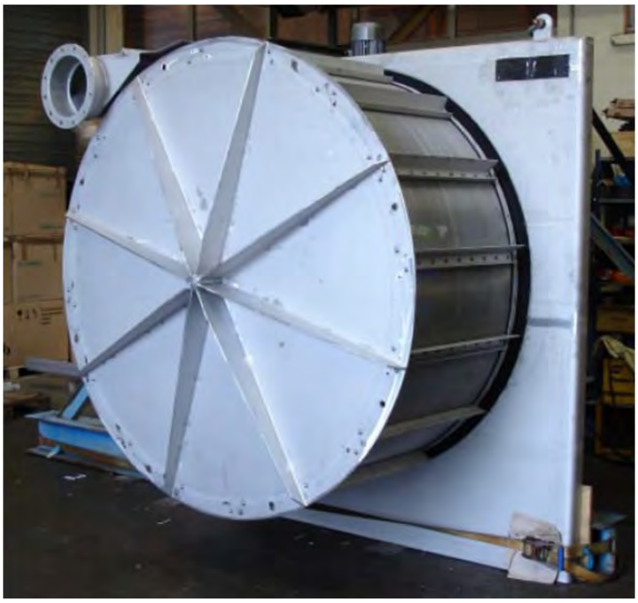


Figure 6: SWIFF Screen operational diagram and photograph of small SWIFF drum (Beaudrey, https://www.beaudrey.com/swiff-screens)

Design and Construction Requirements

Due to the wide operating range over which Snowy 2.0 will operate in both reservoirs and the low velocity requirements through the SWIFF drums, the dimensions of the fish exclusion structures are considerable and need to be accommodated in the respective power intake approach channels at the Tantangara and Talbingo Reservoirs. During the feasibility design phase the location of the intake in relation to the shoreline was determined based on constructability and ensuring the free flow of water into and out of the intakes and or Talbingo Reservoir, along the Yarrangobilly Arm from the Yarrangobilly River. Locating the intake further out in the reservoirs was considered to avoid large excavation volumes, however this would have required the construction of large cofferdams as the intake needs to be constructed in dry conditions. Pushing the intake back into the side of the reservoir, though requiring more excavation was determined to be the best option when considering cost, safety and environmental factors associated with placing a cofferdam within the reservoir. The addition of the SWIFF drum structure does not change this conclusion and so the intake would be pushed further back into the side of the reservoir to accommodate the larger intake required for the SWIFF drums rather than pushing out into the reservoir and requiring a cofferdam. Having the exclusion structure protruding into the reservoirs, particularly at the narrow section at Talbingo Reservoir may also create an impediment to the free flow of water into and out of the intakes and may lead to increased clogging from debris and sediment washed down from the Yarrangobilly River during high flow periods.

The invert level of the enclosure pit is driven by the minimum submergence requirements of the SWIFF drum at Minimum Operating Level. The top level of the structure has been selected to ensure accessibility during the maximum flood level and was set as being equal to the dam crest levels of Talbingo and Tantangara dam, respectively.

The approximate overall dimensions of the fish exclusion structures are given in Table 3.

Table 3: Overall Size of Fish Exclusion Structures

Dimensions [m]	**Tantangara Reservoir**	**Talbingo Reservoir**
Height	49	41
Width	136	109
Depth	98	85

Construction costs and assessment of environmental impacts

The estimated costs for the construction of the intake structures incorporating the fish exclusion structures are provided in Table 4. After excluding the cost of the existing intake structures, the estimated cost to install fish exclusion structures at the intakes in each reservoir for Snowy 2.0 is an additional $619 million (Table 4).

Table 4: Estimated additional construction costs for SWIFF screens at Talbingo and Tantangara

Description	**Cost [$]**
Talbingo	
Excavation & Spoil Disposal	169,923,644
Concrete	45,267,000
Reinforcement	16,040,840
Miscellaneous civil and e&m works	23,275
Electrical and Mechanical works	70,554,851
Additional	250,000
Contingency (25%)	74,889,940
Total Cost Talbingo Structure for fish exclusion	**376,949,550**
Tantangara	
Excavation & Spoil Disposal	289,760,899
Concrete	61,223,618
Reinforcement	21,695,236
Miscellaneous civil and e&m works	29,094
Electrical and Mechanical works	86,766,799
Additional	250,000
Contingency (25%)	114,868,911
Total Cost Tantangara Structure for fish exclusion	**574,594,556**
Total Cost Fish Exclusion Structure at Talbingo and Tantangara	**951,544,107**
Deduction of obsolete Dispersion Structures	- 332,975,474
Total Additional Cost Fish Exclusion Structure at Talbingo and Tantangara	**618,568,633**

A large portion of the costs for the fish exclusion structures is the volume of rock which needs to be excavated to accommodate the structures on the shore of the Tantangara and Talbingo Reservoirs. This also results in the need to dispose of the excavated material preferably in an area close to the structures to reduce haulage costs. The total additional rock excavation required for the fish exclusion structures is approximately 2.5 million m^3 (3.75mil m^3 bulked). For comparison the total volume of excavation for the current design of the Snowy 2.0 project including intakes, wet and dry tunnels, power station complex and surface works is about 9.0 million m^3 (13.5mil m^3 bulked). Although the cost of land based excavated material management has been included in the estimate, it is likely that the need to dispose of this additional material will necessitate additional space to be found and would result in a higher cost of disposal above the existing price included within this estimate.

The excavation and management of an additional 3.75mil m^3 of material, much of it below the FSL of the two reservoirs, would be expected to significantly increase the aquatic impacts associated with dredging and blasting for intake construction that are detailed in Appendix M.2 of the Main Works EIS due to the increase in disturbance area and extended duration of the works. This would include areas known to be habitat for Murray Crayfish (*Euastacus armatus*), listed as vulnerable in the FM Act, in Talbingo reservoir (Cardno, 2019). The disposal of the additional material would necessitate a larger footprint of disturbance for sub-aqueous placement in the reservoirs and/or for on land placement near the reservoirs with consequent impacts to the aquatic or terrestrial environment that otherwise would not occur. The additional disturbance could also potentially increase the value of offsets required for the project.

The installation of the screening structures in both reservoirs will significantly increase the anticipated visual impact at the intake areas. Under the fine screening concept, during MOL a vertical concrete face with embedded trashracks of approximately 25 m and 26 m height will protrude above water level at Talbingo and Tantangara, respectively (Figure 3 and Figure 4). Under the current design without the fish exclusion structures, at Talbingo Reservoir, only about 8 m of the vertical concrete face would be visible with the lower part of the structure backfilled with a sloping rockfill embankment. For Tantangara, under the existing design, the entire intake structure would be permanently submerged below MOL and only a sloped rockfill face would be visible from the reservoir.

Given the immense scale of the works proposed and geological uncertainties associated with the excavation aspects of the works, a contingency of 25% has been included in the cost estimate. This is itemised separately in Table 4.

The design approach and estimated costs is based on woven wire mesh with an aperture size of 0.5mm and an approach velocity of 0.26m/s. If the mesh type, aperture size and/or approach velocity subsequently needs to be altered, the screening area will need to be increased with consequent increases to the cost of the design, disturbance footprint and operation and maintenance costs.

Operation and Maintenance (O&M) Costs

A preliminary estimate of the operational and maintenance costs for the project was prepared to give an indication of the ongoing costs for the fine screens installation. Due to the site dependent performance of factors such as blockage rates, the estimate is considered to be highly uncertain and could potentially significantly increase.

The ongoing energy (electricity) costs were estimated to be between $20,000 p.a. up to as high as $1,100,000 p.a. dependent on the frequency of backflushing operations required. The lower limit was based upon the necessity to backflush for six minutes every six hours and the upper limit was based upon the requirement for continuous backflushing. The higher estimate has been used in the cost estimate due to the high reliability requirements of the plant and the need to minimise the risk of blockages at all times.

The estimated maintenance activity costs of $2,900,000/year have been estimated based upon the requirement to employ a team of two for ongoing inspections and maintenance activities and the assumption that the complete electrical and maintenance assembly would need to be replaced approximately every 20 years.

In the event of a severe bushfire, or other weather event, such as the recent fires in January 2020, the cost of maintenance of the screens would be expected to increase exponentially to deal with the high volumes of ash, debris and sediment plus any resulting increases in algal productivity that could occur as a result. Large increases in debris and ash, such as those anticipated to occur in Talbingo in the coming months, as well as increasing maintenance requirements, would also increase the risk that rates of cleaning would not be able to keep pace with the inputs of debris leading to screen blockages that would reduce the ability of the station to operate at full capacity. As noted in Section 1.4, if this were to occur at a time when other suppliers are also constrained through damages to plant or transmission lines, this could have implications for the security of electricity supply to the grid.

2.1.3. Drum Screens

Drum screens comprise a large rotating cylindrical structure with woven wire filtration panels attached to the periphery and supported by a horizontal, revolving centre shaft (Figure 7). A key feature of drum screens are that they are required to operate with part of the drum above the water surface meaning that the diameter of the drum is proportional to the reservoir level variation as illustrated in Figure 8.

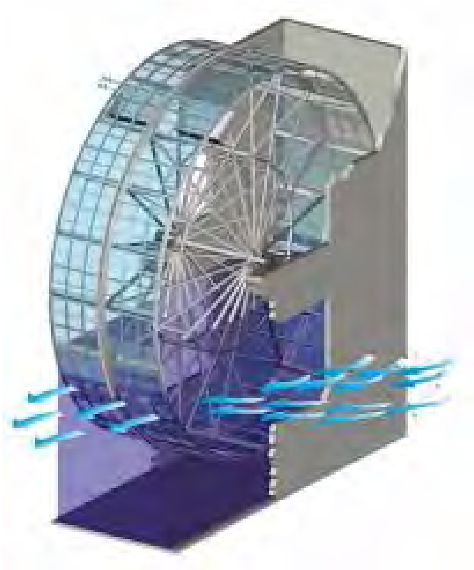


Figure 7: Brackett Green in-to-out drum screen (Ovivo 2018 cited in THA Aquatic, 2019)

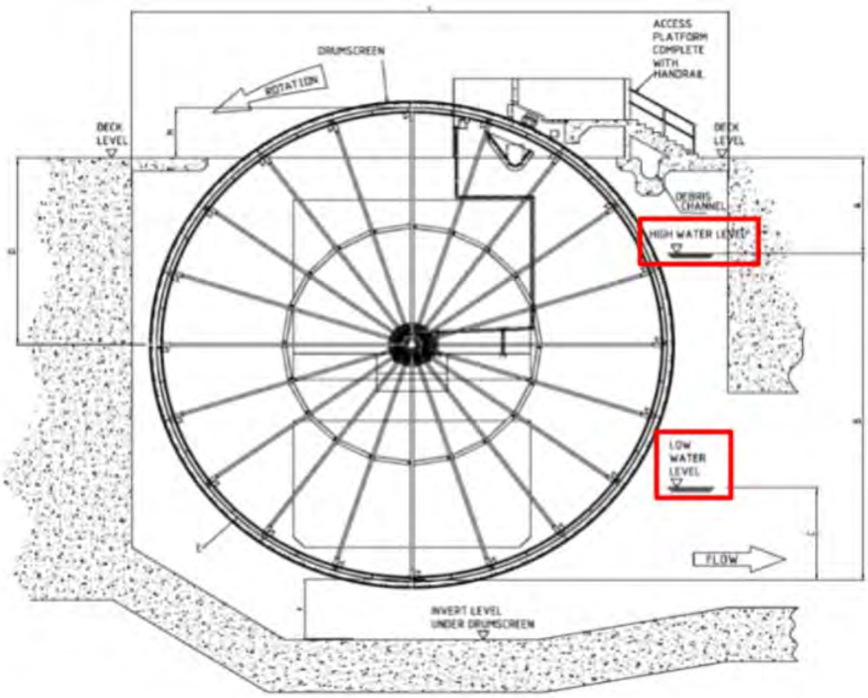


Figure 8: Conceptual Drum Screen Arrangement (Ovivo, pers comm)

As observed in Figure 7 and Figure 8, the drum operates partially submerged under Full Supply Level (FSL) however still needs sufficient surface area to pass the maximum flow rate at Minimum Operating Level (MOL). Putting this into perspective, Talbingo Reservoir has a variation of approximately 9m between MOL (534 mAHD) and FSL (543 mAHD) which the supplier estimated would result in a minimum drum diameter of 18m. As screening is also required at Tantangara Reservoir (to prevent trash loading of the Talbingo screens) which has a variation of approximately 23m between MOL (1206 mAHD) and FSL (1229 mAHD), this would result in a drum diameter potentially approaching 46m. The effectiveness of any rotating seals being able to effectively maintain a gap of <0.5mm at these diameters is highly questionable. Accommodating the required number of drums at these diameters would require immense civil works in excess of that required for the SWIFF screens discussed above leading to likely construction costs above the estimate presented for SWIFF screens. For this reason they have not been considered further.

2.1.4. Flat Panel Screens

Flat panel wedge wire passive screens can be considered a favourable alternative to cylindrical or drum screens due to the lower operating costs associated with fewer moving parts. However, this also makes them more prone to biofouling (Figure 9). They are typically applied in riverine environments where a high sweep velocity is able to naturally clean the screen, a condition that will not be present in the lentic environment of Talbingo Reservoir. In the absence of adequate sweeping flows and in high debris areas, cleaning via the use of compressed area or brushes is required. Maintenance can also be more challenging as the screens are permanently submerged (Hendrick, 2018).

As noted in THA Aquatic (2019), the largest known installation of flat panel screens is at the Red Bluff Diversion Dam, located on the Sacramento River in California. The 1,100-ft (335m) long flat-panel fish screen has 60 screen bays with four sections containing 15 screen bays each. The fish screen panels are constructed of stainless steel profile-wire with 1.75 mm gaps. The as-built pumping plant capacity is limited to 2,000 ft3/sec (57cumecs) with a build-out capacity of 2,500 ft3/sec (71cumecs) (Vermeyan, 2018). Figure 9 below shows that even in an ideal environment with high sweep velocities, an automated screen cleaning system and relatively wide spacing of 1.75mm (compared to the required 0.5mm for Snowy 2.0), clogging from aquatic growth can be a significant issue.

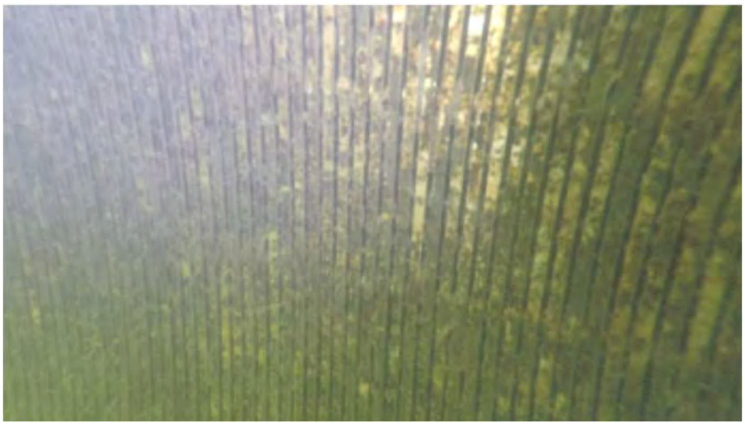


Figure 9:Photograph of aquatic growth on a flat panel fish screen at a depth of 7feet at the Red Bluff Diversion Dam (Vermeyen, 2018, p.15)

The flat panel screen option was also considered to be poorly suited to the reservoir environments of Talbingo and Tantangara due to the large water level variations. To effectively screen the intake, the screens would need to be situated from the base of the proposed intake to the deck level (above FSL). As with the drum screens, the flat panel screens would be required to be sized to ensure the required flow rates for the Snowy 2.0 station could be achieved at MOL. For Talbingo Reservoir, THA Aquatic (2019) calculated that this would necessitate a wetted screen area in the order of 2,400 m^2 (inclusive of c. 20% redundancy to accommodate debris blinding) to sit below MOL to ensure approach velocities during the pumping phase at MOL of approximately 0.15m/s. Considering the high station reliability requirements (see Section 1.4), it is likely that the blinding allowance would need to be higher than this. As noted by THA Aquatic (2019), the array and associated civil structure required to achieve the screening criteria would be immense and larger than any of the other alternatives investigated leading to likely construction costs above the estimate presented for SWIFF screens. For this reason they have not been considered further.

2.1.5. Conclusion

The general duty under the Biosecurity Act is not an absolute duty to prevent, eliminate or minimise risk, but rather is to be based on an assessment of what measures are reasonably practicable (and what is 'reasonably able to be done') in the circumstances of each individual case taking into account and weighing up all relevant matters including the factors specified in s16 of the Act. Applying this, SHL considers that due to:

- the more limited degree of biosecurity impact that might arise as a consequence of the transfer of pest fish between Talbingo Reservoir and Tantangara Reservoir (as compared to the degree of biosecurity impact that might arise in the catchments beyond Tantangara Reservoir);
- the secondary controls proposed at Tantangara Reservoir as detailed in section 4.2 below and in the Main Works EIS which limit the potential area of impact and thus minimise the biosecurity risk in the catchments beyond Tantangara Reservoir;
- the visual amenity and environmental impacts associated with the significant increase in underwater blasting and dredging and excavated material management;
- the design complexity and experimental nature of 0.5mm fine mesh screens deployed for bi-directional flow on a project of this scale for which there are no precedents anywhere else in the world such that its effectiveness cannot be assured;
- the potential detrimental impact of the screens on the reliability of the Snowy 2.0 station and therefore the impact to system security; and

- the estimated cost of $619 million, which is grossly disproportionate to the risk,

the installation of fine mesh screens at Talbingo and Tantangara intakes to prevent the biosecurity risk of pest fish transfer, is not reasonably practicable.

2.2. Electrical Euthanasia

An electrical fish barrier was also considered since this option would provide a reduced risk of outages posed by blockages compared to fine mesh screens. Electrical barriers have been shown to be very effective in reducing fish passage in an upstream direction, however, typical deterrent barriers are not considered as effective in downstream applications, such as Snowy 2.0, because any fish unable to swim away from the flow can become stunned and carried along the flow path (THA Aquatic, 2019). One way to address this limitation would be to install a graduated array of electrical barriers that increased in strength to the point where any fish (or other life stage) entering the intake would be electrically euthanized.

As with the screening infrastructure, in order to ensure that electrical equipment is sited in a low velocity zone where fish could detect the current and move away from it before being entrained, the size of the intake would need to be increased significantly with consequent increases to the volume and depth of excavation. The intake opening would be required to increase from 35m wide by 10m deep intake structure to one that is 200m wide by 20m deep (Figure 10). The preliminary estimated construction costs are in the order of an additional A$ 535 million including a contingency of 25 percent (Table 5). Although excavation quantities would not be as large as those required for fine screening, significant additional disturbance would be expected within Talbingo reservoir due to the additional blasting and dredging works as well as the added complexity and size of the intake.

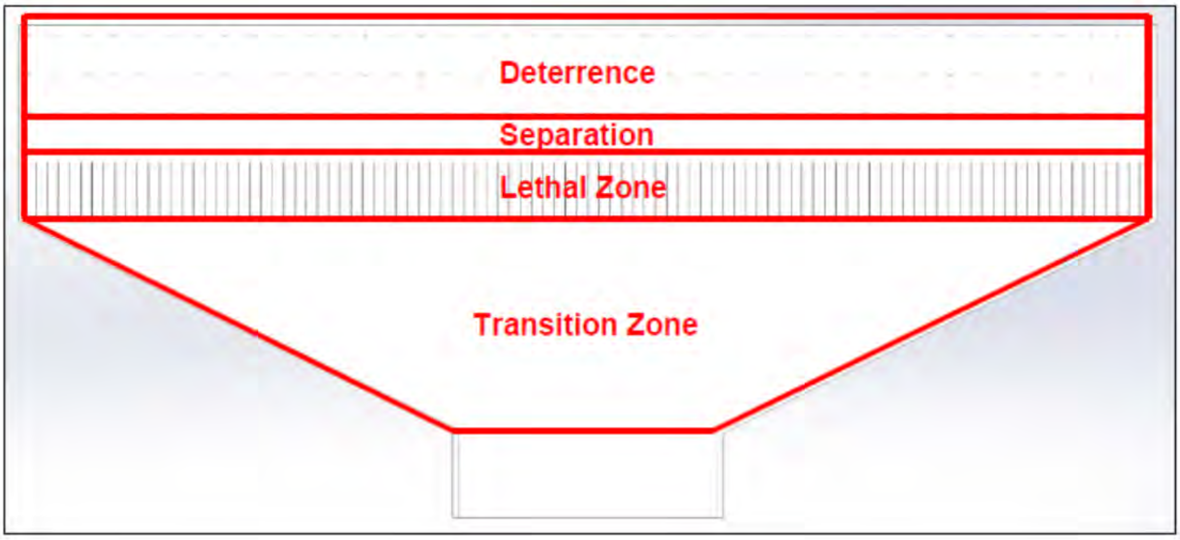


Figure 10: Conceptual design of an electrical fish barrier including euthanasia.

Table 5: Estimated construction costs for Electrical Fish Barrier at Talbingo

Description	Cost [$]
General	18,197,743
Cofferdam	60,400,000
Excavation & Spoil Disposal	16,968,150
Concrete	76,758,000
Reinforcement	38,977,557
Miscellaneous civil and e&m works	3,442,152
Electrical and Mechanical works	97,409,000
Additional	70,125,798
Contingency (40%)	152,911,360
Total Additional Costs	**535,189,760**

In addition to high capital construction costs, ongoing power requirements were estimated at 21MW, with the arrangement required to operate continuously to prevent fish entry into the intake. Even assuming wholesale electricity prices of $80/MWh, this equates to an electricity cost of $14.7million/year, with a total estimated cost for operations and maintenance of $15million/year. THA Aquatic (2019) also cited safety concerns over the application of such technology as the estimated voltages required would be lethal to humans. Whilst the array was operating, it would not be safe for anyone to enter the area. Given the array would need to operate continuously to prevent fish from entering the intake during periods of non-operation, access by people for inspections and maintenance of the array or other intake features would be difficult. The array would also be non discriminatory meaning that any fish, including native and recreationally important species, or any other animal entering the area would be euthanized.

An electrical array across the intake would also represent a single point of failure in the event of a power supply interruption to the intake that could render the entire Snowy 2.0 Station out of service should a condition of station operation be the continued operation of the electrical array. As noted in Section 1.2, such a design issue would have implications for the reliability of Snowy 2.0.

2.2.1. Conclusion

Applying the considerations for what is reasonably practicable in the context of the general duty under the Biosecurity Act, SHL considers that due to:

- the more limited degree of biosecurity impact that might arise as a consequence of the transfer of pest fish between Talbingo Reservoir and Tantangara Reservoir (as compared to the degree of biosecurity impact that might arise in the catchments beyond Tantangara Reservoir);
- the secondary controls proposed at Tantangara Reservoir as detailed in section 4.2 below and in the Main Works EIS which limit the potential area of impact and thus minimise the biosecurity risk in the catchments beyond Tantangara Reservoir;
- the environmental impacts associated with the increase in disturbance footprint within Talbingo reservoir including increased blasting and dredging;
- the safety risks associated with the high voltages required which would be lethal to any humans, other animals and fish that entered the area;
- the design complexity and experimental nature of electrical euthanasia for which there are no precedents anywhere else in the world;
- the uncertain efficacy of electrical euthanasia as a means to comprehensively prevent all live fish transfer;
- the potential detrimental impact of the electrical array on the reliability of the Snowy 2.0 station and therefore the impact to system security; and
- the estimated construction cost of $535 million and the ongoing estimated electricity consumption costs of >$14million/year, which is grossly disproportionate to the risk,

the installation of electrical euthanasia at the Talbingo intake to prevent the biosecurity risk of pest fish transfer, is not reasonably practicable.

3. Options to Eliminate the Biosecurity Risk

The only way to eliminate the risk of pest fish transfer associated with the operation of Snowy 2.0 would be to remove the source populations of redfin and other pest fish from within Talbingo Reservoir.

Potential options for removal include:

a) Physical removal (i.e. fishing, netting);
b) Harvest regimes (i.e. intentional over-fishing of target species or modification of angling regulations);
c) Chemical treatments such as antimycin or rotenone;
d) Biological control (e.g. introduction of predators, competitors, sterilization or targeted pathological reactions);
e) Environmental (e.g. lowering water level);
f) Other (e.g. explosives); or
g) A combination of the above methods (Rytwinski et al. 2019).

Although these methods have been reported to successfully eradicate non-native species, there are few documented studies from large and complex environments like Talbingo Reservoir. Typically, eradications have been most frequently successful when applied in small, shallow, sparsely vegetated, easily accessible, and closed lentic systems (Closs, et al. 2003; Rayner and Creese, 2006). Eradication attempts have been identified as most likely to fail due to one or a combination of the following factors:

- ineffective capture techniques (e.g., size-specific efficiencies);
- habitat complexity (e.g., areas of refuge and plant density);
- large water-body size;
- the degree of site enclosure (i.e., open versus closed water bodies);
- species-specific factors (e.g., size and habitat preferences); and
- physical water properties (e.g., water chemistry, temperature, and water depth) (Rayner and Creese, 2006; Rytwinski et al. 2019).

Unfortunately many of these factors are key issues for a potential redfin and other pest fish eradication program at Talbingo Reservoir. The large area (1,943ha at FSL) and depth (up to 140m) of Talbingo Reservoir, coupled with the habitat complexity including standing timber and a high density of aquatic vegetation (Elodea) (Zukowski, 2019), the linkages to the Yarrangobilly River and Jounama Pondage (where water can be pumped via the Tumut 3 power station) where redfin are also known to occur (Cardno, 2019) and the known redfin utilisation of habitats of up to 50m depth (Thorpe 1977; Imbrock et al. 1996) means that there would be a low probability of complete success for all possible options. An unsuccessful eradication attempt where some redfin are left or are able to recolonise also has the potential to lead to high juvenile redfin recruitment due presumably to the loss of larger cannibalistic adults (Closs et al. 2003) which could actually increase the number of redfin in the reservoir that would be susceptible to entrainment.

Efforts to control redfin using physical removal, harvesting, chemical treatment and/or explosives would be hampered by the inability to drain Talbingo by more than 14m below MOL, i.e. even if the reservoir was drained as far as possible (rendering Tumut 3 power station out of service), sections of the reservoir would still be over 110m deep.

Chemicals such as rotenone are known to impact aquatic macroinvertebrates as well as fish (Lintermans and Raadik, 2003). Although decapods are considered less susceptible than other types of invertebrates (Dalu et al., 2015), the presence of Murray crayfish (listed as vulnerable under the NSW FMA 1994) (Zukowski, 2019) as well as a stocked population of trout cod (listed as endangered under the NSW FMA 1994) (Cardno, 2019) within Talbingo Reservoir makes the use of rotenone or other non-selective chemicals or explosives undesirable. There are also no biological controls (other than EHN virus) known to be selective for redfin or other pest fish present in Talbingo.

As a result of these factors, the elimination of redfin and other pest fish populations in Talbingo reservoir to eliminate the biosecurity risk of pest fish transfer is not reasonably practicable.

4. Options to Minimise the Biodiversity Risk

When considering how SHL could minimise the potential biosecurity risk posed by Snowy 2.0, consideration was given to measures that could potentially reduce the number of fish transferred to Tantangara Reservoir (Entrainment Reduction) and measures that could reduce the scale of biosecurity impact i.e. minimise the area over which pest fish could potentially establish and cause an impact (Secondary Controls).

4.1. Entrainment Reduction through Snowy 2.0

4.1.1. Physical and behavioural barriers

As noted earlier in the document, there are inherent features of the existing design that will act to minimise fish entrainment at the Talbingo intake, such as the depth of the intake and the construction of an approach channel (which will remove vegetation and complex habitat from around the intake). Physical and behavioural barriers that could further reduce fish entrainment and details on their potential efficacy are detailed in THA Aquatic (2019). Options investigated by THA Aquatic (2019) included:

- Static screens
  - Flat Panel Screens - Mesh, bar and passive wedge-wire screens
  - Passive Wedge-Wire Cylinder (PWWC) screens
- Inclined, pivoting screens
  - Eicher screens
  - Modular Inclined Screens (MIS)
- Rotating and traveling screens
  - Brushed cylinders
  - Travelling band screens
  - Drum Screens

- MultiDisc Screen
  - Water Intake Protection (WIP) Screens
  - Submerged Water Intake Fish-Friendly (SWIFF) Screens
- Other physical barriers
  - Barrier nets
  - Aquatic Filter Barrier (AFB) or Marine Life Exclusion System (MLES)
  - Porous Dikes
  - Sub-Gravel Intakes and Wells
- Behavioural Deterrents
  - Light
  - Acoustic fish deterrents
  - Air-bubble screens
  - Electrical barriers
  - Hybrid fish deterrents
- Electric screens for euthanasia
- Hydraulic deterrents
  - Veneer intake

Although some of the options listed above would be considered technically feasible to reduce fish entrainment at the Talbingo intake, a key consideration in SHL's assessment of these options centred on whether these options would have an overall material impact in minimising the biosecurity risk and the scale of any potential biosecurity impact. See section 4.1.7 below for a discussion on this point.

It is important to note that even for options such as behavioural deterrents that would not be expected to obstruct the flow of water through the proposed station, significant re-engineering of the intake area within Talbingo Reservoir would still be required to locate the structure in a low velocity zone to effectively minimise entrainment as noted in the following sections. This would lead to high construction and operation costs, and additional impacts to the aquatic and terrestrial environments in and around the reservoirs.

As detailed for the fine screen option discussed above, additional excavation during intake construction would be expected to increase the aquatic impacts associated with dredging and blasting for intake construction that are detailed in Appendix M.2 of the Main Works EIS due to the increase in disturbance area and extended duration of the works. This would include areas in Talbingo known to be habitat for Murray Crayfish (Cardno, 2019). The disposal of the additional material would necessitate a larger footprint of disturbance for placement in the reservoirs and/or for on land placement near the reservoirs with consequent impacts to the aquatic and/or terrestrial environment that otherwise would not occur. The additional disturbance could also potentially increase the value of offsets required for the project.

In order to demonstrate this, high level concept designs have been prepared for:

- Coarse (20mm) flat panel screens;
- A Barrier net; and
- A behavioural deterrent (a combined sound and light array).

Other options considered that are discussed below include increasing the depth of the intake and controlling the size of the redfin population in Talbingo Reservoir.

4.1.2. Coarse flat panel screens

The vertical bar spacing of the coarse trash rack could be reduced from the current 120-150mm to prevent larger size fish passing through the trashracks. If for example, trash rack spacing was reduced to 20mm, it could be assumed that any fish with a head width greater than 20mm would be excluded from passing into the intake whilst any eggs, larvae or fish smaller than this could still be able to pass through into the intake.

As with the fine screens, the adjustment in trash rack spacing would need to occur in both reservoirs in order to avoid debris becoming impinged and blocking flow on the upstream face of the screens at Talbingo during generation. In order to accommodate the greater closed area associated with the narrower racks, reducing the bar spacing to 20 mm would require the width of the intake structure to be increased from 30 m to a minimum of 140 m at Talbingo reservoir and to 110 m at Tantangara reservoir resulting in larger excavation and concrete volumes. A trash raking machine would also be required to clear trapped debris during operation.

Based on a preliminary concept design, reducing the bar rack spacing to 20mm would equate to a $220 million increase in the cost of intake construction (Table 6). As noted in earlier sections, increasing the volume of excavation in the reservoirs, would be expected to increase aquatic and terrestrial environmental impacts associated with underwater blasting, dredging and excavated material management.

Table 6: Estimated additional construction costs for 20mm flat panel screens

Description	Cost [$]
General	-
Cofferdam	-
Excavation & Spoil Disposal	23,145,279
Concrete	83,300,333
Reinforcement	29,518,354
Miscellaneous civil and e&m works	900,000
Electrical and Mechanical works	43,126,462
Additional	600,000
Contingency (25%)	39,211,287
Total Additional Costs	**219,801,715**

As noted above, this option will not be effective at preventing the entrainment of any eggs or larvae and would still allow the transfer of any fish with a head width of less than 20mm. As will be discussed in section 4.1.7 below, the transfer of only small fish, larvae and eggs is unlikely to reduce the rate of fish transfer to such an extent that the likelihood of a biosecurity impact is materially reduced. As a result, SHL does not consider this option to be a reasonably practical means of minimising the potential biosecurity risk associated with the operation of Snowy 2.0.

4.1.3. Barrier Net

As noted in THA Aquatic (2019), coarse mesh barrier nets have been successfully used at a pumped hydroelectric storage plant to reduce fish entrainment into the station. A 2.5-mile (4km) long, ½-inch (13mm) bar wing mesh and ¾-inch (19mm) bar central mesh barrier net set in open water is seasonally deployed around the 1,872 MW Ludington Pumped Storage Plant intake, Lake Michigan (THA Aquatic, 2019). Although less effective in early years, subsequent modification to the design has allowed it to meet its targeted effectiveness of reducing entrainment of 80% of game fish and 85% of forage fish over five inches (13cm) in length (Alden Research Laboratory, 2016).

Given the high operating range of Talbingo Reservoir (9m), the net would have to be anchored to the reservoir floor and suspended off a floating boom to adjust in height as the water in the reservoir rises and falls. Alternatively, the net could be suspended from a steel wire rope strung across the intake approach channel and supported on intermediate concrete piers. A rope and pulley system would allow the height of the net to be adjusted to the prevailing reservoir level. A secondary net would have to be installed to be available during periods when the first net has to be withdrawn to remove biofouling clogging the net and for repairs. A system of manually clearing debris impinged on either side of the net will also need to be developed. In order to minimise large volumes of debris clogging the net during electricity generation, nets would also be required at Tantangara Reservoir.

Based on a preliminary concept design, the cost of installing barrier nets at Talbingo and Tantangara is estimated at $55 million (Table 7). Published figures by EPRI (2005) on capital costs for barrier nets were used to compare costs for the estimate produced for Talbingo. Using the weighted average construction cost of installing a barrier net relative to the flow capacity of the station during pumping, the construction cost would be estimated at A$13 million per reservoir (2002 values). As the basis of these numbers is not directly comparable to Talbingo and the Snowy 2.0 project, with the high reservoir depth and large range of water level variability (between FSL and MOL) as well as the bidirectional flow conditions under which the net has to operate, it is more likely that costs would be higher than average. Using the high cost estimate provided in EPRI (2005) of US$6000/cfs gives an estimate of A$100 million (2002 values).

Table 7: Estimated additional construction costs for barrier nets in Talbingo and Tantangara reservoirs

Description	Cost [$]
General	-
Cofferdam	1,500,000
Excavation & Spoil Disposal	802,923.25
Concrete	25,995,991
Reinforcement	5,598,253.16
Miscellaneous civil and e&m works	200,000
Electrical and Mechanical works	2,296,706
Additional	650,000
Contingency (25%)	18,196,936.71
Total Additional Costs	**55,240,810**

A barrier net would be difficult to maintain from an operational perspective due to challenges associated with condition monitoring, access and cleaning. Given the size of the net required and the need to operate over a large water level operating range, a barrier net would be prone to failure and overtopping. A complete seal at the reservoir edges would be difficult to achieve and it is uncertain how blockages and breakages could be detected other than periodic removal and/or regular visual, underwater inspection by remotely controlled submersibles and in-water repair by divers or net removal. The operation of the station therefore could not be made dependent on the performance of the net as the condition could not be ascertained in real time. This also means that the barrier could not be used as a means of reliably excluding all fish of a certain size class, as the results of the monitoring and targeted performance (i.e. exclusion of 80-85% of fish over 13cms long) of the net at Ludington demonstrates (Alden Research Laboratory, 2016).

The annual maintenance cost of the nets at Ludington is estimated at > $2.8M USD (>A$4.1M) for 6 months of operation (Alden Research Laboratory, 2016). While in operation, net cleaning is an ongoing process that also requires boats, divers and pressure washers. Permanent, bottom-anchor piles and anchor chains are used to keep the barrier net in place. THA Aquatic (2019) also noted the maintenance intensive nature of barrier nets with an observation of a 2,000 ft fine mesh barrier net operated at Pickering Nuclear Generating Station Fish Diversion System in Ontario, Canada, necessitating a large team of approximately 16 staff that operated from boats in a 3-shift pattern round the clock to maintain the anchorage and air back flushing systems during certain times of the year. Considering the remoteness of the project, its location in an alpine environment, SHL high safety standards, the large distance between the two intakes and the need to deploy the net all year round, it is not unreasonable to assume that maintenance costs could be similar or higher to the net at Ludington.

This option will not be effective at preventing the entrainment of any eggs or larvae and would still allow the transfer of any fish with a head width less than the width of the mesh. Larger fish would also be expected to pass over or through the mesh due to overtopping and/or net damage. As will be discussed in section 4.1.7 below, the transfer of lower numbers of adult fish is unlikely to reduce the rate of fish transfer to such an extent that the likelihood of a biosecurity impact is materially reduced. As a result, SHL does not consider this option to be a reasonably practical means of minimising the potential biosecurity risk associated with the operation of Snowy 2.0.

4.1.4. Behavioural controls

A number of behavioural deterrents have been developed to prevent fish from becoming impinged and entrained at water intakes. These have been comprehensively reviewed by THA Aquatic (2019).

Although some studies have been able to demonstrate relatively high levels of effectiveness in repelling juvenile and adult fish, including redfin, the use of behavioural deterrents for Snowy 2.0 was not considered appropriate by THA Aquatic (2019) as these will have little or no effect in preventing entrainment of early life stages and would not provide a total barrier for juvenile or adult fish.

Even when used in the context of minimising entrainment, it is important that any behavioural controls are deployed in a low velocity zone where motile fish life stages will have the ability to sense the stimulus and be able to swim away from it (THA Aquatic, 2019). The anticipated maximum velocities at the current intake during pumping of 2m/s are well above the known swimming capacity of redfin (THA Aquatic, 2019). This, coupled with the relatively confined nature of the intake area, would mean that deployment of behavioural controls at Talbingo would require significant levels of excavation to ensure they were located in a low velocity zone well beyond the intake.

A supplier of one of the higher performing behavioural deterrents available, (incorporating both sound and light) has recommended a maximum approach velocity of 0.15m/s in the area where the system is to be installed. The estimated cost of the civil excavation and concrete works would be in the order of $140 million. The total construction cost for the behavioural structure at Talbingo including electrical and mechanical equipment for sound and light barriers is therefore estimated to be in the order of $207 million (Table 8). Operating and maintenance costs have been approximated to amount to around $1,000,000 per year.

Table 8: Estimated additional construction costs for a behavioural deterrent in Talbingo reservoir

Description	Cost [$]
General	6,568,921
Cofferdam	28,700,000
Excavation & Spoil Disposal	22,624,200
Concrete	65,980,785
Reinforcement	22,942,213
Miscellaneous civil and e&m works	2,448,851
Electrical and Mechanical works	10,750,000
Additional	8,350,748
Contingency (25%)	38,361,512
Total Additional Costs	**206,727,231**

As access to the system would be required for inspections and maintenance, infrastructure would need to be located above FSL. As these systems are typically only effective over a depth of approximately 10m, arrays would either need to be stacked or a wall or roof over the structure would be required. This would mean that the visual impact would be similar to the artist's impression in Figure 4. A fanned-out structure with a submerged roof was the option costed in Table 8.

This option will not be effective at preventing the entrainment of any eggs or larvae and would only be expected to deter a portion of juvenile and adult fish. As will be discussed in section 4.1.7 below, the transfer of lower numbers of adult fish is unlikely to reduce the rate of fish transfer to such an extent that the likelihood of a biosecurity impact is materially reduced. As a result, SHL does not consider this option to be a reasonably practical means of minimising the potential biosecurity risk associated with the operation of Snowy 2.0.

4.1.5. Increased Intake depth

Investigations were undertaken to increase the depth of the Talbingo Reservoir intake. Initial investigations into the habitat requirements of redfin indicated that they had a relatively narrow depth range and were unlikely to utilise deeper sections of the Talbingo Reservoir (L. Faulks, DPI Fisheries pers. obs.). Accordingly, SHL assessed the option of lowering the Talbingo Reservoir intake to minimise the possibility of entraining redfin. Subsequent further research has identified studies which indicate that redfin can utilise habitat in excess of 50m depth (Thorpe 1977; Imbrock et al. 1996).

As a result, lowering of the Talbingo Reservoir intake would be unlikely to materially minimise the biosecurity risk of redfin being transferred between Talbingo Reservoir and Tantangara Reservoir and this option was not proposed as part of Snowy 2.0. A key point to add however is that, based on the reference design for the project and hydraulic performance considerations, at minimum operating level (MOL), the top of the Talbingo Snowy 2.0 intake will be up to 9m below the water surface and up to 18m at full supply level (FSL) with the base of the intake and the intake channel another 10m below these depths. This means that much of the time, the Talbingo Snowy 2.0 intake will be located below the common depth range for fish, especially eggs and larvae. In particular, this depth is well outside the typical depth range of Gambusia (often 15-20 cm) (Pyke, 2005). These depths are close to the maximum depth range that adult (5–10 m depth; juvenile (12–15 m) and larval (13–14 m) redfin have been observed to occupy in reservoirs (Ning at el., 2019) although as noted above there are instances of adults being observed at depths greater than this (Thorpe 1977; Imbrock et al. 1996).

4.1.6. Population Management

Fish control methods were also considered to reduce the density of fish within Talbingo Reservoir. The assessment by THA Aquatic (2019) found that strategies that sought to control smaller fish and retain large adult redfin, which are known to be cannibalistic, could be effective in regulating the numbers of smaller fish that are most susceptible to entrainment. However, THA Aquatic also highlighted that skewing the population towards larger adults, may actually increase the rate of reproduction and recruitment which may be counterproductive. THA Aquatic (2019) concluded that stock management will require significant resources and finances with no guarantee of success in reducing or eliminating the risk of transfer. The effectiveness of any program of population control would also be hindered by the features of Talbingo reservoir discussed above in Section 3.

4.1.7. Assessment of efficacy

Key to the assessment of whether the potential biosecurity risk could be minimised via measures to reduce entrainment relates to whether reducing the number of fish transferred through the Snowy 2.0 tunnels could materially reduce the risk of a biosecurity impact occurring.

Although it is by no means certain that conditions in Tantangara Reservoir will favour redfin reproduction and a reproducing population will establish in the reservoir, SHL does not consider it reasonable to employ measures to reduce the number of fish that could potentially be entrained into the Talbingo intake when this is unlikely to materially reduce the actual risk of redfin establishing in Tantangara Reservoir. As noted in the introduction, the initial introduction of redfin into Tasmania consisted of only 11 individuals (Harris, 2013) and populations have been known to establish following introductions of relatively few individuals associated with contaminants of fish stocking, their use as live bait by fishermen, escape from outdoor ponds and dams, deliberate legal stocking and deliberate illegal stocking (Lintermans, 2004).

If the intent was to minimise the loss of fish from a source population (i.e. Talbingo Reservoir) in order to protect commercial, recreational or environmental fishing interests, as is the case in the majority of applications in the United States (USA) and elsewhere, it may be appropriate to apply measures that could reduce fish entrainment and consequently fish mortality. However, in this instance, the goal is to prevent, eliminate or minimise the potential transfer and establishment of pest species into Tantangara Reservoir. It is SHL's position that none of the measures discussed above are likely to be effective either alone or in combination at reducing transfer to such an extent that the risk of establishment is materially minimised.

Options to minimise entrainment typically target adult life stages. This includes physical controls that limit the size of individuals that can be entrained and behavioural controls that aim to influence the behaviour of motile life stages. Options to manage early life stages are limited. According to DPI (2019b), when they spawn, each individual mature redfin lays several hundred thousand eggs. As these eggs are laid in vegetation or on other substrate, they would not be expected to be entrained at a high rate (EPRI, 2004) but the larval stage which is planktonic may be. For example, a review of entrainment studies by EPRI (2011) at coastal and freshwater power plant cooling water intakes with capacities above 50MGD (2m^3/s) in the USA and Puerto Rico, indicate that entrainment of small and early life stage organisms is very variable but rates are typically very high, i.e. well into the millions per year (Figure 11). Although specific details are not provided, many of these facilities use 10mm (3/8inch) travelling band screens to manage debris loads into the intakes (EPRI, 2004). The depths of the intakes were not specified.

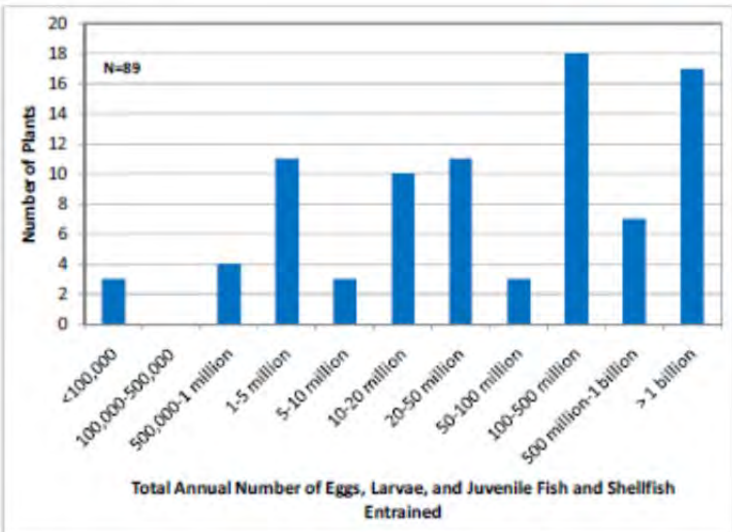


Figure 11: Entrainment estimates for the number of fish and shellfish entrained into power plant cooling water intakes with a capacity above 50MGD (2m^3/s) at power facilities in the EPRI database in the US and Puerto Rico (EPRI, 2004, p.3-30).

Whilst it is impossible to use this data to derive an estimate for the number of fish, and in particular pest species, likely to be entrained by pumping at Talbingo Reservoir due to the diversity of intake conditions, habitat types and different species composition in the EPRI study area, these data indicate that the number of early life stages individuals transferred has the potential to be significant even if fish protection measures such as those discussed in the sections above are put in place.

It is acknowledged that natural mortality rates of larvae and juveniles are high compared to adults. However, this is offset by the potentially high number that may be entrained. Based on estimated survival rates of Yellow Perch (a closely related species to redfin – see THA Aquatic (2019)) published by EPRI (2004), the entrainment of 100,000 larvae is estimated to be equivalent to 240 one year old fish.

A commonly held view is that the number of individuals of a pest species introduced to a new area is likely to increase the risk of establishment (Cassey et al., 2018). A quantitative review of this assumption by Cassey et al. (2018) confirmed this point but was also able to identify that the correlation between establishment success and the number of individuals was strongest in the range of 10-100 individuals, i.e. when the number of individuals introduced is less than 10, the establishment probability is low whereas establishment is highly likely (but never certain) when the number of introduced individuals is above 100 (Cassey et al. 2018). This research suggests that if entrainment reduction activities could limit the number of fish entrained and surviving transfer to less than 10 individuals, then the probability of establishment in Tantangara is likely to be low. SHL consider it highly unlikely that any of the available options to reduce fish entrainment into Snowy 2.0 would have the capacity to reduce the number of individuals entrained and surviving transfer to less than 10, or even to less than 100, even when survival rates to adulthood and the estimated mortality rates developed by Ning et al. (2019) are factored in.

4.1.8. Conclusion

This section has demonstrated that technically feasible options exist to reduce the rates of entrainment into the Talbingo intake during the operation of Snowy 2.0. However, due to limitations in the potential effectiveness of any option at minimising potential fish transfer and the fact that transfer of even a small number of individuals could potentially lead to population establishment if conditions in Tantangara Reservoir prove favourable, coupled with the high cost of construction and maintenance and environmental impacts associated with construction, SHL does not consider the implementation of any of these options to be reasonably practical either alone or in combination with other measures.

4.2. Secondary Controls

Should redfin or other pest fish be transferred and establish within Tantangara Reservoir (noting that it is not certain that this will in fact occur), SHL will minimise the potential biosecurity risk and impact of fish transfer by installing barriers that will seek to avoid the subsequent spread of these fish to other catchments. The containment of individuals to a confined area is a recognised technique for pest species management (Lintermans, 2004; Rytwinski et al. 2019).

No threatened fish species, populations or ecological communities listed under the Fisheries Management Act 1994 (NSW) (FMA)) or the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) (EPBC) are known to occur within Tantangara Reservoir. However the following fish species and communities are known to occur in the vicinity and have the potential to be impacted if redfin (and/or other species) are able to move through hydrologically connected waterways:

(a) Stocky Galaxias;[1]
(b) Macquarie Perch;[2]
(c) Trout Cod;[3]
(d) Murray Cod;[4] and
(e) Snowy River aquatic ecological community.[5]

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[1] *Galaxias tantangara* (Critically endangered, Sch 4A FMA). Only known from one locality – the headwaters of Tantangara Creek, upstream of the Tantangara Reservoir, Kosciuszko National Park NSW. It is restricted to a 4km stretch of the creek above a waterfall.

[2] *Macquaria australasica* (Endangered, Sch 4 Part 1 FMA; Endangered, EPBC Act) Known to occur downstream of Tantangara Dam from approximately Yaouk

[3] *Maccullochella macquariensis* (Endangered, Sch Part 1 4 FMA). Known to occur and stocked downstream of Tantangara Dam

[4] *Maccullochella peeli* (Vulnerable, EPBC Act). Known to occur and stocked downstream of Tantangara Dam.

Further details on these species and an assessment of potential impacts pre- and post-mitigation can be found in Appendix M.2 of the Main Works EIS (Cardno, 2019). SHL considers that, with the implementation of the secondary mitigation measures proposed below, the risk of a biosecurity impact arising from the operation of Snowy 2.0 can be effectively minimised by restricting the potential area of spread to a defined area and avoiding to the greatest extent reasonably practicable the potential impacts to species listed under the FM and EPBC Acts.

SHL has considered a number of potential mitigation measures to prevent transfer of pest fish out of Tantangara Reservoir, should they become established. The options considered include:

(a) A fine mesh physical barrier at the Tantangara Dam River outlet works and Murrumbidgee-Eucumbene tunnel intake;
(b) Behavioural deterrents at these locations;
(c) An electrical deterrent including the capacity for euthanasia at these locations;
(d) Closure of the Murrumbidgee-Eucumbene tunnel; and
(e) A weir on Tantangara Creek to prevent fish movement upstream into the habitat of the Stocky Galaxias.

A summary of each of these options is provided in Table 9.

Table 9: Summary of fish deterrents and barriers considered to minimise the potential range expansion of pest fish out of Tantangara Reservoir

Potential Mitigation Measure	**Description**	**Conclusion on efficacy**
A fine mesh physical barrier at the outlets	Taking the learnings from the investigations undertaken on the station intakes, a number of options were assessed for screening using fine mesh screens. These included: • Rotating Wedge Wire Screens • Rotating Woven Wire Screens • Panel Wedge Wire Screens. As described for the main intakes, it was again observed that the wedge-wire solutions had a significantly greater demand in gross screening area to achieve the very low flow velocities to obtain any confidence of efficacy. These vast array requirements caused excessively large and unreasonably expensive installations. The conclusion of the investigation was that the woven-wire screens were deemed to be the preferred solution.	A combined screening system for the dam and the tunnel has been included within the project scope in the Main Works EIS and is proposed to be constructed to prevent the transfer of all life stages of all fish species of concern into the Upper Murrumbidgee River and Eucumbene Reservoir.

[5] (Endangered Ecological Community Sch 4 Part 3 FMA). The listing includes all native fish and aquatic invertebrates within all rivers, creeks and streams of the Snowy River catchment. The listing includes the river bed channels inundated by the artificial impoundments of Jindabyne, Eucumbene, Island Bend and Guthega dams, but excludes the ecological communities that have developed in the waters of these impoundments.

Potential Mitigation Measure	Description	Conclusion on efficacy
Behavioural Deterrents	A concept and quote was sought from a leading supplier of combined light and sound behavioural barriers.	The results of previous studies on redfin deflection using acoustics suggests that a reasonably high deflection efficiency of juvenile and adult redfin could be achieved, but the system will not be even close to 100% effective and is therefore inferior to the proposed screens detailed above. As with the Main Intake, SHL considers that measures that would not be likely to materially reduce the likelihood of population establishment in connected catchments could not be considered reasonable to implement as they will not materially minimise the biosecurity risk.
An electrical deterrent including the capacity for euthanasia	A concept design was prepared for the Tantangara Reservoir outlets that incorporated an electrical deterrent zone to deter mobile life stages from entering the intakes and a lethal zone to euthanize any eggs/larvae or fish that moved past the deterrent zone.	As with the main intake, the estimated cost of construction was very high with very high ongoing power demands (>12MW). As discussed above, there are also no known applications of downstream electrical barriers targeting complete fish exclusion via the use of lethal voltages. Given the risk to public safety, high construction and ongoing operation costs and experimental nature of the technology, this option has not been considered further.
Closure of the Murrumbidgee-Eucumbene tunnel	Although, this option would not be able to prevent the transfer of fish to the Upper Murrumbidgee River, permanently closing the Murrumbidgee-Eucumbene tunnel could prevent the transfer of undesirable fish to Eucumbene Reservoir.	An assessment by SHL has determined that this option would unreasonably restrict the operation of Tantangara Reservoir and would have flow on impacts throughout scheme operations. The estimated annual value of the Murrumbidgee-Eucumbene tunnel once Snowy 2.0 is complete is $4million to $20million per year. This assessment is based on increases to the amount of forced generation required and lost pumping opportunity at the Snowy 2.0 station of water that would otherwise be sent through the tunnel for long term storage. There would also be a lost opportunity of storage value in acute wet periods with flow on consequences that less water will be available in long term storage when conditions are dry.
A weir on Tantangara Creek to prevent upstream fish movement	In addition to the downstream barriers proposed, the EIS for Snowy 2.0 Main Works also includes a proposed upstream fish barrier on Tantangara Creek. The intent of this structure is to prevent the potential incursion of Climbing galaxias into the habitat of the Stocky galaxias. Design criteria were sought from Tarmo Raadik (2019).	The preliminary investigation and subsequent workshops with SHL and Tarmo Raadik found that a suitable and effective solution could be designed. The concept identified a suitable weir location approximately 200m upstream Tantangara Creek off the Alpine Creek Trail.

As a result of these investigations, SHL has identified secondary fish barriers to be an effective and feasible measure for the Snowy 2.0 project to meet its General Duty under the Biosecurity Act. The barriers will utilise the best available technology in fish screening to prevent the transfer of fish out of Tantangara Reservoir to other catchments to the greatest extent practicable and therefore reduce the potential biosecurity risk and associated social and environmental impacts. The secondary fish barriers that are proposed as part of the Snowy 2.0 project comprise:

a) A fine mesh screening system located near Tantangara Dam wall. This barrier is designed to prevent the potential movement of all fish species into the Murrumbidgee River below Tantangara Dam and Lake Eucumbene; and
b) a specially designed fish barrier in Tantangara Creek (just upstream of the waterfall above Alpine Creek Trail) to prevent the potential movement of climbing galaxias into the Upper Tantangara Creek Catchment where stocky galaxias are found.

4.2.1. Fine mesh screening at Tantangara

The proposed fine mesh fish screening system at Tantangara Dam and the Murrumbidgee-Eucumbene tunnel (M-E tunnel) demonstrates SHL's commitment to preventing and if it cannot prevent, minimising the potential biosecurity risk and associated social and environmental impacts posed by the operation of Snowy 2.0, as far as reasonably practicable. Effectively restricting the area over which redfin and other pest fish could establish, will materially reduce the potential biosecurity impact associated with the risk of transferring these fish through Snowy 2.0 and will minimise the potential impact on threatened species and EEC's.

The preferred option consists of a combined filtration station that has variable water intakes to maintain water discharge from above the thermocline and services both the M-E Tunnel and the Tantangara Dam ROW releases. The station is envisaged to consist of four chambers fitted with rotating woven mesh SWIFF drums using a backflushing system to remove debris such as vegetation which may pass the coarse trashracks and accumulate on the screen. The four chambers consist of three duty and one standby system with each chamber able to be isolated and drained for inspections and maintenance. Post filtration, the water is piped out of the station to be discharged through either or both the Tantangara Dam ROW or M-E Tunnel (Figure 12). The estimated cost of this structure is in excess of A$25million with an estimated operating cost of A$400,000/year.

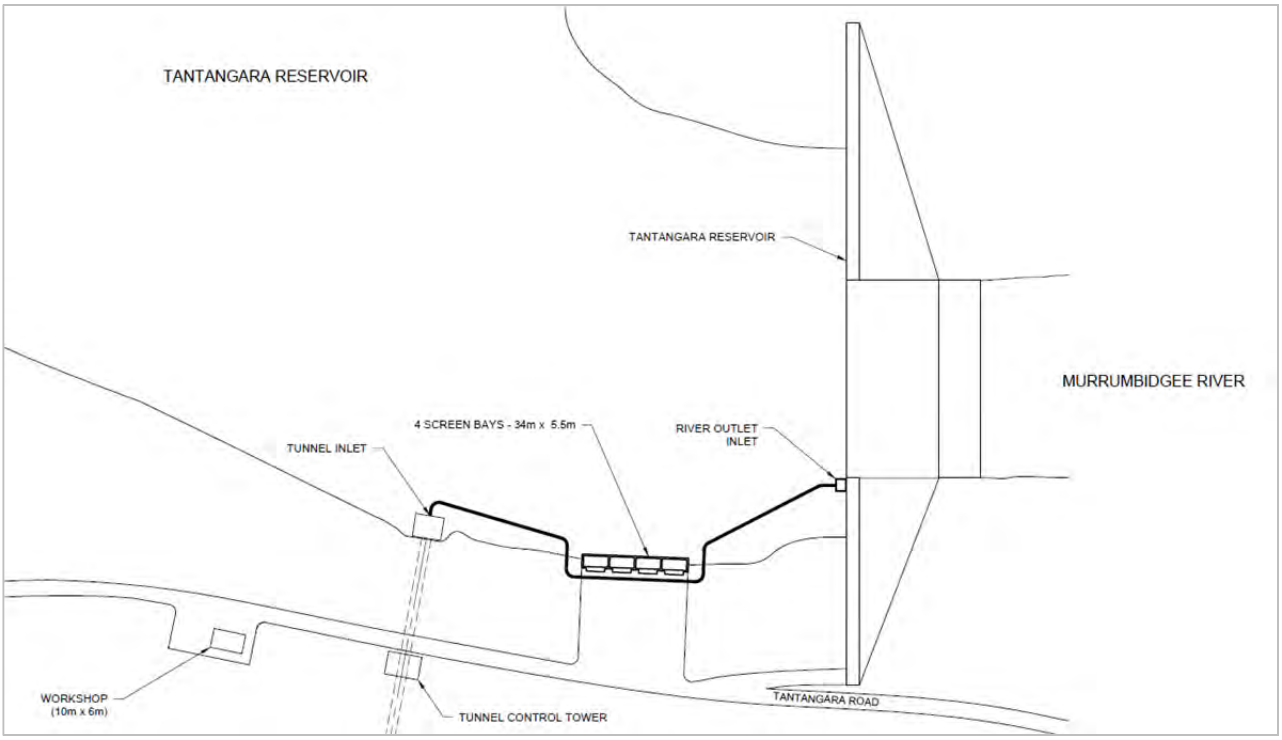

Figure 12: Concept design for SWIFF fish screening structure for Tantangara Dam and the M-E Tunnel.

Questions have been raised in discussions with DPI and in the recent letter sent to SHL regarding the potential effectiveness of the proposed secondary controls. Whilst this structure will likely be the largest fine mesh screening system designed for fish exclusion in the world, current published literature and design work indicates that a technically feasible, effective design can be built at this location. SHL also considers this design to be the best available technology to screen fish at this location.

It is important to note once again that whilst SHL is confident an effective screening system will be able to prevent entrainment and transfer through Tantangara Dam and the M-E Tunnel, the illegal or inadvertent transfer of redfin and other fish by others to locations where they are currently absent is not within SHL's control and will remain a current and future risk in all locations where redfin and other pest fish are currently absent.

A key reason for choosing to install this mitigation measure, as opposed to mitigation measures at the main intakes, is the increased level of confidence regarding the potential effectiveness of these controls, due primarily to the reduced discharge requirements, uni-directional flow and lower asset reliability requirements. Given the nature of the release points and planned redundancy features, SHL anticipates a high degree of confidence around being able to detect and respond to potential failures and blockages in a timely manner that will minimise the risk of fish being transferred through the system.

The potential for blockages and impact damage to the fine screens is anticipated to be minimised via the use of small diameter trash racks at the intake to the structure which will prevent the ingress of large debris and fish into the screening chamber. Sensors will be installed to monitor changes to head loss (that could indicate a blockage or damage to the screen). The proposed redundancy of an additional screen and chamber will allow any chamber requiring maintenance or repair to be isolated, drained, and accessed for inspections, maintenance and repairs whilst not impacting the operation of the remaining screens or providing conditions that could lead to fish transfer.

Although still high, the reliability requirements for the releases from Tantangara Dam and water transfers through the Murrumbidgee-Eucumbene (M-E) Tunnel are considerably less than those of the Snowy 2.0 tunnel and power station between Talbingo Reservoir and Talbingo Reservoir. Coupled with the lower discharge ($21m^3$ compared to $>300m^3/s$) and single direction flow, this means that SHL have high confidence in being able to operate and maintain the proposed screens at this location to meet water release requirements under the Snowy Water Licence without affecting the reliability or operation of Snowy 2.0 or any of the Scheme's other power assets.

Recent experiments

Discussions with DPI Fisheries following the submission of the Snowy 2.0 Main Works EIS indicated that an unpublished study had recently been undertaken that suggests redfin larvae may pass through wedgewire mesh with an aperture of 0.25mm. SHL has been unable to obtain a copy of this study as the client for the work has indicated that the study has not been written up and was considered to be conceptual only in its approach.

From conversations with the client and other people aware of the research, SHL understands that the study involved recently hatched redfin larvae being placed in a pipe and pushed towards mesh under two scenarios, very high water velocity and no water velocity. Specific results have not been provided for both scenarios but SHL understands that 'some' larvae passed through the mesh during the high velocity test and that one individual fish was observed on the other side of the mesh following an unspecified period of time when fish were left unsupervised within the device. The study assessed immediate survival but did not monitor whether any larvae may have been subjected to delayed mortality as a result of injuries sustained during passage through the mesh.

The need for low intake velocity to minimise potential impingement rates is well known (EPRI, 2003) and ensuring low velocity immediately in front of the screens is a key feature of the proposed design for Tantangara. The proposed design also utilises fine woven mesh, which has a square aperture, compared to the wedgewire used in the aforementioned study which is composed of bars arranged vertically (Figure 2). This is due to previously presented research into various mesh options, which found that for wedgewire mesh size of 0.5mm, yellow perch larvae (a close relative of redfin) could be impinged and extruded if velocity through the mesh is higher than 0.15m/s (EPRI, 2003).

A key feature of the cylindrical rotating screen design, proposed for Tantangara, is that the system includes a fish recovery system which aims to minimise the amount of time that larvae may be impinged against the screen to minimise the risk that they are subsequently extruded through the mesh under water pressure. The design of the aforementioned study where larvae were trapped within a pipe and forced towards the mesh (during the velocity replicate) with no means of escape fails to test this crucial design element.

For the reasons outlined above, SHL is of the view that this study does not provide any value with regards to predicting the likely efficacy of the screening system proposed by SHL at this location. However, some general key points can be made.

If this new study is published and concludes that contrary to currently published literature, a proportion of redfin at a particular larval stage may be small enough to pass through 0.5mm square mesh or smaller (noting that this study used vertical wedgewire bars (Figure 2)), it is important to recognise that this risk will only occur for some fish (i.e. the smaller end of the size classes) for a very small part (a maximum of 2-3 days) of the fish's life cycle. For this risk to materialise at Tantangara reservoir, a breeding redfin or other pest fish population would need to have established in Tantangara and newly hatched larvae would have to occur in the vicinity of the intake and be drawn towards the screens.

Whilst the design work and published literature consider that entrainment and transfer of larvae through the proposed screening system at Tantangara will already be a very low likelihood, SHL proposes that the risk could be further reduced by considering the following additional management measures in the event that redfin or other pest species establish in Tantangara Reservoir as a result of transfer during the operation of Snowy 2.0:

- During construction, the area around the intake will be cleared of any material that could be considered favourable spawning habitat.
- Minimise or even avoid releases to the upper Murrumbidgee River during the period when pest fish larvae are present. Under the SWL, SHL is required to make releases from Tantangara Dam in accordance with volumes and a pattern of releases prescribed by DPIE-Water. The various departments within DPIE may choose to work together to dictate a pattern of releases to SHL that ceases/minimises releases during the highest risk period.
- Make releases from deeper sections of the reservoir. The SWL also requires that SHL make releases from Tantangara Dam using water drawn from the near surface horizons. As larvae are more likely to be found in shallower water (THA Aquatic, 2019), the risk of transfer will be higher if releases are made from this part of the reservoir. As redfin spawn during late winter, early spring (DPI, 2019), stratification within the reservoir is unlikely to be well developed at this time. The various departments within DPIE may choose to request that SHL make releases from deeper in the reservoir during the highest risk period.

Avoiding Spill from Tantangara Dam

Another critical element in preventing the potential spread of pest fish through Tantangara Dam (should redfin or other pest fish establish in Tantangara Reservoir) will be ensuring that all water which enters the Murrumbidgee River has passed through the proposed fine mesh screening system. This means avoiding releases over the Tantangara Dam spillway.

As already detailed in the Snowy 2.0 Main Works EIS (Cardno, 2019), SHL has a sound track record of managing the head ponds of its generation storages. The combination of flexible, remotely controlled assets and in-house weather forecasting skill has meant that there has never been an uncontrolled spill of the Snowy Scheme's generation headponds, being Geehi, Tumut Pond and Talbingo Reservoirs. The change in Tantangara Reservoir's operating function from a large diversion and storage pond to the headpond for Snowy 2.0 will be accompanied by a significantly increased diversion capacity and flexibility to integrate with the rest of the Scheme's operation to manage spill risks.

The current diversion capacity of the Murrumbidgee-Eucumbene Tunnel is 20 cubic metres per second (cumecs) in pressure flow operation. The diversion capacity of Snowy 2.0 will be approximately 380 cumecs. Coupled with the minimum 21 cumec capacity of the proposed fine mesh filtration station, the maximum capacity that can be routinely relied on to divert water out of Tantangara Dam will be approximately 400 cumecs or 34.5 GL/ day.

The highest recorded historical daily inflow into Tantangara Reservoir is 21 GL, which occurred in March 2012. This is equivalent to a 1:60 year Annual Exceedance Probability (AEP) flood. The peak inflow to the reservoir on that day is estimated to be approximately 350 cumecs. The maximum recorded 3 and 7 day inflow volumes of 40 GL and 80 GL respectively, also occurred during the same inflow event. Had the same historical event occurred with Snowy 2.0 in place, the event could have been managed in its entirety from any starting storage level.

Currently without Snowy 2.0, a 3 day event of a 1:100 AEP magnitude with peak inflows approaching 1000 cumecs can be managed to avoid spill. With the additional diversion capacity afforded by Snowy 2.0, even with a conservatively high start storage level of 80% the day before the event, a 1:2000 AEP flood, with peak inflows approaching 2000 cumecs, will also be manageable without spill.

The ability to manage inflows through Snowy 2.0 is dependent on the station being available for service, and sufficient airspace being available in Talbingo, Jounama and Blowering to receive discharges. The likelihood of a full station outage impacting diversion capability over 3 days (conservatively estimated at 3 days in 25 years) coincidental with a 3 day 1:100 AEP inflow event is considered to be extremely rare, in the order of 1:37,000,000.

SHL has significant discretion over the airspace and release rates from Talbingo and Jounama Reservoirs, with the ability to discharge 1100 cumecs from Tumut 3 power station. Blowering storage, which is downstream of Jounama pondage, is a very large storage at 1630 GL total active capacity. SHL has the ability to forecast potential spill risk months in advance and can proactively manage releases into the Tumut valley and nominate an "airspace" in Blowering to flexibly manage inflows of comparable volumes to those set out above.

As a result of the above, following the construction of the Snowy 2.0 project, SHL has high confidence in being able to avoid spill from Tantangara Dam and ensure that all releases to the Murrumbidgee River are made through the proposed fine mesh filtration station.

4.2.2. Climbing Galaxias Barrier on Tantangara Creek

If transferred, redfin are unlikely to move very far into the tributaries upstream of Tantangara Reservoir, due to their relatively poor swimming ability and preference for lentic environments (Pratt, 1979; Lintermans, 2007). However, as identified in the EIS (Cardno, 2019) there is potential that climbing galaxias, a native but not endemic fish, may access upstream lotic areas if transferred from Talbingo Reservoir. In the absence of data specific to climbing galaxias, entrainment and transfer of this species through the Snowy 2.0 project is considered possible. The reason for the lower likelihood rating is due to the fact that only a few individuals of climbing galaxias have been observed in the Yarrangobilly River and not within Talbingo Reservoir *per se*. It is also unknown whether the observed individuals form part of a breeding population.

Although climbing galaxias are known to coexist with other galaxids such as Mountain galaxias in their natural habitat of the Snowy River (Stoessel, 2011), there is evidence that they can compete or even predate on other galaxiid species (Chilcott et al, 2013). As such, SHL has taken the precautionary approach of proposing to construct an instream barrier designed to prevent the potential movement of climbing galaxias from Tantangara Reservoir (should they become established) into the known habitat of the stocky galaxias in the Upper Tantangara Creek catchment in order to prevent any potential impact to this critically endangered fish species.

Initial design criteria for a barrier to prevent potential upstream migration of climbing galaxias was provided by Dr Tarmo Raadik (Arthur Rylah Institute), an eminent fisheries biologist specialising in the taxonomy and life history traits of Genus Galaxias. Dr Raadik provided input into the selection of a preferred location of the barrier and described key design features needed to prevent climbing galaxias from navigating past the barrier (Raadik, 2019).

The Raadik (2019) report was then used to develop a concept design for the barrier. Critical design features of the weir include:

- A V-notched spillway to concentrate and maintain high flow velocities during normal flows while containing flood events.
- The downstream face of the weir will consist of path obstruction features to prevent upstream passage of the Climbing galaxias. The concept envisaged these features to be a steel flange and the spillway protruding beyond the downstream face of the weir to prevent a direct wetted pathway being established.
- A concrete apron extending from downstream face to prevent ponding and potential 'jump' locations for other species, such as trout.
- Extended critical velocity zone at spillway to prevent resting location for any species.

A review of the concept and a workshop between engineers and Dr Raadik found opportunities to optimise and refine the design. More detailed design of the barrier will occur after consent to undertake detailed survey is obtained from OEH.

Barrier location is a key factor in determining its potential effectiveness. To minimise the size of the required structure and the area of impounded water, the barrier needs to be located in a natural valley constriction with a steep stream gradient (Raadik, 2019). A detailed contour analysis of landform along Tantangara Creek was undertaken to identify locations possibly suitable as barrier sites. A subsequent field inspection of each location identified the area immediately upstream of the waterfall on Tantangara Creek as the only suitable location in the Tantangara Creek system (Raadik, 2019). Figure 13 highlights the difference in valley relief between the section of creek upstream of the waterfall and that downstream and highlights why a barrier could not be practically constructed downstream. The final location and design of the barrier in this area will be determined during detailed design in consultation with OEH and DPI Fisheries.

(a) 

(b) 

Figure 13: Photographs showing (a) the waterfall on Tantangara Creek facing upstream and (b) Tantangara Creek facing downstream of the waterfall

If DPIE proposes that a second barrier is desirable to provide an additional level of confidence, the only reasonable option would be to augment the existing waterfall with features that would make it less able to be navigated by climbing galaxias. Whilst feasible, SHL has not proposed this option due to the known amenity value of the waterfall due to its proximity to the Alpine Creek trail. Augmentation of the waterfall by modifying flow paths and undertaking other engineering to make it unable to be navigated by climbing galaxias would be expected to significantly alter the visual aesthetic.

5. EHNV

There is potential that water transfer between Talbingo and Tantangara Reservoirs as a result of the operation of Snowy 2.0 could increase the range of the fish disease EHNV. Despite EHNV not being identified in either Tantangara or Talbingo Reservoirs (Song et al., 2018), redfin (and, to a lesser extent, rainbow trout) are known hosts for this disease (Hick et al., 2019). Several native species, including Macquarie perch, have been reported as being susceptible to EHNV under controlled laboratory conditions, although natural disease events caused by EHNV have never been detected in species other than redfin and rainbow trout (Hick et al., 2019).

The assessment by Hick et al. (2019) concluded that the risk of EHNV transmission to the Murrumbidgee River below Tantangara Dam and Lake Eucumbene is increased if the range of redfin is increased. The likelihood of transmission would be low in the absence of an outbreak and high if an outbreak occurs. The likelihood of transmission to Lake Eucumbene and the Murrumbidgee River below Tantangara Dam would be significantly lower if redfin do not establish in these locations. The fish barriers proposed at the outlets to Tantangara Reservoir described below would be expected to minimise, but not eliminate, the risk of EHNV being transferred to the Murrumbidgee River downstream of Tantangara Reservoir or to Lake Eucumbene in the event of an EHNV outbreak in either reservoir.

5.1. Prevent

There are no known options to prevent the transfer of EHNV from Talbingo to Tantangara should it occur there or arise at some point in the future.

Although EHNV has been shown to be susceptible to UV treatment, this option is not considered feasible at the Talbingo intake for Snowy 2.0. Features that render this option unfeasible include the high flow rates through Snowy 2.0, the large tunnel diameter, the need for bi-directional flow, the high velocity through the tunnels leading to short residence times, inaccessibility of the tunnels for maintenance and the likely intermittent operation of the station. The flow rates during pumping exceed the largest UV treatment system in the world by a large margin.

5.2. Eliminate

EHNV has been shown to be highly resistant to desiccation and can survive for long periods in the aquatic environment and on fomites (Langdon, 1989; Hick et al., 2019). There are no known ways to eliminate EHNV from a waterbody once it is present.

5.3. Minimise

As with options to minimise the biosecurity risk associated with potential fish transfer, when considering how SHL could minimise the potential biosecurity risk from EHNV posed by the operation of Snowy 2.0, consideration was given to measures that could potentially reduce the volume of EHNV infected material that could be transferred to Tantangara Reservoir (*Entrainment Reduction*) and measures that could reduce the scale of the biosecurity impact, i.e. minimise the area over which EHNV could be transferred to (*Secondary Controls*).

5.3.1. Entrainment reduction

Many of the options considered in Section 4.1 above would also serve to reduce the volume of EHNV infected material that could be transferred to Tantangara. However, as with the assessment above, a key consideration in the assessment of these options centred on considering whether these options would have a material impact in reducing the scale of any potential biosecurity impact.

As EHNV is known to persist freely in water and disease transmission has been observed in the absence of fish (Hick et al. 2019), none of the measures investigated would be considered reasonable given the cost required and low probability of success.

As noted in the Snowy 2.0 Main Works EIS and detailed in Appendix A, SHL has committed to undertaking EHNV monitoring in Talbingo to improve confidence in the current assessment of freedom from disease and to monitor for future outbreaks.

In the event of a positive EHNV detection or observation of a fish kill event, notifications will be undertaken in accordance with the 'Protocol for Investigating and Reporting Fish Kills' (DPI, 2019). Any subsequent actions will be undertaken in consultation with the relevant departments of DPI and the EPA.

5.3.2. Secondary controls

As with considerations for fish, SHL investigated the potential for minimising the potential biosecurity risk and impact that could arise from EHNV by researching ways to contain the potential area over which an impact could occur. For EHNV, this also included measures at Tantangara Dam and the M-E Tunnel including the proposed screening system and UV treatment.

UV treatment

An assessment of the potential installation of UV treatment systems at the outflows of the Tantangara Dam and M-E Tunnel found that whilst these systems could be technically feasible, they would be some of the largest in the world and therefore untested in their efficacy.

The assessment of the UV treatment facility illustrated the necessity to have a facility within proximity of the discharge location. For the Murrumbidgee - Eucumbene tunnel, this would be required within close proximity of the Providence Portal outlet and for the Tantangara ROW, near the toe of Tantangara Dam.

To ensure sufficient exposure time for effective neutralisation, the velocity of the water through the facility would need to be very low, at 0.1m/s, dictating the size of the structure. Initial estimates have shown the area of the facilities to be approximately 1000m^2 each. Due to the steady flow conditions required, it is possible that the size of these structures may actually need to be larger in order to ensure sufficient energy dissipation prior to entering the treatment zones.

Based upon the initial concept, approximate quantities for the civil works structures were prepared to provide an estimate for construction costs, with initial estimates of a total of $14.9 million, being $7.2 million and $7.7 million calculated for the M-E tunnel and ROW structures respectively.

In addition to the upfront construction costs, ongoing operation and maintenance commitments will be required. It is anticipated that a dedicated 2 person maintenance crew will be required on a full-time basis to maintain the UV treatment plant and replace lamps.

In UV systems it is important that the water is clean and free from other contaminants such as sediment when transferred through the system. Whilst, the proposed screening system will filter the majority of debris, there is still potential for material to reduce the transmission of UV light through the water, which will reduce the UV dose that would reach the virus, if present, and potentially reduce the effectiveness of the treatment system.

As well as the high cost of construction and high ongoing operation and maintenance, the consideration for what could be considered reasonably practicable also needs to consider the likelihood of a biosecurity risk eventuating as a result of the operation of Snowy 2.0 which in the case of EHNV is uncertain. As noted by Hick et al. (2019), there has never been an outbreak observed in either Talbingo or Tantangara Reservoir and the frequency and virulence of outbreaks appears to be declining throughout the known range of the disease. The last known outbreak in NSW occurred in Blowering Reservoir in 2009. Another important point to make is that the Murrumbidgee River below Tantangara has already been exposed to EHNV via an outbreak which occurred at a trout farm near Adaminaby in 1986 (Hick et al. 2019).

6. Offset strategy

The proposed offset strategy for Snowy 2.0 is detailed in Appendix M.3 of the Main Works EIS.

As detailed in this report and in the Main Works EIS, the mitigation measures proposed to prevent, eliminate or minimise biosecurity impacts as far as is reasonably practicable during the operation of Snowy 2.0 including the fine mesh screening at the Tantangara Outlets and the weir on the Upper Tantangara Creek seek to use the best available technology to prevent the transfer of any pest species into the habitat of listed threatened species to the greatest extent practicable.

Based on the mitigation measures proposed, the likelihood of an impact as a direct result of potential fish transfer associated with the operation of Snowy 2.0 to Stocky galaxias in the Upper Tantangara Creek catchment and to other threatened species, including Macquarie Perch, in the Mid-Murrumbidgee River below Tantangara Dam is considered to be rare, as is the likelihood of harm to the Snowy River EEC and recreational fishing interests in Lake Eucumbene. As no direct impacts are anticipated to listed threatened species as a result of potential fish transfer during the operation of Snowy 2.0, no offsets are proposed for this purpose.

The Recovery Plan for the Macquarie Perch, notes that a small population is known to occur in the Murrumbidgee River below Tantangara Dam between about Yaoak and Cooma. Irrespective of Snowy 2.0, this population, as well as others throughout the State, are subject to a number of threatening processes listed within the Plan. The Plan identifies a number of actions to ensure the recovery and ongoing viability of Macquarie perch populations throughout the species' range (Commonwealth of Australia, 2018). SHL would consider supporting these actions, if the risk and impacts of pest fish transfer to the Murrumbidgee River below Tantangara Reservoir eventuate as a result of a failure of controls proposed by Snowy 2.0. As noted in the Main Work EIS and in this report, SHL consider the likelihood of this occurring to be very low.

As noted in the proposed determination for the listing of Stocky Galaxias under the FMA Act, the very small range of this species, limited to the upper 4km of Tantangara Creek, renders it extremely vulnerable to stochastic effects, such as the recent bushfires. A number of other threatening processes, such as habitat damage from pest species, are known to be active within the species range (Fisheries Scientific Committee, 2015). DPI list a number of draft actions for the Stocky Galaxias on their website (DPI, 2020). As above, SHL would consider supporting these actions, should the risk and impacts of pest fish transfer to the upper Tantangara Creek beyond the proposed barrier eventuate as a result of a failure of the controls proposed by Snowy 2.0. As noted in the Main Work EIS and in this report, SHL consider the likelihood of this occurring to be very low.

As noted in the Main Works EIS, if redfin are transferred to Tantangara Reservoir and establish there, impacts to the recreationally important salmonid populations, including potential reductions in abundance or changes to demographics could occur. For this reason, as noted in the Main Works EIS, SHL has committed to supporting DPI Fisheries and the local community to develop measures to stock Tantangara Reservoir with large salmonids (above the typical fingerling size) which would be better able to avoid the impacts of competition or predation from any redfin in the reservoir. SHL anticipates working closely with DPI Fisheries and members of the local fishing community to implement this program in such a way that the positive impacts to the local community and recreational fishing in the region are maximised.

7. Conclusion

As highlighted in this report, although studies have indicated that survival of pest fish may occur during transport through the proposed Snowy 2.0 pipeline from Talbingo to Tantangara reservoir, a biosecurity impact will only occur if the following series of events occur:

1. Pest fish occur in the vicinity of and are entrained into, the Talbingo intake;
2. A proportion of these fish survive the effects of extreme pressure, high shear stress and avoid being fatally struck by the turbine blades during transport through the Snowy 2.0 tunnels and station;
3. Sufficient numbers of these fish are transferred and survive such that breeding in Tantangara Reservoir is possible;
4. Conditions in Tantangara Reservoir prove favourable for breeding success leading to population establishment; and
5. The population numbers increase to such an extent over such an area that an adverse effect on the economy, the environment or the community occurs.

Whether this series of events will occur cannot be known with certainty until Snowy 2.0 becomes operational.

If each of the steps in this pathway are realised, there may be impacts to native fish and/or recreationally important salmonids. A key point is that the aquatic environment of Tantangara Reservoir and the catchment upstream (with the exception of the Tantangara Creek headwaters) are dominated by introduced salmonids and there are no known threatened fish species or EEC's present within Tantangara Reservoir or immediately upstream (Cardno, 2019).

There are however, threatened species known to occur in the headwaters of Tantangara Creek, in the Mid-Murrumbidgee River downstream of Tantangara Dam and the catchment of Lake Eucumbene forms part of the Snowy River EEC (Cardno, 2019). As such, the severity of the degree of potential biosecurity impact arising from the potential inadvertent transfer of pest species is different within Tantangara Reservoir, where no threatened species are known to occur, compared to locations outside of Tantangara Reservoir which include areas of habitat for threatened species. The degree of biosecurity impact is one of the express factors required to be taken into account in determining what is reasonably able to be done as provided by s16 of the Biosecurity Act.

SHL has exhaustively reviewed the available options to prevent, eliminate or minimise the potential biosecurity risk associated with the operation of Snowy 2.0. This review has included an assessment of all known technologies to prevent all transfer or minimise rates of fish entrainment into the Talbingo intake of Snowy 2.0, options to minimise the scale of the potential biosecurity impact arising from Snowy 2.0 by limiting the area over which it may occur and investigations into elimination of the source redfin population. Thorough investigations regarding the potential to prevent or manage the spread of EHNV have also been undertaken.

Based on the material presented in the Main Works EIS and in this document, SHL considers that there are no reasonably practicable measures available that could be incorporated into the design of Snowy 2.0 to prevent or eliminate the risk of transfer of pest fish and/or EHNV between the two reservoirs. Options available to minimise the rate of entrainment and transfer of fish are considered unlikely to reduce the numbers of fish transferred down to a level that would materially reduce the risk of redfin establishment in Tantangara Reservoir, should conditions within the reservoir prove favourable for redfin reproduction (and accordingly would not minimise the biosecurity risk).

Mitigation measures proposed in the Main Works EIS and detailed in this document, including installing best available technology in fish screening on the outlets to Tantangara Reservoir and in the Upper Tantangara Creek catchment are expected to prevent the transfer of fish out of Tantangara Reservoir to other catchments to the greatest extent practicable and therefore represent the most appropriate and reasonably practicable measures to minimise the potential biosecurity risk associated with the operation of Snowy 2.0. By undertaking these measures, the risk to any threatened species and EECs is dramatically reduced as are any potential impacts to recreationally important salmonid populations in Lake Eucumbene and connected catchments.

SHL also considers that for the reasons outlined in this report, the measures proposed within the Main Works EIS meet the requirements of the general duty under the Act and also, in light of the critical significance of the Snowy 2.0 project to NSW and the broader NEM, provides sufficient justification for the Secretary to grant an exemption from both the general duty and the mandatory measures pursuant to section 402 of the Act, and a permit or exemption pursuant to s216 of the *Fisheries Management Act 1994*.

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Appendix A

DRAFT EHNV Monitoring Program

9. DRAFT EHNV Monitoring Program

DRAFT prepared for discussion with DPIE

9.1. Background

There is potential that water transfer between Talbingo and Tantangara reservoirs could increase the range of the fish disease Epizootic Haematopoietic Necrosis Virus (EHNV) although the virus has not been identified in either reservoir. Redfin perch (*Perca fluviatilis*), and to a lesser extent rainbow trout (*Oncorhynchus mykiss*) are known hosts for this disease. Several native species, including Macquarie perch (*Macquaria australasica*), have been shown to be susceptible to EHNV under laboratory conditions, although natural disease events caused by EHNV have never been detected in species other than redfin perch and rainbow trout (Hick et al. 2019).

Testing undertaken in Talbingo Reservoir during preparation of the EIS was negative of EHNV (Song et al., 2018). In order to increase confidence around this result, a monitoring program for EHNV was proposed as part of the Main Works EIS for Snowy 2.0 (Cardno, 2019).

This draft document sets out details of the proposed EHNV monitoring program. If Snowy 2.0 is approved, a final version of this program will form part of the project Aquatic Habitat Management Plan (AqHMP).

9.2. Proposed Program

The process for monitoring of potential EHNV outbreaks will mirror the current conditions contained in Table 5.1 of the *Snowy 2.0 - Exploratory Works - Aquatic Habitat Management Plan* (replicated below) which was approved by the NSW Department of Planning and Environment in May 2019 and will be in accordance with the current version of the DPI 'Protocol for Investigating and Reporting Fish Kills'.

A fish kill is defined as "any sudden and unexpected mass mortality of fish or other aquatic species".

AqH005 - In the event of the discovery of any fish kills within or adjacent to the work area, DPI Fisheries are to be notified immediately after Snowy Hydro or the Contractor becomes aware of the fish kill in accordance with Appendix D. Within 24 hours of initial notification to DPI Fisheries form Fish Kill Notification & Investigation Report (Part A) will be emailed to ahp.central@dpi.nsw.gov.au and the relevant regional offices of DPI and EPA.

DPE are to be notified in writing immediately after Snowy Hydro becomes aware of an incident in accordance with Section 6 of the EMS and schedule 4, condition 5 of the Approval.

Where the fish kill is potentially related to the project further investigation and reporting will be conducted in accordance with the EMS Section 6. Any subsequent actions will be undertaken in consultation with the relevant departments of DPI and the EPA.