REPORT

North Bank Tunnel Project

Summary of Pre-feasibility Study

Prepared for

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Introduction

The North Bank Tunnel Project is a hydro generation proposal located on the lower Waitaki River in the South Island of New Zealand. The North Bank Tunnel Project (NBTP) proposes to take water directly from an intake portal in the existing Lake Waitaki immediately upstream of the existing 21m high Waitaki Dam, the most downstream Meridian hydro asset on the Waitaki River.

The river has a mean flow of approximately 389 m^3/s. Waitaki Dam currently passes all flows from Lake Waitaki through a power station and, during high flow events, over a spillway. NBTP will divert a significant proportion of these flows by way of an approximately 34 km long tunnel before being discharged back to the lower Waitaki River. A power station will be configured with the tunnel, either upstream (underground) or downstream (at the surface), to utilise the diverted flow for electricity generation (refer to Figure 1). The NBTP will generate 4 to 5 times more energy from the same water than the Waitaki Power Station by creating more head.

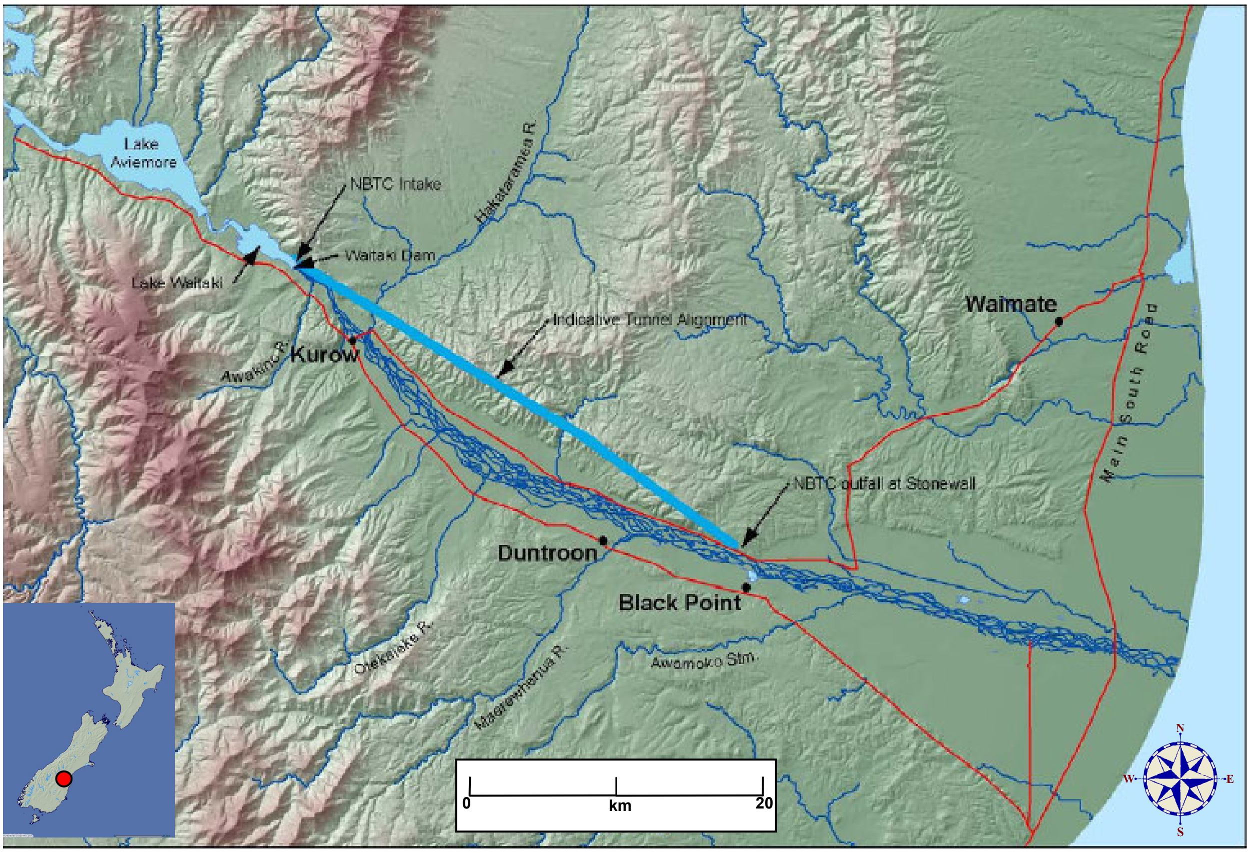

Figure 1. Indicative layout of North Bank Tunnel Project

To date, Pre-Feasibility engineering work has been completed. This work has included an engineering and overall project risk assessment, preliminary geologic mapping, focussed aerial electromagnetic surveys and a number of design studies. In addition, detailed assessments of the environmental effects on the Waitaki River associated with taking and use of the water have been conducted.

The assessment of the environmental effects of the proposed project, and the above-described Pre-feasibility engineering work, has allowed Meridian to apply for water-only resource consents (i.e. permits to divert and use the water). The Resource Consent applications were processed through the final hearing stage in August 2008. For this project, Meridian elected to apply for water-only permits which essentially provide access to the “fuel” for the scheme. Land use permits to construct and operate the scheme are still required. During the next stage of the project a full Feasibility Study will be conducted to provide input to the permit applications.

Although much of the engineering effort has been desk-top based, the geological materials involved occur throughout New Zealand and some published and unpublished information is available on their likely behaviour. The combination of pre-engineering studies, geological information and risk assessments have been used to identify significant project issues that will need to be addressed in greater detail as part of a Feasibility Study. The issues include, but are not limited to, location of the power station, tunnel alignment, tunnel diameter, tunnel support requirements and construction methodology. Although preferred options have been identified as part of the engineering efforts, it is anticipated that additional evaluation, consideration and innovation will result in an improved scheme.

This Project Summary provides a brief synopsis of the work conducted to date. It is intended that this summary will be used by prospective Consultants as a familiarisation document during the tender process.

Development of Scheme Options

During the Preliminary Concept Assessment (2004) stage of the studies, a total of nineteen possible layouts and options were identified and evaluated.

From the Preliminary Concept Assessment study, two broad concept options were taken forward to more detailed evaluation in the Pre-feasibility Study (2005) stage, concentrating on tunnel based options upstream of Stonewall in the greywacke rock. These were:

- an underground power station near Hakataramea with a short headrace tunnel and a long tailrace tunnel, or
- a high level long headrace tunnel to a surface power station near Stonewall.

Both schemes were based on discharging back to the Waitaki River via an RL 95m outfall at Stonewall.

The two schemes were further divided into five upstream underground power station options and three downstream power station options for the Pre-feasibility Study. This was done as part of the optimisation process to determine the most viable combinations of scheme layout, power station location, tunnel diameter and design flow. The economics of utilising either two or three Tunnel Boring Machines (TBM) were also considered.

A sixth upstream power station option, with the discharge point moved upstream by approximately 1.5 km to discharge at about RL 103 m, upstream of the Borton’s Pond irrigation intake on the right bank, was also considered.

The final options study undertaken, the Alternative Downstream Power Station Option Study (2007) investigated four additional options based around a downstream conventional surface power station in the Waitaki Riverbed, with a tailwater level of RL 107m and discharging to the river at RL 105m across a 2m high fish barrier at a new outfall location. This study incorporated all the previous scheme refinements.

Summary Description of Preferred Schemes

The Pre-Feasibility resulted in two preferred scheme options, both based on an assumed maximum design flow of 260 m^3/s. However, only a limited number of scheme parameters are fixed. As such, this preliminary work should not be viewed as representing any preference by Meridian for a scheme. The two schemes identified as the preferred options during the Pre-Feasibility studies are:

1. An upstream underground power station (termed Hakataramea Power Station), located approximately 200 metres downstream of the true left abutment of the Waitaki Dam, and

under the ridge, with a 34 km long tailrace tunnel to the assumed Stonewall outfall at RL 105 m; and

2. A downstream surface power station (termed Stonewall Power Station), located in the vicinity of Stonewall, serviced by a 35 km long headrace tunnel, and discharging back to the river at RL105m.

The general layout for the tunnel is shown on Drawing C001, which shows the Option D (Stonewall) power station.

An intake structure approximately 40m upstream from the left abutment of Waitaki Dam is common to both options. It was initially assumed that no fish screens would be required, but this has subsequently been changed to 25 mm screens on scientific advice to exclude adult eels.

A 300 m long outfall/tailrace channel incorporating a fish barrier that discharges back to the Waitaki River at RL 105 m has been assumed for both options.

For both options the Pre-Feasibility tunnel alignment was selected to minimise known or conjectured fault intersections while crossing the major known or conjectured faults as near as possible to normal. The optimisation of this alignment was a key outcome of Pre-Feasibility Study. A largely TBM excavated tunnel was assessed on the basis of using two 12m (nominal) diameter TBM's. The TBM diameter needs to be optimised during the Feasibility Study after consideration of the system hydraulics, cost and energy output.

Hakataramea (underground) Power Station

The upstream underground powerhouse scheme identified in the 2005-2006 studies comprises the following features (Drawing C004):

- A concrete intake structure on the left bank of Lake Waitaki.
- Twin intake tunnels leading directly into twin 6.5 to 7m diameter, 45° inclined, concrete lined penstocks supplying an underground power station.
- A conventional underground power station, comprising a 1.7 km long access tunnel, machine hall, penstocks up to the intake, transformer bays, draft tubes and stoplogs and a downstream spiral surge chamber. This power station concept design has many similarities with both Manapouri and Rangipo Power Stations.
- A 32 km long tailrace tunnel with a diameter of 12 m (nominal).
- An outlet at about RL 107 m with a 300m long outfall channel to the river. The geometry of the outfall takes into account the site constraints of the State Highway and the river.
- A fish barrier at the outfall to prevent spawning salmon and other fish from entering the tailrace channel.

Stonewall (surface) Power Station

The Alternative Downstream Power Station Option Study (2007) indicated that the most optimum surface power station comprises the following features (Drawing C008):

- A concrete intake structure on the left bank of Lake Waitaki.
- A conventional surface power station located on the river side of State Highway 83, discharging into the Waitaki River via a 300m long tailrace channel incorporating a fish barrier.
- A 34 km long, 12m diameter (nominal) headrace tunnel, between the intake and the downstream penstock tunnels located immediately upstream of the surface powerhouse location.

- Twin 8 metre diameter penstock tunnels ~200 m long to accommodate 6.5 to 7 m diameter penstock steel liners, with an upstream bifurcation from the headrace tunnel. The length and final diameter of the penstock tunnels and steel liners will need to be determined during detailed design.
- A riser shaft and headrace surge chamber to about RL 256 m, about 1 km upstream of the power house on the plateau above. Transient analyses will be required during the feasibility study and detailed design stages to develop the surge chamber design.

Energy Estimates

The following table summarises the energy outputs estimated for the two preferred options, assuming the BTS model series flow duration curve.

Station	**Hakataramea**	**Stonewall**
Option Number	**260/12H2U**	**D-12/DS-LL**
Design Flow (m^3/sec)	260	260
Tunnel Diameter (m)	12	12
Generator Max. Continuous Output (MW)	2 x 130	2 x 130
MW Peak	252.5	251.4
Annual Energy (GWh/yr)	1810	1809

Geology

The geology of the Lower Waitaki area is dominated by a sequence of Cretaceous and Tertiary age marine and non-marine sedimentary strata that rest unconformably on older basement rocks. Torlesse ‘greywacke’ forms the hills on the left (north) side of the valley as far down valley as Stonewall opposite Black Point, about 35km downstream from Waitaki dam. The left bank tunnel route proposed for the NBTP thus allows the intake and tunnels to be constructed almost entirely within greywacke. The surface option power station/tailrace and outfall sites are underlain by gravels and Tertiary-age weak, poorly indurated sedimentary rocks.

Preliminary geological mapping of the tunnel corridor was undertaken in mid-2007 to improve geological knowledge of the project area. The mapping report (URS 2008) provides an overall picture of the geology (rock types and distribution, structure, rock mass fracturing and discontinuity orientations) along the indicative tunnel corridor and at specific structure sites (see Drawing C002). Prior to this mapping, it had been expected that the tunnel would cross five major faults (Kirkliston, Hakataramea, Little Roderick, Dryburgh and Stonewall) and that bedding would strike subparallel to the tunnel, with a steep dip to the NE. It had been assumed that 50% of the greywacke rockmass would be argillite, which still needs to be confirmed.

The new mapping identified, in addition to the previously known faults, three ‘new’ faults (Station Peak, Corrie and Penticotico) and several possible faults that are represented by prominent lineaments with associated topographic steps. It also showed that the Kirkliston Fault reaches the Waitaki River (and Dryburgh Fault) as a 2.5km wide zone of shears/splinter faults and associated deformation.

The new mapping confirmed that the tunnel will be constructed subparallel to the strike of bedding over much of its length. Bedding measured throughout the project corridor generally indicated dips greater than 60˚, typically 70 to 90˚, with dip direction most commonly towards the northeast and little variation except within the zone of the Kirkliston Fault close to Waitaki dam.

In the Preliminary Concept Assessment study the upstream (Hakataramea) powerhouse was located some distance from the intake, requiring a headrace tunnel and upstream surge chamber. Relocation of this powerhouse close to the intake removed the need for an upstream surge chamber. However, a key outcome from the new geological mapping for the project (URS 2008) is that the Kirkliston Fault Zone forms a broad zone of shearing and rockmass deformation that includes the intake site and the first 2 km of tunnel downstream from the intake. The underground powerhouse option is located within this zone. The new mapping indicates that any future design and construction considerations for a large underground complex will have to be mindful of this feature.

Expected Tunnelling Conditions

Rock Mass Classification

The descriptive Rock Mass Classification system provisionally used for the greywacke in the project area is presented below. At this stage it has been assumed, for the purposes of predicting underground support requirements, that the majority of the underground excavations will be carried out within Grade III rock, which is described as 'blocky/disturbed to disintegrated' in the Geological Strength Index (GSI) classification. This class has been divided into categories where sandstone or argillite dominate as it is thought that where the argillite is dominant it will control stability and support requirements.

Support System and Lining Requirements

The Pre-feasibility assessment of underground rock support requirements for the project is based upon rock bolts, mesh, shotcrete and, where ground is particularly poor, steel sets and shotcrete. Shotcrete lining over the steel sets has been assumed rather than concrete lining because of the high cost of a concrete form for the relatively short lengths of this ground expected, and the disruption resulting from a concreting operation. The Pre-feasibility study assumes that approximately 90% of the exposed rock in the tunnel will be shotcrete lined. In order to accommodate this approach, a contingency measure involving one or more rock traps installed upstream of the penstock tunnels will be required to prevent rock entering the turbines (for the downstream power station option).

The shotcrete lining has been assumed to be an "off-the-gun" finish, which will have a high rugosity (surface roughness) and hence result in additional head loss over the 34 km long tunnel. Additional work is needed at the Feasibility study stage to examine the economics of applying a secondary gunite lining to the shotcrete to reduce this surface roughness.

Short sections of tunnel with relatively low cover at the Hakataramea River and at Penticotico Stream (Stonewall power station option) will need to be analysed to determine whether any additional lining treatment is required.

TBM Tunnels

Over 90% of the headrace/tailrace tunnel is expected to be excavated by full face TBM's. The TBM's are expected to be open, hard rock machines with a closed face cutting head and rear loading cutters.

As the TBM advance rate is likely to be constrained by the level of support required rather than the penetration rate, it has been assumed that a secondary shotcrete and rockbolting gantry will also be used remotely from the TBM to complete support installation and lining. Damage to rock surrounding TBM-excavated tunnels is significantly lower than when using drill and blast tunnel support classes methods with commensurately less rock stabilisation measures required.

Rock support will be achieved with rock bolts, shotcrete and steel sets encased in shotcrete. For the purposes of the Pre-feasibility analysis and estimating, four broad tunnel support categories have been assumed, with support systems loosely based on the Manapouri tunnel design assuming an open hard rock TBM, but analysed to take account of the anticipated rock conditions in the more fractured Waitaki Valley greywacke (bedded sandstone and argillite). The rock support systems proposed for each rock class are summarised in Table 2.

The support categories will need to be better defined during subsequent stages of the project after further geological investigation and characterisation of the expected ground conditions, and further analysis of stresses around the tunnel.

Drill and Blast Excavations

The extent of drill and blast required for the project will depend on the final scheme option selected. In the studies to date, rock support for drill and blast operations has been evaluated on the basis of Grade III rock, which is inferred to make up the bulk of the rock mass.

Table 1. Descriptive Classification of Greywacke

GSI Structure Class	Gwke Class	*Typical Lithologies*	*Intact Rock Strength*	*Defects*
Very Blocky	I	Homogeneous or faintly bedded medium-grained sandstone. Fine-grained sandstone with some widely spaced interbeds of mudstone.	Extremely strong to very strong	Joint spacing >150mm, typically 200-300mm, surfaces rough to smooth. Sheared, shattered or crushed zones generally absent. Bedding shear rare
Blocky/ Disturbed	II	Fine or very fine-grained sandstone with mudstone laminae. Interbedded sandstone and mudstone. Mudstone/sandstone with coarse podding.	Very strong to strong	Joint spacing 60-200mm, surfaces rough to slickensided. Minor narrow (<300 mm wide) sheared, crushed or shattered zones. Some bedding shear in mudstone beds.
Blocky/ Disturbed to Disintegrated	III	Fine or very fine-grained sandstone with mudstone laminae. Interbedded sandstone and mudstone, often with podding and some veining	Strong to moderately strong	Joint spacing <100mm, surfaces smooth to slickensided. Narrow (<300 mm wide) sheared, crushed or shattered zones Sheared zones parallel to bedding present, with clayey weak seams up to 150mm wide.
		Mudstone or very fine sandstone with extensive veining	Moderately strong	Joint spacing <100mm, surfaces smooth to slickensided. Narrow (<300 mm wide) sheared, crushed or shattered zones. Sheared zones parallel to bedding common, with clayey weak seams up to 150mm wide.
Disintegrated to Sheared	IV	Interbedded sandstone and mudstone with extensive podding Mudstone or very fine sandstone with extensive veining	Strong to moderately strong	Joint spacing <60mm, surfaces smooth to clay-coated. Sheared with crushed zones (typically <500mm wide), and may contain thin (<25mm) gouge zones
Sheared	V	Mudstone or fine sandstone (rock material generally sheared and crushed)	Strong to moderately strong (or n/a)	Joint spacing <20mm, surfaces slickensided to clay-lined. Generally sheared or crushed zones which contain gouge zones

Table 2. Proposed rock support classes for TBM tunnels

Class	Dominant Rock Type	Support Requirement (12m diameter tunnel)
T1	135 MPa greywacke sandstone	24mm rock bolts alternating 3.6m and 1.8m long @ 1.5m centres for 120° across crown. 8 bolts per ring. Longitudinal spacing 1.8m. WRF and 50mm shotcrete.
T2A	135 MPa sandstone with shears	24mm rock bolts alternating 3.6m and 1.8m long @ 1.5m centres for upper 180° of tunnel. 12 bolts per ring. Longitudinal spacing 1.5m. WRF and 80mm shotcrete.
T2B	Argillite with sheared zones	24mm rock bolts alternating 3.6m and 1.8m long @ 1.5m centres for upper 240° of tunnel. 20 bolts per ring. Longitudinal spacing 1.5m. WRF and 120mm shotcrete.
T3	Faults/wide sheared zones	WRF mesh beneath full circumference steel sets at 1.2m centres. Shotcrete cover to all rock/WRF surfaces with 50mm cover to steel sets.

It is expected that the depth of overbreak will be generally limited due to the close joint pattern and low persistence of joints. The close jointing of rock mass suggests that rock failure from blasting will be predominantly along the joints and relatively little breakage of the intact rock will occur. Muck piles will therefore tend to have rock sizes determined by the geology rather than purely by the blast pattern. Reinforcement of shotcrete in the D&B tunnels is expected to use steel fibres instead of WRF (welded reinforcement fabric) to minimise shotcrete volumes.

Risk Assessment

At the completion of the Pre-feasibility Study (2005) a full ***quantitative*** risk assessment workshop covering engineering and non-engineering risks was undertaken to identify any high risk areas for future reference. These were summarised in and addressed in subsequent studies.

A ***qualitative*** engineering risk assessment workshop was conducted in December 2007 and provides an initial risk register for risk assessment and mitigation through subsequent stages of the project. Risks were ranked in five categories from Low to High. Sixty eight specific risks were identified and assessed, with the number of risks ranked in each category as follows:

- High: Nil
- Moderate to High: 4
- Moderate: 14
- Low to Moderate: 19
- Low: 31

No risks were identified that were considered a threat to the engineering feasibility of the preferred scheme options, and it was concluded that the majority of risks can be adequately addressed and mitigated through the feasibility and design phases of the project.

While there are a number of design and construction issues that will need to be addressed during subsequent stages of the project to provide more certainty, these are all considered to be within the normal range of uncertainty for a project at the pre-feasibility stage.