# Connection of the Second Manapouri Tailrace Tunnel

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**The provision of a temporary bulkhead within the existing tailrace at a point close to the underground Manapouri power station in New Zealand was the method used to create a dewatered area in which to accomplish the junction between the existing and the new tailrace tunnels. The bulkhead solution provided several major advantages over the original proposal to build a cofferdam in the outlet channel, and significantly reduced the dewatering necessary to undertake the tasks.**

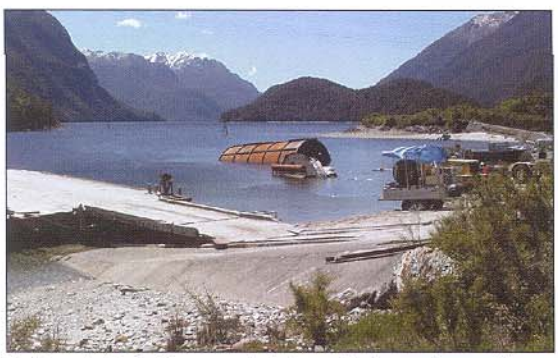
Excavation of the second tailrace tunnel for the Manapouri hydro station on the South Island of New Zealand began in 1998. Excavated using a 10 m-diameter Robbins TBM, the 10 km-long tunnel runs parallel to the original tailrace tunnel built with the power station in the 1960s.

In 1997, the Electricity Corporation of New Zealand (ECNZ) let a contract to an international joint venture of Fletcher (NZ)/Dillingham (USA)/Ilbau (Austria) for the construction of the Second Manapouri Tailrace Tunnel (2MTT). ECNZ was subsequently divided into three competing companies as part of New Zealand's energy deregulation policies. One of these companies, Meridian Energy Ltd, was assigned ownership of the project. The second tailrace tunnel was required to increase the capacity of the first tunnel to optimise the station's 700 MW power generating potential.

## Connection of the tunnels

Along with the excavation of the TBM tunnel, one of the most critical items for the project was connecting the new tailrace to the existing tunnel. The substantial contribution of the Manapouri plant to Meridian Energy's generation capacity made it necessary to keep the length of any outages to a minimum. The original contract conditions called for a maximum 21 day outage of the power station for the tunnel connection to be completed. Because of the substantial risk involved, the construction contract allowed for separate and specific liquidated damages of $NZ250 000 per day for any overruns on the outage period and a bonus of $NZ125 000 per day for potential early completion.

The planned connection was located within a section of the existing tailrace tunnel which would normally be under water during shutdown of the power station.



*Delivery in Lake Manapouri of the steel tube mock-up of the tunnel section, which was used for trials of the bulkhead installation.*

This necessitated a method of temporarily dewatering the area while the connection was completed. Originally, this was to be accomplished by the construction of a cofferdam system across the tailrace channel, 10 km away at the Deep Cove portal. Once the cofferdam was in place, the tunnel water could be pumped down to facilitate the connection work.

However, shortly after mobilizing on site, the contractor completed a number of subsurface borings and pump tests which indicated that large, highly permeable rockfall deposits were underlying the cofferdam location. This brought into question the feasibility of the cofferdam system to accomplish the outage objectives.

## The temporary bulkhead

An alternative method for dewatering the connection area was therefore devised by ECNZ. This method consisted of a temporary bulkhead wall installed by divers within the existing tunnel near the power station draft tube manifold. The bulkhead comprised five buoyant steel tanks, the largest being approximately 1.75 m high by 9 m wide and 1 m deep, weighing 10.5 tonne. This alternative bulkhead system had several major advantages. It significantly reduced the pumping capacity required for dewatering a limited area at the connection near the power station rather than dewatering over the cofferdam at the tailrace outlet channel. The pieces of the bulkhead could be manufactured off the critical path of the outage, thereby significantly reducing the risk for both the owner and the contractor. It also provided an easy, repeatable method

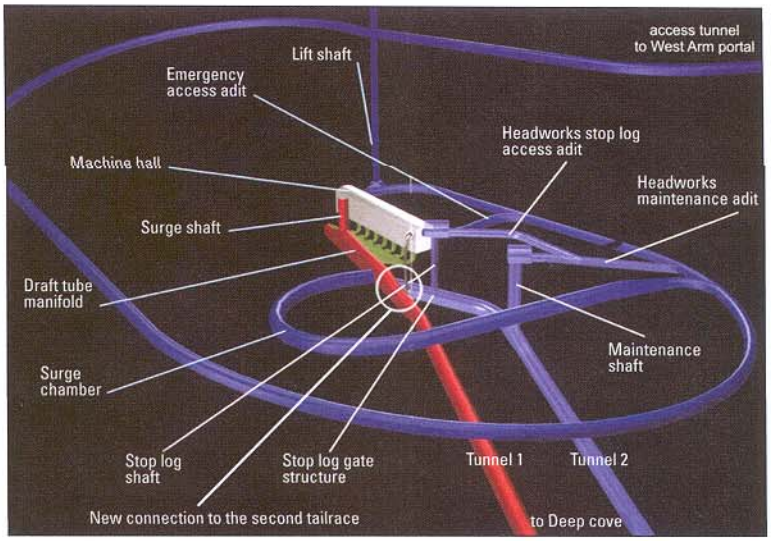



*Fig. 1. Perspective of the underground powerplant and tunnels, showing the new connection to the second tailrace tunnel.*

*The completed connection between the original tunnel (right) with the temporary bulkhead, and the new tunnel, before rewatering.*

for dewatering the tailrace tunnel bifurcation area in the future for inspection and maintenance purposes.

Because of the unique features of the bulkhead system, ECNZ had to retain a variety of sub-consultants to complete the design. The team of consultants included Meritec (formerly Worley Consultants), New Zealand Diving & Salvage, and OCEL Engineering. The engineers from these companies worked closely with engineers from FDI and ECNZ to prepare a design that was functional and easy to construct.

Before the outage, divers carried out several field trials within Lake Manapouri in a specially manufactured steel mockup of the tailrace tunnel. These trials allowed the divers to practise fitting the bulkhead pieces underwater to eliminate the learning curve from the actual outage time. It also provided an opportunity to make final modifications to the bulkhead sections based on any difficulties that were encountered during the trials.

## Installation of the bulkhead system

Once the power station was shut down for the planned outage, the bulkhead sections were transported to the water's edge on a special trailer. The sections were launched and then floated into place with divers manoeuvering and stacking the pieces into position to close off the existing tunnel. Valved tanks inside each piece allowed for the injection of water or air to ballast and trim each piece and assist installation. The perimeter of each section and the areas between were fitted with rubber seals to control the amount of any leakage through the bulkhead. Access was provided in the top bulkhead section to allow the divers to pass through to the downstream side and place the perimeter seals. The installation of the bulkhead was completed by eight divers in 13 hours and without difficulty or delay.

Once complete, divers used float bags to transport and attach four Flygtt BIBO 4150 pumps onto a bypass manifold in the bulkhead base section to dewater the connection area. With a combined capacity of 880 litres/second, the pumps required about 3 hours to pump some ten million litres of water in the manifold to the downstream side of the bulkhead wall. From within the dewatered manifold, the two tunnels were connected by conventional drill-and-blast methods. Leakage around the installed bulkhead was limited to about 30 l/s, which was easily handled by one of the dewatering pumps. At the end of the operation the manifold was rewatered and divers were employed once again to dismantle and remove the bulkhead sections.

The total outage time to complete the connection of the two tunnels was reduced to eleven days, saving ten days off the original schedule. This resulted in a substantial bonus for Fletcher/Dillingham/Ilbau and expedited Meridian Energy's ability to bring the facility back online earlier than anticipated.

A permanent stoplog gate was constructed as part of the new tailrace tunnel contract. This allowed the finished connection to be kept separate from the new TBM excavated tunnel upon its rewatering, and made it possible for the TBM to hole-through at the power station end of its drive in the dry. The TBM broke through in March 2001 and the tunnel was put into service in May 2002. ◊

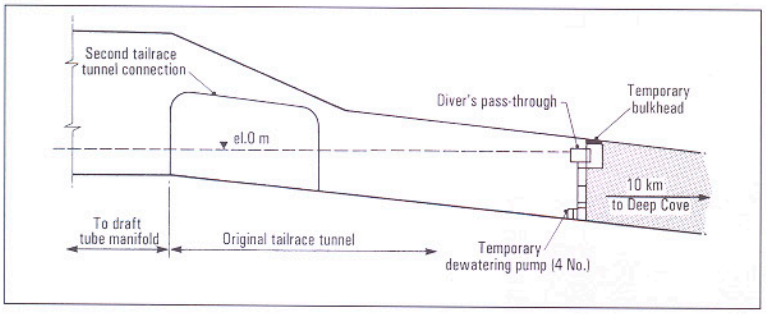



*Fig. 2. Elevation on the tunnel centreline.*

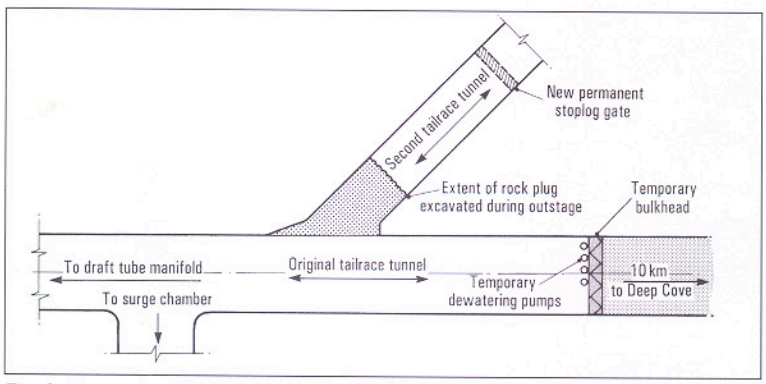



*Fig. 3. Plan at the tunnel bifurcation.*


### Acknowledgement

This article is dedicated to my good friend and colleague the late Brian Heer, former 2MTT Assistant Project Director for Meridian Energy Ltd, who co-authored previous versions of this article.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**R. John Caulfield** is a Registered Professional Engineer with 18 years of experience in the planning, design and construction management of underground facilities. He specializes in the repair and rehabilitation of tunnels and the planning and risk management for outages of critical public works facilities. He received his BSCE from the University of California at Berkely, USA, and an MSCE (Construction Management) from Stanford University, California. He was the Project Engineer for ECNZ and Meridian Energy Ltd on the Second Manapouri Tailrace Tunnel project. In 1999 he joined Jacobs Associates, in San Fransisco, USA, where he is currently Chief Operations Officer.

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