Battery of the Nation – Pumped Hydro Energy Storage Projects

Prefeasibility Studies Summary Report

August 2019

Contents

Hydro Tasmania Standard			
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Glossary

AEMO	Australian Energy Market Operator
AHD	Australian Height Datum
ARENA	Australian Renewable Energy Agency
CAPEX	Capital expenditure
FSL	Full supply level
LiDAR	Light (Imaging) detection and ranging
MW	Megawatts
NEM	National Electricity Market
NMOL	Normal minimum operating level
OPEX	Operational expenditure
RL	Reduced level

1. Executive summary

Hydro Tasmania has completed prefeasibility studies into fourteen potential Tasmanian pumped hydro energy storage projects, as part of the *Battery of the Nation* initiative. The primary objective of the prefeasibility studies was to identify 2500 MW of pumped hydro capacity. This objective has been met and exceeded. Six projects have been identified that are suitable to progress to feasibility studies with a total installed capacity of 3400MW.

This activity received funding from the Australian Renewable Energy Agency (ARENA) as part of its Advancing Renewables Program.

The preceding concept study recommended sites for prefeasibility studies. Early in the prefeasibility stage, a preliminary assessment of potential sites was undertaken. This assessment led to groupings of potential sites based on a multi-criteria analysis. The multi-criteria analysis ranked sites using a number of technical, environmental, social and commercial criteria. The result of the analysis led to the 14 project options being divided into four groups based on three broad criteria:

- they are of sufficient scale to support the *Battery of the Nation* objectives
- they are relatively low cost (in $/MW) and have a positive net present value (NPV) under a number of plausible market scenarios
- they balance risks across technical complexity, environmental and social risks and impacts on existing system operations.

The status of the groupings was verified through the remainder of the prefeasibility studies and these groups are summarised below. The groupings inform a staged approach to the prioritisation of feasibility studies in the next stage.

Group 1 projects

Three sites (Lake Cethana, Lake Rowallan and Tribute pumped hydro energy storage projects) were identified as the most promising sites based on multi-criteria analysis. Their status has been verified through the remainder of the prefeasibility studies and it is recommended that these three should proceed to feasibility studies.

Group 2 projects

Based on prefeasibility assessment, a further three sites are considered suitable to proceed to feasibility studies at the appropriate time, including the Margaret–Burbury, Parangana and Poatina sites. These projects are of sufficient scale to support the *Battery of the Nation* objectives and relatively low cost. However, there is a higher level of uncertainty at a prefeasibility level of assessment relating to technical complexity, environmental and/or system operation risks compared to Group 1 projects.

Group 3 projects

A further two sites – Lake Echo and Wilmot – are considered suitable to proceed to feasibility studies, but have higher overall costs. This makes them lower priorities for future assessment.

Group 4 projects

Six of the 14 identified projects are not considered suitable to progress to feasibility studies, due to a range of factors, including the smaller size of the projects, difficulty in accessing sufficient water depth in lower reservoirs, or no acceptable locations available for construction of an upper reservoir within environmental and other considerations.

In addition to this shortlist of 14 sites, other potential pumped hydro project sites in Tasmania do exist, but have not been assessed beyond concept stage to date.

The findings from the prefeasibility studies confirm the opportunity for Hydro Tasmania to provide low-cost, new dispatchable capacity through the development of pumped hydro energy storage.

2. Introduction

2.1 Background

As the National Electricity Market (NEM) continues to transform, the market will need low-cost, dispatchable capacity to firm new variable renewable energy. Hydro Tasmania can help meet this market need through optimising the use of its existing hydropower portfolio to firm renewable energy and by developing new pumped storage projects.

More interconnection between Tasmania and Victoria will unlock the full potential of the Tasmanian hydropower system (both existing assets and future development potential) to support the NEM as it transitions over coming decades.

With the support of Australian Renewable Energy Agency (ARENA) funding, Hydro Tasmania is undertaking studies into:

- future state NEM analysis
- pumped hydro energy storage (pumped hydro) assessment and
- augmentation and improvement of the existing hydropower scheme.

An options study completed in 2018 identified 14 potential pumped hydro projects to undergo prefeasibility studies. The overarching objectives of the prefeasibility studies were to:

- identify 2500 MW of suitable pumped hydro projects ready for commencement of feasibility studies, in the context of future NEM projections, the timing of new interconnection development, and existing assets and water resources
- identify a development pathway for projects while acknowledging the dependency on potential development of additional interconnection
- implement early stakeholder and community engagement to build understanding of the Tasmanian opportunity and pumped hydro development process.

The full scope of prefeasibility studies has been completed on eight of these sites. For the remaining six sites a reduced scope of prefeasibility studies was completed due to the identification of unacceptable risk factors or insufficient contribution to the objectives of the study in terms of installed capacity.

This report summarises the findings of the studies that were conducted of the 14 potential sites.

2.2 Scope of this report

This report:

- outlines the scope of the individual project prefeasibility studies
- discusses the opportunities for pumped hydro in the future NEM
- summarises the findings of the prefeasibility studies
- provides an overview of project risks and uncertainties based on prefeasibility outcomes and
- makes recommendations on the suitability of the projects assessed to proceed to full feasibility studies.

3. Scope of studies

The scope of the individual prefeasibility studies for projects included:

Technical

- prepare a basis of design suitable for the prefeasibility study
- undertake desktop geological, geotechnical and seismological reviews
- identify potential siting for the project and associated infrastructure
- detail and compare the potential options for project layout
- prepare a nominal operations and maintenance plan for the project's design life.

Environmental and social:

- assess impacts and opportunities associated with environmental, heritage, planning and social aspects
- identify potential development and environmental approval processes
- identify potential impacts and opportunities for the community and stakeholders
- identify potential requirements for heritage management.

Commercial

- prepare cost estimates to order of accuracy suitable for a prefeasibility study (+/-30%)
- determine preliminary capital costs, operations and maintenance costs and construction program
- perform a high-level financial analysis of the project.

A number of sites were found to not meet the objectives of the project. For these sites, the scope of the prefeasibility study was reduced.

3.1 Input data

Inputs to these studies included survey data, geological maps and reports, stakeholder and community feedback, preliminary modelled hydrological outputs, water quality data, vegetation maps, threatened species registers, land tenure data and cost data. Every effort was made to ensure the most up-to-date and complete datasets were used. Limited site inspections to validate the available data were conducted. Community consultation to validate social impacts and opportunities would be included in a future feasibility stage. A brief description of the type of information used is described below.

3.1.1 Survey

For all the potential projects, topographic survey information was based on LiDAR data acquired since 2013, which was considered to be sufficiently accurate for the purposes of the prefeasibility study. LiDAR surveys were commissioned in mid-2017 for areas where existing data was not available.

Bathymetric survey data was generally not available and was not considered necessary to capture during the course of the study. Judgement was made about the presence of adequate depth for new intake structures in existing reservoirs based on known reservoir conditions. Bathymetric survey will be addressed in future feasibility studies.

3.1.2 Geology

A significant amount of geological data is available for the areas surrounding potential project locations – generally either from historical mining investigations or from investigations associated with the construction and operation of existing hydropower projects. Available geological data has been reviewed and applied to the potential new pumped hydro projects. While many risks cannot be quantified due to a lack of site-specific data, a risk assessment was completed for each potential project site based on interpretation of the available information.

3.1.3 Environmental and social data

Preliminary modelling was conducted to predict changes to lake levels associated with the addition of a pumped hydro project to the existing power system. To discriminate between projects, the model outputs were used to assess environmental and social risks at a high level. The 10^{th} and 90^{th} percentiles of daily water level fluctuation were used to describe the range of fluctuations occurring most of the time. Further refinement of the model and validation of assumptions would be required as part of a feasibility assessment.

A number of databases and maps were accessed for the environmental and social review of the potential pumped hydro project sites including TASVEG vegetation community mapping, the Aboriginal Heritage Register, accessible historical heritage databases, land tenure mapping, historical water quality data and threatened species registers.

Six community briefings and numerous briefings of interest groups, local government and non-profit organisations (NGOs) were held in towns in the vicinity of the potential pumped hydro project locations. Preliminary feedback was collected from key stakeholders. Prefeasibility assessments of social aspects were informed by existing knowledge of the use of Hydro Tasmania lakes and surrounding areas and from preliminary feedback provided by interest groups. Consultation processes and social impact assessment studies in the feasibility stage will provide a more comprehensive assessment of social impacts and opportunities.

4. Future opportunities and impact

4.1 Opportunities to support a low-carbon future

4.1.1 Supply forecasts

Supply to the NEM is currently dominated by coal-fired generation and is supported by gas, hydro, wind and solar generation sources. Coal-fired generation provides baseload and intermediate generation (black coal only) and is an important source of ancillary services to provide network stability. Figure 4-1 shows the proportions of generation from the following categories of generation:

Variable: wind and solar

Inflexible: coal, combined-cycle gas turbines

Flexible: open-cycle gas, hydro, diesel, biomass, battery.

Hydro Tasmania (2018a) forecasts that from 2028 to 2037 about 35% of Australia's existing generation capacity will retire, simply due to age-related deterioration (refer Figure 4-2). There is potential for coal-fired power stations to retire even earlier due to global or national climate change policy and/or inability to maintain reliable revenue in a future market that values dispatchable generation.

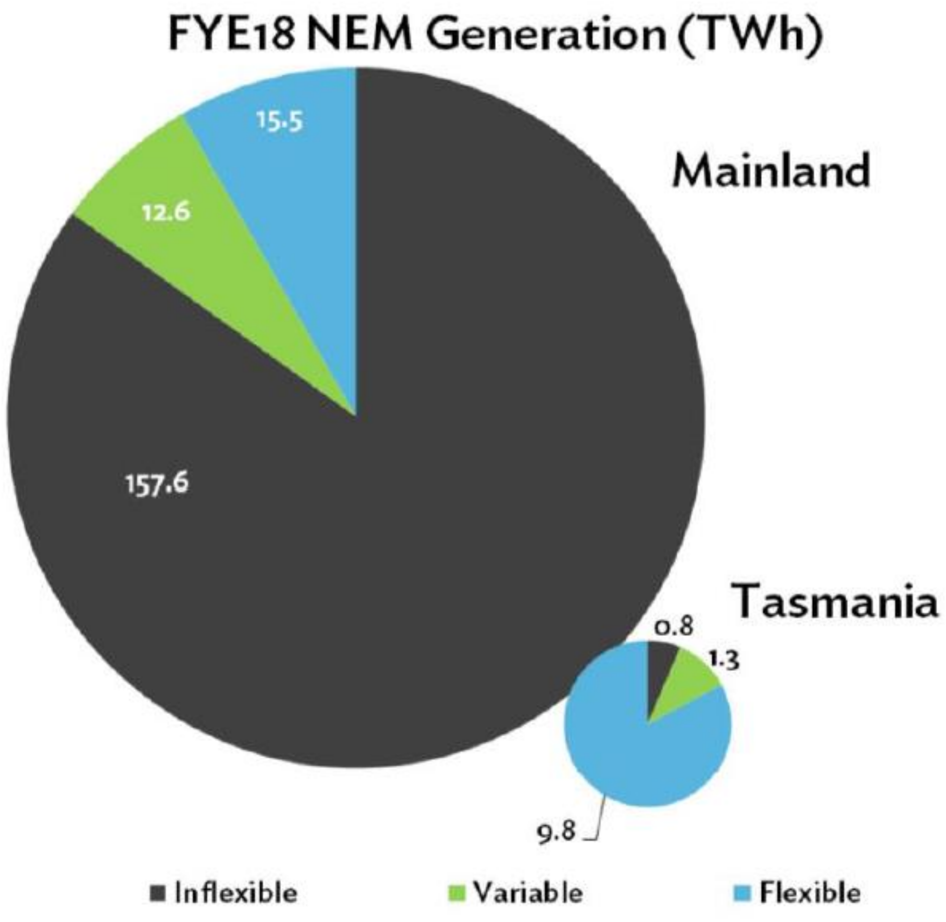

Figure 4-1: Generation NEM-wide and in the Tasmanian region during FYE18 (Hydro Tasmania, 2018b)

Figure 4-2: Expected retirement profile of existing generation assets in the NEM (Hydro Tasmania, April 2018a)

The mix of technologies likely to make up this gap in the future depends on a number of technological and market factors. The major low-carbon generation sources likely to be available in the future NEM are summarised in Table 4-1. Given the scale of the challenge facing the future NEM, there is likely to be ample room for a diverse range of generation sources.

Market modelling suggests that the future gap in energy provision will be filled predominantly by wind and solar (both rooftop and utility scale) supported by utility-scale storage (predominantly pumped hydro energy storage). The projected change in generation resource mix (installed capacity) modelled by AEMO (2018) is presented in Figure 4-3.

4.1.2 The role of interconnection

Interconnection also serves to balance supply and demand between NEM regions. Excess supply in a particular region can be traded to an adjacent supply-constrained region to target the lowest overall cost to consumers. Additional interconnection between Tasmania and Victoria will unlock existing hydropower potential and trigger new renewable energy development including low-cost, long duration pumped hydro. The opportunities associated with the proposed Marinus Link interconnector (refer TasNetworks, February 2019) are shown in Figure 4-4.

Table 4-1: Summary of future low-carbon generation sources

Generation source	Flexibility and ancillary services (refer note)	Factors influencing future supply
Wind	Variable renewable energy; non-dispatchable as it only generates when the wind is blowing; does not provide ancillary services on demand (some demonstration projects are underway but the economics are not clear yet)	Finite number of sites with high capacity factor and close proximity to transmission network; need to manage extended periods of low wind generation across the NEM; capital costs have some potential to decrease further
Solar photovoltaics	Variable renewable energy; non-dispatchable as it only generates when the sun is shining; does not provide ancillary services on demand	High availability of suitable sites around Australia; the energy generated is very highly correlated and may lose value; global technological advancements provide good potential for capital costs to decrease further
Conventional hydropower	Run-of-river hydropower has moderate flexibility; reservoir hydropower has high levels of flexibility; some schemes have environmental and social constraints; high provider of ancillary services	Limited opportunities for new large-scale development; supply impacted by hydrological variability and climate change; opportunities available to repurpose to increase response flexibility
Pumped hydro energy storage	Highly flexible; high provider of ancillary services	High capital cost; long lead time; investment risk associated with market conditions; many potential large-scale sites around Australia; the duration of storage will still be limited
Grid-scale battery energy storage systems	Highly flexible; high provider of ancillary services	High unit cost; short design life; highly flexible but cannot provide large-scale storage

Note: Ancillary services provide essential network stability and include frequency control (e.g. frequency raise/lower), network support and control (e.g. synchronous condensers and inertia support) and system restart (following a complete or partial blackout). Refer to AEMO (2015) for detailed information on ancillary services in the NEM.

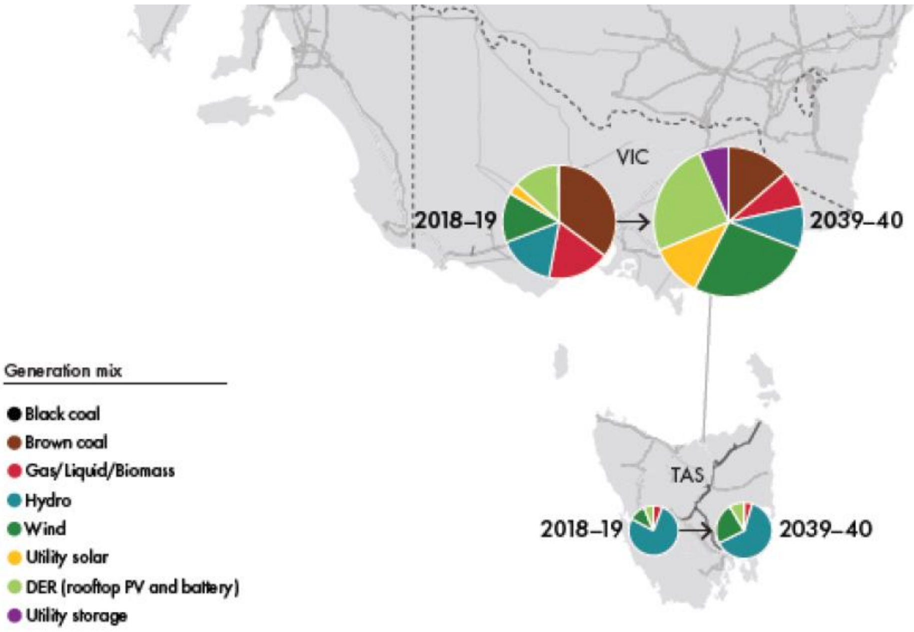

Figure 4-3: Projected change in generation resource mix (extract) (AEMO, 2018)

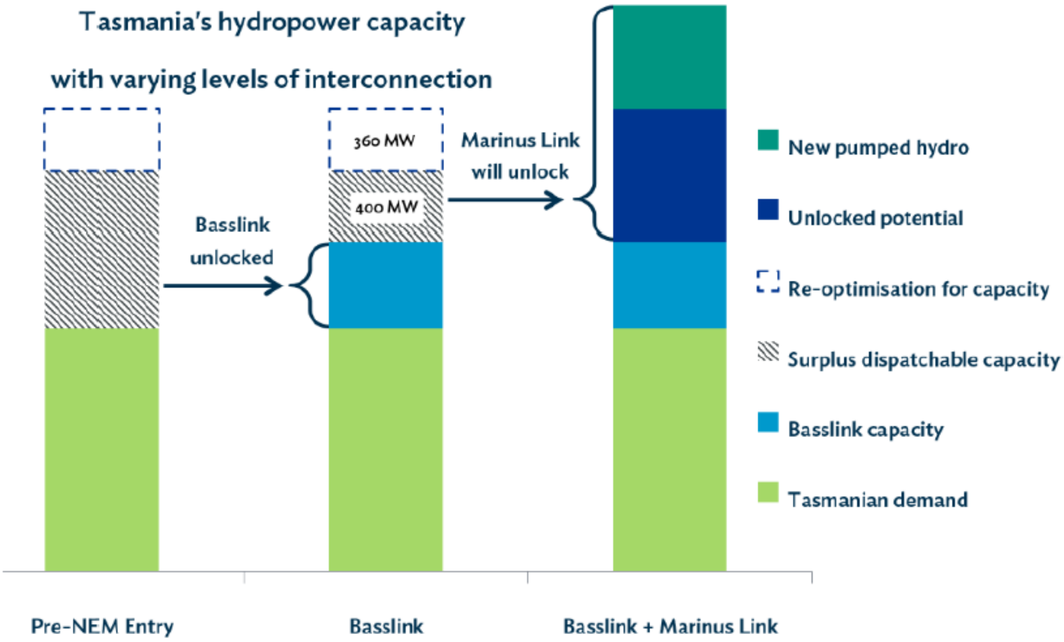

Figure 4-4: Increasing interconnection between Tasmania and the mainland will unlock existing potential and new cost-effective development (Hydro Tasmania, 2018b)

4.1.3 Hydropower's role

Conventional hydropower can be divided into two main types: run-of-river and reservoir storage. It is a form of dispatchable renewable generation and, depending on its configuration, can provide the full range of market services including baseload, intermediate, peaking generation and ancillary services. Its limitations are primarily hydrological (inflow) variability and environmental and social constraints. There are limited opportunities for development of new, large-scale hydropower in Australia; however, the long asset life of hydropower projects means that existing projects will continue to make a valuable contribution to the NEM into the future.

Pumped hydro energy storage is primarily focused on providing energy storage, peaking generation and ancillary services. Whilst not limited by hydrological variability, pumped hydro operation is usually limited by the volume of water in the storages (typically in the range of 6–24 hours). Pumped hydro relies on volatility in the wholesale market spot price (arbitrage) between low price times (pumping) and high price times (generation) to operate and be profitable. There are many potential sites for development of pumped hydro projects in Australia, although each will have unique challenges to overcome as highlighted in the prefeasibility risk assessment presented in the sections below.

4.2 Potential value of using existing water assets for pumped hydro

Existing water storage assets and infrastructure across the nation hold potential pumped hydro opportunities. There are over 500 large dams in Australia[1] and any one of these (or indeed smaller reservoirs) could hold potential for development of pumped hydro projects.

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[1] ANCOLD, 2012, *Dams Information*, https://www.ancold.org.au/?page_id=24, viewed on 20 June 2019

Assessment of pumped hydro potential for existing assets requires a similar scope to that required for greenfield sites. Key considerations include:

- the relative height between the reservoirs, together with the distance separating the reservoirs
- the desired installed capacity and amount of energy in storage
- the geological conditions for creation of new storages and transmission of water between storages
- the potential impacts on environmentally sensitive areas
- the strength of local community support for the potential project
- the distance to adequate transmission infrastructure
- the value of a new pumped hydro project in the market.

Through the course of the prefeasibility studies on Tasmanian opportunities, Hydro Tasmania has prioritised the evaluation of existing water assets for pumped hydro potential and has gained an understanding of the specific requirements associated with the use of existing storages. These include:

- Energy storage – The design storage volume of existing reservoirs must be sufficient to supply the required hours of storage. Most pumped hydro projects under consideration in Australia have energy in storage of at least eight hours. The volume of water required to meet the storage requirements will depend on the head available at the site and the installed capacity.
- Water availability – One of the key challenges with any pumped hydro project is having the ability to fill a closed-loop system initially and then to top up the closed-loop system during operation. Utilising an existing run-of-river reservoir means that there is an existing catchment of water to provide inflow to the scheme for initial filling and ongoing top-up.
- Intake design – Submergence requirements for intakes means deep setting of these structures – many metres below normal minimum operating level. If there is insufficient depth in the reservoir, major civil works (excavation – potentially underwater) may be required to ensure water can flow freely to the intake. Bathymetry surveys of existing reservoirs provide valuable information to inform design and construction of the pumped hydro scheme.
- Environmental implications – The impacts of a hydropower station being installed on a lake where no station already exists need to be considered (in regards to things like endangered species), and the environmental values of existing lakes need to be protected.
- Ongoing operation and maintenance of the project – The choice of hydro-mechanical equipment for the project will be affected by the operational requirements of the existing reservoir. Isolation gates and trashracks may be required rather than relying on the ability to control reservoir water levels for maintenance activities.
- Linking two existing reservoirs – In addition to the factors above, when linking existing reservoirs, additional issues must be understood. Transferring water between the existing reservoirs, particularly those in different catchments, can have significant environmental implications if elements such as water quality, endangered species or invasive species are present in one reservoir but not in the other. These issues need to be identified early in the process.

5. Prefeasibility study findings

5.1 Site selection process

To select potential sites suitable for further feasibility studies, multi-criteria analysis (MCA) was used. This process assesses sites across a number of technical, environmental and social criteria.

The criteria used included:

- environmental impacts
- social impacts
- engineering risks and costs
- topography
- geology
- constructability (a range of engineering criteria)
- ease of transmission connection.

Early in the program of prefeasibility studies, a preliminary assessment of all 14 sites was conducted. This assessment led to groupings of potential sites as described in the following sections.

5.2 Group 1 sites

Potential projects at Lake Rowallan, Lake Cethana and the Tribute power scheme emerged as the most promising sites. The prefeasibility assessment results for these sites indicate that all three sites are technically and financially suitable to progress to the feasibility stage.

For feasibility studies on any of the selected projects, more detailed, field-based information would need to be collected to confirm assumptions and assess the suitability of a site for development, as well as to identify a preferred project design and layout.

5.2.1 Cethana pumped hydro energy storage project

Project description

The Cethana pumped hydro energy storage project (Cethana project) would be located at Lake Cethana in Hydro Tasmania's Mersey–Forth scheme. The project would have an installed capacity of 600 MW and would have energy storage of about 6700 MWh (11 hours).

Five potential layouts were considered as part of this prefeasibility study. The option recommended for feasibility assessment would consist of a new upper reservoir on the western side of Lake Cethana with an operating range of 10 m and an active storage of 5.2×10^6 m^3. This arrangement is illustrated in Figure 5-1. Lake Cethana has a current operating range of 3.4 m and would function as the lower reservoir. Based on preliminary modelling, the fluctuations in Lake Cethana per generation/pumping cycle would be expected to range from 0.4 to 1.1 m; however, this finding would need to be validated by additional modelling as part of a feasibility study. Water conveyances connecting the upper and lower reservoir would be underground and would have a total length of about 3550 m (including shaft). An underground power station and transformer cavern would house four

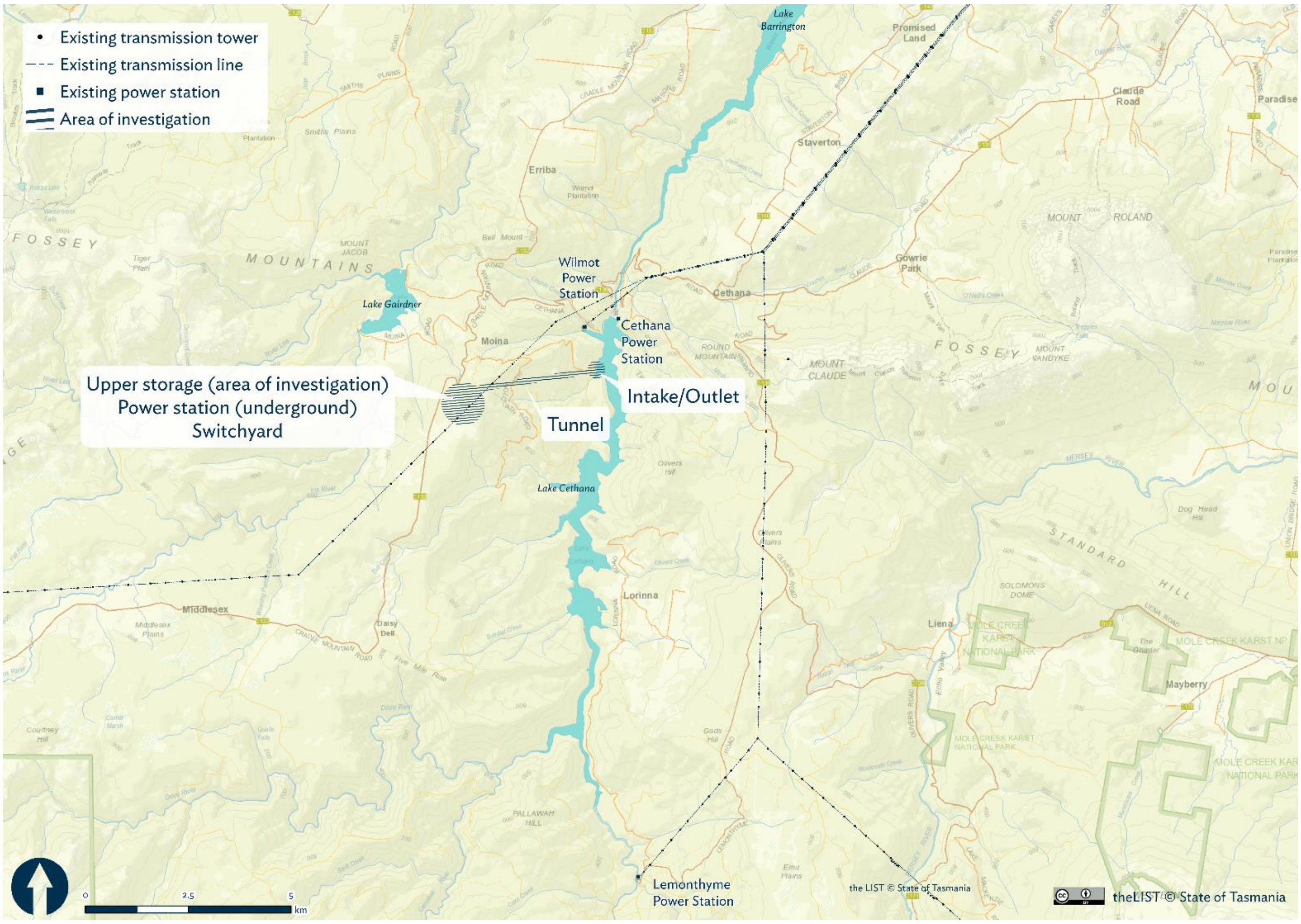

Figure 5-1 Cethana project potential layout

reversible fixed-speed pump-turbines with 600 MW total installed generation capacity, a maximum gross head of 539 m and a generation duration of 11 hours.

The potential layout developed in the prefeasibility study would be further reviewed and optimised during a feasibility study. This would include reviewing the location and size of the upper reservoir to consider identified risks, costs and benefits.

Geology assessment

A significant amount of geological data is available for the area surrounding Lake Cethana – generally either from historical mining investigations or from investigations associated with the construction and operation of the Forth River power development. Available geological data has been reviewed and applied to the potential layout. While many risks cannot be quantified due to a lack of site-specific data, a risk assessment was completed based on interpretation of the available information. One of the most significant risks for the potential project would be if underground works were to encounter poor-quality rock or high inflows of water. A detailed geological investigation program would need to be performed during a feasibility study, including mapping, test pits, drilling and seismic refraction surveys. Those investigations would result in a geological model and a geotechnical baseline report, which would ensure a better understanding of the engineering geology of the potential site and help to reduce the geological risks of the project.

Environmental and social assessment

A key environmental consideration identified in this prefeasibility study for the potential upper reservoir site on the western side of Lake Cethana was the presence of the highland *Poa* grassland vegetation community, which is listed as threatened under the *Nature Conservation Act 2002.* Highland *Poa* grassland is potential habitat for the ptunarra brown butterfly (*Oreixenica ptunarra*) which is listed as vulnerable under the *Threatened Species Protection Act 1995* and endangered under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999.* A survey at the potential upper reservoir site for the ptunarra brown butterfly was undertaken in March 2019 and did not record any butterflies; however, a follow-up survey in 2020 is recommended.

An alternative arrangement for the upper reservoir was developed that excludes the highland *Poa* grassland from the footprint of the upper reservoir, and design options would be further assessed during a feasibility study. Further onsite ecological surveys would be required during a feasibility assessment.

The potential Cethana pumped hydro would include above-ground infrastructure, most notably the upper reservoir, but also transmission lines and access roads (using existing alignments where possible), intake/outlet structure and switchyard. The visual impact on the surrounding environment, particularly on nearby communities, visitors and road users, would be an important consideration for further assessments. A visual impact assessment, consultation and potential mitigations would form key components of a future feasibility assessment.

Preliminary modelling indicates that there would be an increase in the daily frequency and extent of lake level fluctuation in Lake Cethana if the pumped hydro project was operated on a daily cycle. Historically, daily lake level variation has been less than 0.5 m for most of the time. It would not be expected that seasonal water level patterns would change. No significant hydrological changes are anticipated in the rest of the Mersey–Forth scheme. Additional modelling would need to be completed during a feasibility assessment to verify these findings.

Lake Cethana provides suitable habitat for the giant freshwater crayfish (*Astacopsis gouldi*), listed under the Tasmanian *Threatened Species Protection Act 1995* (TSP Act) and Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) although surveys completed in 2019 did not find the species. Hydrological changes in Lake Cethana as a result of a pumped hydro project has potential to impact *Astacopsis gouldi*, so further survey would be required during a feasibility assessment to determine whether it is present. Further monitoring of water quality and surveys of onsite aquatic ecology would also be required during a feasibility assessment.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

The Cethana layout includes a large section of land categorised as Permanent Timber Production Zone Land (PTPZ). A feasibility study would include an assessment of land tenure impacts and opportunities.

Construction schedule and cost estimate

Analysis of potential construction activity suggests that the project would take about 4.5 years to construct, including the commissioning of the station.

Construction cost estimation for the project indicates a unit cost of approximately $1.50 million per MW installed and a total project investment of $900 million (including contingency).

Recommendation

The potential Cethana project has a low to moderate level of uncertainty with respect to the geological conditions of underground works. It also has an upper storage site that can provide flexibility to mitigate potential impacts.

At a unit cost of approximately $1.5 million per MW installed and with 11 hours of energy in storage, the Cethana option is considered attractive.

It is recommended that a feasibility study be performed to further define the project and better evaluate the project risks and benefits. This recommendation is predicated on the assumption that further interconnection will provide increased access to the National Electricity Market.

5.2.2 Rowallan pumped hydro energy storage project

Project description

The Rowallan pumped hydro energy storage project (Rowallan project) would be located at Lake Rowallan in Hydro Tasmania's Mersey–Forth scheme. The project would have an installed capacity of 600 MW and would have energy storage of about 14 500 MWh (24 hours).

Two potential layouts were developed as part of this prefeasibility study. The option recommended for further assessments consists of a new upper reservoir on the western side of Lake Rowallan with an operating range of 10 m and an active storage of 14.65 x 10^6 m^3. This arrangement is illustrated in Figure 5-2. Lake Rowallan has an operating range of 21 m and would function as the lower reservoir. Based on preliminary modelling, the daily fluctuation per generation/pumping cycle would mostly be expected to range from 0.2 m to 0.8 m; however, this would need to be validated by additional modelling as part of a feasibility study. Water conveyances connecting the upper and lower reservoir would be underground and would have a total length of about 2840 m (including shaft).

An underground power station and transformer cavern would house four reversible fixed-speed pump-turbines with 600 MW total installed generation capacity and a maximum gross head of 403 m. The generation duration would be 24 hours. A new transmission connection to Sheffield substation would be required, and existing transmission line easements would be used to the extent possible.

The potential layout developed in the prefeasibility study would need further review and optimisation during a feasibility study. This would include reviewing the location and size of the upper reservoir to consider identified risks, costs and benefits.

Geology assessment

A significant amount of geological data is available across the area surrounding Lake Rowallan from investigations associated with the construction and operation of the Mersey–Forth River power developments. Available geological data has been reviewed and applied to the potential project. While many risks cannot be quantified due to a lack of site-specific data, a risk assessment has been completed based on interpretation of the available information. The most significant geological risk for the project is encountering poor-quality ground and/or groundwater in the underground works. There is a moderate level of uncertainty with respect to geological conditions of underground works.

A detailed geological investigation program would need to be performed during a feasibility study, including mapping, test pits, drilling and seismic refraction surveys. Those investigations would result in a geological model and a geotechnical baseline report, which would ensure a better understanding of the engineering geology of the potential site and help to reduce the geological risks of the project.

Environmental and social assessment

The potential Rowallan project would include above-ground infrastructure, most notably the upper reservoir, but also transmission lines and access roads (using existing alignments where possible), intake/outlet structure and switchyard. The visual amenity and scenic quality of the area, in proximity to the Tasmanian World Heritage

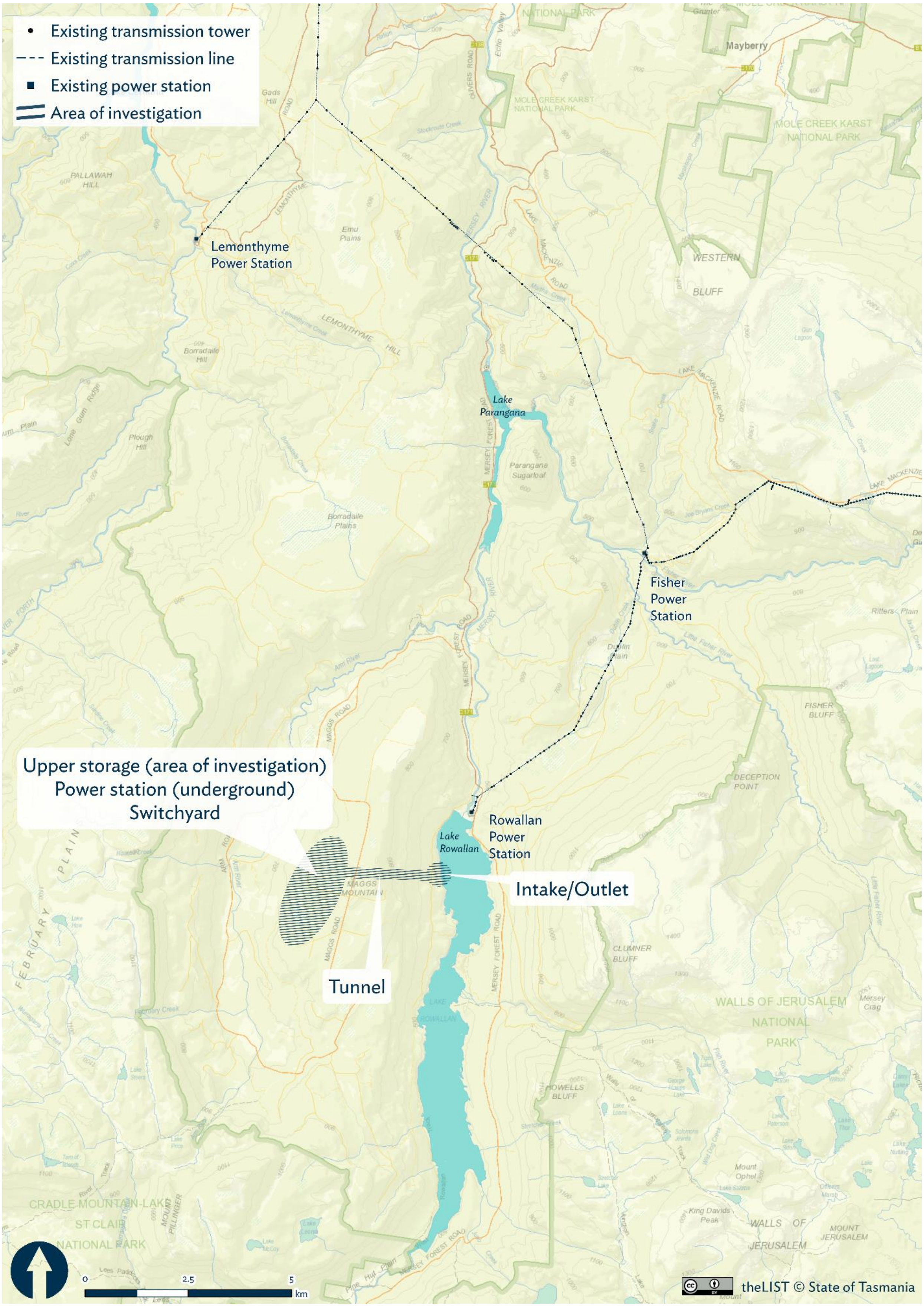

Figure 5-2 Rowallan project potential layout

Wilderness Area (TWWHA) and popular bushwalking tracks, would be a key consideration for further assessments and siting options. A detailed visual impact assessment including public consultation would be conducted as part of a feasibility study.

There are two patches of *Sphagnum* peatland (MSP) and one small patch of highland *Poa* grassland mapped within the potential project footprint. *Sphagnum* peatland and highland *Poa* grassland are listed as threatened under the *Nature Conservation Act 2002*. *Sphagnum* peatland is also a component of the Alpine Sphagnum Bogs and Associated Fens ecological community which is listed as endangered under the *Environment Protection and Biodiversity and Conservation Act 1999*. If onsite surveys during a feasibility study verify the presence of these species, the arrangement of the upper storage would be reviewed.

Preliminary modelling indicates that there would be an increase in the daily frequency and extent of lake level fluctuation in Lake Rowallan if the project were operated on a daily cycle. Historically, daily lake level variation has been less than 0.5 m for most of the time. It would not be expected that seasonal water level patterns would change. Based on the preliminary modelling, no significant impacts on water quality or the aquatic ecology of Lake Rowallan or the Mersey–Forth scheme are expected. The preliminary modelling had limitations, and additional modelling together with water quality monitoring and onsite aquatic ecology surveys would need to be completed during a feasibility assessment to verify findings.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

The Rowallan layout includes a section of Sustainable Timber Tasmania (STT) land categorised as Permanent Timber Production Zone Land (PTPZ). A feasibility study would include an assessment of land tenure impacts and opportunities.

Construction schedule and cost estimate

Analysis of potential construction activity suggests the project would take about 4.5 years to construct, including the commissioning of the station.

Construction cost estimation for the project indicates a unit cost of approximately $1.65 million/MW installed and a total project investment of $990 million (including contingency).

Recommendation

The potential Rowallan project would be a long-duration storage and it has alternative layout options that would enable opportunities to mitigate impacts and to reduce costs.

At a unit cost of approximately $1.65 million/MW installed and with 24 hours of energy in storage, the Rowallan project is considered attractive. It is recommended that a feasibility study be performed to further define the project and further evaluate project risks. This recommendation is predicated on the assumption that further interconnection will provide increased access to the NEM.

5.2.3 Tribute pumped hydro energy storage project

Project description

The Tribute pumped hydro energy storage project (Tribute project) would be located near Rosebery on Tasmania's west coast. The project would have an installed capacity of 500 MW and would have energy storage of about 15 600 MWh (31 hours). Natural inflows to Lake Plimsoll would also provide capacity without pumping.

A potential layout was developed as part of this prefeasibility study, consisting of a duplication of the existing scheme with larger diameter waterways and a deeper set powerhouse housing the pump-turbines. The existing Lake Plimsoll has an operating range of 8.1 m and an active storage of 22.2 x $10^6 m^3$ and would be used as the

upper reservoir. This arrangement is illustrated in Figure 5-3. Based on preliminary modelling, the fluctuation in Lake Plimsoll's water level per generation/pumping cycle would be expected to mostly range from 0.7 m to 1.7 m; however, this would need to be validated by more sophisticated modelling as part of a feasibility study.
Lake Murchison has an operating range of 22.15 m and would act as the lower reservoir. The daily fluctuations per generation/pumping cycle would be expected to mostly range from 0.9 to 3.0 m. Water conveyances connecting the upper and lower reservoir would be underground and would have a total length of about 7470 m.

An underground power station and transformer cavern would house two reversible fixed-speed pump-turbines with 500 MW total installed generating capacity and a maximum gross head of 294 m available for generating, with a generation duration of 31 hours.

The potential layout developed in the prefeasibility study would need further review and optimisation during a feasibility study.

Geology assessment

A significant amount of geological data is available from the investigation and construction of the existing Anthony power development. Available geological data has been reviewed and applied to the potential new project. On the assumption that the potential new alignment is sub-parallel to the existing Anthony tunnel, the geological risks are relatively well understood. These assumptions would be confirmed in feasibility studies through additional investigations. These investigations would result in the development of a geological model and a geotechnical baseline report, which would ensure a better understanding of the engineering geology of the potential site and help to reduce the geological risks of the project.

Environmental and social assessment

Preliminary modelling indicates that there would be notable hydrological changes in Lake Plimsoll as a result of a Tribute pumped hydro, with an increase in the frequency and extent of lake level fluctuations, and a change in the seasonal pattern of water levels. Historically, daily lake level variation in Lake Plimsoll has been less than 0.5 m for most of the time. Modelled hydrological changes in Lake Murchison also show an increase in the daily frequency and extent of water level fluctuation; however, the seasonal water level pattern is not expected to change. Historically, daily lake level variation in Lake Murchison has been less than 1.7 m for most of the time. Despite the hydrological changes modelled for Lake Plimsoll and Lake Murchison, no significant impacts are expected on water quality, shoreline erosion or the aquatic ecology of Lake Plimsoll, Lake Murchison or the rest of the Anthony–Pieman scheme. It is recommended that modelling is refined and that the assessment is continued of potential water quality and aquatic impacts through onsite surveys as part of a feasibility assessment.

Lake Plimsoll is a brook trout fishery and is one of only two that are regularly stocked by the Tasmanian Inland Fisheries Service (IFS). The impact of a pumped hydro project on the lake amenity for angling would be further investigated during a feasibility stage.

The project footprint is located mostly within the Mount Murchison and Lukes Knob regional reserves, which are managed by the Tasmanian Parks and Wildlife Service (PWS). No terrestrial vegetation communities, flora or fauna that are listed as threatened under State or Commonwealth legislation were identified in the project footprint. The eastern half of Lake Murchison is located within the Tasmanian Wilderness World Heritage Area (TWWHA). The Tribute project is not anticipated to have any impact on the TWWHA.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

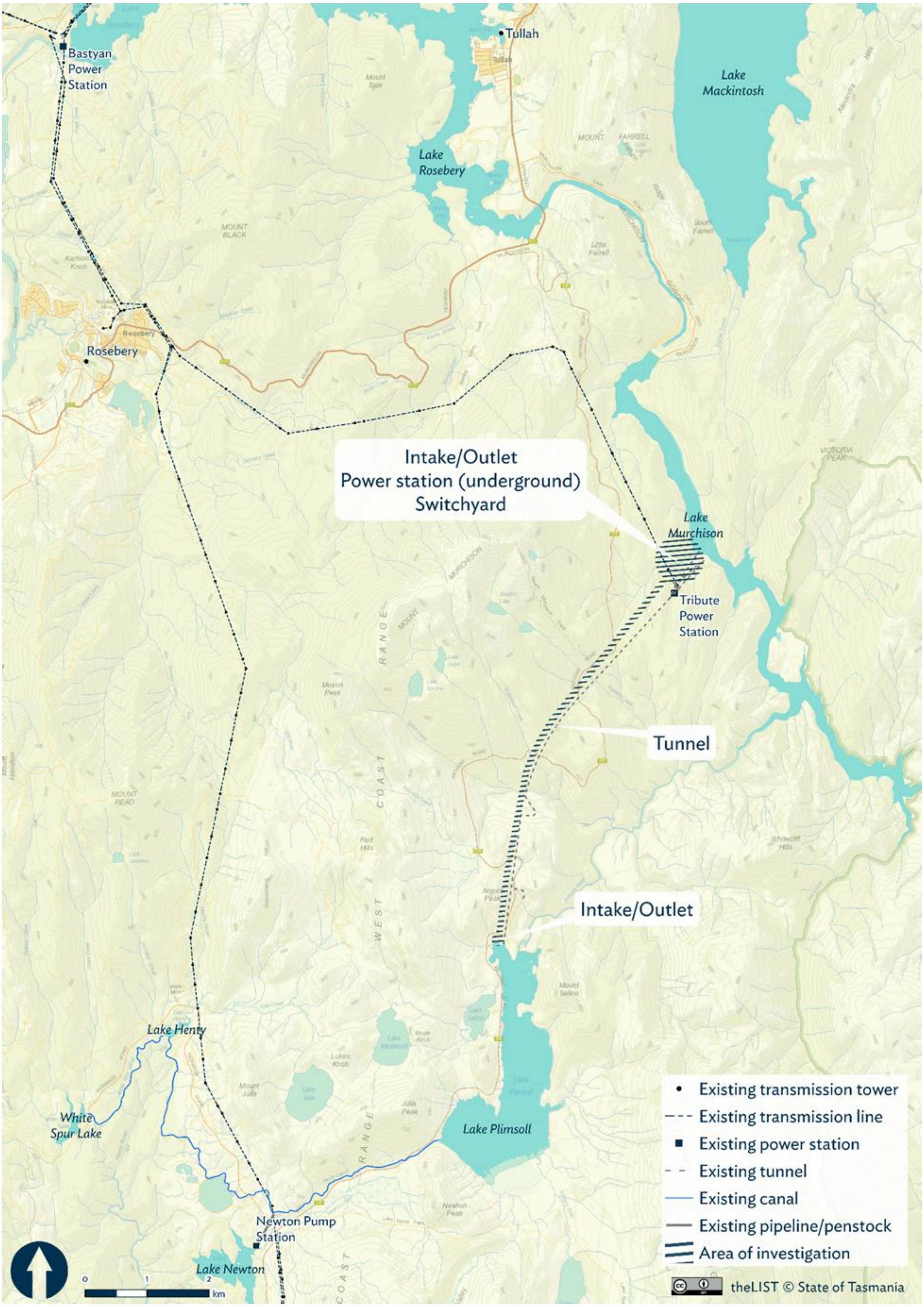

Figure 5-3 Tribute project potential layout

Construction schedule and cost estimate

Analysis of potential construction activity suggests that the project would take about five years to construct, including the commissioning of the station. Construction cost estimation for the project indicates a unit cost of approximately $1.83 million/MW installed and a total project investment of $915 million (including contingency).

Recommendation

At a unit cost of approximately $1.83 million/MW installed and with 31 hours of energy in storage, the Tribute project is considered attractive. A feasibility study is recommended to further define the project and better evaluate the project risks and benefits. This recommendation is predicated on the assumption that further interconnection will provide increased access to the NEM.

5.3 Group 2 sites

In addition to the three preferred sites, a further three potential sites (Margaret–Burbury, Parangana and Poatina) are considered technically and financially suitable to proceed to the feasibility stage at an appropriate time, but are not currently a priority to progress relative to other options. This recommendation should be subject to review dependent on future pumped hydro development stages and future market conditions. Prefeasibility studies have identified key opportunities, risks and uncertainties that could be further investigated in feasibility stage.

5.3.1 Margaret–Burbury pumped hydro energy storage project

Project description

The Margaret–Burbury pumped hydro energy storage project (Margaret–Burbury project) would be located near Queenstown on Tasmania’s west coast. The project would have an installed capacity of 800 MW and would have energy storage of about 16 000 MWh (20 hours). Natural inflows to Lake Margaret would provide capacity without pumping

A potential layout was developed as part of the prefeasibility study that involves a connection of the existing Lake Margaret and Lake Burbury storages. Lake Margaret, which has an operating range of 11.5 m and an active storage of $15.4\text{x}10^6\,m^3$, would be used as the upper reservoir. This arrangement is illustrated in Figure 5-4. Based on preliminary modelling, the fluctuation in Lake Margaret’s water level per generation/pumping cycle would be expected to be in the range of 1.0 to 6.0 m most of the time; however, this would need to be validated by more sophisticated modelling as part of a feasibility study. Lake Burbury, which has an operating range of 9.3 m and an active storage of $410\text{x}10^6\,m^3$, would be used as the lower reservoir. The fluctuation in Lake Burbury’s water level per generation/pumping cycle would be expected to be less than 0.2 m most of the time. Water conveyances connecting the upper and lower reservoir would have a total length of about 5830 m (including shaft).

An underground power station and transformer cavern would house four reversible fixed-speed pump-turbines with 800 MW total installed generating capacity and a maximum gross head of 436 m available for generating, with a generation duration of 20 hours. A new transmission line connection to Farrell substation would be required. This line would require a short section of new easement but would generally follow the existing transmission easement between Farrell and John Butters substations.

The potential layout developed in the prefeasibility study would need further review and optimisation during a feasibility study.

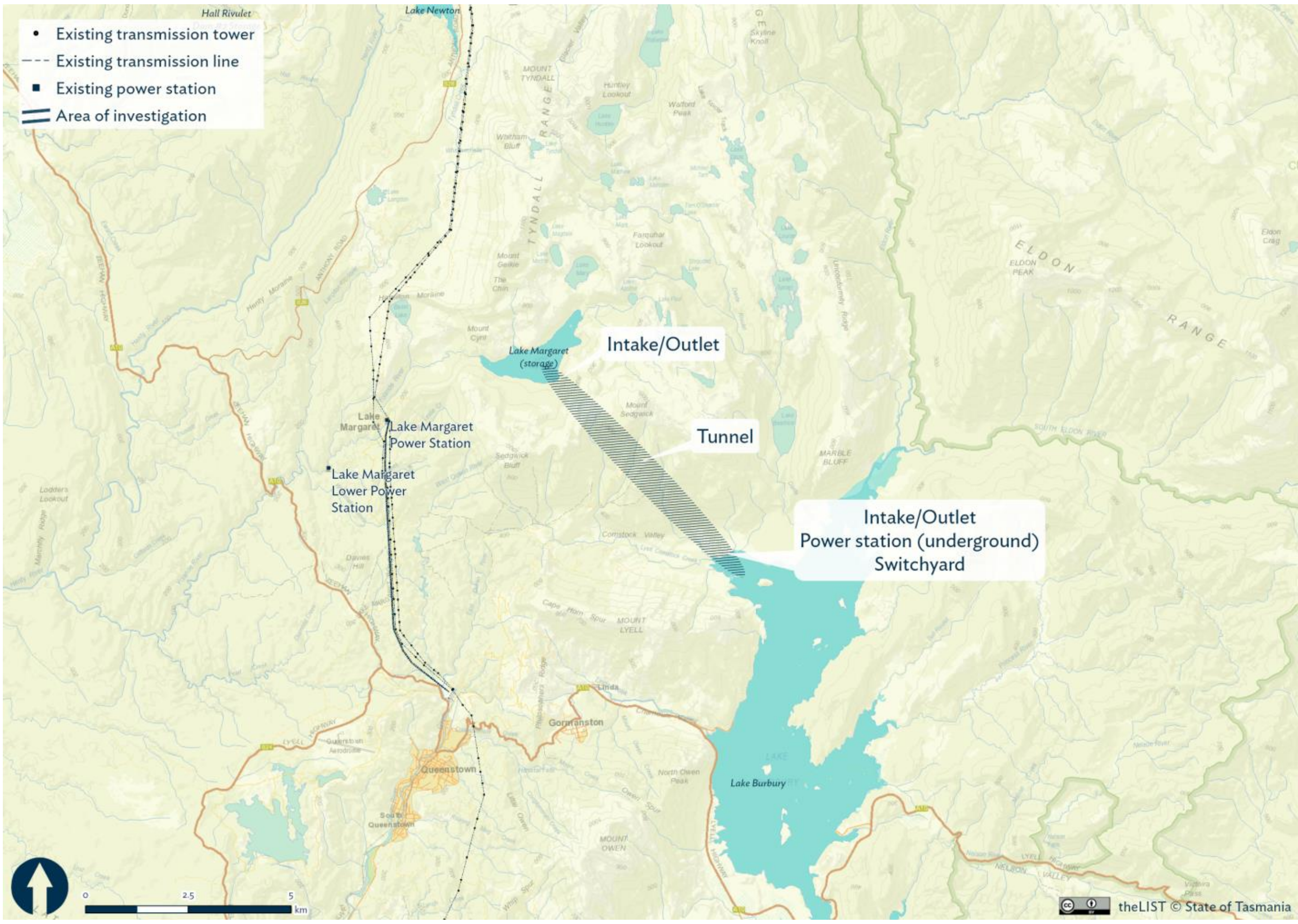

Figure 5-4 Margaret–Burbury project layout

Geology assessment

Available geological data has been reviewed and applied to the potential new project. There is considerable uncertainty with respect to the actual geological conditions in the vicinity of the project. Further geological investigation is recommended as part of a feasibility study in order to better understand and mitigate geological risks.

Environmental and social assessment

Lake Burbury lies within a catchment affected by historical mining operations. Concentrations of both copper and zinc in Lake Burbury exceed the ANZECC guideline; however, the characteristic tannic waters of the west coast provide a significant moderating impact on the toxicity of heavy metals. The transfer of water from Lake Burbury associated with the potential Margaret–Burbury pumped hydro project would result in the mixing of water with different pH and heavy metal concentrations. This has potential to impact water quality both in Lake Margaret and downstream, through the Yolande River. As part of a feasibility study, further assessment of Lake Margaret and downstream catchments and Lake Burbury would be required along with assessment of potential impacts.

Preliminary modelling indicates that there would be hydrological changes in Lake Margaret, with an increase in the frequency and extent of lake level fluctuations and a change in the seasonal water level pattern. Historically, daily lake level variation in Lake Margaret has been less than 0.2 m for most of the time. Changes in Lake Burbury are modelled to be less notable, with a projected smaller increase in the daily frequency and extent of water level fluctuation and no change in seasonal patterns. Historically, daily lake level variation in Lake Burbury has been less than 0.13 m for most of the time.

The change in water quality and increase in daily fluctuation in Lake Margaret has the potential to have a negative impact on native fish species. There are no recorded protected species in either Lake Margaret or Lake Burbury and few native fish species. The diversity and abundance of shoreline species in Lake Margaret is unknown and field surveys and habitat mapping would be needed to quantify the potential impact of a pumped hydro project. No significant impacts are expected on aquatic ecology in Lake Burbury. Limitations of the preliminary modelling are noted and should the project proceed to a feasibility study, it is recommended that additional modelling be completed and the assessment of potential aquatic impacts be continued through onsite surveys.

The King River is used by a number of tourist operators. Preliminary modelling indicates that a Margaret–Burbury pumped hydro project would not impact flows from John Butters Power Station and hence have no impact on downstream tourist operators.

Lake Burbury is a popular recreational trout fishery and the King River supports a smaller recreational fishery. Based on the results of preliminary modelling a Margaret–Burbury pumped hydro project would not impact these fisheries.

Lake Margaret power station and Lake Margaret village have significant historical values and are a popular destination for commercial tours and community events. The Margaret–Burbury project would not affect the historical values associated with Lake Margaret power station or village.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

The potential Margaret–Burbury layout would include underground infrastructure that would follow an alignment below the Tyndall Regional Reserve, which is managed by the Tasmanian Parks and Wildlife Services (PWS). Minimal surface infrastructure would be required and would be sited to avoid or minimise impacts to natural values. No vegetation communities listed as threatened under the *Nature Conservation Act 2002* would be likely to be disturbed by the project. Five species (four flora species and one fauna species) listed as threatened under the *Threatened Species Protection Act 1995* have been recorded in the vicinity of the alignment, and the alignment contains suitable habitat for the species to occur. Onsite surveys would be required during a feasibility assessment to determine the presence of these species and to inform the design to avoid or minimise impacts.

Construction schedule and cost estimate

Construction scheduling has been performed through an analysis of the duration of likely critical path activities. This analysis suggests that the project would take about five years to construct, including the commissioning of the station. Construction cost estimation for the project indicates a unit cost of approximately $1.56 m/MW installed and a total project investment of $1250 million (including contingency).

Recommendation

At a unit cost of approximately $1.56 m/MW installed and with 20 hours of energy in storage, the Margaret–Burbury project is considered to be potentially suitable to proceed to the feasibility stage at an appropriate time.

Relative to other options, the Margaret–Burbury project is not currently considered a high-priority project to progress to a feasibility study. This recommendation should be subject to review depending on future pumped hydro development stages and future market conditions. A future feasibility study at this site would need to further investigate environmental impacts and geological conditions at the site.

5.3.2 Parangana pumped hydro energy storage project

Project description

The Parangana pumped hydro energy storage project (Parangana project) would be located at Lake Parangana in Hydro Tasmania's Mersey–Forth scheme. The project would have an installed capacity of 300 MW and would have energy storage of about 2460 MWh (8 hours).

A potential layout was developed as part of this prefeasibility consisting of a new upper reservoir on the western side of Lake Parangana with an operating range of 10 m and an active storage of 2.1×10^6 m^3. Lake Parangana has an operating range of 2.44 m and would function as the lower reservoir. This arrangement is illustrated in Figure 5-5. Based on preliminary modelling, the daily fluctuation per generation/ pumping cycle would range from 0.3 m to 2.4 m most of the time; however, this would need to be validated through additional modelling as part of a feasibility study. Water conveyances connecting the upper and lower reservoir would have a total length of about 1680 m (including shaft).

An underground power station and transformer cavern would house two reversible fixed-speed pump-turbines with 300 MW total installed generating capacity and a maximum gross head of 479 m available for generation. The generation duration would be eight hours.

The potential arrangement developed in the prefeasibility study would be subject to further review and optimisation during a feasibility study.

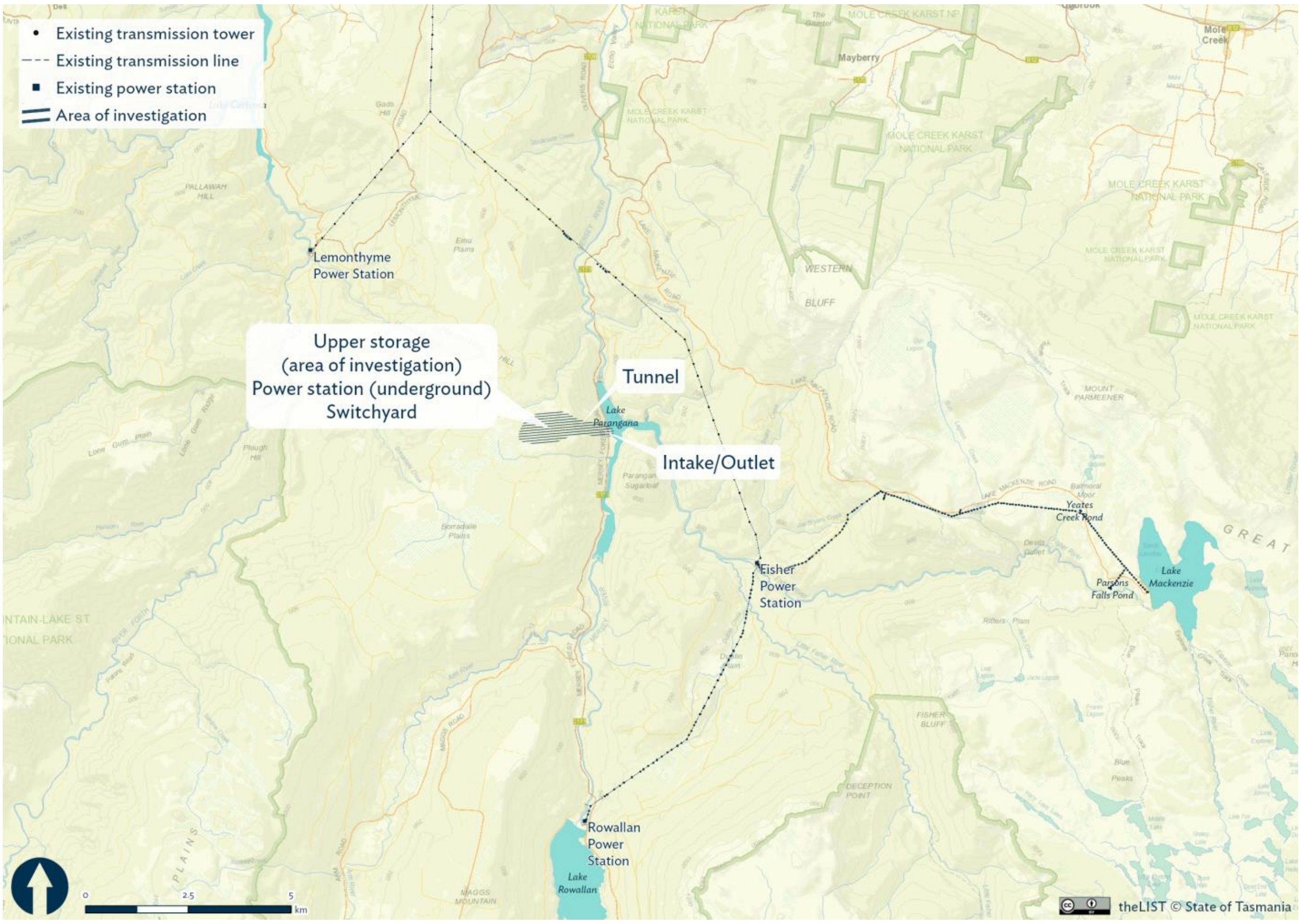

Figure 5-5 Parangana project potential layout

Geology assessment

Available geological data has been reviewed and applied to assessment of the potential pumped hydro project. The geological conditions of the underground works are generally unknown. Of particular concern for the construction of the project is the potential for poor-quality ground and/or groundwater inflow within the tertiary sediments through which the vertical shaft would pass.

Environmental and social assessment

A preliminary assessment indicated that a Parangana pumped hydro project would have a significant impact on existing system operations, or result in significantly constrained operations of the pumped hydro project while Lake Parangana is near or above full supply level (FSL). Preliminary modelling indicates that there would be a notable increase in the frequency and extent of daily lake level fluctuations in Lake Parangana as a result of the Parangana project. Historically, daily lake level variation has been less than 0.8 m for most of the time. A feasibility assessment would need to further investigate the predicted lake level fluctuations, assess potential impacts to the recreational use of Lake Parangana, and explore potential mitigation options. An increase in daily lake level fluctuations may lead to increased shoreline erosion and also affect the shoreline habitat of Lake Parangana. Both these potential impacts would need further investigation during a feasibility assessment. The preliminary modelling had limitations, and it is recommended that additional modelling be completed during a feasibility assessment. In particular, modelling of the spill regime and downstream flows is required to assess potential impacts on aquatic values (including *Barbarea australis*) in the Mersey River.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

The Parangana layout includes a large section of land categorised as Permanent Timber Production Zone Land (PTPZ). A feasibility study would include an assessment of land tenure impacts and opportunities.

Five flora species listed under the Tasmanian *Threatened Species Protection Act 1999* and four fauna species listed under the *Threatened Species Protection Act 1999* and the Commonwealth *Environment Protection and Biodiversity and Conservation Act 1999* have been recorded from within 5 km of the potential Parangana alignment. Surveys to verify the presence of these species would be undertaken during a feasibility assessment.

Construction schedule and cost estimate

Construction scheduling has been performed through an analysis of the duration of likely critical path activities. This analysis suggests the project would take about four years to construct, including the commissioning of the station.

Construction cost estimation for the project indicates a unit cost of approximately $1.70 million/MW installed and a total project investment of $510 million (including contingency).

Recommendation

At a unit cost of approximately $1.70 million/MW installed with eight hours of energy in storage, the Parangana project is considered potentially suitable to proceed to the feasibility stage at an appropriate time. Relative to other options, this option is not currently considered a high-priority project to progress to a feasibility study. This recommendation should be subject to review depending on future pumped hydro development stages and future market conditions. A future feasibility study at this site would need to further investigate impacts on recreational use and cascade operations, and geological conditions at the site.

5.3.3 Poatina pumped hydro energy storage project

Project description

The Poatina pumped hydro energy storage project (Poatina project) would be located at Poatina in Hydro Tasmania's Great Lake power scheme. The project would have an installed capacity of 600 MW and would have energy storage of about 18 600 MWh (31 hours).

As part of the prefeasibility study, a potential arrangement was developed along a similar alignment as the existing scheme, with larger diameter water conveyances and a deeper set powerhouse housing the pump-turbines. The existing *yingina* / Great Lake has an operating range of approximately 21.3 m and would function as the upper reservoir. Based on preliminary modelling, the fluctuation per generation/pumping cycle would be less than 0.1 m most of the time; however, this would need to be validated by more sophisticated modelling as part of a feasibility study. A new lower reservoir would be located at the toe of the hill to the east of Great Lake with an operating range of 12 m and an active storage of 9.6 $\times 10^6$ m^3. New water conveyances connecting the upper and lower reservoir would have a total length of about 11 200 m (including shaft).

An underground power station and transformer cavern would house four multi-stage reversible fixed-speed pump-turbines with 600 MW total installed generating capacity and a maximum gross head of 812 m available for generating. The generation duration would be 31 hours. A surface switchyard and new transmission line, generally on existing easements to Palmerston substation, would be required.

The potential arrangement developed in the prefeasibility study would be subject to further review and optimisation during a feasibility study.

There may also be a requirement to upgrade the existing capacity of the tailrace canal, the existing Poatina re-regulation pond and Brumbys Creek to cater for an emergency spill event from the lower reservoir. This is considered a key project risk due to considerable cost and potential downstream impacts. This potential requirement and risk would need to be confirmed before proceeding with a feasibility study.

There is considerable technical risk associated with the high head for the potential Poatina project. It is at the upper limit of existing multi-stage reversible pump/turbines for which there are limited suppliers. The alternative of using ternary sets for the machines would add significant cost and a suitable layout has not been developed for this alternative.

Geology assessment

The geology and general geotechnical risks associated with the underground works are relatively well known, assuming a similar alignment to the existing scheme is followed. Additional information is, however, required in order to better understand the geological risks associated with specific structures.

Environmental and social assessment

Preliminary modelling indicates that an increase in the frequency and extent of daily lake level fluctuation in *yingina* / Great Lake would be minor (<10 cm). The aquatic values of *yingina* / Great Lake are very high, as it contains a number of endemic and protected aquatic species, many of which depend on shoreline habitat and are therefore vulnerable to daily lake level fluctuations. Whilst the small increase in daily fluctuation modelled is unlikely to affect aquatic species in *yingina* / Great Lake, further investigation would be undertaken during a feasibility study to quantify the area of shoreline that would be dewatered over the full range of daily lake level fluctuations. This would enable a more detailed assessment of potential impacts.

yingina / Great Lake is a world-recognised trout fishery that, together with other lakes in the central highlands, forms a key component of the regional tourism industry. Although preliminary modelling indicates that the trout fishery would not be affected, potential impacts on commercial and recreation trout fishing would be considered as part of a feasibility assessment.

Flora and fauna species listed under either or both of the *Environment Protection and Biodiversity Conservation Act 1999* and the *Threatened Species Protection Act 1999* have been recorded within the *yingina /* Great Lake impoundment and within 5 km of the project footprint. During a feasibility assessment, the presence of these species would need to be validated and potential impacts considered carefully.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

A section of the potential Poatina alignment would pass through (and under) the Tasmanian Wilderness World Heritage Area (TWWHA) on land vested to Hydro Tasmania. A feasibility study would assess land tenure, environmental and land management risks and opportunities.

Construction schedule and cost estimate

Construction scheduling has been undertaken through an analysis of the duration of likely critical path activities. This analysis suggests that the project would take about 4.5 years to construct, including the commissioning of the station.

Construction cost estimation for the project indicates a unit cost of approximately $1.79 million/MW installed, and a total project investment of approximately $1075 million (including contingency).

Recommendation

At a unit cost of approximately $1.79 million/MW installed with 31 hours of energy in storage, the Poatina project considered potentially suitable to proceed to the feasibility stage at an appropriate time. Relative to other options, the option is not currently considered a high-priority project to progress to a feasibility study. This recommendation should be reviewed depending on future pumped hydro development stages and future market conditions. Prior to a decision to proceed to feasibility at this site, further investigation of technical risks and downstream impacts would be required.

5.4 Group 3 sites

A further two potential sites – Lake Echo and Wilmot – are considered technically feasible but are unlikely to meet financial objectives due to their higher overall costs. This makes them lower priorities for future assessment.

5.4.1 Wilmot pumped hydro energy storage project

Project description

The Wilmot pumped hydro energy storage project (Wilmot project) would be located near Moina in Hydro Tasmania's Mersey–Forth scheme. The project would have an installed capacity of 300 MW and would have energy storage of about 3360 MWh (11 hours). Natural inflows to Lake Gairdner would provide capacity without pumping.

A potential layout was developed as part of the prefeasibility study, consisting of a duplication of the existing scheme with larger diameter water conveyances and a deeper set powerhouse housing the pump-turbines. The existing Lake Gairdner has an operating range of 11.73 m and an active storage of $7.4 \times 10^6 m^3$. This arrangement is illustrated in Figure 5-6. Based on preliminary modelling, the fluctuation per generation/pumping cycle would be expected to be mostly between 3.0 m and 8.0 m; however, this would need to be validated by more sophisticated modelling as part of a feasibility study.

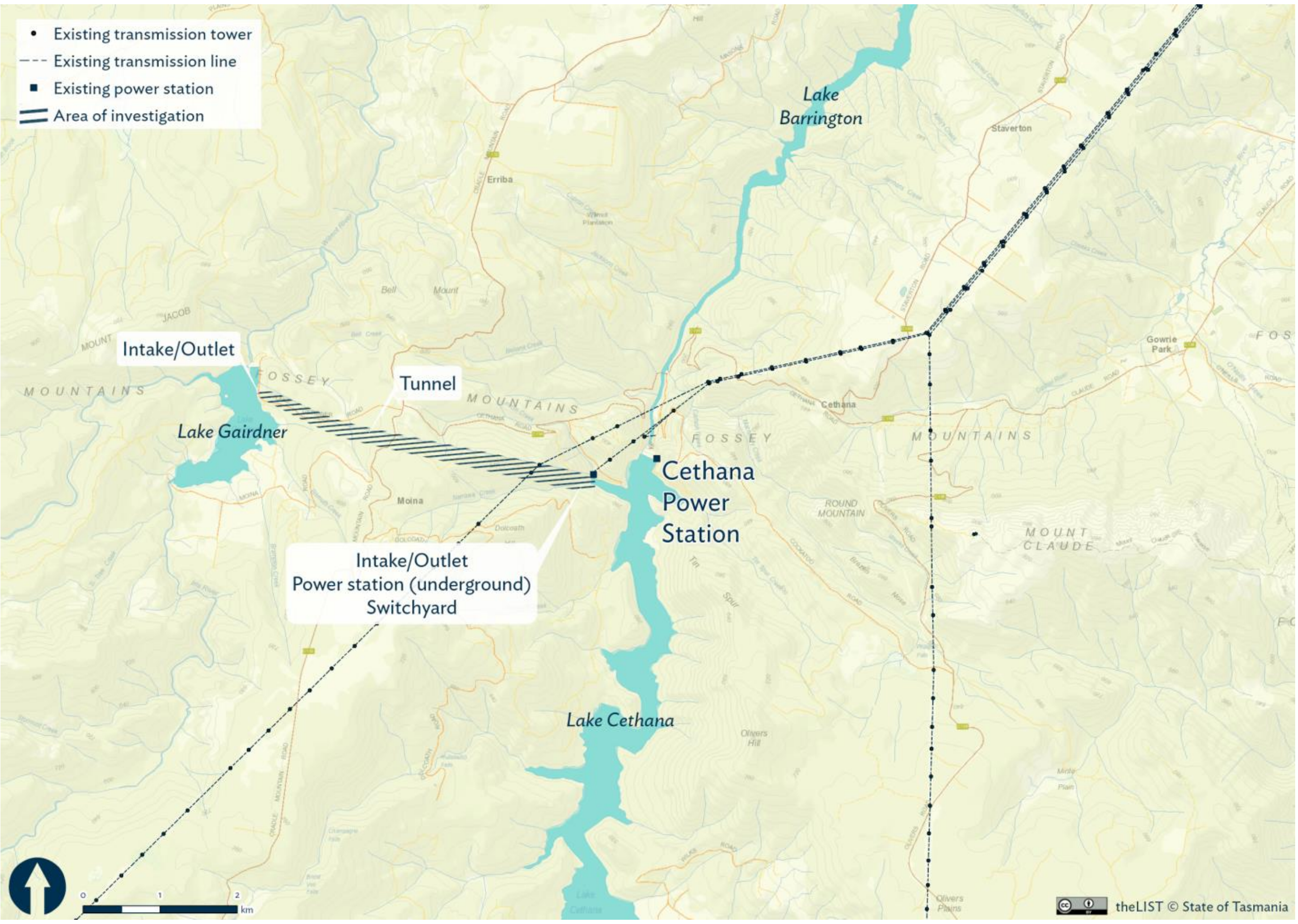

Figure 5-6 Wilmot project potential layout

The existing Lake Cethana has an operating range of 4.57 m and would act as the lower reservoir. The fluctuation per generation/pumping cycle would be expected to be mostly between 0.5 m and 1.2 m. New underground water conveyances connecting the upper and lower reservoir would be a total length of about 5030 m (including shaft). An underground power station and transformer cavern would house two reversible fixed-speed pump-turbines with 300 MW total installed generating capacity and a maximum gross head of 256 m available for generating. The generation duration would be 11 hours. The potential arrangement developed in the prefeasibility study would need further review and optimisation during a feasibility study.

Geology assessment

A significant amount of geological data is available from the investigation and construction of the existing Wilmot power development. Available geological data has been reviewed and applied to the potential project. On the assumption that the alignment of a new pumped hydro project is sub-parallel to the existing Wilmot tunnel, the geological risks are relatively well understood; however, further geotechnical investigations would be required to better understand the engineering geology of site-specific infrastructure and quantify risk.

Environmental and social assessment

Preliminary modelling indicates that there would be an increase in the daily frequency and extent of lake level fluctuation in lakes Gairdner and Cethana. Historically, daily lake level variation in Lake Gairdner and Lake Cethana has been less than 1.2 m and 0.5 m respectively for most of the time. Hydro Tasmania currently has storage operating rules in place for Lake Gairdner that aim to keep the lake high during periods of high use. The predicted hydrological changes have the potential to constrain the recreational use of Lake Gairdner for fishing and boating. An assessment of recreational impacts to Lake Gairdner including public consultation would be conducted as part of a feasibility study. Preliminary modelling indicated that the hydrological changes in Lake Cethana would be unlikely to impact either the recreational or commercial use of the lake. No significant hydrological changes are anticipated in the rest of the Mersey–Forth scheme.

Lake Cethana provides suitable habitat for the giant freshwater crayfish (*Astacopsis gouldi*), listed under the Tasmanian *Threatened Species Protection Act 1995* and Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*, although surveys completed in 2019 did not find the species. Hydrological changes in Lake Cethana as a result of a Wilmot pumped hydro project would have potential to impact *Astacopsis gouldi*. Further survey would be required as part of a feasibility assessment to determine whether it is present. Preliminary modelling indicates that spills from Wilmot Dam would almost cease with a Wilmot pumped hydro project. Reduced spill in the Wilmot River has the potential to affect habitat and flow cues for several species listed on the *Threatened Spies Protection Act 1999* and/or *Environmental Protection and Biodiversity Conservation Act* 1999 recorded from the Wilmot River downstream from Wilmot Dam. Further hydrological modelling would be required at additional downstream locations to further assess the potential impact of reduced spill on aquatic values.

The Wilmot project alignment does not traverse any vegetation communities listed as threatened under the *Nature Conservation Act 2002*. One flora species listed under the *Threatened Species Protection Act* and six fauna species listed under the *Threatened Species Protection Act* and *Environmental Protection and Biodiversity Conservation Act* have been recorded within 5 km of the alignment. Surveys to verify the presence of these species would be required.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

A significant section of the Wilmot project alignment passes under private land. Consultation with land-owners would be carried out if access to private land were required for construction of the project. In addition, the alignment traverses Sustainable Timber Tasmania (STT) land categorised as Permanent Timber Production Zone Land (PTPZ).

Construction schedule and cost estimate

Construction scheduling has been performed through an analysis of the duration of likely critical path activities. This analysis suggests the project would take about five years to construct, including the commissioning of the station. Construction cost estimation for the project indicates a unit cost of approximately $2.1 m/MW installed and a total project investment of $630 million (including contingency).

Recommendation

At a unit cost of approximately $2.1 m/MW installed and with 11 hours energy in storage, the Wilmot project is considered potentially suitable to proceed to the feasibility stage at an appropriate time.

However, given the relatively high cost and identified risks, the Wilmot project is not currently considered a high-priority project to progress to a feasibility study relative to other options. This recommendation should be reviewed depending on future market conditions and future studies of the identified risks.

5.4.2 Lake Echo pumped hydro energy storage project

Project description

The Lake Echo pumped hydro energy storage project (Lake Echo project) would be located at Lake Echo in Tasmania's central highlands. The project would have an installed capacity of 200 MW and would have energy storage of about 1600 MWh (8 hours).

A potential layout was developed as part of this prefeasibility study consisting of a new upper reservoir on the north-western side of Lake Echo with an operating range of 10 m and an active storage of 2.9 x 10^6 m^3. This arrangement is illustrated in Figure 5-7. Lake Echo has an operating range of 10.23 m and would act as the lower reservoir. Based on preliminary modelling, the fluctuation per generation/pumping cycle would be between 0.04 m and 0.1 m most of the time; however, this would need to be validated by more sophisticated modelling as part of a feasibility study. Water conveyances connecting the upper and lower reservoir would have a total length of about 2050 m (including shaft).

An underground power station and transformer cavern would house two reversible fixed-speed pump-turbines with 200 MW total installed generating capacity and a maximum gross head of 224 m available for generation. The generation duration would be eight hours.

The potential layout developed in the prefeasibility study would be further reviewed and optimised during a feasibility study.

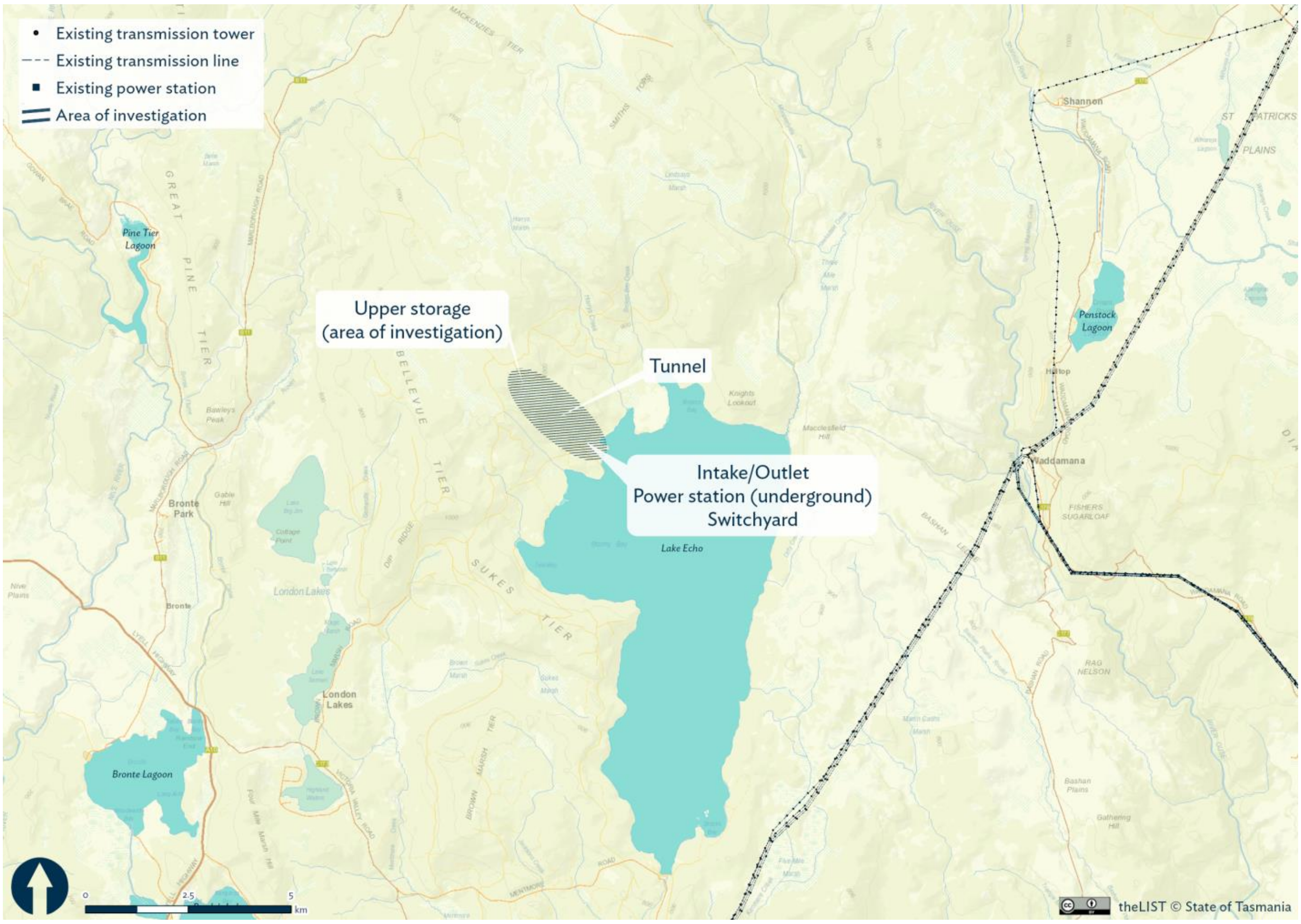

Figure 5-7 Lake Echo project potential layout

Geology assessment

Available geological data has been reviewed and applied to the potential new project. There is considerable uncertainty with respect to the actual geological conditions in the vicinity of the project. Geological investigations would be required in order to better understand and mitigate geological risks.

Environmental and social assessment

Preliminary modelling indicates that there would be limited hydrological change in Lake Echo as a result of the Lake Echo pumped hydro project, with only a slight increase in the frequency of daily lake level fluctuation (up to 0.06m per day). No significant impacts are expected to water quality or the aquatic ecology of Lake Echo or downstream Dee Lagoon as a result of a Lake Echo pumped hydro project. Additional modelling would need to be completed during a feasibility assessment to verify these findings.

The potential upper reservoir and tunnel alignment include some small patches of the highland grassy sedge land vegetation community which is listed as threatened under the Tasmanian *Nature Conservation Act 2002*. It is expected that the loss of approximately 5 ha of this threatened vegetation community would require an offset of an equivalent or greater area of the same vegetation community type.

The upper reservoir and majority of the tunnel alignment would be located on land categorised as Permanent Timber Production Zone Land (PTPZ), and a feasibility study would include an assessment of land tenure impacts and opportunities.

A desktop assessment of Aboriginal and historical heritage has been completed. Onsite assessment would be required as part of a feasibility assessment.

Lake Echo is designated as a premium wild trout fishery by the Tasmanian Inland Fisheries Service (IFS) and forms part of the world-recognised recreational trout fishery located in Tasmania’s central highlands region. Based on the results of preliminary modelling, no impacts to the trout fishery would be expected.

Construction schedule and cost estimate

Construction scheduling has been performed through an analysis of the duration of likely critical path activities. This analysis suggests the project would take about 4.5 years to construct, including the commissioning of the station.

Construction cost estimation for the project indicates a unit cost of approximately $2.7 million/MW installed and a total project investment of $540 million (including contingency).

Recommendation

At a unit cost of approximately $2.7 million/MW installed with eight hours of energy in storage, the Lake Echo project is considered potentially suitable to proceed to the feasibility stage at an appropriate time. However, given the relatively high cost and the identified risks, the Lake Echo project is not currently considered a high-priority project to progress relative to other options. This recommendation should be subject to review depending on future market conditions and future studies of the identified risks.

5.5 Group 4 sites

Of the 14 projects identified in the concept study, eight have been proven to be technically suitable to proceed to the feasibility stage at an appropriate time. A number, however, do not meet the objectives of the project and are therefore not recommended to proceed to further studies. These projects include:

- Wilmot Power Station redevelopment

- Cethana Power Station redevelopment
- Lemonthyme Power Station redevelopment
- Tribute Power Station redevelopment
- Lake Margaret pumped hydro project
- Lake Rosebery pumped hydro project.

The projects are not recommended for further assessments for the reasons outlined below. The key findings for each of the individual projects are summarised in Table 5-1.

Wilmot Redevelopment and Lemonthyme Redevelopment:

The sizes of the potential projects were small, and would not contribute significantly to the target of 2500 MW of new pumped hydro capacity of the *Battery of the Nation* project.

Cethana Redevelopment and Tribute Redevelopment:

The projects would be technically difficult, and therefore likely to be significantly more expensive than the initial cost estimate.

The Tribute redevelopment project would also be mutually exclusive with the more attractive option of a Tribute pumped hydro project.

Lake Margaret pumped hydro and Lake Rosebery pumped hydro:

LiDAR survey of the area showed that suitable locations for an upper reservoir could not be located.

Table 5-1 - Summary of Group 4 projects

Project name	Nominal capacity (MW)	Est unit cost* ($M/MW)	Key issue
Wilmot Power Station Redevelopment	32	1.5	The key issue is the constraint on the size to 32 MW of the existing station, being relatively small in comparison to the targeted 2500 MW of new generation.
Cethana Power Station Redevelopment	100	1.5	Technically difficult due to arrangement of existing water conveyances and distance downstream to achieve sufficient submergence/operating volume. Not likely to be cost-effective. Does not contribute significantly to 2500 MW target.
Lemonthyme Power Station Redevelopment	54	1.5	The key issue is the constraint on the size to 54 MW of the existing station, being relatively small in comparison to the targeted 2500 MW of new generation. Distance downstream to achieve sufficient submergence/operating volume means it is not likely to be cost-effective.
Tribute Power Station Redevelopment	84	1.5	Technically difficult due to the required depth for pump centreline and not likely to be cost-effective. This project is also mutually exclusive of the Tribute pumped hydro option, which is a more attractive project.
Lake Margaret pumped hydro	300	1.2	A suitable site for an upper reservoir could not be located following LiDAR survey of the area.
Lake Rosebery pumped hydro	400	2.3	A suitable site for an upper reservoir could not be located following LiDAR survey of the area. Alternative siting options were dismissed due to their potential impact on areas of high conservation value.

* Cost estimates from concept study reports

6. Project development considerations

There are common elements across all of the pumped hydro energy storage projects, including the approvals pathway and the development and construction schedule.

6.1 Approvals pathway

One of the most significant activities during the development of any infrastructure project is securing project approvals. For a project of this scale, significant effort would be required to prepare documentation ahead of submission to approval agencies. This can include specialist planning, environmental, visual, heritage, social and economic studies and stakeholder and community consultation. Prior to commencing this work, a strategy for securing approvals must be decided upon. This strategy would set out the choices available and define a development approvals process for the projects.

Approvals have been separated into:

- primary approvals which have the most complex assessment process and must be secured for the project to proceed
- all other 'secondary' approvals, consents and licences.

Development of an approvals strategy requires knowledge of the legislation and regulations that regulate the development of projects. An initial assessment for the development of a pumped hydro project in Tasmania has identified the following relevant State and Commonwealth acts, as well as the possible project approval requirements for each (Table 6-1).

Table 6-1 – Primary and secondary approvals requirements

Primary approvals	**Secondary approvals**	
	Authorities, consents and licences	Other 'secondary' approvals
Hydro-electric Corporation Act 1995 - Parliamentary approval for a new major power facility *Land Use Planning and Approvals Act 1993* - Approval for development in accordance with applicable council planning scheme *Environmental Management and Pollution Control Act 1994* - Environmental impact assessment of a Level 2 activity by Environment Protection Agency *Environment Protection and Biodiversity Conservation Act 1999* - Referral and approval may be required in respect of potential impacts upon matters of national environmental significance *Water Management Act 1999* - Dam work permit required for new dam *National Parks and Reserves Management Act 2002* - Authority to undertake works on reserved land *Forest Management Act 2013* - Securing of land tenure	*National Parks and Reserves Management Act 2002* - Amendment of reserve boundaries (if affected) *Forest Management Act 2013* - Revocation of permanent timber production zone land requiring parliamentary approval *Mineral Resources Development Act 1995* - Mining lease and exploration licences *National Electricity Rules* - Connection agreement with TasNetworks	*Threatened Species Protection Act 1995* - Permit to 'take' or 'disturb native fauna' may be required *Aboriginal Heritage Act 1975* - Permit to 'disturb' Aboriginal relics may be required *Wildlife Act Regulations 2010* - A permit to 'take' protected wildlife may be required *Building Act 2000* - Building permit issued by council

6.2 Development and approvals schedule

Throughout the development of a pumped hydro opportunity, a number of activities must be completed, which would culminate with financial close and the execution of construction contracts. Activities and indicative timeframes include:

- feasibility study – 12 to 18 months
- environmental impact statement (EIS), including specialist studies – 18 months
- grid connection process – 24 months
- preparation of reference design and documentation – 6 months
- development and environmental assessment process including public consultation – 18 months
- contractor procurement – 14 months (including early contractor involvement process)
- commercial activities (drafting of contracts, financing negotiations, etc.) – 12 months.

Generally, multiple work streams would progress in parallel.

7. Benefit-sharing framework

7.1 Introduction

The key benefits of hydropower development and operation relate primarily to various energy services (generation, flexibility, ancillary services, storage, etc.) However, there are also a variety of other benefits that can be realised when developing hydropower assets including local employment and other socioeconomic activity, improved local infrastructure (e.g. roads, telecommunications) and recreational and tourism opportunities. The development of hydropower assets can affect local communities in a number of ways and it is broadly recognised that benefit-sharing programs with local and regional communities should be included in hydropower planning and development.

Benefit sharing in hydropower projects is defined by the International Finance Corporation (IFC) as 'those deliberate measures undertaken by hydropower developers to share benefits with local communities that go beyond the obligatory requirements related to compensation and mitigation measures'[2].

For this study, Hydro Tasmania has identified various types of benefit sharing, and conducted a high-level review of benefit-sharing arrangements that have been developed alongside hydropower developments internationally. These examples of benefit sharing could be used to inform the development of Hydro Tasmania's benefit-sharing framework for future developments.

7.2 Types of benefit sharing

The IFC considers that there are four key categories relevant to benefit sharing. These categories are:

1. **Revenue sharing and shared ownership** – This refers to recurring payments to local governments and communities, preferential electricity rates and discounts and shared ownership of projects.
2. **Public services and infrastructure** – This refers to provision of essential or basic services, support for community wellbeing, amenities, electrification and other energy services.
3. **Local skills and livelihoods** – This refers to local employment and procurement, alternative skills and livelihoods, and local institutional capacity building.
4. **Environmental stewardship** – This relates to environmental enhancements and climate resilience benefits resulting from the implementation of a project. It may also relate to payment for ecosystem services.

Hydro Tasmania has identified relevant case studies where hydropower developers have delivered benefits to local communities under each of these benefit-sharing categories. These case studies identify that, if formed appropriately, benefit-sharing arrangements can produce positive social, economic and environmental outcomes for a variety of stakeholders. These are examples only, as benefit sharing can mean different things in different contexts (economic/geographic/demographic, etc.) – no two projects are the same.

7.3 Case study: Revenue sharing and shared ownership

In developing a framework for a benefit-sharing model, opportunities to create a 'line of sight' for affected communities could be developed by communicating how dividends are being (or would be) appropriated (by the

[2] Arsenova, M., Wojczynski, E., 2019, *Local Benefit Sharing in the Hydropower Sector – IFC Study*, presented at IHA World Hydropower Congress, 14 – 16 May 2019, Paris

shareholder) to benefit the affected communities. In this way, the direct benefit from the PHES development can be demonstrated.

Hydropower has been a key driver of economic development in Norway. The distribution of income from hydropower development is recognised in Norwegian laws. The direct benefits from hydropower in the Glomma and Laagen basin have been through the provision of jobs during construction, and permanent employment for power station operators and personnel for maintaining associated infrastructure including reservoirs. Other direct benefits include revenues to Municipal Authorities in the form of taxes, licence fees and from owner incomes in the form of dividends.[3]

7.4 Case study: Public services and infrastructure

An interpretive facility is proposed at the lower reservoir of the Swan Lake Pumped Storage Project in the USA. The facility includes educational and historical signage and a staging area for periodic guided tours of the hydroelectric facility to enhance recreational opportunities in the project area. This facility would provide a way for the public to enjoy the scenic quality of the area, learn more about the history of the area, and understand the function and operation of a pumped hydro project.

7.5 Case study: Local skills and livelihoods

Australian projects currently under development include the Kidston Stage 2 hydro project in North Queensland and the Snowy 2.0 project in New South Wales. These projects are expected to create 500[4] and 2400[5] jobs respectively, each with a number of ongoing operational roles.

In the lead up to the implementation phase of a project, local contractors should be supported to capitalise on the development opportunities as required.

Indirect economic spinoffs would benefit local businesses in the area throughout the construction and operational phases due to the sourcing of local products, materials and services (such as accommodation, food, fuel, and construction supplies and materials).

7.6 Case study: Environmental stewardship

An example of good practice in environmental stewardship can be found at the Semla IV project in Sweden where water flows from a 2200 km^2 catchment area. Water quality in the area is generally moderate to good, although the consequences of contamination would be serious. To maintain local water quality, stakeholders in the region formed a water management association. The association brings together 53 municipalities, public sector organisations and private businesses that are authorised to use the river, or whose activities have an impact on the river. Most are mandatory members by law. The association finances water quality monitoring and other joint efforts, such as flood management studies. Water quality monitoring is comprehensive, and the results of the water monitoring are accessible to everyone online. Sweden has an exceptionally thorough system for nationwide, long-term programs to monitor and respond to problems in water quality.

At the Santo Antônio Hydropower Project in Brazil, an environmental education program was run involving workshops, lectures and meetings with local communities to improve knowledge about environmental protection.

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[3] http://www.hydrosustainability.org/getattachment/8f5b41e5-4970-4ce6-8271-e3d769a61332/Glomma---Laagen-Rivers,-Norway.aspx

[4] https://www.minister.industry.gov.au/ministers/canavan/media-releases/naif-funds-groundbreaking-kidston-hydro-project

[5] https://www.australianfifominingjobs.com.au/news/2144/nsws-snowy-2-0-project-given-funds-and-approval-5-000-direct-and-indirect-jobs

Each year, Odebrecht (the developer) offers awards for employee innovation. As a result, one of the project's employees came up with a proposal to replace the use of aluminium sulphate in wastewater treatment in favour of a new system using tree bark.

7.7 Next steps/process to develop Tasmania's framework

As there has been no hydropower developed in Australia in recent decades, it is important that Hydro Tasmania leverages the insights and expertise of international hydropower peers to develop an appropriate benefit-sharing framework for *Battery of the Nation* projects.

As a member of the International Hydropower Association (IHA) and the International Energy Agency's Technical Collaboration Program on Hydropower (IEA Hydro), Hydro Tasmania is well positioned to draw upon the knowledge of other hydropower developers and operators.

To develop a suitable benefit-sharing framework in future, Hydro Tasmania will:

1. undertake community engagement activities to understand community values that may interact with proposed projects and identify opportunities to return value to impacted regions
2. engage and participate with international hydropower peers and learn from industry experience to inform pumped hydro benefit-sharing options in Tasmania
3. conduct a desktop review of benefit-sharing arrangements in other sectors across Australia (such as the Australian mining industry) and consider how these arrangements may inform or be applied to *Battery of the Nation* projects
4. work collaboratively with key national and Tasmanian stakeholders to develop benefit-sharing arrangements.

8. Conclusion

Prefeasibility studies into selected Tasmanian pumped hydro opportunities have been completed. A total of 14 projects were considered, which were identified through an options study completed early in 2018. The prefeasibility studies have confirmed that six of the 14 projects are suitable for feasibility studies at an appropriate time. The combined installed capacity of the six projects is 3400 MW, which exceeds the stated objective of the study of identifying 2500 MW installed capacity in potentially suitable projects. Summary data of the six suitable projects is provided in Table 8-1.

Table 8-1 Summary data for suitable projects to proceed to the feasibility stage

Power scheme	Site name	Nominal capacity (MW)	Energy in storage (MWh)	Est unit cost ($M/MW)
Group 1 – Most promising sites				
Mersey–Forth	**Cethana Project** New upper reservoir	600	6 700 (11 hours)	1.50
Mersey–Forth	**Rowallan Project** New upper reservoir	600	14 500 (24 hours)	1.65
West Coast	**Tribute Project** Connecting Lake Plimsoll to Lake Murchison	500	15 600 (31 hours)	1.83
Group 2 – Recommended for feasibility study at an appropriate time				
West Coast	**Margaret–Burbury Project** Connecting Lake Margaret to Lake Burbury	800	16 000 (20 hours)	1.56
Mersey–Forth	**Parangana Project** New upper reservoir	300	2 460 (8 hours)	1.70
Great Lake / South Esk	**Poatina Project** New lower reservoir	600	18 600 (31 hours)	1.79

The prefeasibility studies have assessed siting and design options, reviewed available geological information, carried out desktop environmental and social studies (with limited field work in some cases), estimated construction schedules and costs for the projects and carried out risk assessments. The findings of these studies will inform future feasibility studies.

Future feasibility studies would further reduce uncertainties around the selected projects.

Feasibility studies would explore key considerations of the selected sites, including:

- ensuring avoidance of high conservation areas with respect to land disturbance associated with new upper storages – field studies are required to confirm environmental values at each site
- impacts of pumped hydro projects on the aquatic environment
- suitability of the sites for underground infrastructure and to refine cost estimates – geological and geotechnical field studies are required

- impacts on landscape and visual amenity of the project areas
- confirmation of assumptions and informing detailed design, through further engineering studies
- development of a preferred option for transmission connection
- potential impacts and benefits for local communities, recreation and tourism in consultation with key stakeholder groups.

9. References

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