MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

BRIEFING

New Zealand Battery Project – update on hydro and other technologies

Date:	26 August 2021	**Priority:**	Medium
Security classification:	Sensitive	**Tracking number:**	2122-0424

Action sought		
	Action sought	**Deadline**
Hon Dr Megan Woods **Minister of Energy and Resources**	**Note** that in December 2020 Cabinet agreed that the NZ Battery Project will assess the viability of pumped hydro as part of its primary objective, and consider this solution against alternative technologies if they are identified through the process **Note** the NZ Battery Project is focussed on large-scale, long-term energy storage or flexibility options, but smaller options could have supplementary benefits **Note** the NZ Battery Project has identified potential hydro developments that could be full alternatives, partial alternatives, or complements to a pumped hydro scheme at Lake Onslow **Agree** to further investigation into the technical potential of the following hydro-based options: • Lake Moawhango (pumped hydro) • Taruarau River (pumped hydro) • Lake Pukaki (non-pumped hydro) **Note** that engagement with iwi and stakeholders will form the first step of any further investigation of other hydro sites, and that officials will report back to you on the outcome of this engagement **Agree** to the long-list of options and our current screening assessment being published on the NZ Battery Project webpage of the MBIE website	3 September 2021

Contact for telephone discussion (if required)				
Name	**Position**	**Telephone**		**1st contact**
Andrew Millar	Manager, Energy Projects and Programmes	Privacy of	Privacy of	✓
Bridget Moon	Senior Policy Advisor, Energy Projects and Programmes	Privacy of		

The following departments/agencies have been consulted
Department of Conservation

Minister's office to complete:

- ☐ Approved
- ☐ Declined
- ☐ Noted
- ☐ Needs change
- ☐ Seen
- ☐ Overtaken by Events
- ☐ See Minister's Notes
- ☐ Withdrawn

Comments

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Date:	26 August 2021	**Priority:**	Medium
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Purpose

The purpose of this briefing is to provide you with an update on our two workstreams that relate to potential alternatives to a pumped hydro scheme at Lake Onslow:

- other hydro options, including other pumped hydro options, and
- other comparator technologies (i.e. non-hydro options).

In relation to the 'other hydro options' workstream we seek your agreement to proceed with further investigation into the technical potential of three hydro-based options that could be alternatives or complements to Lake Onslow.

Executive summary

The purpose of the New Zealand Battery Project (NZ Battery Project) is to identify the best option or options for managing dry year risk in a highly renewable electricity system. The prime focus of the project is investigating the potential of a pumped hydro scheme at Lake Onslow.

However, the NZ Battery Project is also considering alternative hydro options and non-hydro technologies that are through the project identified.

Managing dry year risk requires a large amount of long-term energy storage or flexibility. Our work to date has identified many options that are unlikely to efficiently meet that need in a 100 per cent renewable electricity system. For example, we have ruled out:

- options that are not renewable, including continuing with the status quo (which relies on fossil fuels during dry years), an interconnection with Australia, and fossil-fuelled options that manage emissions through carbon capture and storage,
- unplanned demand reduction, which can have broader social effects that have a high cost because it can affect a business' operations for a long period, affecting jobs and communities,
- several electrically-charged storage options (e.g. lithium ion batteries), because they are small-scale, can lose charge over time, and rely on frequent cycling to recover their high costs,
- short-term demand response, which shifts demand over hours or days, and energy efficiency, which reduces overall demand (both these options are beneficial to the energy system for other reasons, but neither shifts demand between dry and wet periods, nor offsets the difference in supply required),
- baseload or inflexible generation, which are generally not cost-effective to use in a dry-year role (this currently excludes geothermal generation, given New Zealand's advantages with geothermal resources),
- several small-scale hydro development options that have been identified by stakeholders, but are below the scale of development required to materially mitigate or manage dry year risk, and

- Pumped hydro at most geographic basins around New Zealand, because the basins do not have the technical potential to support a pumped hydro scheme, could only store a relatively small amount of energy, or because flooding them would inundate significant infrastructure or sensitive conservation areas.

We have identified three locations that could potentially support a large-scale hydro-based dry year solution. These could potentially act as full alternatives to a pumped hydro scheme at Lake Onslow, partial alternatives, or could potentially be complementary. We consider that there is merit in investigating further the technical potential energy storage at these locations.

There are no easy solutions to the dry year problem. All options that rely on geography will inevitably impact the local flora and fauna, and the people that draw value from those environments. In taking steps to determine whether these locations could effectively help manage dry year risk, we need to respect the significance of these locations to mana whenua and other stakeholders by engaging with them, and the Department of Conservation in the first instance.

We seek your agreement to proceed with further investigation into the technical potential of:

- **Pumped hydro at Lake Moawhango**: Lake Moawhango is in the Central North Island and already contributes to the Tongariro Power Scheme. A secondary lake could be developed to allow for a pumped hydro scheme storing around 1,000 GWh. The development potential of the area was identified by a geographic information scan (GIS) performed by NIWA to identify potential pumped hydro sites. It was also identified as an option by Genesis Energy, so some previous work exists into its technical potential.
- **Pumped hydro at Taruarau River**: The Taruarau River is a tributary of the Ngaruroro River which flows into Hawkes Bay. NIWA’s scan identified that the river valley has the physical features necessary to develop a pumped hydro scheme of around 1,000 GWh. We are not aware of any previous consideration of the area for hydro development. The area is not conservation land, but may have relatively high cultural, environmental and recreational values.
- **Extending Lake Pukaki**: Lake Pukaki is already New Zealand’s largest hydro storage lake and is part of the Waitaki hydro chain in the South Island. It can currently store 2,300 GWh of energy. There is the potential to raise the lake to provide a further 5,000 GWh of storage. This would enhance the use of existing hydro stations and transmission infrastructure. It is in an area of well-known geology, and may be much lower cost than a pumped hydro development at Lake Onslow. However, its technical potential may not justify the impact on its cultural, environmental and recreational amenity.

Our work continues to identify the potential of options using bio-energy, hydrogen or other green energy vectors, compressed air, and geothermal energy. We have begun a process to procure support for technical investigations into these options.

Alongside this work, we continue our investigation of pumped hydro at Lake Onslow. We are currently preparing a briefing on that engineering, geotechnical and environmental investigation, which will be available in the coming weeks.

Recommended action

The Ministry of Business, Innovation and Employment recommends that you:

a **Note** that in December 2020 Cabinet agreed that the NZ Battery Project will assess the viability of pumped hydro as part of its primary objective, and consider this solution against alternative technologies if they are identified through the process

Noted

b **Note** the NZ Battery Project is focussed on large-scale, long-term energy storage or flexibility options, but that smaller options could have supplementary benefits

Noted

c **Note** the NZ Battery Project has identified potential developments that could be full alternatives, partial alternatives, or complements to a pumped hydro scheme at Lake Onslow

Noted

d **Agree** to further investigation into the technical potential of the following hydro-based options:

- Lake Moawhango (pumped hydro)

Yes / No

- Taruarau River (pumped hydro)

Yes / No

- Lake Pukaki (non-pumped hydro)

Yes / No

e **Note** that engagement with iwi and stakeholders will form the first step of any further investigation of other hydro sites, and that officials will report back to you on the outcome of this engagement

Noted

f **Agree** to the long-list of options and our current screening assessment being published on the NZ Battery Project webpage of the MBIE website

Yes / No

Andrew Millar
Manager, Energy Projects and Programmes
Building, Resources and Markets, MBIE

26 / 08 / 2021

Hon Dr Megan Woods
Minister of Energy and Resources

..... / ...... / ......

Background

1. The purpose of the New Zealand Battery Project (NZ Battery Project) is to identify the best option or options for managing dry year risk in a highly renewable electricity system, with a particular focus on pumped hydro. We are currently in Phase 1 of the project, which is a feasibility study with recommendations due to Cabinet in May 2022.

2. We provided you with an update on the NZ Battery Project in June 2021 [Briefing 2021-3822]. As noted in that update, the NZ Battery Project has four primary workstreams:

- Workstream 1 - Pumped hydro scheme at Lake Onslow
- Workstream 2 - Other pumped hydro and existing hydro assets
- Workstream 3 - Other comparator technologies (i.e. non-hydro options)
- Workstream 4 - Market interactions and implications

3. Workstreams 2 and 3 relate to potential alternatives to a pumped hydro scheme at Lake Onslow. This briefing provides a detailed update on these two workstreams, including the shortlist of alternative options that we have identified for further investigation.

4. We are also continuing our work on the engineering, geotechnical and environmental investigation of pumped hydro scheme at Lake Onslow as part of Workstream 1. A briefing is currently being prepared and will be available in the coming weeks.

We are identifying a short-list of other potential options

5. As agreed by Cabinet in December 2020 [CBC-20-MIN-0090 refers], the NZ Battery Project is assessing the viability of pumped hydro as part of its primary objective, and considering this solution against alternative technologies identified through the assessment process.

6. We have been working to identify what alternative pumped hydro or existing hydro options may exist. Several alternative, non-hydro technologies have also been identified that could potentially achieve the objective of mitigating or managing dry year security of supply under 100 per cent renewable electricity generation.

7. Our work to date has highlighted several reasons why there is value in exploring the other hydro and non-hydro options that exist beyond a pumped hydro scheme at Lake Onslow. For example:

- there may be engineering, environmental or geotechnical constraints for Lake Onslow,
- the transfer limits of the HVDC link between the North and South Islands may place practical constraints on the size of any South Island development,
- there would be material benefit from North Island options even if they are relatively small, since they would avoid HVDC constraints and reduce transmission losses by being closer to demand and new renewable ‘spill’, and
- there are resilience benefits to multiple solutions as they can provide geographical and technological diversity.

8. Some of the options that we have identified could potentially act as a full alternative to Lake Onslow, partial alternatives, or could potentially be complementary to a Lake Onslow pumped hydro solution.

9. We are working to narrow down the long-list of potential options identified (shown in Annex One) to a viable short-list of specific options that best meet the evaluation criteria agreed by

Cabinet in December 2020. For many of these options only limited information exists, and further information is required in order to make a full assessment of their viability.

10. Solving the dry year problem requires a large amount of long-term energy storage or flexibility. For hydro based options, we are focussing our efforts on large-scale solutions that provide around 1,000 – 5,000 GWh of storage or flexibility. We expect that options at the lower end of this range are only likely to present partial or complementary solutions to the problem, but could particularly add value if they are in the North Island.

11. Hydro developments that are smaller than 1,000 GWh could have security of supply benefits in a 100 per cent renewable system—either alone or in combination with a development like Lake Onslow. We do not intend to explore smaller options at this stage. However, it may be appropriate to reconsider them if we identify specific issues or opportunities that are introduced or left unresolved by a dry year solution. We would seek your agreement before investigating other options in that instance.

Workstream 2: Other pumped hydro and existing hydro assets

This workstream is investigating hydro-based alternatives to Lake Onslow

12. Workstream 2 is focussed on:

- identifying whether there are any realistic locations for alternative pumped hydro schemes in New Zealand, and
- exploring what role existing hydro generation assets could play.

13. We have approached identifying options using both a top-down and a bottom-up approach. Specifically, we have:

- commissioned NIWA to undertake a GIS scan of the country to identify potential large-scale pumped hydro in both the North and South Island; and
- engaged directly with large generators to hear their ideas about pumped hydro and existing hydro assets.

14. We discuss our options identification process and our findings below. We seek your agreement to further investigate three options.

15. All the options we discuss have key identifiable stakeholders—including iwi, landowners and environmental groups—that would be impacted by any suggestion of development. We consider these options as highly sensitive, and would seek to engage with relevant parties before taking the options any further.

We commissioned NIWA to undertake a GIS scan of New Zealand

The GIS scan identified the physically available pumped hydro options

16. We commissioned NIWA to use its super-computer to scan the country to identify the full range of locations that have the geographical features necessary to support a large pumped hydro development—as described by certain search parameters. We worked with NIWA to set and then refine those search parameters. We received the final results of the GIS scan in July 2021.

17. The GIS scan is a true prospecting study in that it gives no consideration to factors beyond physical geography, prioritising only the technical potential for a pumped hydro scheme.

18. We have analysed further the potential pumped hydro sites that NIWA has identified with technical potential to identify those locations we think are worth investigating further, taking account of the:

- potential of the options to help manage or mitigate dry year risk through large-scale, long-term energy storage or flexibility,
- potential of the options to perform against the broad evaluation criteria agreed by Cabinet, and
- timeframes we are working to and progress of the wider project, noting the completely undeveloped nature of the options that come from this study.

19. We tested our work with our Technical Reference Group (TRG) who supported our approach.

20. We have also had our screening approach peer reviewed by Doug Hattersley, a professional engineer with extensive New Zealand and global experience in the investigations, design and construction of hydro electric and water storage projects. He provided a detailed review of our search parameters and our analysis of the basins the GIS scan found.

We have had to apply our judgement in identifying options for further investigation

21. We provided NIWA with search parameters that described the geographic features necessary for a large pumped hydro scheme.

22. A pumped hydro scheme needs a geographic basin that can be closed off with a dam to form a lake, with enough water nearby to fill it. The energy that it can hold is determined by the volume of water held by the lake, and the height difference between the lake and point where the water would pass through turbines.

23. Table 1 outlines how we translated this into search parameters, and the limits we applied.

Table 1: Search parameters used by NIWA in GIS scan and limits applied

	Criteria	**Limit applied**	**Explanation**
Fixed search parameters	Distance to water source	Max 30 km	Sets the length for the tunnel through which water would be pumped / expelled. Limit reflects practical construction limits and effect of longer tunnel on efficiency and response time due to higher friction.
	Difference in elevation between upper and lower reservoirs	Min 300 m	A lower height difference: • reduces the potential to install at or near 1,000 MW of capacity. • puts greater reliance on the stored volume of water to achieve the desired energy
Flexible parameters applied after search	Volume of water in basin	Min: 1,000 million m^3 for North Island 2,000 million m^3 for South Island	With a 300 m water column, this sets the minimum energy storage of the basins found at: • 1,000 GWh for the North Island • 2,000 GWh for the South Island
	Time to fill the basin	Max 2 years	Determined by the flow of the water source. Limit reflects economic and risk

			considerations, as utility of scheme is reduced by a slow fill rate.[1]
	Height of dam	Max 120 m	Affects cost of construction – set based on comparison with Lake Onslow
	Length of dam	Max: 3 km if straight 6 km if curved	Affects cost of construction – set based on comparison with Lake Onslow

24. There is considerable scope for judgement in setting the parameters in Table 1.

25. We treated the maximum distance to a water source and minimum height difference as fixed limits, as these are limits beyond which the practicality of a scheme would be affected. In his review, Doug Hattersley agreed with the limits we applied to these parameters.

26. The remaining parameters are ones that are more flexible as they primarily represent an economic or design consideration. We purposely set the search criteria for these much wider than the limits we applied, and did not use them to automatically rule sites out. Rather, we considered them in our subsequent analysis of the GIS scan outputs, which allowed us to weigh them up in the context of the other features of each site.

27. In addition to these flexible parameters, we also considered whether sites identified by the GIS scan would significantly inundate:

- towns,
- significant infrastructure—for example, there were options that would flood the HVDC and large sections of state highways with no obvious alternative route, and
- high-value conservation areas.

We reviewed our approach based on independent feedback

28. Doug Hattersley questioned whether we should have relaxed some of the limits we set for the flexible parameters. He also suggested an additional limit that would require the lake to refill within each year, given certain assumptions about its use.

29. We reconsidered our full short-listing process given Mr Hattersley's feedback.

30. After factoring the inundation impacts, relaxing the limits we applied did not change our overall assessment of the options.

31. The additional limit suggested by Mr Hattersley applies a more stringent test than the fill time limit we used, and would have excluded the only options that we had otherwise identified for further investigation. We have therefore considered this limit in the broader context of the merits of the options.

We progressively narrowed the options down and have short-listed two North Island options

32. With our broadest parameters, NIWA's GIS scan identified 106 potential pumped hydro sites. Of these, 68 were in the South Island, and 38 were in the North Island.

33. The sites are generally spread across the Southern Alps and mountains through the Central North Island, which are the main areas where the height parameter can be met. Annex Two

[1] Filling 1,000 GWh from a river requires a flow rates of 20m3/s, or 40m3/s if only half the flow of the river it taken to fill. Only 2% of New Zealand rivers have median flow greater than 40m3/s.

shows all 106 sites on maps of the North and South Islands. The lake that would be created is shaded in grey, with a purple line drawn from the notional dam to the water source.

34. We progressively narrowed the 106 sites down to a short-list of three options, as outlined in Table 2. This is also demonstrated in Annex Three, which shows the energy storage potential of the 106 sites that the automated GIS scan found. An explanation for why we excluded each option that met the volume limit is given in Annex Four.

Table 2: Number of sites that passed progressive application of criteria

Hierarchy of criteria	**Number of sites**
Meets fixed search parameters	106
Additionally meets volume limit (1,000 million m^3 for North Island 2,000 million m^3 for South Island)	31
Additionally meets other flexible parameter limits, and does not inundate towns or significant infrastructure	10
Additionally does not inundate large areas of conservation land	3

35. Lake Onslow is a clear stand-out from the scan. It has the largest energy storage potential of all the sites identified at 8,000 GWh. It is one of the remaining three sites for investigation as a pumped hydro scheme, and the only one in the South Island.

36. We note that a pumped hydro scheme at Lake Onslow would inundate some conservation land, as shown in Annex Five.[2] However, it would affect much smaller areas of conservation land, compared to the seven we excluded in the final step of our analysis. Those seven would affect larger areas of conservation land that may be more sensitive by comparison.

37. We identified two potential North Island options. Both are relatively small at around 1,000 GWh, but could be complements or partial alternatives to Lake Onslow.

38. One of these options—Lake Moawhango—has also been identified by stakeholders as a potential development option, as discussed below. The Taruarau River is an option that had not been identified prior to this study. Both options are in the mountains South East of Lake Taupō.

39. Maps of both Lake Moawhango and Taruarau River are shown in **Error! Reference source not found.**. NIWA's scan identifies multiple ways a lake could be made depending on where dams are placed—potentially including multiple curved dams. We have included just two examples for each location on these maps, noting NIWA is not scientific in its dam placement. We emphasise that the maps do not represent a scheme design and are intended as illustrative only.

We have been engaging with industry to hear their ideas for development options

40. Generators have been forthcoming in presenting potential hydro options of which they are aware. These have included studies that were held by the Electricity Corporation of New Zealand, which were passed on to generators after reform, as well as options of their own development. Other interested parties have also offered ideas.

[2] The impact of a pumped hydro scheme on these conservation areas is included within the scope of Workstream 1.

41. While these contributions have been positive, their options are largely outside the scope of the NZ Battery Project, which is investigating large scale options to address dry-year risk. For example:

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42. Commercial identified a potential pumped hydro development at Moawhango that was passed on by the Electricity Corporation of New Zealand. The same site was also short-listed from the GIS scan. This potential development is in the North Island, and would potentially be large enough to help manage or mitigate dry year risk. We consider pumped hydro at Lake Moawhango justifies further investigation, as discussed below.

43. Other parties have suggested the potential to raise Lake Pukaki to increase hydro storage. We also discuss this option below, as we consider it has potential merit, but may have some potentially significant environmental and stakeholder impacts.

44. Stakeholders have also suggested options that would involve drawing Lake Taupō down further. Lake Taupō's size and relationship with the Waikato River hydro chain makes it technically appealing.

45. However, Lake Taupō has a large number of stakeholders that would be affected by drawing down the lake, including thousands of local residents and businesses. Ngāti Tūwharetoa is mana whenua and holds ownership rights of Lake Taupō so would need to support any changes to its use. Residents, businesses and iwi associated with the Waikato River would also be affected because of consequential changes to the river's flow.

46. Given the complex stakeholder issues, we do not propose pursuing this option further while there are other options that can be explored.

47. We remain open to further suggestions for hydro developments from all stakeholders.

We seek your advice on whether to further investigate three options

We consider that three options warrant further investigation

48. We consider that our work to investigate other hydro options has been comprehensive, and identified some promising options.

49. However, options that rely on geography will inevitably impact the local flora and fauna, and the people that draw value from those environments.

50. Making the trade-off between the potential national benefit of a development and the potential consequences for communities and the environment is not straight-forward. We have excluded potential options where we can be confident the latter would take precedent, including those that would affect large areas of conservation estate or large numbers of stakeholders. For other options, we consider more information on the options and its impacts would be required to make that assessment.

51. The options we have identified are at the very earliest stages of development, and are largely hypothetical. Further investigation into their technical potential may allow us to quickly determine that they could not provide an effective solution to the dry year issue, making a detailed analysis of their impacts unnecessary.

52. Alternatively, further investigation may determine that one or more of the options below could be an effective substitute or compliment to pumped hydro at Lake Onslow. This would then require a more detailed investigation of impacts and trade-offs.

53. However, in undertaking any further work, we need to respect the cultural and environmental significance of the locations by engaging with mana whenua and the Department of Conservation (DOC) in the first instance. This early engagement may also determine the value of proceeding further.

54. We consider it would be appropriate to undertake preliminary investigations to understand the technical potential of three options. We have also sought an initial high-level view from DOC on the environmental, recreational and cultural values of each option. The three options are:

- **<u>Lake Moawhango 1,000 GWh pumped hydro, Central North Island</u>**

  There is an existing artificial lake at Moawhango, which was formed by damming the Moawhango River. It currently provides energy storage for the Tongariro Power Scheme, which is owned by Genesis Energy. It is located entirely within New Zealand Defence Force operations in the Waiouru Military Training Area. A second, upper lake had been proposed during the original investigations of the Tongariro Power Scheme, but was not pursued. Developing an upper lake would allow water to be pumped between the two in a similar way to the Lake Onslow proposal.

  Lake Moawhango has spiritual significance for Ngāti Tūwharetoa.

  DOC agreed that Lake Moawhango could be worth investigating further with Ngāti Tūwharetoa, noting that Lake Moawhango has similar landscape and recreational values to Lake Onslow. They also note that there are some environmental values (wetlands and fish species) present at Lake Moawhango.

  Lake Moawhango is an attractive option, as water from Lake Moawhango travels through Rangipo and Tokaanu Power Stations, plus the nine hydro stations on the Waikato River. As a result, each cubic meter of water released from the lake can generate a large amount of energy on its path to the sea. Even so, it is still at the smaller end of the scale of what we are considering under the project. Furthermore, previous work done on the idea suggests there would be limits on how wide the outflow tunnel could be, which would cap the energy it could provide across the day.

  The potential to develop Moawhango was raised to us Commercial Information It was also identified by the GIS study discussed above.

- **<u>Taruarau River 1,000 GWh pumped hydro, Central North Island</u>**

  The Taruarau River rises in the Kaimanawa Ranges. It is a tributary of the Ngaruroro River, which flows into the sea between Napier and Hastings. NIWA's study identified the potential to dam the Taruarau River to create a lake, and feed from/into the Ngaruroro River further downstream from its natural ingress.

  The lake that would be created appears to affect an area of un-improved land that is neither productive farmland, forestry land, nor a conservation area. It is remote from infrastructure.

  The Taruarau River is located within the traditional boundary of two Treaty Settlement Entities—Heretaunga Tamatea and Ngāti Tūwharetoa—who may oppose a development. More broadly the Taruarau River is associated with the early origins of

Kahungungu and iwi associations with the Ruahine Range, and has high spiritual value.

DOC notes that the Taruarau River is currently under an application for a Water Conservation Order (WCO) as part of the Ngaruruoro River. There are mapped hot springs present in the catchment. Three species of indigenous fish have been found in the Taruarau River, and recreational values are also present.

DOC agreed that Taruarau River could be worth investigating further, while providing some caution around the cultural and recreational values.

- **Lake Pukaki 5,000 GWh non-pumped hydro, South Island**

  Lake Pukaki is New Zealand's largest hydro storage lake, and can hold around 2,300 GWh of energy. The water stored flows through Meridian's Waitaki hydro chain. Raising the existing lake by 29 metres has the potential to add a further 5,000 GWh of storage.

  This development would not have the same capability as a pumped hydro scheme at Lake Onslow. However, the extra storage would support dry year security of supply by allowing the Waitaki hydro scheme to run harder and longer during dry periods. Some extra generation capability could be added, including at the new dam. There is also the potential to add the ability to pump water from Lake Pukaki back up-stream into Lake Tekapo. This capability could be added at a later stage when, and if, it was deemed valuable.

  This option has some strong attractions, in that it would affect an already developed area with well-known geology, and utilise a long chain of existing power stations and transmission infrastructure. The dam construction would be the primary cost. It could hence be a much less costly option than Lake Onslow, which requires extensive tunnelling.

  The inundation area from raising Pukaki would be quite small, given the high-sided nature of the ravine. However, some roading (including State Highway 80) and homesteads would be impacted. There is also some conservation land on the Tasman River bed, and DOC has suggested several fish species and waterfowl could be impacted.

  Further, while the lake has already been manipulated for hydro development, Ngāi Tahu may have concerns about extending water use in the area as the lake has particular cultural significance and is a significant taonga.[3] DOC suggested that these concerns may make this option a difficult proposition, even for further investigation.

  This option was not identified by the GIS scan, as it was outside the scope of that work. It is attractive due to its sheer size and likely lower construction costs. However, we note DOC's concerns, and suggest that this option be investigated further only after discussion with Ngāi Tahu.

  Commercial Information

55. Maps of these three options are attached in **Error! Reference source not found.** and Annex Seven.

[3] Ngai Tāhu has statutory acknowledgement for Lake Pukaki in their 1998 settlement legislation. "Pukaki is referred to in Ngāi Tahu tradition as the basin that captures the tears of Aoraki: a reference to the melt waters that flow from Aoraki into the lake in the spring time".

56. We seek your agreement to progress preliminary scoping investigations into the three options above. These options each have potential benefits as alternatives or complements to pumped hydro at Lake Onslow, so may support a more successful project outcome, but further investigation of their technical storage potential is required.

57. However, investigating these further would require careful stakeholder and communications management. The complexity and time involved in effective stakeholder and communications management also increases with the number of stakeholders involved.

58. If we were to further investigate the technical storage potential of these different hydro based options, the next steps would be to:

- engage with relevant iwi and stakeholders (including local government) that we wish to undertake initial high-level scoping investigations of these options, and offer to discuss the project and nature of the investigations with them,
- report back to you on the outcomes of these conversations,
- commission desktop level studies of each option to understand their storage potential, engineering challenges, and environmental values, and
- incorporate these options into our consideration of the market interactions and implications under workstream 4.

Workstream 3: Other comparator technologies

This workstream is investigating all other potential solutions

59. Workstream 3 is focussed on identifying other non-hydro developments that could meet the objectives of the NZ Battery Project.

60. Under this workstream we have:

- undertaken an internal desktop study to rule out options where we can attain sufficient information,
- begun a process to procure support for technical investigations into options for which we do not have sufficient information to form a robust view of their feasibility, and
- engaged with stakeholders to draw out their ideas for non-hydro developments, and test our approach to date.

61. We discuss each of these pieces of work and our findings in turn.

We have excluded several options based on a desk-top study

62. The project team undertook an internal desk-top study in the first instance to narrow the long-list of non-hydro options down into a more manageable short-list.

63. Our current assessment of whether the options are likely to perform against the evaluation criteria agreed by Cabinet is indicated in Annex One. We tested this evaluation with the TRG and refined the assessment based on their feedback. It will also be peer reviewed as part of the Technical Scope of Work drafting discussed in the next section.

64. In some cases, we are confident we have sufficient information to determine whether options were likely to perform against the evaluation criteria. We have ruled out options that:

- **Are not renewable**. This includes the status quo (i.e. continued extensive use of fossil fuels in a dry year), an interconnection with Australia, and fossil-fuelled options that manage emissions through carbon capture and storage.
- **Have broader social effects that have a high cost**. This is the case for large-scale, ad-hoc demand response, which could affect a business' operations for a long period, affecting jobs and communities.
- **Are not technically suited** to providing the long-term response necessary to address the dry year issue, and/or come at a cost that is an order of magnitude greater than what we expect for other options. This includes:
    - i. most electrically-charged storage options (e.g. lithium ion batteries), which are small-scale, can lose charge over time, and rely on frequent cycling to recover their high costs,
    - ii. short-term demand response, which shifts demand over hours or days, and energy efficiency, which reduces overall demand (both these options are beneficial to the energy system for other reasons, but neither shifts demand between dry and wet periods, nor offsets the difference in supply required), and
    - iii. baseload or inflexible generation, which are generally not cost-effective to use in a dry-year role (nothing this excludes geothermal, which we are still considering given New Zealand's advantages with geothermal resources).

65. There are several options for which we do not have sufficient information to form a robust view of their feasibility.

66. In particular, bio-energy and hydrogen are technologies of emerging interest, within which there is a spectrum of options. They also have nascent international and domestic markets, with risks and opportunities that should be explored.

67. Compressed air is similarly attracting attention overseas. We anticipate compressed air may prove better suited to short-term, small scale energy storage, but consider further investigation is appropriate before making that conclusion.

68. The TRG advised that we further investigate geothermal energy for dry year security, though we had initially discounted it. There were two reasons it advised this. One is that there are novel geothermal technologies emerging. The other is that the traditional approach of operating geothermal generation in a 'baseload' mode is an economic one made by profit-maximising businesses. Lower utilisation may be better for the geothermal resource, and may come at a cost within a similar ballpark to other options we are considering. Given this advice, we consider it appropriate to continue our investigations into the potential of flexible geothermal.

We are procuring expert support on the feasibility of other technology options

69. We are seeking support to further investigate the options that we have not been able to rule in or out with the information we have.

70. As a first step, we have commissioned ARUP New Zealand Limited (ARUP) to undertake the drafting of a Technical Scope of Work for a technical investigation of the remaining options. This small piece of work is underway, and will also provide a peer review of our assessment of the options so far. The Technical Scope of Work will be used as an important input to a subsequent procurement for a provider to:

- undertake a study that would identify the range of practical options for generating 1,000-5,000 GWh per year of electricity for dry-year support from 2030 using:

    i. biomass, biogas, and biofuels,

    ii. hydrogen, or other green energy vectors (e.g. green ammonia),

    iii. compressed air, and

    iv. geothermal energy.

- work with us to narrow down the practical options into a small number of options that best meet our criteria, and
- develop preferred options to a level of detail that they can be usefully compared with the hydro options being assessed under other workstreams.

71. We are aiming to begin procurement for the investigations in September. We expect the study to identify between one and three options that could be alternatives or complements to Lake Onslow.

Stakeholders have identified options of which we are keeping abreast

72. We have been engaging with a wide range of stakeholders that have provided suggestions for dry year solutions, or are undertaking their own relevant studies. These conversations have been on a confidential basis. Some specific options are:

- **Firing Huntly on biomass**

  Genesis Energy is undertaking a three-part study to understand the potential to transition one of the Huntly coal units to biomass. Genesis has suggested they are open to keeping us up to date with their progress. The study will involve:

  - an engineering assessment of the Huntly boilers' current condition and likely life-span,
  - a desktop assessment of biomass fuel options focussing on domestic sources in the first instance, including the associated transport and storage options, and
  - a plant capability study and test-burn. This will involve assessing the boiler's ability to operate on biomass and the implications for the plant of doing so. Genesis Energy is aiming for a test-burn early in 2022.

- **Hydrogen production in Southland**

  Contact and Meridian are undertaking a study of the potential to produce hydrogen in the lower South Island. They have sought registrations of interest in developing the plant, which could include contract terms providing for planned dry-year demand response. We are planning conversations with Contact and Meridian in coming weeks to better understand their proposal and its relevance to the project.

  You also received a briefing on 29 July [Briefing 2122-0256 refers] regarding a proposal from Fortescue Future Industries on a hydrogen development in Southland.

- **Eavor geothermal**

  Eavor is a new technology development that utilises oil and gas drilling technology and a closed-loop geothermal system (i.e. not relying on geothermal fluids). At this stage we are unsure of its potential to provide dry year security of supply at a realistic cost, but we are continuing to engage with Eavor to determine this.

73. We will continue to engage with stakeholders on all potential developments that could meet the project purpose, and consider how we incorporate them into our advice.

74. The expert support we are procuring will provide an independent view-point on these options, which will allow for sense-checking and could inform the extent to which these options could justify government support.

Next steps

75. If you agree to the recommendations, we will initiate conversations with mana whenua and stakeholders related to specific hydro options, and will report back to you on their outcome. We will also start preparing the procurement process for further technical investigations.

76. We propose updating the NZ Battery Project webpage of the MBIE website with our current assessment of the long-list of options in order to provide stakeholders with visibility around this screening process.

77. The project team will also continue:

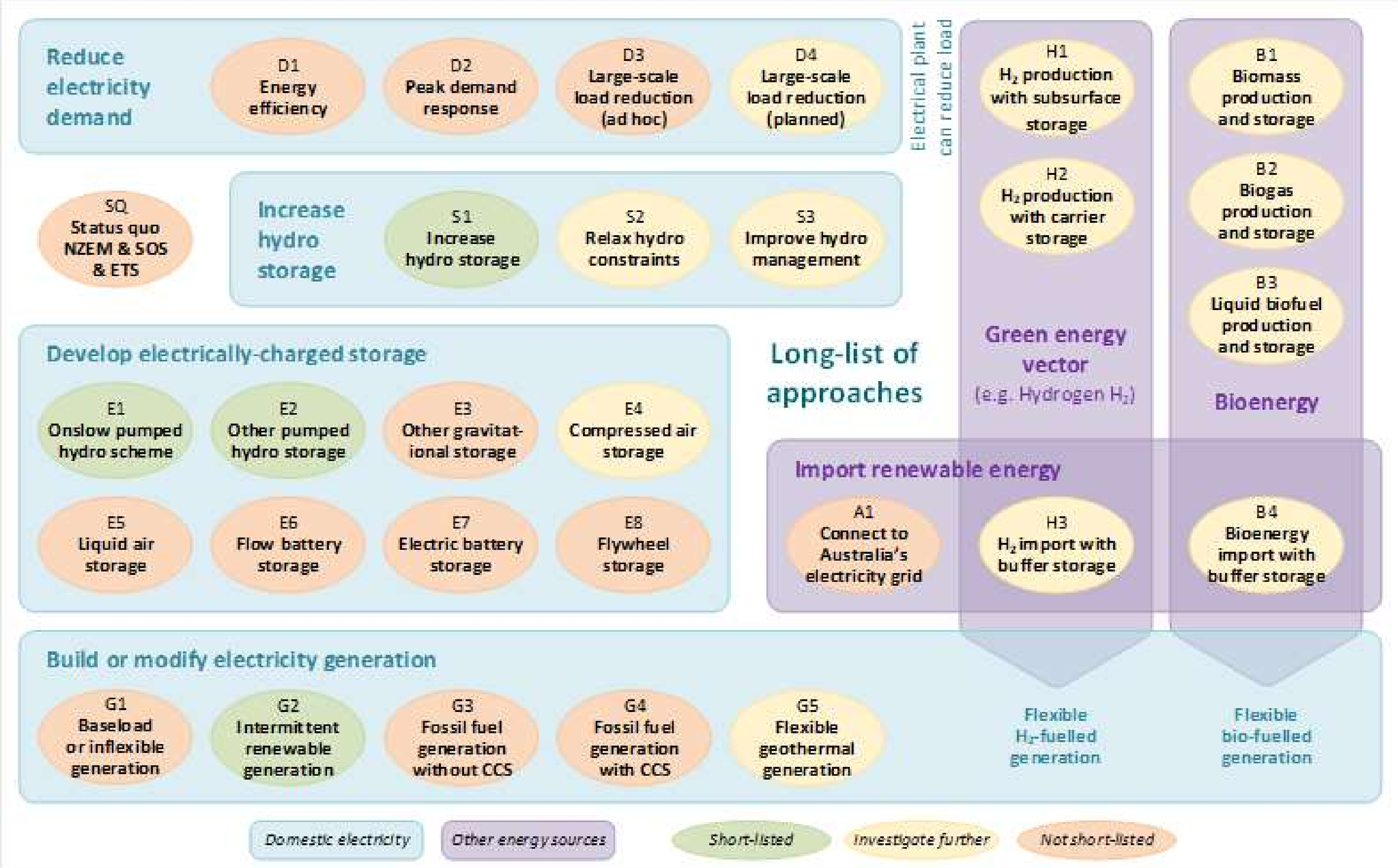
- advancing its procurement for the technical investigation into other technology options, and managing the work already commissioned,
- working with the TRG to ensure appropriate consideration and review of the work undertaken, and
- providing you with regular updates through the weekly report.

78. We expect to provide you another comprehensive update on our investigations and progress in December, or earlier if matters arise.

Annexes

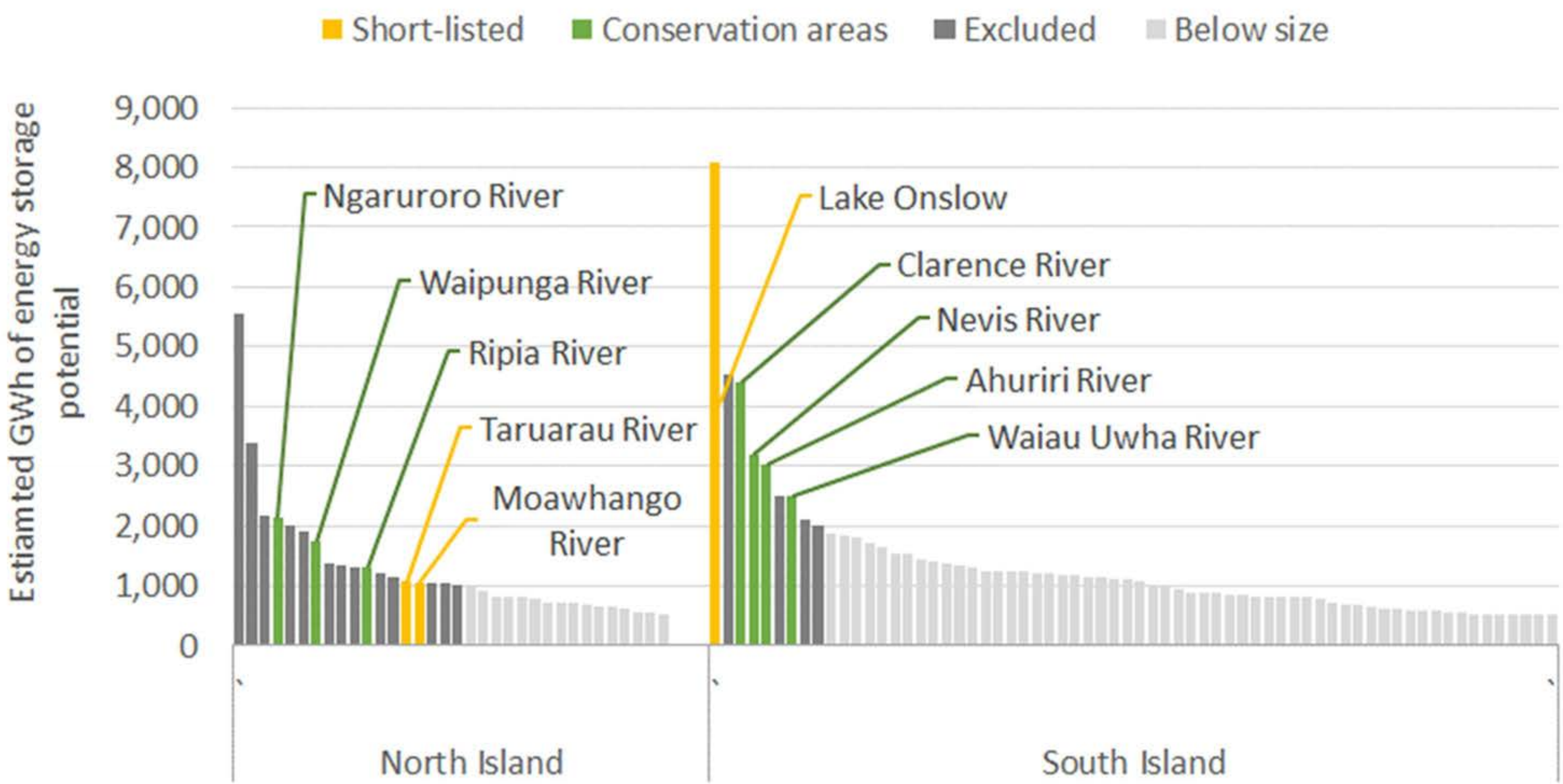
Annex One:	Long-list of development options
Annex Two:	Basins identified by NIWA GIS scan – North Island and South Island
Annex Three:	Energy storage potential of sites identified by NIWA GIS scan
Annex Four:	Reasons for excluding long-listed pumped hydro options
Annex Five:	Land ownership around raised Lake Onslow
Annex Six:	Maps of Lake Moawhango and Taruarau River
Annex Seven:	Increasing storage in Lake Pukaki

Annex One Long-list of development options



Annex Two Basins identified by NIWA GIS scan – North Island and South Island

Annex Three Energy storage potential of sites identified by NIWA GIS scan



Annex Four Reasons for excluding long-listed pumped hydro options

Option	Island	Location	Stored energy [TWh]	Dam height [m]	Dam length [km]	Fill time [y]	Min fill time [y]	Operable Factor*				Comment
								1	2	3	4	
Lake Onslow	South	Lammerlaw Range, Otago	8.1	100	2.67	1.51	0.6	6.29x	5.76x			Relocate of transmission line, may inundate portion of conservation land – depending on size
Lake Rotoroa	South	Nelson Lakes, Nelson	4.5	120	2.82	6.73	4.4					Protected area - Nelson Lakes National Park
Clarence River	South	Inland Kaikoura Range, Marlborough	4.4	120	2.76	2.46	1.7	2.07x	1.89x			Inundates HVDC link, protected area - Molesworth recreation reserve
Nevis River	South	Hector Mountains, Otago	3.2	120	2.96	0.70	0.7	5.31x	4.87x			Protected area - Remarkables conservation area
Ahuriri River	South	Barrier Range, South Canterbury	3.0	100	2.86	0.92	0.9					Protected area - Ahuriri conservation park
Waiau River	South	Spenser Mountains, North Canterbury	2.5	120	2.60	2.01	2.4	1.45x	1.33x			Fails on storage size, protected area - St James Conservation Area
Lake Waikaremoana	North	Huiarau Range, Eastland	5.5	60	2.98	8.15	1.5					Unphysical - built on lake surface, protected area - former Urewera NP
Motu River	North	Raukumara Range, Eastland	3.4	120	2.33	8.44	2.5					Inundates State Highway 2, Motu & Matawai, min fill time >2y, protected area - Waioeka Gorge scenic reserve
Aniwaniwa Stream	North	Huiarau Range, Eastland	2.2	120	4.14	2.68	1.2	0.94x	0.86x			Dam length > 3km, Protected area - former Urewera NP
Ngaruroro River	North	Kaimanawa Mountains, Hawke's Bay	2.1	120	2.00	4.45	2.1	0.56x	0.51x			Protected area - Kaweka & Kaimanawa Forest Park

Option	Island	Location	Stored energy [TWh]	Dam height [m]	Dam length [km]	Fill time [y]	Min fill time [y]	Operable Factor*				Comment
								1	2	3	4	
Mohaka River	North	Kaimanawa Mountains, Hawke's Bay	2.0	120	1.28	6.37	3.2	0.35x	0.32x			Protected area - Kaimanawa Forest Park, min fill time > 2y
Takaputahi River	North	Raukumara Range, Eastland	1.9	120	1.23	5.63	2.9					Min fill time > 2y, protected area - Raukumara Conservation Park
Waipunga River	North	Huiarau Range, Eastland	1.8	100	2.91	1.47	0.8	1.39x	1.27x			Protected area - Kokomoka & Waipunga Forest
Koranga River	North	Raukumara Range, Eastland	1.4	120	2.05	3.46	2.5					Min fill time > 2y, protected area - Waioeka Conservation Area
Rangitikei River	North	Ruahine Range, Whanganui-Manawatu	1.3	120	2.58	3.39	2.5	0.46x	0.42x			Inundates Taihape-Napier Road
Hautapu River	North	Huiarau Range, Eastland	1.3	120	2.26	0.78	0.6					Protected area - Waipunga Forest & Whirinaki Te Pua-a-Tane Conservation Park
Ripia River	North	Kaimanawa Mountains, Hawke's Bay	1.3	120	1.57	1.56	1.2	0.96x	0.88x			Protected area Rangitaiki Conservation Area
Inangatahi Stream	North	Kaweka Range, Hawke's Bay	1.2	120	5.66	1.48	1.2	0.95x	0.87x			Dam length > 3km, Protected area - Hutchison Scenic Reserve
Mangaetoroa Stream	North	Adjacent to Raetihi, Whanganui-Manawatu	1.2	100	1.10	0.42	0.4					Inundates Pipiriki-Raetihi Road
Taruarau River	North	Kaweka Range, Whanganui-Manawatu	1.1	100	2.97	1.72	1.6	0.75x	0.69x	1.75	1.44	No inundation of major infrastructure of protected areas

Option	Island	Location	Stored energy [TWh]	Dam height [m]	Dam length [km]	Fill time [y]	Min fill time [y]	Operable Factor*				Comment
								1	2	3	4	
Moawhango River	North	Kaimanawa Mountains, Whanganui-Manawatu	1.1	100	2.97	1.86	1.8	0.64x	0.59x	1.50	1.23	No inundation of major infrastructure of protected areas
Waipakihi River	North	Kaimanawa Mountains, Whanganui-Manawatu	1.1	120	2.99	1.41	1.3					Inundates State Highway 1 - Desert Road
Hautapu River	North	Between Waiouru & Hihitahi, Whanganui-Manawatu	1.0	120	5.84	1.92	1.9	0.60x	0.42x			Dam length > 3km, protected area - Hihitahi Forest Sanctuary
Mangoiwa Stream	North	Northwest of Taihape, Whanganui-Manawatu	1.0	100	5.99	2.36	2.3					Dam length > 3km, min fill time > 2y

*Operable factors – Recommendation of Doug Hattersley. Ratio of volume of water able to be pumped up in remainder of year over the volume released in operating mode (listed below)

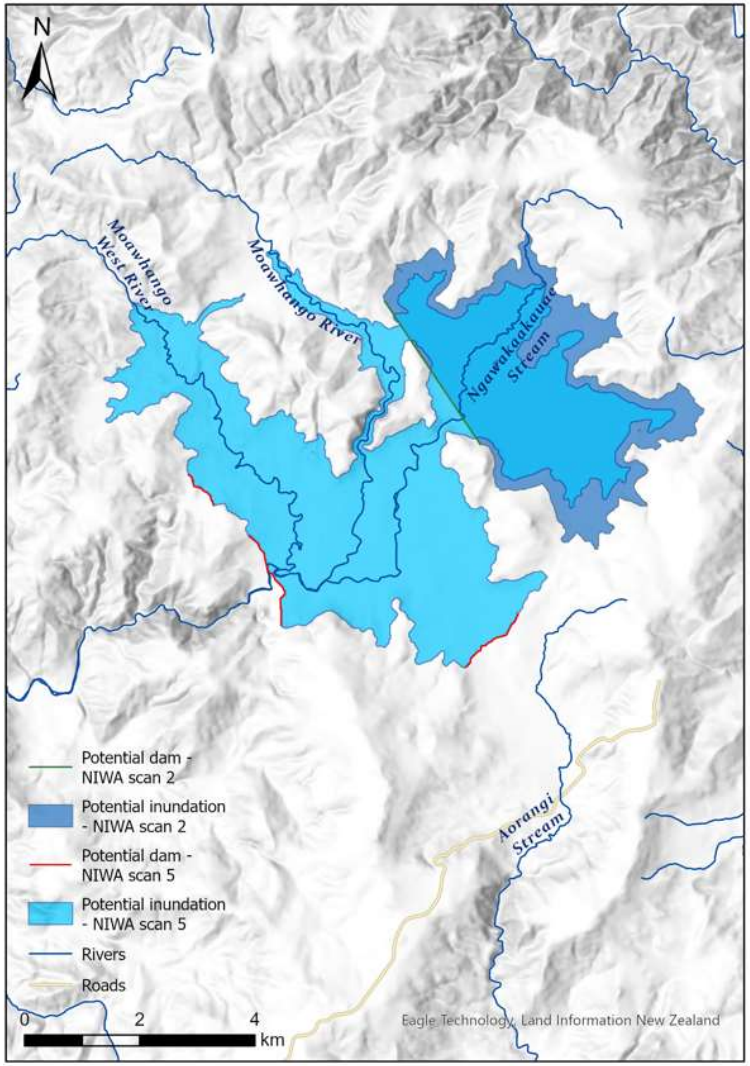
1. 250MW plant operating at capacity, continuously for 3 months – leaving 9 months to refill.
2. 1,000MW plant operating at capacity, continuously for 1 month – leaving 11 months to refill.
3. 250MW plant operating at capacity, for 12 hours per day for 3 months (releasing half the volume as case 1)– leaving 9 months to refill.
4. 1,000MW plant operating at capacity, for 12 hours per day for 1 month (releasing half the volume as case 2) – leaving 11 months to refill.

Annex Five Land ownership around raised Lake Onslow

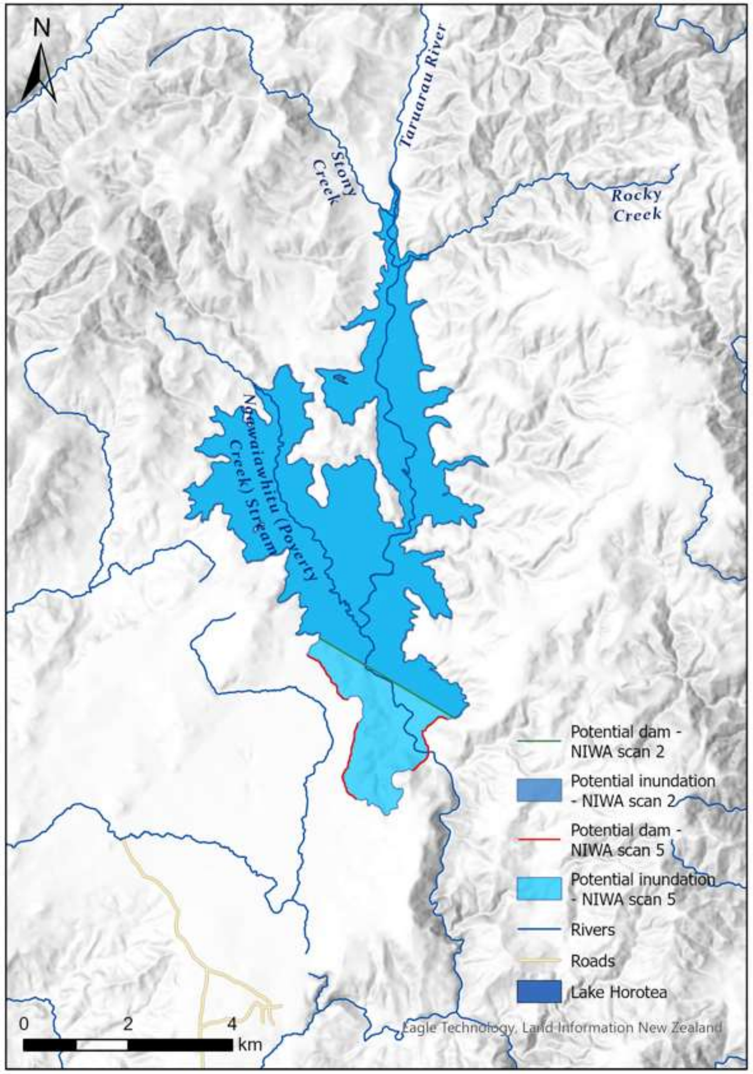
Commercial Information

Annex Six Maps of Lake Moawhango and Taruarau River

Lake Moawhango



Taruarau River



Annex Seven Increasing storage in Lake Pukaki