Jindabyne Dam Spillway Upgrade and Outlet Works
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ABSTRACT: Under the Snowy Water Licence and as a result of the Snowy Water Inquiry, Snowy Hydro Limited (SHL) is required to release environmental flows into the lower Snowy River below Jindabyne Dam at lake levels as low as the minimum operating level (MOL). The construction of new outlet works is necessary to meet this requirement. The other issue driving the project is the limited spillway capacity. A new spillway is required to pass the design flood recommended in the guidelines of the NSW Dam Safety Committee. The design of the outlet works and new spillway has been completed and a contract to construct the works has been let and construction has commenced. This paper summarises the process used to develop the selected design arrangement. It includes discussion on the design of modifications to the existing spillway and the part played by the hydraulic model study in that design and discussion on the auxiliary spillway design and the design of the outlet works to pass a peak flow of 58 m$^3$/s.

1 Introduction

Under the Snowy Water Licence and as a result of the Snowy Water Inquiry, Snowy Hydro Limited (SHL) is required to release environmental flows into the lower Snowy River below Jindabyne Dam at lake levels as low as the minimum operating level (MOL). The construction of new outlet works are necessary to meet this requirement, as the existing outlet works are limited in terms of capacity and range of draw-off levels.

The other issue driving the project is the limited spillway capacity which was identified in the review of hydrology for the Snowy Mountains Scheme and the latest dam surveillance review. The existing spillway passes a 1 in 7500 annual exceedance probability (AEP) event with the initial lake level at full supply level (FSL) and 1 in 29,000 AEP event when the joint probability effects of the actual reservoir water level at the commencement of the flood event are considered. A new spillway is required to pass the design flood recommended in the guidelines of the NSW Dam Safety Committee.

The design included an assessment of the most appropriate and cost-effective solution for providing environmental releases and increased spillway capacity and the development of the design for the preferred option.

The general process from concept through to construction involved the following tasks:

- Concept design;
- Preliminary design including preparation of tender documents;
- Invitation and selection of preferred contractors;
- Best and Final Offer process involving preferred contractors and constructability issues;
- Final detailed design and preparation of construction drawings;
- Final offer and contract award;
- Construction.

2 General Description

Jindabyne dam is located on the Snowy River, about 1.5 km southeast from the town of Jindabyne.

It is a 72 m high rockfill dam with a thin sloping earth core. The crest length of the dam is 335 m. The existing spillway is located on the right abutment of the dam. It comprises an open channel controlled by a concrete ogee crest with automatically operating balanced radial gates.

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The dam was constructed by the Utah, Brown and Root Joint Venture. Construction work was completed in mid-1967 and initial filling of the lake commenced on 17 April 1967. A photograph of the construction of the spillway is shown below.

**Spillway during Construction**

The dam stores water for diversion, via the Jindabyne pumping station, to the western side of the Great Dividing Range for use in the Murray 1 and Murray 2 Power Stations.

### 3 Release requirements

The development of the project forms part of the legislated requirement to return water to the lower Snowy River, which came out of the Snowy Water Inquiry Outcome Implementation Deed. The Snowy Water Licence held by SHL requires that daily releases with a peak rate of up to 5 GL/day (58 m³/s) can be released from the lake for reservoir levels down to MOL and a peak rate of release of up to 20 GL/day (230 m³/s) to be released for flushing flow events. Strict deadlines apply to the development works, by which time, the engineering works must be in place and operable.

### 4 Adopted Arrangement

A thorough evaluation of all the potential options was undertaken and the following works were assessed to be required:

- The existing/service spillway chute would be lined and a flip bucket and plunge pool added to control the energy of water entering the Snowy River. The existing spillway would be used to release environmental flows between 58 m³/s and 230 m³/s. For floods larger than the 1 in 600 year AEP event, flow will occur in the auxiliary spillway as well as in the existing/service spillway.

- A 90.5 m wide new auxiliary spillway controlled by 7.6 m high Hydroplus Fusegates constructed on the right abutment to the west of the existing spillway. These Hydroplus fusegates will be the highest in the world to date and are designed to tip at floods larger than the 1 in 4000 AEP flood. The auxiliary spillway in combination with the service spillway will pass the 1 in 1,000,000 AEP joint probability flood as per the NSW Dam Safety Committee requirements.

- An intake structure capable of selective water level draw-off leading to a 3.6 m diameter tunnel to meet the requirements for the daily releases. The releases are discharged through cone valves or diverted to the mini-hydro power station located near the flip bucket of the service spillway.

- A mini-hydro power station located to the left (east) of the existing spillway alignment.
• Realignment of the Mowamba Aqueduct through the right (west) wall of the auxiliary spillway. The Mowamba Aqueduct diverts flow from a catchment downstream of the dam back into the Jindabyne reservoir and the aqueduct is required to be relocated as a result of the construction of the auxiliary spillway.

Artists Impression of Upgraded Works

5 Outlet Works

The Outlet Works have been designed to release water from selected levels in the reservoir for flows up to 5 GL/day (58 m³/s). To achieve this the following main components were required:

• An intake channel and intake tower.
• A 3.6 m diameter outlet tunnel.
• A bifurcation splitting flow from the 3.6m diameter tunnel into two 2m diameter steel conduits.
• Two cone valves and two butterfly valves as guard valves. The flow from the valves discharge into the service spillway plunge pool.
• An offtake to the mini-hydro power station

A three dimensional finite element analysis of the bifurcation was undertaken to confirm that the stresses were within acceptable design limits. The stresses determined from the assessment are indicated in the following figure.

ANSYS plot of Stress Distribution in Bifurcation

Water will be released from the reservoir using a set of infinitely variable automatically controlled shutters as indicated in the intake tower section below.

Intake Tower Typical Section
The transfer of earthquake load from the intake tower into the rock below the top of the concrete infill (RL 907.5) was assessed using the finite element programme ALGOR. It was assumed that the interface between the concrete and the rock foundation was “fully glued” and the elastic modulus of the concrete was 20 GPa and the rock 15 GPa. A rigid boundary was assumed to exist at the limits of the model. The force on the interface between the concrete and the rock varied according to the modal shape developed. The maximum stress at the interface in the upstream direction and at right angles to the tunnel are indicated in the table below.

<table>
<thead>
<tr>
<th>Direction of excitation</th>
<th>OBE (kPa)</th>
<th>MDE (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream-Downstream</td>
<td>78</td>
<td>93</td>
</tr>
<tr>
<td>At right angles to tunnel</td>
<td>70</td>
<td>98</td>
</tr>
</tbody>
</table>

Because of the nature of the earthquake loading these stresses can be positive or negative. The anchors were designed to resist the equivalent load resulting from these stresses assuming that the structure/rock interface was unable to transmit tensile load.

6 Service Spillway Model Study

SMEC Australia Pty Limited (SMEC) was engaged to undertake a physical model study of the proposed service spillway to test the adequacy and safety of the design, develop a more effective and safer design and to measure and record a range of hydraulic parameters as design data for the detail design of the works. The physical model study was undertaken for a range of discharges up to approximately 3,500 m³/s. Both gate controlled and without-gate controlled tests were undertaken. A number of modifications were made to the model to improve flow conditions and these were incorporated into the final design.

Design of the stilling arrangement was primarily aimed at controlling flow entering the Snowy River for 250 m³/s and 2000 m³/s. These flow conditions were chosen as the regular flow conditions when releasing the maximum environmental flow and the flow occurring prior to the first fusegates tipping.

6.1 Maximum Environmental Flow 250 m³/s

Flip bucket jet, plunge pool conditions and river conditions for a discharge of 250 m³/s and river (tailwater level) of RL 856.7 m are shown in the photograph below.

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**Discharge into Plunge Pool with 250 m³/s flow**

From the photograph, it can be seen that the energy dissipation in the pool was effectively complete for these test conditions. Current velocities around the periphery of the plunge pool and in the river downstream were generally found to be less than 3 m/s. The flow was almost uniform about 40 m downstream of the plunge pool, where the measured velocities ranged from 1.5 m/s to 3 m/s. Between the plunge pool and the mini-hydro station, which is located to the left of the service spillway, the velocities were generally less than 1.5 m/s.

6.2 Spillway Design Flood 2000 m³/s

Flip bucket jet, plunge pool conditions and river conditions for a discharge of 2,000 m³/s and river (tailwater level) of RL 861.6 are shown in the Photograph below.
Discharge into Plunge Pool with 2000 m$^3$/s flow

From the photographs and by visual study, it was concluded that the energy dissipation in the pool is satisfactory for the flows up to the flow when the fuse gates would commence operation. The measured current velocities around the periphery of the plunge pool were less than 7 m/s. About 40 m downstream of the plunge pool the velocities ranged from 1.4 m/s to 6 m/s. Between the plunge pool and the mini-hydro station the velocities were generally less than 3 m/s. Flow conditions upstream of the spillway crest were satisfactory at 2,000 m$^3$/s; but at higher discharges there was substantial separation of flow from the left side of the approach channel and the training wall. This left side flow separation resulted in a significant drop in the hydraulic efficiency of the spillway.

7 Conclusions

The design of the Jindabyne spillway upgrade and outlet works has included a thorough review of the alternative options, detailed physical modelling of the service spillway, and complex three dimensional finite element modelling. This work has been undertaken over a relatively short time frame. The process has led to a number of changes in concept as the project developed.

The contract for the works was awarded to Belmadar Pty Ltd in March 2004 and work is proceeding.

8 Acknowledgements

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The support given by Brett Jones of SHL in reviewing this paper is gratefully acknowledged as is the skill and untold hours put in by the engineers and draftsmen in GHD to develop the design of the works.

9 Bibliography

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