BEFORE THE FRESH WATER HEARINGS PANEL APPOINTED BY THE OTAGO REGIONAL COUNCIL

IN THE MATTER OF	of the Resource Management Act 1991
AND	
IN THE MATTER OF	the Proposed Otago Regional Policy Statement 2021 Fresh Water Planning Instrument Hearing
SUBMITTER	Contact Energy Limited

STATEMENT OF EVIDENCE BY BOYD MUNRO BRINSDON

28 JUNE 2023

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1. INTRODUCTION AND BACKGROUND

1 My name is Boyd Munro Brinsdon.

2 I am the Head of Generation – Hydro at Contact Energy Limited (**Contact**). I have held this role since 2015. I have been employed at Contact since January 1997, and have held several other roles including Generation Controller, Market and Dispatch Manager and Head of Electricity Trading. I have a Diploma in Electricity Supply / Power System Management, and a background in business management and electrical contracting.

3 I am familiar with the Clutha Hydro Scheme (**CHS**), its role in the broader Aotearoa New Zealand Electricity Market (**NZEM**), and the conditions of resource consent that enable its continued operation.

4 This statement is corporate evidence and not expert evidence. I am authorised by Contact to provide this evidence on its behalf.

2. SCOPE OF EVIDENCE

5 The purpose of my evidence is to provide:

(a) an overview of Contact's assets in the Otago Region, being the CHS, including a description of its key features, its current resource consents, its land-holdings, how it operates within the broader electricity generation network and what the future operation of the CHS might be;

(b) an overview of how the form and function of the Clutha Mata-Au has changed as a result of the CHS, and how this impacts the flow of sediment through the catchment along with the regimes in place to manage this;

(c) an overview of the condition frameworks for the CHS relating to fish passage and habitat, and the work Contact is undertaking in respect of those conditions; and

(d) a discussion of the key issues and concerns that Contact has with the proposed Otago Regional Policy Statement 2021 - Fresh Water Planning Instrument (**proposed RPS**).

3. EXECUTIVE SUMMARY

6 Contact is the second-largest electricity generator/retailer in Aotearoa New Zealand with a flexible and largely renewable portfolio of electricity generation assets. Contact

owns and operates 11 generating stations across the country, and generally produces 80-85 percent of its electricity from renewable hydro and geothermal resources.

7 Contact is committed to contributing to the achievement of Aotearoa New Zealand's climate change targets and assisting the New Zealand Government to meet its climate change goals. To that end, Contact's target is to reduce Scope 1 and 2 greenhouse emissions by 45% compared to a 2018 baseline; and is currently investigating new renewable electricity generation (**REG**) opportunities in the lower South Island and New Zealand more broadly.

8 A commitment to REG is also a core part of Contact's sustainability tikanga which informs and guides the way we run our business.

9 Within the Otago region, Contact operates the CHS. This is nationally significant infrastructure and contributes 10 percent of Aotearoa New Zealand's overall electricity supply and on average 12 percent of country's REG. Within the broader electricity system, the CHS has a critical role providing an important source of flexibility which is needed to counter hourly, daily, and seasonal variations in demand and supply. This is discussed in more detail in **Mr David Hunt's** (**Mr Hunt**) statement of evidence (attached as **Appendix A**) which was presented at the hearings on the non-freshwater components of the RPS earlier this year.

10 The construction and operation of the CHS has significantly altered the form and function of the Clutha Mata-au. The presence of two large structures, being the Clyde and Roxburgh Dams, has not only resulted in the formation of both Lake Roxburgh and Te Wairere / Lake Dunstan but impacted upon the natural flow of sediment through the catchment, and the ability for native fish to move from the upper and lower parts of the river (and vice versa). Contact has requirements in its conditions of consent to manage sediment, and to implement the best practicable option for native fish passage.

11 Contact wants to ensure that the provisions of the proposed RPS appropriately protect and provide for this critical infrastructure now and in the future and recognise its increasing role in *firming* our electricity system.

12 In terms of the proposed RPS, Contact has several concerns, which are addressed in detail in section 6 of this evidence. To address these concerns, Contact supports the amendments to the proposed RPS set out in the expert planning evidence of **Ms Claire Hunter** (**Ms Hunter**).

4. CONTACT ENERGY LIMITED

13 I am conscious that a statement of evidence from **Ms Jacqueline Nelson** (**Ms Nelson**), Contact's Chief Development Officer, was provided to the Panel hearing the non-freshwater provisions of the proposed RPS. This provides a comprehensive overview of Contact, including its key activities and operations, objectives as they relate to its contribution to the Government's greenhouse gas emission reduction targets, and sustainability programme.

14 I do not intend to repeat what was in Ms Nelson's statement, and instead in the following paragraphs will summarise the key points. I have also provided a copy of Ms Nelson's statement of evidence as **Appendix B**.

15 In summary, Contact:

(a) Is the second-largest electricity generator/retailer in Aotearoa New Zealand and is listed on both the New Zealand and Australian Stock Exchanges.

(b) Commenced operations in 1996, and today has 11 generation stations across the country, and 80-85 percent of this from renewable hydro and geothermal resources.

(c) Has increased the proportion of its generation portfolio from renewable sources from 55 percent in 2008 to almost 95 percent by 2025.

(d) Has a vision to "(b)uild a better Aotearoa / New Zealand by leading the decarbonisation of its economy". This involves the development of new REG assets and the on-going decarbonisation of its current generation portfolio.

16 Contact also seeks to continuously improve its sustainability and environmental performance using the ISO 14001:2015 Environmental Management System.

5. CLUTHA HYDRO SCHEME

17 As noted in **Ms Nelson's** evidence, Contact's key asset in the Otago region is the CHS. The CHS in its entirety has a maximum output of 752 MW with an average annual output of about 3,900 GWh.

18 The CHS contributes almost 10 percent of Aotearoa New Zealand's overall electricity supply and on average 12 percent of its REG. It is also a source of controllable energy which helps in balancing the overall electricity system (as discussed further in the evidence of **Mr Hunt**).

19 The CHS is operated as one integrated / interdependent management unit from our control room at Clyde. There are three primary structures associated with the CHS being the Hāwea Dam, the Clyde Dam, and the Roxburgh Dam. The relationship between these structures is described in **Ms Nelson's** evidence from section 7.3.

20 Contact's right to store water in Lakes Dunstan, Roxburgh and Hāwea and the Hāwea River to its confluence with the Clutha Mata-au is created and controlled by an easement granted to it by the Crown when the power generation assets were sold to it. That right is referred to as an "Operating Easement".

21 The Operating Easement is a series of easements for each of the lakes and relevant sections of the Hāwea/Clutha Mata-au/Kawarau Rivers. Under the easements, Contact's rights include:

(a) the right to store water on the land described;

(b) the right to install and operate electricity works from time to time on that land; and

(c) ancillary rights including the lawful ability to store sediment on the land subject to the easement.

How the CHS operates within the broader electricity generation network

22 **Mr Hunt** provides a comprehensive overview of how the CHS must be operated as an integrated part of Aotearoa New Zealand's total electricity generation system. This is summarised in **Ms Nelson's** evidence as follows:

(a) The CHS is a source of controllable energy (particularly in the short term) which helps in balancing the overall electricity system. Hydro-electricity generation with storage capacity can offer flexibility and speed of response, which is not the case for wind and/or solar plants.

(b) The demand for electricity varies over time (i.e. days and seasons) and generation (supply) must precisely match demand. Swings in demand can be large. Therefore, hydro schemes ideally need to be able to respond not only to daily changes in demand, but also to immediate fluctuations in demand and overall system security. This is enabled through access to water storage. Therefore, water storage is a critical component of hydro-electricity schemes.

(c) There are also operational constraints (both physical and required by consent conditions) due to the requirement to operate the Roxburgh and Clyde Dams in conjunction with one another. For example, to ensure Lake Roxburgh's levels are within the limited consented range, roughly the same flow must pass through the dams.

(d) Each day decisions are made as to how Contact will generate electricity to meet its current and future electricity supply commitments and demand while complying with its consents to operate.

(e) At the same time, Contact must manage its storage and fuel use to avoid risks associated with disruptions to supply or meeting its commitments. This means generation opportunities at CHS need to be carefully managed, particularly given the limited water storage available within the scheme.

(f) As noted in **Mr Hunt's** evidence, the CHS plays a critical role in meeting the electricity demands of Aotearoa New Zealand (including through its intraday and intraweek flexibility) and therefore contributes significantly to the country's economic and social well-being.

Future operation of the CHS

23 As noted in **Ms Nelson's** evidence, the CHS forms a key component of both Contact's REG portfolio, and Aotearoa / New Zealand's at large. As an existing physical asset that contributes an average of 12 percent of the country's renewable generation, it is critical that the efficient operation of the CHS continues to be both protected and enabled.

24 Contact does not have any immediate plans to make significant infrastructural upgrades or undertake further development of the CHS. However, with the New Zealand Government's ambitious target to decarbonise the economy, the role of hydro-generation will become increasingly important. This is because REG will not only have to increase to meet growth projections, but also to enable the conversion from thermal sources to renewable ones.

25 Most new electricity generation will come from intermittent sources such as wind and solar. The nature of the country's energy system will therefore change from being *energy-constrained* to one that is *capacity-constrained* (ie peak demand may coincide with low periods of wind and solar generation). Without thermal generation, matching electricity supply with demand becomes more difficult.

26 As discussed by **Mr Hunt,** hydro-generation has an ability to buffer the variability between electricity supply and demand by being flexible and responsive to changes in both. It is therefore a valuable form of *firming* and therefore balancing our electricity system in both the short and the long-term.

27 In addition to this, as the infrastructure is already in place, upgrading and repair work will need to occur and may include (for example) replacing turbines and managing the visual and recreational impacts of sediment deposition in the hydro lakes. Whilst the investment in upgrading is large (ie $20M this year), the impacts on the environment will be negligible.

28 Programmes to improve the operability, efficiency and sustainability of the system are common and ongoing, and have an emphasis on the sustainable use of the natural resource and the cultural values and wāhi tapū of rūnaka. Examples of this include improvements to our native fish management programme (which is provided in detail in the following sections) and seeking resource consent to undertake works in the Bannockburn Inlet to maintain the bed profile to enable its on-going recreational use.

Overview of the CHS's existing condition frameworks

29 In 2001, Contact lodged resource consent applications to continue operating the Hāwea, Clyde and Roxburgh Dams as part of the operation of the CHS. **Table 1** below sets out a list of the resource consents applied for and held by Contact in relation to the operation of the CHS.

Table 1: Resource consents applied for and held by Contact in relation to the operation of the CHS

Hāwea Dam	Water permit to dam (2001.383)
	Water permit to discharge (2001.389)
	Discharge permit (2001.392)
	Discharge permit (2001.395)
	Water permit to take and use (2001.399)
Gladstone Gap Stop Bank	Water permit to dam (2001.384)
Clyde Dam	Water permit to dam (2001.385)
	Water permit to divert (2001.387)
	Water permit to take and use (2001.390)
	Discharge permit (2001.393)
	Discharge permit (2001.396)

Roxburgh Dam	Water permit to dam (2001.386)
	Water permit to divert (2001.388)
	Water permit to take and use (2001.391)
	Discharge permit (2001.394)
	Discharge permit (2001.397)
	Land use consent (2001.398)

30 The consents were granted by independent Commissioners appointed by the Regional Council on 10 September 2003, subject to conditions. Contact, and several other submitters, appealed the decision to the Environment Court. In *Alexandra District Flood Action Society Inc v Otago Regional Council*, the Court granted the consents, again subject to conditions. The consents have 35-year terms and expire on 23 May 2042.

The changed (and changing) form and function of the Clutha Mata-Au

31 The CHS, and in particular the construction of the Roxburgh Dam and Hāwea control gates in the 1950s, and then the Clyde Dam in the early 1990s, has significantly altered the natural form (how it looks) and function of the Clutha Mata-Au. This is particularly the case for sediment which would have traditionally flowed through the Clutha Mata-au to the Pacific Ocean - but has instead accumulated (and is continuing to accumulate) behind two large dam structures.

32 Mr **Peter Foster's** (**Mr Foster**) statement of evidence (from the previous hearing on the non-freshwater provisions of the RPS and which is attached as **Appendix C**) provides a comprehensive overview of how sediment is transported within the CHS and how it accumulates behind structures such as dams. Briefly, **Mr Foster** states:

(a) About 1.2 million cubic metres of sediment from the Shotover River being transported down the Kawarau River each year.

(b) This sediment flows "freely" in the faster-moving waters of the Kawarau River. But when this river meets the stiller waters of the Kawarau Arm, the heavier and coarser sediment material "drops-out" to rest on its bed.

(c) Over time, this accumulated sediment on the bed of the Kawarau Arm forms a delta, and this delta progresses towards the confluence of the Kawarau Arm with the Clutha Mata-au – like a glacier.

33 As **Mr Foster** explains in his evidence, this means that the "form" of the Kawarau Arm (which looks like a still body of water today) will eventually transition to a meandering or semi-braided channel pattern with "point bars" in the inside of bends and "medial" bars (or islands) mid-stream. In short – the visual appearance, form and function of the Kawarau Arm and Clutha Mata-Au has changed, and will continue to change, as sediment accumulates upstream of the Clyde Dam.

34 Intervening to "move sediment" through the system is simply not straightforward or practicable – at the moment. This is because the tipping face of the sediment delta is currently at the confluence of the Kawarau Arm and the Clutha Mata-Au at Cromwell, and to do so would require major disturbance to the waterbody itself in order to "push" sediment along towards the Clyde Dam. Options such as dredging sediment from the Kawarau Arm and trucking it downstream to discharge it into the Clutha Mata-au below Roxburgh (or at the coast) are not practicable given (for example) the annual volumes (1.2 million cubic metres), and (from my understanding) the sediment would potentially liquify making it very difficult to actually transport.

35 It was anticipated, as discussed by **Mr Foster**, that the sediment tipping face may reach the Clyde Dam 100 years after the dam's inception. It is closer to this point in time that options for moving sediment through the system may become more practicable – this is also noting that it would have to pass through the Roxburgh Dam as well. As noted in **Mr Foster's** evidence this may have implications for flood management and therefore lower-lying land in and around Alexandra.

36 Due to the complexity and nature of sediment flows in a hydro-generation system, Contact has several conditions of consent that require it to proactively monitor sediment accumulation upstream and downstream of the Clyde Dam, regulate flows (when required) to minimise the potential for flooding downstream of the Clyde Dam, manage the visual amenity and landscape effects of the "transition" within the Kawarau Arm, and to ensure that recreational activities remain provided for within the Bannockburn Inlet. It is in my opinion that these conditions reflect the most practicable way to manage sediment upstream of the Clyde Dam at this point in time.

37 It is therefore important that the provisions of the RPS appropriately recognise that:

(a) the form and function of the Clutha Mata-Au has been significantly altered because of the CHS and its two primary dam structures being the Clyde and Roxburgh Dams; and

(b) the landscape within which the CHS resides is not "natural" and it will continue to change as sediment accumulates upstream of the Clyde Dam.

Consent condition framework for native fish passage and habitat

38 The consents for Hāwea and Roxburgh Dams provide specific conditions relating to fish passage and habitat. **Table 2** below identifies the key consent conditions that relate to fish passage and habitat.

Table 2: Resource consents conditions relating to fish passage and habitat

Hāwea Dam	Water permit to dam (2001.383)	Condition 13 – Fish Passage into Tributaries
	Discharge permit (2001.392)	Condition 14 – Biological Monitoring and Reporting
Roxburgh Dam	Water permit to dam (2001.386)	Condition 19 – Passage of Native Fish
	Discharge permit (2001.394)	Condition 15 – Fish Habitat Enhancement
		Condition 16 – Native Fish Management Programme

39 By way of summary, these consent conditions require Contact to:

(a) provide for fish passage in the stipulated manner;

(b) undertake works, in consultation with Fish & Game New Zealand (Otago Region) (**Fish & Game**) and DOC, for fish habitat enhancement;

(c) develop and commence a monitoring programme, in consultation with Kai Tahu and key stakeholders, to monitor native fish stocks and habitats of the Hāwea River;

(d) commission (in consultation with DOC) and implement (in consultation with Kai Tahu and key stakeholders) a native fisheries mitigation programme; and

(e) in respect to the monitoring and mitigation programmes in (c) and (d) above, report on the results of monitoring, and implementation of the mitigation programmes, to the Otago Regional Council.

40 The CHS consent conditions require Contact to undertake works in respect to both native fish and to consult with Kai Tahu and key stakeholders, including DOC and Fish

& Game. This next section of my evidence is focused on works Contact is undertaking in respect to the conditions that relate to fish passage and habitat restoration for native fish.

Native fish passage

41 Several options have been investigated for fish passage in the CHS since the consents were granted, and as required under the consent conditions. The relevant consent conditions require Contact to:

(a) prepare a report on, and establish a system for, downstream passage for adult eel (tuna) past the Roxburgh Dam; and

(b) investigate options to facilitate effective tuna and lamprey (Kanakana) passage upstream and downstream past the Roxburgh, Clyde and Hāwea Dams and implement the BPO.

42 Contact has commissioned two reports in response to those conditions:

(a) Options to facilitate tuna and kanakana passage upstream and downstream past the Roxburgh, Clyde and Hāwea Dams, by Ryder Consulting Ltd, 14 August 2011 (**Ryder 2011 report**); and

(b) Options to facilitate tuna and kanakana passage upstream and downstream past the Roxburgh, Clyde and Hāwea Dams – Recommendations for 2018-2022, by Greg Ryder, 9 August 2018 (**Ryder 2018 report**),

(together, **the Ryder reports**).

43 The Ryder 2011 report identified and assessed five options for upstream fish passage in the CHS and identified "trap and transfer" as the most effective option for upstream fish passage. In response to this Contact has undertaken fish trapping and transfer since 2012. The reasons for selecting this option included:

(a) collecting elver from the lowest dam and moving them upstream to the highest dam, means the elver are not required to make their own way through several dams and through upstream barriers;

(b) there was already some existing infrastructure for a trap and transfer system at Roxburgh Dam from 1996 (although the ramps were considered too long to be effective, so changes would need to be made to the infrastructure to make it effective);

(c) operations for this method are suited to monitoring and collecting information, and are easy to adjust depending on the results; and

(d) with additional ongoing cost, catch can be transferred to specific habitats.

44 It also recommended upstream passage protocols for 2011-2014. These included:

(a) constructing a new elver and kanakana trap at Roxburgh Dam (near the existing trap and ramp) with certain design requirements - this was commissioned in the 2017/18 season;

(b) on-going monitoring requirements and identification of species; and

(c) exploring the transfer of larger juvenile tuna from the lower River and developing a timeline for the implementation of a programme in 2012-2013.

45 The Ryder 2011 report also identified trialing passage over the spillway, together with upstream netting and manual transfer, as the BPO for downstream passage (and for juvenile kanakana, confirmed that because of their length, it is expected that some survive passage through turbines, so only providing upstream passage of the adults is acceptable). It also recommended downstream passage protocols for 2011 – 2012 which included:

(a) assisting in passage below the Roxburgh Dam by assessing the suitability of the Roxburgh and Clyde Dam spillways for safe passage; and

(b) establishing or investigating a monitoring programme to record the numbers of tuna transferred below Roxburgh Dam or passing through the Roxburgh and Clyde turbines.

46 The Ryder 2018 report was commissioned by Contact to review the 2011 report and provide an update to this. It confirmed that, in Aotearoa New Zealand generally the trap and transfer method is still the preferred and most effective option over fixed structures, particularly on high dams.

47 The Ryder 2018 report also provided an overview of the changes (including their effectiveness) to Contact's trapping programme at the Roxburgh Dam. In response to this Contact improved the design of the trap and installed it closer to the surface of the water therefore increasing the likelihood of elver capture.

48 The Ryder 2018 report also provides further recommendations and a work plan for the remainder of 2017 through to 2022, including:

(a) changes to the trap and transfer systems to enhance upstream passage of eels, including further reporting on the mechanics of the operation and through appropriate monitoring;

(b) installing a camera to detect kanakana at Roxburgh Dam at the base of the ramps, to assist in assessing the effectiveness of the new submerged trap and ramp at attracting lamprey;

(c) to target migrant eels by setting large fyke nets over a longer period (this was identified as the most appropriate method for downstream passage at present

49 Following the recommendations in the 2018 Ryder report, and subsequent changes made to the system, for the 2021/22 season:

(a) there was a significant increase in the total number of elver caught (a weight of 198kg compared to 52 kg in 2020/21 and 7kg in the 2019/20); and

(b) a total of 227 eels (migratory and large) were transferred below Roxburgh Dam.

50 Contact also installed a camera at the Roxburgh Dam to monitor lamprey activity and improve understanding of their migratory patterns. It is intended that a kanakana-dedicated ramp will be installed for trap and transfer of kanakana in the next 12-18 months following consultation with Kāi Tahu.

51 Contact is committed to continuously improving upstream and downstream native fish passage within the CHS. The Ryder reports reflect ongoing investigations into the BPO for native fish passage based on development and improvements in knowledge and scientific understanding (national and local) as well as Contact's ongoing monitoring and experiences.

Habitat restoration

52 Contact has undertaken significant work to restore fish habitats in the CHS, as required under the consent conditions. Habitat restoration is required as part of the native fisheries mitigation programme required by the consent conditions to be developed in consultation with DOC.

53 Contact and DOC developed a native fisheries mitigation programme from Roxburgh Dam to the sea in 2012. Contact has contracted DOC to carry out the work under the programme, including:

(a) riparian habitat restoration for adult inanga, inanga spawning and giant kōkopu (planting trees and shrubs, installing fencing and plant release work); and

(b) monitoring and reporting on inanga and giant kokopu populations, and other native fish stocks and habitat values.

54 Contact's native fish programme is reviewed annually, and this involves discussions with (in the first instance) and feedback from Kāi Tahu and DoC. These discussions are important to ensure the programme's on-going improvement and that Contact is both responding to new knowledge and technology (both nationally and internationally), and continually looking to improve fish passage and habitat for native species.

Comments on the provisions relating to native fish passage

55 The new LW – FW – O1A provides region-wide objectives for freshwater, including sub-clause (3) which seeks to enable indigenous species to migrate as easily and naturally *as possible*.

56 The key issue that Contact has with this new objective is that it fails to reflect the reality that the dams have significantly altered the natural form and function of the river and interfered with – essentially stopped - the natural migration of native fish species without specific human intervention.

57 A requirement to provide for natural fish passage as naturally as "possible" could, if applied to the CHS, result in significant and unforeseen adverse effects on renewable generation at a local, regional, and national scale.

58 This new objective also conflicts with Contact's consent conditions that focus on adopting the best practicable option (**BPO**) for native fish passage. This BPO condition framework has been developed to commit Contact – within this 35-year consent term – to review current methods (which were considered "best" at the start of the consent term) for native fish passage and seek independent expert advice to identify and implement *better* options as they become known, proven and technically and financially feasible.

59 As discussed above, Contact has undertaken significant work in the CHS to investigate and identify the BPO for fish passage and has worked with Kāi Tahu in developing and implementing the trap and transfer programme as well as the native fish restoration programme. Contact does not deny, as the s42A report infers that provisions cannot be imposed in relation to fish passage – and that is exactly what occurred in Contact's consent conditions. As I have set out above, recent improvements to the trap and transfer scheme have resulted in a significant increase in elver being transferred. Contact remains concerned that retention of the word 'possible' steps the RPS away from the BPO approach imposed in its conditions and sets up the potential for a fanciful position that ignores the significant scale and

effects of the nationally significant hydrogeneration scheme and what can 'practically' be done to address fish passage in the catchment.

6. COMMENTS ON THE PROVISIONS OF THE PROPOSED RPS

60 Contact supports the intention and purpose of the proposed RPS to maintain or enhance the quality and quantity of the Otago region’s freshwater resource, and to protect the mauri of water bodies.

61 Contact made submissions and further submissions on the proposed RPS. Contact’s submissions and further submissions centre around the following key concerns:

(a) providing a policy framework that appropriately recognises and prioritises REG and its role in achieving Aotearoa New Zealand's emissions reduction targets and in providing for wellbeing;

(b) protecting significant REG assets such as the CHS and ensuring that its operation, maintenance and minor upgrading is provided for;

(c) recognising that the environment of the CHS is significantly modified and cannot realistically be returned to a "natural" state; and

(d) recognising that what is possible is not always practicable in terms of enabling indigenous species to migrate along the Clutha / Mata-au.

62 These concerns are addressed in detail in Ms Hunter’s evidence. The key points that I would like to make in relation to the proposed provision are:

(a) the development of the CHS has had, and will continue to have over its life, a significant impact on the Clutha catchment and its environment;

(b) these impacts are irreversible and extend well beyond the large-scale dam structures and their respective storage lakes –the CHS is of a scale that it has fundamentally altered the nature of the catchment and the development around it. Therefore, provisions that seek for waterways to be returned to a "natural" state are unlikely to be practical or sensible in respect of the Clutha and CHS;

(c) if climate change is a significant national issue and if it is an urgent issue to address (which I believe it is) then for New Zealand to meet its climate change commitments, and decarbonise its economy, documents such as the RPS must prioritise climate change (especially greenhouse gas reductions);

(d) protecting existing, and enabling new, REG developments are key for New Zealand to reduce greenhouse gas emissions and to do its part in avoiding or reducing the effects of climate change on New Zealand (both on people and on our natural resources); and

(e) Contact does not seek a 'free ride' for such activities, effects must be appropriately managed and in some cases development at a particular site may not be appropriate but what is critical is that projects can be assessed, both for their benefits and costs, through a consenting process and not prevented at a policy level.

63 For these reasons, Contact prefers the amendments that **Ms Hunter** has recommended and set out in her evidence.

7. CONCLUSION

64 Contact owns and operates the CHS which is a nationally significant infrastructure asset located within the Otago region. The CHS has a critical role in providing renewable electricity into the broader electricity system, and its role in terms of firming (or balancing supply and demand) will increase as we transition towards a net-zero economy.

65 The environment within which the CHS exists is heavily modified due primarily to the existence of the two large dams, being Roxburgh and Clyde. These structures have impeded the flow of sediment through the Clutha Mata-au, and its consequently the form and function. It is important to note the environment upstream of the Clyde Dam will continue to change as it transitions from a "still" lake to a semi-braided river.

66 The provision of native fish passage (in particular) in a *natural way* is no longer possible without significant implications on the CHS to provide a significant proportion of REG into the Aotearoa New Zealand electricity system. However, and in saying this, Contact has a responsibility – both legally and as part of its social licence to operate – to continue investigating options to improve and enhance fish passage and to implement them as they become proven, and technologically and financially feasible. We are committed to working with our partner, DoC and other stakeholders and the community on improving native fish passage and habitat as it relates to the CHS.

Boyd Munro Brinsdon

28 June 2023

Appendix A

Evidence in Chief of Mr David Hunt on behalf of Contact Energy Limited

(Proposed Otago Regional Policy Statement 2021 Fresh Water Planning Instrument Hearing)

BEFORE THE HEARING COMMISSIONERS APPOINTED BY OTAGO REGIONAL COUNCIL

Under	the Resource Management Act 1991
In the matter	of the proposed Otago Regional Policy Statement 2021 (excluding provisions renotified as part of a freshwater planning instrument)

STATEMENT OF EVIDENCE OF DAVID THOMAS HUNT (ECONOMICS) ON BEHALF OF CONTACT ENERGY LIMITED

23 November 2022

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CONTENTS

1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is **David Thomas Hunt**.

1.2 I am a Director of Concept Consulting Group Ltd (**Concept**) which is a specialist energy and economics consultancy providing services to clients in New Zealand, Australia and the wider Asia Pacific region. I have been a Director of Concept since joining the firm in 2006.

1.3 In my role, I undertake a range of consulting assignments for government agencies and companies in the energy and utilities sectors with a strong emphasis on economic analysis.

1.4 For the last 25 years, my career has been energy focussed. By way of an overview:

(a) Between 1986 and 1996, I held a number of government roles including Manager, Energy Policy at the Treasury and Economic Advisor to the Minister of Finance. I provided advice on a wide range of energy policy issues including market design, competition issues, and structural reform.

(b) Between 1996 and 2005 I held various roles at Contact Energy Limited (**Contact**) in the finance, business development and strategy areas.

(c) In 2005, I was appointed Executive General Manager of Corporate Development at Origin Energy based in Sydney. At that time, Origin was a large producer of oil, gas and LPG, had a sizeable electricity generation portfolio, and was a retailer of gas, LPG and power. During my time at Origin, I oversaw a number of strategic initiatives, including analysis regarding potential expansion of Origin's LPG retail business.

(d) Between 2005 and 2006, I was Chief Executive at Contact. That was the last management role I held before joining Concept.

(e) At a governance level, I have served as a Director of Synergy, the largest electricity generator and retailer in Western Australia, and I am currently a board member of the Accident Compensation Corporation.

1.5 I have a BA Hons (First Class) in economics and a BA in statistics.

2. CODE OF CONDUCT

2.1 I have read the Environment Court's Code of Conduct for Expert Witnesses, and I agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues addressed in my brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

3. SCOPE OF EVIDENCE

3.1 In preparing my evidence I have reviewed at a high level the relevant provisions of:

(a) the proposed Otago Regional Policy Statement (**proposed RPS**);

(b) Contact's submissions and further submissions; and

(c) the Otago Regional Council's (**Regional Council**'s) section 42A report, including the version showing recommendations from the Regional Council's supplementary evidence and additional supplementary evidence (**section 42A report (October version)**); and

(d) the other statements of evidence prepared on behalf of Contact (including both corporate and expert evidence).

3.2 The purpose of my evidence is to provide an overview of the following matters:

(a) the New Zealand electricity system;

(b) the future of the electricity system and the role that renewable electricity will play;

(c) the benefit of existing and new renewable electricity schemes, including for decarbonisation;

(d) the Clutha Hydro Scheme's contribution to the New Zealand electricity system; and

(e) the economic and decarbonisation benefit of the Clutha Hydro Scheme.

4. EXECUTIVE SUMMARY

Electricity sector overview

4.1 Over half (57%) of New Zealand's electricity demand is currently met by hydro generation. The remaining demand is met by a mixture of thermal and other forms of renewable generation. The electricity system must always be kept in tight balance at all locations on the electricity grid. As demand and intermittent generation (such as wind and solar) constantly fluctuate, flexible generation such as hydro or thermal is important to maintain this balance.

4.2 The electricity industry is entering a period of massive change. Electricity is already important in our daily lives, but it is expected to become even more vital due to New Zealand's decarbonisation goals. Achieving these goals will require electrification of many parts of the economy currently dependent on fossil fuels (such as the use of light vehicles) and a phase down of much or all fossil-fuelled thermal generation. To meet demand growth and phase down fossil-fuelled thermal generation, new renewable generation sources will need to be developed at an unprecedented rate. Much of this new renewable generation will be intermittent generation, with the proportion of intermittent generation expected to increase from around 6% of total electricity supply at present to about 50% in 2050. As a result, the importance of flexible hydro generation (including from the Clutha Hydro Scheme) will grow in the future.

The benefit of existing and new renewable electricity schemes

4.3 There is both economic and decarbonisation benefit from allowing existing renewable generation to continue to operate to its full capability and allowing new renewable generation to be built. The economic and decarbonisation benefit can be considered by looking at the costs (including the emissions impact) that would incur if existing renewable power stations were not allowed to continue operating to their (current) full capacity, or if some otherwise attractive new renewable generation resources were not allowed to be developed.

4.4 I consider that these costs can be grouped into three parts:

(a) Higher electricity-sector costs due to more expensive renewable generation resources needing to be developed. The increase in costs would be particularly large if existing renewable generation needed to be replaced. This is because it is much less costly to run existing plant than build new generation. Restricting the development of otherwise attractive new generation will also raise electricity sector costs. This is because the cost of electricity from different new generation projects varies, and the cheapest generation resources are generally developed first. If these cheaper generation resources can't be developed this will require more expensive renewable generation resources to be developed.

(b) Carbon emissions and electricity costs could increase due to an increased need for fossil-fuelled thermal generation. If the generation capacity of existing renewable generation was reduced with minimal warning or the development of new renewable generation resource was hindered, then more fossil-fuelled thermal generation would likely be required to 'fill the gap' until alternative new renewable generation could be developed. In most cases, fossil-fuelled generation is both more expensive to operate and has higher carbon emissions than renewable electricity resources.

(c) An increase in electricity prices, due to environmental restrictions on renewable generation, is also likely to result in increased 'indirect' emissions for the rest of the economy. This is because electrification has been identified as one of the key means of decarbonising significant parts of our economy and higher electricity prices will tend to discourage energy consumers from moving away from fossil fuels to electricity.

4.5 In the body of my evidence, I set out broad estimates for some of the potential costs described above.

The economic and decarbonisation benefit of the Clutha Hydro Scheme

4.6 The Clutha Hydro Scheme is made up of two power stations on the Clutha River that generate approximately 3,900 GWh of electricity each year. For a sense of scale, this is roughly the same as the total consumption of all South Island residential electricity consumers.[1]

[1] According to Electricity Authority data, total energy consumption for South Island residential consumers was 3,832 GWh in 2021. This excludes transmission and distribution losses conveying the power to customers' homes.

4.7 If the generation from Clutha Hydro Scheme needed to be replaced at short notice, the only viable alternative would be increased thermal generation. I estimate it would cost between $326 million and $625 million per year in the short run to replace Clutha Hydro Scheme using existing thermal generation capacity. This would also increase New Zealand's emissions by between approximately 1.5 million and 3.6 million tonnes of carbon dioxide equivalent per year.

4.8 In the longer run, if the Clutha Hydro Scheme were unavailable, its output could be replaced with new renewable generation. The most likely alternatives are geothermal, solar, or wind generation, or some mix of these. On a dollar per unit of energy basis, they would have lower economic costs than thermal generation, but they would all involve upfront capital expenditure and take some time to build.[2] I estimate this would cost between $3.3 billion and $4.3 billion (in present value terms).

4.9 The Clutha Hydro Scheme also provides some short-term flexibility (intraday and within a week). This means that in the short term it can generate more when electricity is valued more (eg when demand is high in the morning and evening peaks) and less when electricity valued less (eg overnight). I expect the electricity system benefits provided by this short-term flexibility to increase in the future as the proportion of intermittent generation on the system increases substantially.

5. ELECTRICITY SYSTEM OVERVIEW

Summary – electricity system overview

5.1 Regulation of the electricity generation sector is designed to encourage competition. At its centre there is a regulated auction-based spot market in which generators make supply offers every 30 minutes. The generators with the lowest offer prices are selected to satisfy demand in each half hour.

5.2 Spot prices vary depending on the relative balance of electricity supply and demand at different times of the day and year. Prices also vary by location on the national grid (**grid**), reflecting the local supply/demand balance and the extent of network constraints and power losses which occur when electricity is transported on the grid.

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[2] This investment in new generation would also be in addition to the substantial investment in renewable generation required to help New Zealand meet its decarbonisation goals.

5.3 The spot prices generated in the electricity market provide important information about the value of different types of generation, such as whether it has controllable output or not, and where it is located on the grid.

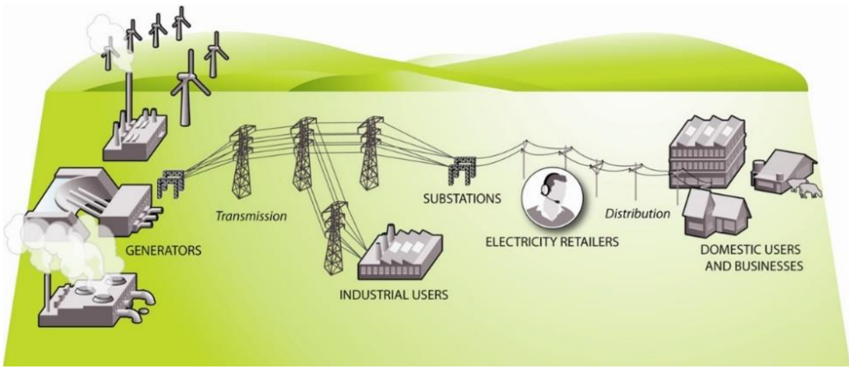
Electricity industry structure

5.4 The electricity supply chain can be divided into four main segments: generation, transmission, distribution, and retail sales. This is shown diagrammatically in Figure 1 below.

5.5 Competition is possible in the generation and retailing segments and regulation of these sectors has been focussed on facilitating competition.

5.6 The transmission and distribution segments are not subject to competition because it is generally uneconomic to replicate electricity networks. These businesses are regulated under Part 4 of the Commerce Act 1986. This provides for price control of their services, except where there is strong alignment of supplier and consumer interest via community ownership of a network.

Figure 1: Overview of electricity industry structure



Source: Ministry of Business, Innovation and Employment

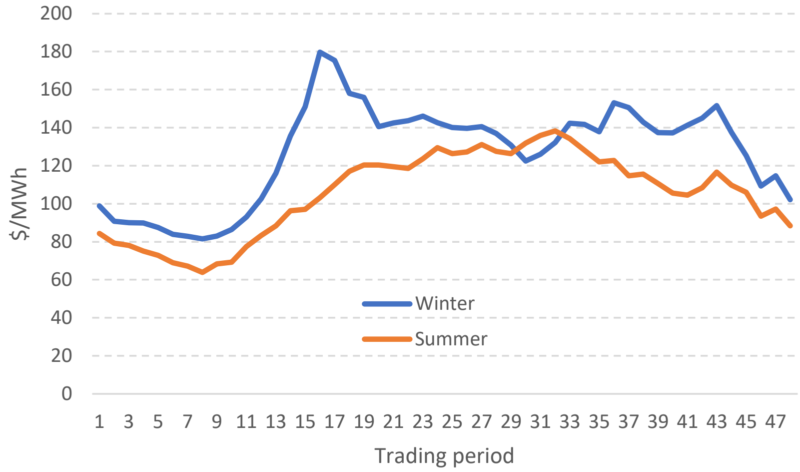
Wholesale electricity market

5.7 The platform that underpins generation sector competition is the wholesale electricity spot market. All generators connected to the grid are required to participate in this market where their electricity is sold in a half-hourly auction process. The cheapest combination of generation offers that will securely meet demand is used to determine which generation will be selected to run in each half hour.

5.8 Supply and demand conditions can vary substantially within a day and across the year. The cost of generating power in peak demand periods is typically much higher than other periods. This leads to relatively predictable variations in spot prices across the year, as shown in Figure 2 below.

5.9 Spot prices will also fluctuate due to unexpected events, such as the early arrival of a cold front which lifts power demand for electric heating, or tighter supply, such as a prolonged calm weather period which reduces wind generation.

Figure 2: Spot prices – illustrative winter day versus summer day



Source: Electricity Authority data

5.10 Because spot prices are higher when the supply/demand balance is tight and vice versa, generators[3] that can control and shift their output are able to earn a premium over those that operate at a constant rate or cannot control their output. The presence of this premium is important to maintain reliable supply because it encourages generators to be available when there is the greatest need for additional supply. I discuss the need for flexible supply in more detail from paragraph 5.14.

Supply and demand must be balanced at all times

5.11 Electricity is unusual because supply and demand must always be kept in a tight balance at all locations on the grid. If this is not achieved, it can lead to widespread blackouts. In particular, if insufficient electricity is supplied to meet demand, the electrical frequency will begin to drop below the normal level of 50 Hertz (and vice versa). Power plants are designed to operate within a fairly narrow frequency range and if the grid frequency moves

[3] Or other types of resources that can improve the supply/demand balance, such as batteries or electricity consumers who can reduce their usage – known as demand response providers. While battery consumers and demand response providers have not provided much flexibility in the New Zealand electricity system to date, it is widely considered that they will provide much more flexibility in the future.

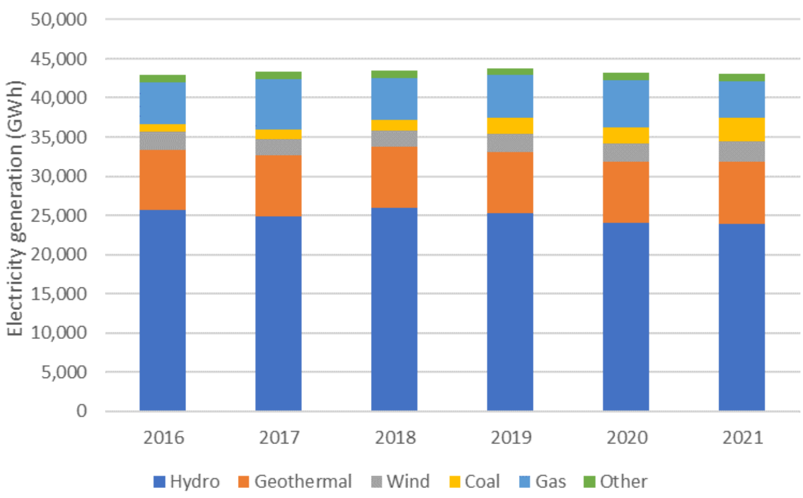
outside this range for too long, the power plant will automatically disconnect from the grid (called a 'trip') to protect itself from damage.

5.12 Ultimately, if too many power plants disconnect due to a frequency disturbance there will be 'sympathetic tripping' by other plant and cascade failure. This can lead to widespread blackouts affecting many customers. For example, over 850,000 customers lost power in Australia in 2016 due to an event of this type. Restoring power after such events can take some time as supply and demand need to be brought back in a way that maintains balance throughout the system.[4] In the Australian event power was restored to some customers within a few hours while for others it took several days.

Current make-up of supply

5.13 Electricity is supplied by a range of generation types as shown in Figure 3 below. During the last five years hydro was responsible for around 57% of electricity generation in New Zealand. The other significant generation types were geothermal (18%), gas (13%), and wind and coal (both 5%).

Figure 3: Historical electricity generation



Source: Energy in New Zealand 2021, MBIE.

Need for flexible supply

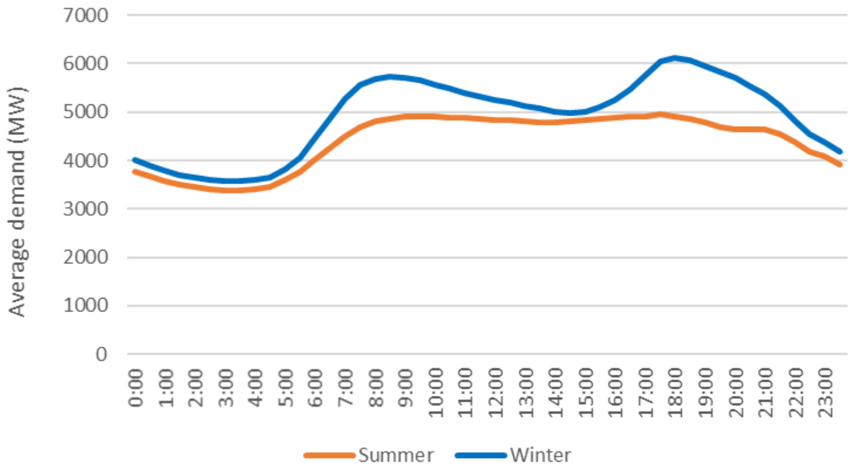
Varying power demand creates a need for flexible supply

5.14 Demand for electricity is not constant through the day or across seasons. Figure 4 below shows grid power demand for a typical summer and winter

[4] See https://www.aemo.com.au/-/media/Files/Electricity/NEM/Market_Notices_and_Events/Power_System_Incident_Reports/2017/Integrated-Final-Report-SA-Black-System-28-September-2016.pdf

day. The chart shows how demand varies between a minimum level of around 3,400 MW and a peak of 6,100 MW – a variation of over 80% between trough and peak. Another point to note is the steep increase in demand on winter mornings, with a rise of around 50% between 5am and 9am.

Figure 4: Average electricity demand for summer and winter days in 2020



Source: Electricity Authority data.

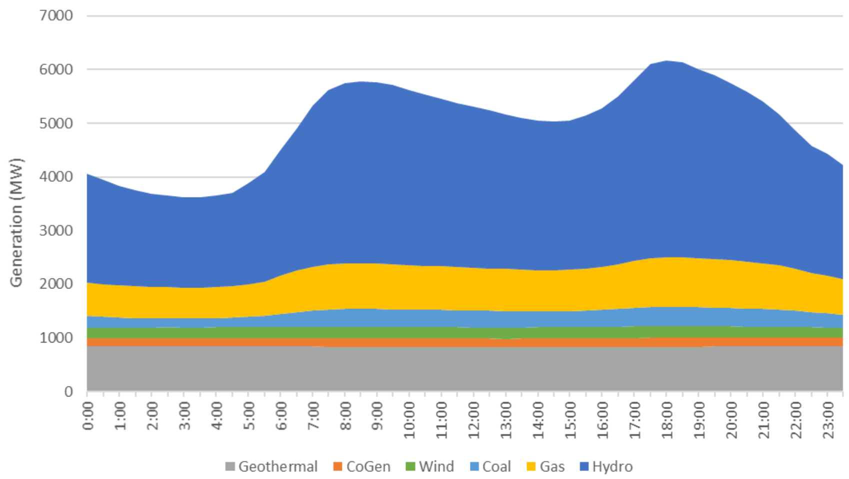
5.15 These sorts of changes in demand mean that the electricity system needs flexible supply sources that can be ramped up or down quickly to ensure that the grid remains balanced.

Uncontrollable generation increases need for other flexible supply

5.16 Some forms of generation cannot be readily controlled – often being referred to as 'intermittent generation' or 'variable renewable generation'. Examples are wind and solar generation, whose power output will vary with prevailing weather and solar conditions. Another intermittent source is 'run-of-river' hydro generation. These are hydro power stations that have little or no access to storage lakes, and hence generate according to natural flows in the river.

5.17 By contrast, hydro stations with sizeable storage reservoirs are an important source of flexible supply. These stations provide much of the short-term flexibility needed to counteract hourly, daily, and seasonal variations in demand and intermittent supply. This is illustrated by Figure 5 below which shows the variation in hydro generation at the national level across a typical winter day, and how this is a major source of flexibility to meet varying levels of demand.

Figure 5: Average generation by generation type for winter 2020



Source: Electricity Authority data.

5.18 However, even hydro stations with storage are exposed to supply fluctuations. This is because they are dependent on rainfall and/or snow melt to fill their storage lakes. Accordingly, after prolonged dry periods storage lakes will be lower, limiting the amount of power that the associated hydro stations can generate.

5.19 Thermal stations (running on diesel, gas and coal) also provide flexibility in the New Zealand electricity system, including during prolonged dry periods. However, as I discuss later, fossil-fuelled thermal generation will have a lesser role in the New Zealand electricity system in the future due to New Zealand's decarbonisation goals.

6. FUTURE OF THE ELECTRICITY SYSTEM

The electricity industry is entering a period of massive change

6.1 Electricity is important in our daily lives. Many of the social and economic benefits we enjoy stem directly from technologies relying on electricity. Looking ahead, electricity is expected to become even more vital as New Zealand moves to decarbonise the economy using renewable generation sources.

6.2 To meet its decarbonisation objectives, New Zealand needs to develop new generation sources at an unprecedented rate (as discussed below). Much of that generation will be from wind and solar power. Although these are very cost competitive, their output is subject to fluctuations due to weather and other factors.

6.3 While batteries are expected to help in smoothing out much of the very short-term fluctuation in supply from these sources, they are not suitable for addressing variations which occur from week to week or longer. Other sources of flexibility will be needed. One of the most important sources is expected to be hydro generation that has access to stored water. This type of generation has the twin benefits of being renewable and controllable – both of which will be increasingly important as New Zealand decarbonises its economy.

New Zealand's decarbonisation goals

New Zealand law requires net zero emissions by 2050

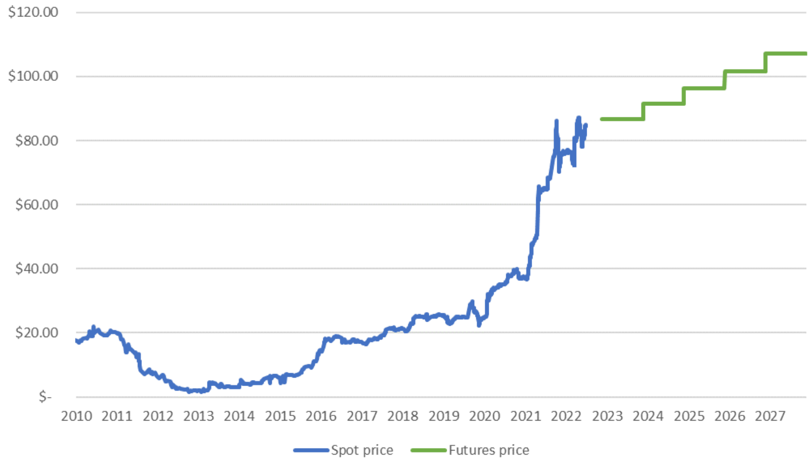
6.4 New Zealand law sets a target for the country to reduce net emissions of greenhouse gases (except biogenic methane) to zero by 2050.[5] The Climate Change Commission was established in 2019[6], which has the role of providing independent expert advice and monitoring to help keep successive governments on track to meet the legislated long-term goals.[7]

6.5 A key instrument for achieving the net emission target is the Emissions Trading Scheme. In essence, this scheme requires greenhouse gas emitters to purchase emission units issued by the New Zealand government to offset their domestic greenhouse gas emissions.[8]

6.6 The market clearing price for emission units in New Zealand is discovered by trading among parties, such as those who need to buy units to acquit their emission liabilities and/or those who generate units. The price of an emission unit has increased substantially in recent years (as shown in Figure 6 below). It is expected to rise even further, as shown by prices of NZU futures for coming years (in green in Figure 6).

[5] Climate Change Response Act 2002, section 5Q.
[6] Climate Change Response Act 2002, section 5A (inserted, on 14 November 2019, by section 8 of the Climate Change Response (Zero Carbon) Amendment Act 2019 (2019 No 61).
[7] Climate Change Commission, 2021 Draft Advice for Consultation, 31 January 2021, p11.
[8] Strictly speaking, the obligation to purchase and surrender units may fall on a party other than the final emitter (eg gas producers rather than consumers). Nonetheless, in such cases, final emitters are likely to bear the cost of acquiring the emission units when they purchase gas from producers.

Figure 6: New Zealand carbon price ($NZ/tonne carbon equivalent)



Source: CommTrade and Carbon News (downloaded 7 November 2022).

100% renewable electricity supply target

6.7 The Government announced an aspirational target to achieve 100% renewable electricity supply by 2030.[9] While not enshrined in legislation, this aspirational target is reflected in various policy documents issued by the Government (including the Emissions Reduction Plan released in May 2022).[10] The target is expected to be reviewed at the 2025 emissions budget.

Decarbonisation is expected to substantially lift electricity demand

6.8 Electricity demand is expected to grow substantially as New Zealand uses more electricity to decarbonise the economy. For example, electricity is expected to largely displace petrol and diesel as an increasing number of electric vehicles take to the country's roads. Likewise, electricity is expected to replace coal and gas for industrial process heat in many applications, and for domestic heating.

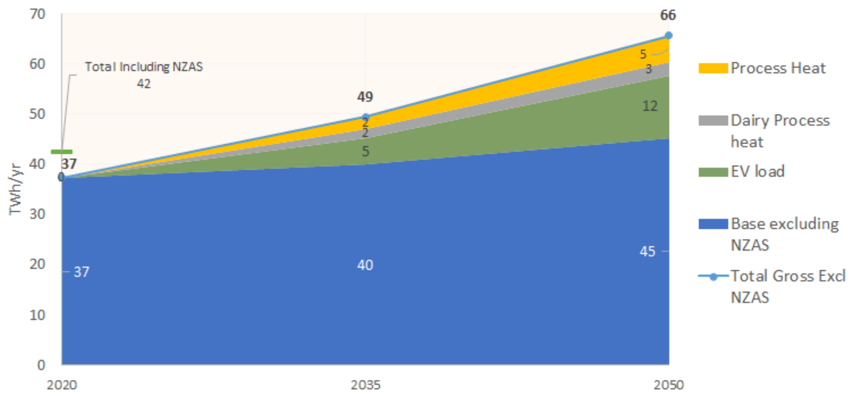
6.9 Figure 7 below shows a projection of future electricity demand published in early 2022 by the Market Development Advisory Group (MDAG), a cross-industry body appointed to provide advice to the electricity regulator.[11]

6.10 Clearly, the very long horizon of the projection (to 2050) means that there is some inherent uncertainty. Having said that, projections from other sources such as Transpower and the Climate Change Commission show a broadly

[9] Speech from the throne | Beehive.govt.nz and New Zealand Labour Party Policy, September 2020.
[10] *Aotearoa New Zealand's first emissions reduction plan*, page 220.
[11] The projection was published in an issues paper which can be found at Price discovery under 100% renewable electricity supply: issues discussion paper | ea.govt.nz.

similar picture.[12] In particular, while there are some differences in pace and scale of electrification, they all predict significant increases in demand over time as major sectors switch from fossil fuels to electricity.

Figure 7: Projected future electricity demand projection



Source: Market Development Advisory Group (Figure 2, Price discovery under 100% renewable electricity supply: issues discussion paper | ea.govt.nz)

6.11 Key points to note from the projection are:

(a) Demand (excluding for the Tiwai aluminium smelter (discussed further below)) is expected to grow by around 32% by 2035, and a further 35% by 2050. This projection assumed the Tiwai smelter would close after 2024. If the smelter remains in operation (see later discussion from paragraph 6.32), this would lift the 'starting point' level of demand, but is not expected to affect the growth trajectory associated with decarbonisation.

(b) Most of the increase is expected to come from electric vehicles and the increasing use of electricity for process heat in industry, especially food processing.

(c) Base demand is projected to be relatively stable – this is because population and economic growth are expected to be largely offset by rising efficiency of energy use (for example through greater insulation of homes).

Substantial growth in renewable electricity supply will be required

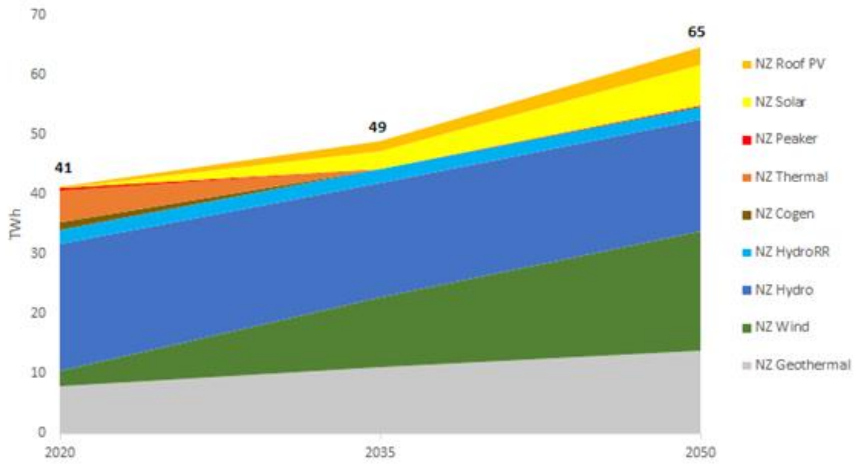
6.12 Very large increases in renewable generation will be required to provide the electricity to meet New Zealand's decarbonisation goals. Some of the new generation will be needed to displace existing thermal generation and

[12] See Whakamana i te Mauri Hiko data report figures | Transpower.co.nz and Electricity market modelling datasets 2021 final advice | Climatecommission.govt.nz.

directly reduce electricity sector emissions, but ultimately an even greater volume will be needed for electric vehicles and electricity for process heat to decarbonise other parts of the economy.

6.13 Figure 8 below shows a recent projection of the potential sources of future supply generation. As with projected demand, given the long horizon there is some inherent uncertainty about the precise mix of sources. Nonetheless, the projection is mainstream and other sources paint a similar picture for new supply.

Figure 8: Projected future electricity supply



Source: Market Development Advisory Group (Figure 3, Price discovery under 100% renewable electricity supply: issues discussion paper | ea.govt.nz)

6.14 Key points to note from the projection are:

(a) Geothermal power is expected to grow over time – reflecting its position as a proven technology with competitive costs. However, its growth is limited by the availability of sites with access to the underlying energy source.

(b) A much larger contribution to new supply is expected to come from wind and solar generation. These have become much more competitive over time with improving technology, and further gains are expected.

(c) In aggregate, the proportion of electricity generated from intermittent sources (solar and wind) is expected to increase from 6% in 2020 to around 50% by 2050. As discussed below from paragraph 6.18, this change has significant implications for the role of flexible hydro generation.

6.15 Achieving New Zealand's decarbonisation goals will require the development of generation at a pace that is unprecedented. We estimate that it will require the development of around 1,100 GWh of new renewable generation capability on average every year until 2050.[13] This pace of development is more than three times the rate achieved in the 30 years up to 2020.

6.16 To provide a sense of scale, it is roughly equivalent to adding a new set of Clyde and Roxburgh hydro stations to the electricity system every 3.5 years until 2050.

6.17 These projections assume that all existing renewable stations will retain their current generation capabilities after their current resource consents expire. However, if the operating capabilities of existing renewable stations are reduced during future reconsenting processes, the required future scale-up in renewable development would be even greater than this. The required generation projections are also dependent on demand growth assumptions. If demand is higher than anticipated (eg if a hydrogen or other so-called 'power-to-X' economy evolves) then additional generation will be required.

Increased need for flexible supply

6.18 As I noted in paragraphs 5.14 - 5.19, the electricity system needs flexible electricity supply that can be ramped up or down quickly to ensure the grid remains balanced at every instant in time. This need for flexible supply will increase in the future due to a substantial increase in the proportion (from 6% in 2020 to approximately 50% in 2050) of electricity generated by wind and solar, which can only generate when the wind blows or the sun shines, respectively.

6.19 To date, fossil-fuelled thermal stations have provided some of this flexibility, but operation of these stations will need to be phased down to meet New Zealand's decarbonisation goals.

6.20 In short there will be a rising overall need for flexibility at the same time that some existing sources of flexibility are being withdrawn.

[13] This assumes an increase in demand of around 29,000 GWh/yr between 2020 and 2050 (consistent with the growth shown in Figure 7 but assuming the Tiwai smelter remains in operation plus a modest new build allowance to replace/repower some existing renewable sources as they reach the end of their lives. For example the Wairakei geothermal station is due to retire before 2031. Likewise the Tararua wind farms are likely to be progressively replaced.

6.21 To fill this gap new sources of flexibility will be required. A range of possible solutions are being explored, including storage options such as batteries or pumped storage hydro, bio-fuelled plant and increased use of flexible demand response (electricity consumers who can reduce their usage at times).

6.22 It is too early to know which of the new flexibility options will be developed in New Zealand given their technical and cost uncertainties. However, it is clear that maintaining access to flexible hydro generation will have substantial electricity system benefits for New Zealand. This is because:

(a) there are significant costs associated with developing any new flexibility source – unlike the hydro generation system which has relatively low costs to maintain (because the build costs have already been incurred);

(b) the hydro generation system produces energy which is relatively flexible. By contrast, some of the flexibility options are storage devices, and therefore need an energy source to operate; and

(c) as discussed in paragraphs 5.17 to 5.18, hydro generation is currently a major source of flexibility for the electricity system. Any reduction in flexibility from this source would increase the need to develop other sources of flexibility and result in additional costs for New Zealand.

Diversity of generation sources will be important

6.23 The expected increase in the proportion of electricity generated by intermittent generation will also increase the need for diversity of generation sources. Relying heavily on one type of intermittent generation, particularly if it is located largely in the same region, will lead to there being a high correlation between when these power stations can generate and when they cannot (for example, if a large proportion of New Zealand's generation capacity was from wind farms located in the same region, it is likely that these wind farms would all stop generating (due to low wind) at the same time). This would likely result in there being excess generation in some periods and shortages of generation in other periods.

6.24 A diversity of generation types (eg wind, solar, hydro, and geothermal) and location reduces the risk of both supply shortages and excess generation occurring. It will also be important for there to be non-intermittent generation supply that can provide “baseload” (constant generation over time) and flexibility (as discussed in paragraphs 6.18 and 6.19 above).

Uncertainties to take into account

6.25 When making predictions about the future it is important to consider any factors which could significantly affect the outlook. In this subsection I briefly discuss the key areas of uncertainty and their implications for the electricity system outlook.

100% renewables policy

6.26 As noted in paragraph 6.7 the Government has announced an aspirational target to achieve 100% renewable electricity supply by 2030. This target is subject to change, with the potential for either the target date or the target itself to change.

6.27 A change in renewables target would change the rate of generation investment needed to replace thermal generation. However, even if the target is softened (by extending the target date and/or reducing the target itself), I still expect investment in renewable generation to be required at an unprecedented rate.

6.28 The key reason for this view is that the target of net zero carbon by 2050 is enshrined in statute. Achieving that target will require decarbonisation of the transport and industrial process heat sectors, shifting from fossil fuels to renewable electricity and other zero carbon energy sources. That in turn will not be possible without major expansion of renewable generation.

Rate of demand growth due to electrification

6.29 The rate of electricity demand growth due to electrification will be affected by a range of uncertainties, such as the extent and uptake of electric vehicle rebates, battery technology improvements, and wider government policy. If the rate of electrification is slower than projected, that would reduce the required rate of renewable development, and vice versa.

6.30 However, there is growing international and domestic concern about climate change. Therefore, I expect that renewable growth projections presented in Figure 8 are more likely to be understated than overstated.

6.31 More generally, the Russian invasion of the Ukraine and other rising international tensions have lifted fossil-fuel prices. If this pressure is sustained, it is likely to accelerate the shift to renewable electricity as an energy source.

Tiwai smelter

6.32 There is uncertainty around whether the Tiwai Point aluminium smelter will continue to operate long term and, if not, when it will cease operation. The smelter's electricity purchase contract with Meridian is currently due to expire at the end of 2024. Therefore, it is possible that the smelter could exit at the end of 2024. Were this to be the case, approximately 5TWh of annual electricity demand would be lost. However, New Zealand Aluminium Smelters, the owner of the smelter, confirmed in July 2022 that it had started exploring options for electricity supply beyond 2024.

6.33 Figure 7 presents a projection of electricity demand excluding the Tiwai Point aluminium smelter out to 2050 and indicates that demand will grow by 78% between 2020 and 2050. However, even if the smelter were to exit, electricity demand is projected to grow by 57% over the same period.

6.34 This would reduce the projected new renewable generation requirement by 2050 from around 33 TWh to 28 TWh.[14] This would still require investment in renewable generation at an unprecedented rate.

7. THE BENEFIT OF EXISTING AND NEW RENEWABLE ELECTRICITY SCHEMES

Summary – the benefit of existing and new renewable electricity schemes

7.1 In this section I discuss the benefit of allowing existing renewable generation to continue to operate at its full capability and allowing new renewable generation to be built.

7.2 I consider the benefit of renewable electricity resources in general terms in this section. Later in my evidence (in section 9) I discuss in more detail the benefit of the existing Clutha Hydro Scheme.

7.3 The economic and decarbonisation benefit of existing and new renewable generation can be considered by looking at the costs (including the emissions impact) that would be incurred if existing renewable power stations were not allowed to continue operating to their (current) full

[14] Based on reference case projection in MDAG's issues paper. Details of the projection can be found here: https://www.ea.govt.nz/assets/dms-assets/29/06-100-Renewable-Electricity-Supply_-Simulation-Assumptions-and-Results-Concept-Consulting-and-John-Culy1341585-v2.1.pdf.

capacity or if some new renewable generation resources were not allowed to be developed.

7.4 I consider the costs incurred in three parts:

(a) increased electricity costs due to more expensive renewable generation resources needing to be developed;

(b) increased carbon emissions and electricity costs due to increased fossil-fuelled thermal generation; and

(c) increased carbon emissions due to electrification becoming more expensive.

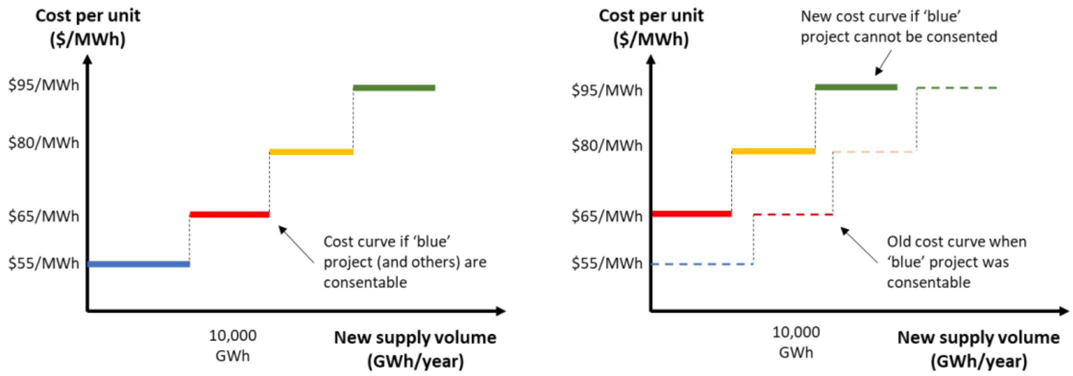
7.5 In the remainder of this section I discuss each of these costs in more detail.

Increased electricity costs if more expensive renewable generation resources need to be developed

7.6 To assess the effect of greater environmental restrictions on existing and new renewable generation on electricity costs, it is useful to apply a simplified model of New Zealand's electricity development choices.

7.7 Each prospective new project has a cost level and annual generation output. Ranking the projects from the lowest cost to the most expensive and graphing cost/volume data will produce a cost stack in the form shown on the left-hand portion of Figure 9.

Figure 9: Illustrative cost stack



Source: Illustrative data

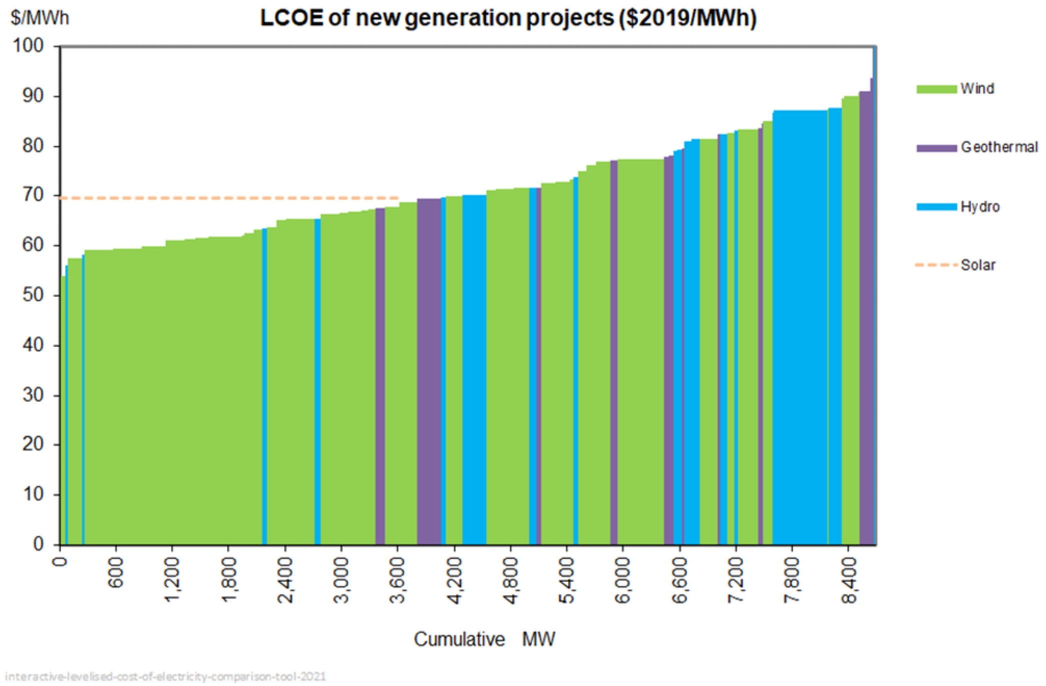
7.8 In this illustrative example, there is a tranche of relatively cheap power available from the blue project ($55/MWh), with progressively more expensive power available from the red, yellow, and green projects. If an additional (say) 10,000 GWh/year of supply was needed by 2030, this could be met from development of the blue and red projects with costs of $55/MWh and $65/MWh respectively.

7.9 Now I consider the effect on electricity costs if it was made impossible for some projects to be developed due to environmental restrictions. This is illustrated on the right-hand side of Figure 9. In this example, the blue project is removed but other project costs and volumes are unchanged. Removing this blue project results in a new cost stack. To satisfy the need for an additional 10,000 GWh of supply, the red and yellow projects are needed, with costs of $65/MWh and $80/MWh respectively. Thus, in this example, costs have increased because the relatively more expensive yellow project ($80/MWh) has needed to be developed to replace the loss of the cheaper blue project ($55/MWh) which is no longer able to be developed.

7.10 A similar effect will occur if environmental restrictions mean that existing renewable generation resources are not able to continue to generate at their existing levels. The reduction in generation capacity of the existing resource will require additional investment in new renewable generation resources in addition to the investment already required to meet increased electricity demand and to replace fossil-fuelled thermal generation (as discussed above from paragraph 6.12). This additional investment will move us further along the cost stack, thereby increasing costs.

7.11 The Ministry of Business, Innovation and Employment (**MBIE**) publishes generation cost stack estimates from time to time. Figure 10 shows the information available in April 2022 (noting the estimates were likely finalised in 2020/2021). I note that the projects are at varying stages of maturity in terms of site selection, resource consents, transmission connection capacity etc. Some projects are shovel ready, whereas others require significant preparatory work before they could be developed.

Figure 10: MBIE estimated cost stack for new renewable generation (2021)[15]



Source: Ministry of Business, Innovation and Employment

7.12 MBIE states that the data shown are "illustrative only".[16] While this health warning should be borne in mind, I consider that the stack nonetheless provides a reasonable guide to the expected costs of potential future generation projects. This is based on a comparison and analysis of the data with other (less comprehensive) public sources. Further, while other sources may have individual projects at higher or lower costs, they all present a picture with an upward sloping cost curve. I also note that despite the caveat above, MBIE itself uses generation stack information in its energy and climate modelling.

7.13 MBIE's stack does not include individual solar farm projects due to limitations in information. In practice I expect solar projects will make up a significant proportion of new generation build over the next 20-30 years. Having said that, solar projects can be expected to vary in their costs to reflect differences in solar levels, infrastructure requirements, etc for each development. Put another way, had individual solar projects been included in MBIE's cost stack, I expect the same overall picture would remain – with

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[15] Source: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/interactive-levelised-cost-of-electricity-comparison-tool/ downloaded 4 April 2022. A different version of the chart appears on the MBIE website. This version has been extracted from MBIE's spreadsheet and shows a fuller range on the x-axis and only renewable generation sources.

[16] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-modelling/interactive-levelised-cost-of-electricity-comparison-tool/ downloaded 12 October 2022.

an upward sloping stack reflecting projects with differing costs, albeit with a less steep gradient.

7.14 On the other hand, MBIE's stack includes some projects which may never be built. In some cases this is because consented projects may no longer represent the most efficient new investment, as they may not be consented for the optimal location or latest technology, so may be put on hold, possibly indefinitely, even in the existing consenting environment. The Castle Hill wind farm, for example, is consented for 860MW of wind generation, but has not been constructed despite the consent requiring construction to begin by 2023. If the consented projects that are unlikely to proceed for location, technology or similar reasons are removed from the cost stack, the gradient becomes steeper.

7.15 In summary, the MBIE cost stack represents one snapshot of possible developments based on information available in 2020/2021. The picture will continue to evolve, but the crucial point is that I expect the cost of electricity from different projects will vary, and this leads to an upward sloping cost stack.

Increased electricity costs and carbon emissions if fossil-fuelled thermal generation needs to generate for longer

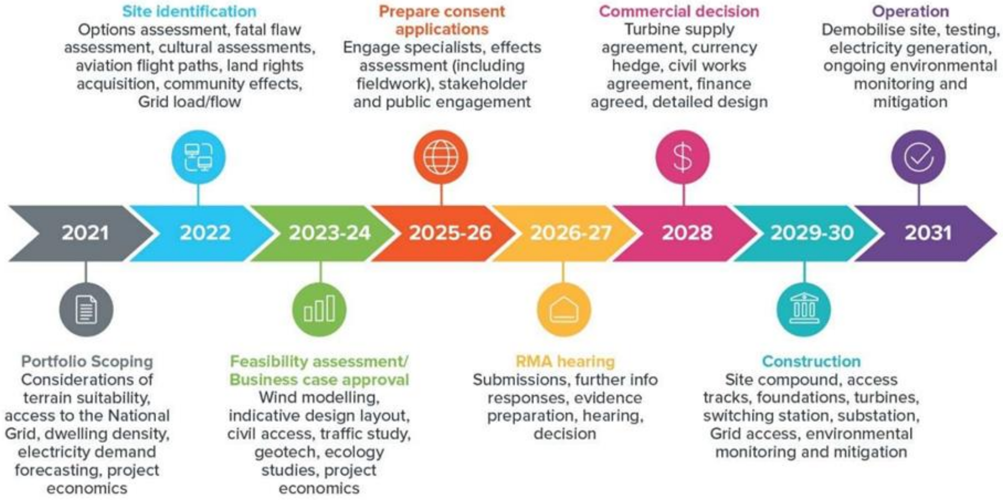
7.16 If the generation capability of existing renewable generation was reduced with minimal warning (eg due to issues with reconsenting) a deficit would likely emerge between the actual level of renewable generation and the level needed to achieve decarbonisation goals. To avoid power cuts, the generation deficit would need to be filled by additional fossil-fuelled thermal generation.[17] The deficit could last for some years as it would take time for additional renewable generation developments to be ready to operate. Furthermore, during the catch-up period there would be a need to develop renewable projects at an even faster rate than projected in section 6 in order to clear the backlog.

7.17 A similar effect is likely if environmental restrictions mean that the current pipeline of potential new renewable generation resources was disrupted. As shown in Figure 11 potential developments typically move through a series of stages over some years. If new restrictions were to disrupt the

[17] However, the extent to which this is possible depends on how much renewable generation capacity is cut. As I note below in paragraphs 9.10 - 9.11 (in relation to the Clutha Hydro Scheme) if capacity is cut considerably there may not be enough thermal generation to replace the lost capacity.

pipeline, it could take some time for pipeline to fill up with sufficient alternative renewable generation projects .

Figure 11: Development timeframe for a windfarm under Resource Management Act



Source: Te Waihanga – Infrastructure Commission[18]

7.18 In most cases, fossil-fuelled generation is both more expensive to operate (due to high fuel and carbon costs) and has higher carbon emissions than renewable electricity resources. Therefore, if higher environmental restrictions on existing and new renewable electricity resources increase the use of fossil-fuelled thermal generation this will likely increase electricity costs and carbon emissions.

Increased carbon emissions if electrification becomes more expensive

7.19 In addition to the direct emissions impact from higher levels of fossil generation (as I discussed in paragraphs 7.16 - 7.18), an increase in electricity prices, due to greater environmental restrictions on renewable generation, is also likely to result in increased 'indirect' emissions for the rest of the economy. This is because electrification has been identified as one of the key means of decarbonising significant parts of our economy, particularly transport, space and water heating, and industrial process heat.[19] An increase in electricity prices will discourage energy consumers from moving away from fossil fuels to electricity.

[18] See www.tewaihanga.govt.nz/assets/Uploads/Te-Waihanga-Natural-and-Built-Environments-Bill-submission-to-Environment-Select-Committee.pdf, downloaded 4 April 2022.
[19] For example, see https://ccc-production-media.s3.ap-southeast-2.amazonaws.com/public/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa/Inaia-tonu-nei-a-low-emissions-future-for-Aotearoa.pdf, paragraph 55.

8. CLUTHA HYDRO SCHEME PROVIDES RENEWABLE AND FLEXIBLE ENERGY SUPPLY

The Clutha Hydro Scheme's contribution to the electricity system

8.1 The Clutha Hydro Scheme contributes to the electricity system in two key ways:

(a) it provides a significant proportion of New Zealand's renewable electricity supply to help power homes and businesses across New Zealand; and

(b) it is a source of controllable energy (particularly in the short term), which helps in balancing the overall electricity system.

8.2 I discuss each of these contributions in more detail in the remainder of this section.

The Clutha Hydro Scheme provides renewable energy

8.3 The Clutha Hydro Scheme is made up of two power stations on the Clutha River – one at Clyde and one at Roxburgh. Together these two power stations have a nameplate capacity of 752 MW. Since 2000, the Clutha Hydro Scheme has produced about 3,700 GWh of electricity each year on average.[20] However, in the past four years (2018-2021) generation has increased to just over 3,900 GWh of electricity per year. Most years, the Clutha Hydro Scheme generates about 12% of New Zealand's renewable generation and about 10% of New Zealand's gross electricity demand.

8.4 For a sense of scale, this is roughly the same as the annual electricity consumption of the South Island's nearly 500,000 residential electricity consumers.[21]

Clutha Hydro Scheme provides some storage capacity

8.5 The level of generation from the Clutha Hydro Scheme can be controlled (ie raised or lowered (within limits)) to reflect the needs of the electricity system. While the Clutha Hydro Scheme is largely run of river, it does have some flexibility in the headponds behind the Clyde and Roxburgh dams. This allows some short-term flexing of output (eg across a day).

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[20] The average between 2000 and 2021 was 3,718 GWh per annum.

[21] According to Electricity Authority data, total energy consumption for South Island residential consumers was 3,832 GWh in 2021. This excludes transmission and distribution losses conveying the power to customers' homes.

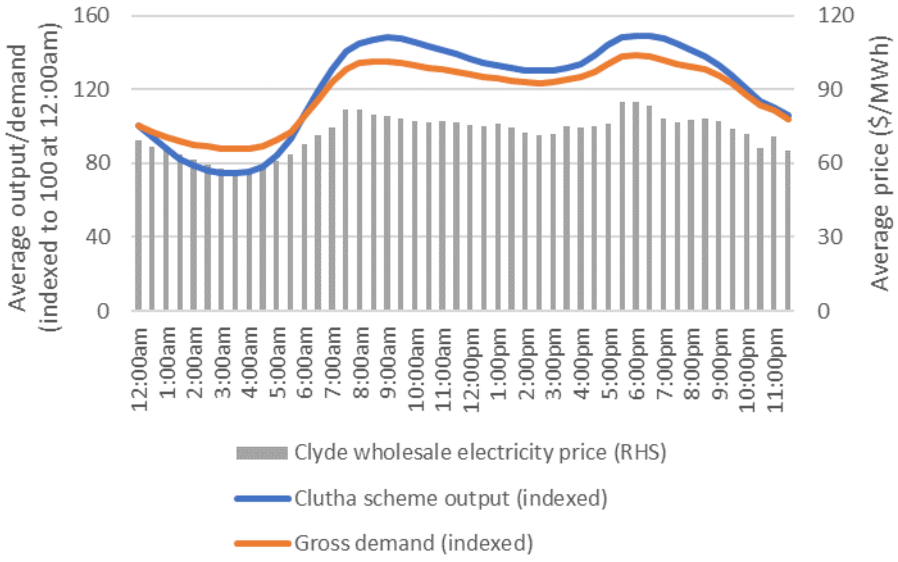
8.6 In addition, the scheme has some seasonal flexibility due to Lake Hāwea's storage capacity of 291.75 GWh.

8.7 While Lake Hāwea's active storage capacity is substantially smaller than some other hydro lakes it is still very useful. For example, it is approximately half the storage of Lake Taupo (587.24 GWh). Lake Hāwea makes up 8% of New Zealand's hydro generation storage.

The Clutha Hydro Scheme provides intraday flexibility

8.8 Clutha Hydro Scheme's intraday flexibility is apparent when comparing the Clutha Hydro Scheme's average output to the average level of electricity demand for the entire country by time of day since 2000. This is shown in Figure 12 below.

Figure 12: Clutha Hydro Scheme – average output by time of day (indexed)



Source: Concept analysis of Electricity Authority data for 2000-2021

8.9 Figure 12 shows how national demand (the orange line) dips in the early hours of the morning, before rising steeply from around 6am as New Zealanders get ready to go to work or school, etc. Demand dips slightly around midday before rising again to the evening peak. These peaks in demand coincide with higher wholesale electricity prices at Clyde (the grey bars).[22] This is because when electricity demand is greater the value of electricity is higher (if supply conditions are unchanged) and vice versa.

[22] The Clyde wholesale price is the time-weighted average price (TWAP) for each trading period in the day. For simplicity I have only presented the wholesale price at the Clyde node. Prices at Roxburgh have a near identical pattern.

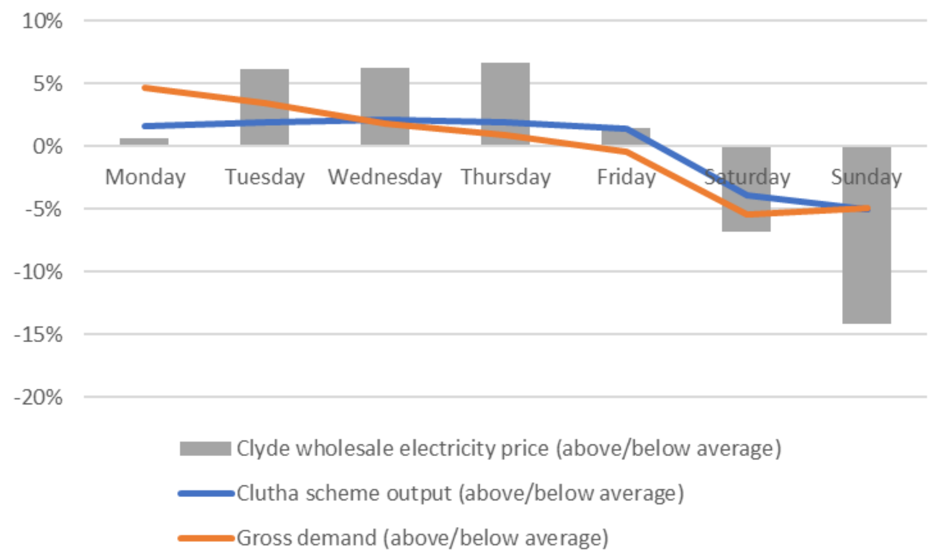
8.10 The average output of the Clutha Hydro Scheme (the blue line) follows the same broad pattern, but with more pronounced peaks and troughs. This illustrates that the Clutha Hydro Scheme varies its output throughout the day to contribute higher supply when the system values it more (ie when national demand is higher each day) and vice versa.

The Clutha Hydro Scheme also provides some within week flexibility

8.11 The Clutha Hydro Scheme also provides some within week flexibility. Over the 22 years from 2000 to 2021, the Clutha Hydro Scheme's output was 6% lower on Saturdays and Sundays than on weekdays (on average). This lower output on Saturdays and Sundays is likely a response to lower electricity demand in the weekend, leading to lower wholesale electricity prices.

8.12 Figure 13 below illustrates how the Clutha Hydro Scheme's output, system demand, and the wholesale price at the Clyde node vary by the day of the week. The blue line shows that on Monday through to Friday, the Clutha Hydro Scheme's output is greater than its average output, while on Saturday and Sunday it is lower. This follows the pattern of gross electricity demand, although Clutha Hydro Scheme's output does not vary by as much as gross demand throughout the week. The greater electricity demand on weekdays relative to weekends is reflected in the wholesale price at the Clyde node – prices on Saturdays and Sundays are significantly lower than prices on weekdays at the Clyde node (as shown by the grey bars).

Figure 13: Clutha Hydro Scheme – output relative to average by day of the week



Source: Concept analysis of Electricity Authority data for 2000-2021[23]

8.13 Being able to vary the Clutha Hydro Scheme's output (to a limited extent) throughout the week is also very important for the electricity system. It means that it has some ability to react to within week changes in the value of electricity, including changes driven by both demand and supply (eg changes in output of intermittent generation (wind and solar) or unplanned generation outages). As I noted in paragraphs 6.18 - 6.19, this will become even more important as the proportion of electricity generated by intermittent supply increases.

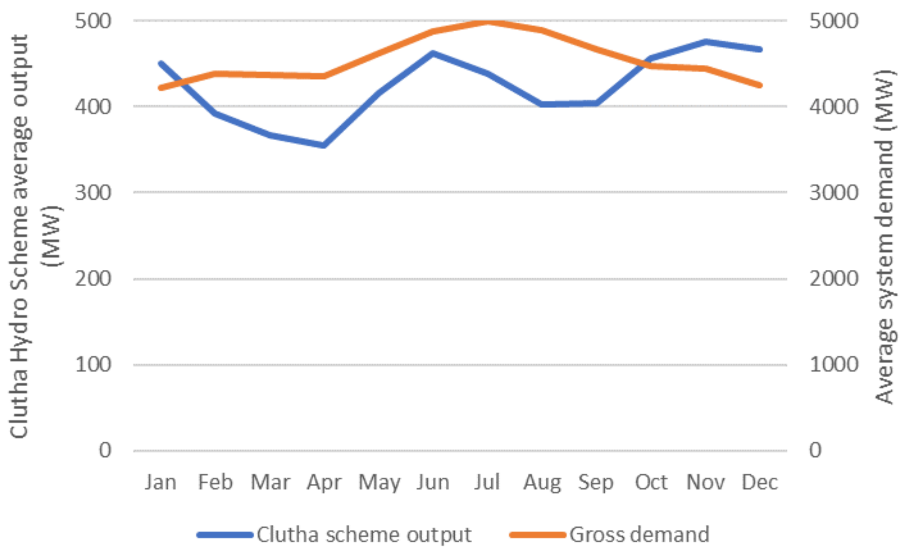
The Clutha Hydro Scheme has a modest ability to alter its output across the year

8.14 The Clutha Hydro Scheme has limited flexibility to alter its level of generation across the year. This is because the storage capacity at Lake Hāwea is modest relative to the annual hydro inflows to the whole scheme.

8.15 This is illustrated by Figure 14 which shows the average monthly generation of the Clutha Hydro Scheme and system demand. While national demand peaks in mid-winter (July), the Clutha Hydro Scheme's output peaks in November-December, with a second (slightly lower) peak in June. While the Clutha Hydro Scheme has (on average) lifted its output temporarily in the lead-in to winter it is not able (in an average year) to sustain that higher output over the remainder of the winter months.

[23] The Clyde wholesale price is the time-weighted average price (TWAP) for each day of the week. For simplicity I have only presented the wholesale price at the Clyde node. Prices at Roxburgh have a near identical pattern.

Figure 14: Clutha Hydro Scheme – average output by time of year



Source: Concept analysis of Electricity Authority data for 2000-2021[24]

The combined effect of Clutha Hydro Scheme's flexibility over different time dimensions

8.16 Figure 12, Figure 13, and Figure 14 illustrate that the Clutha Hydro Scheme is able to provide short-term flexibility (intraday and within a week), but less able to provide flexibility over the course of a year.

8.17 A statistic which summarises the combined effect of multiple flexibility dimensions is the so-called 'capture rate'. This is defined as the average spot price earned by a specific generator divided by the average price received by a notional generator that has constant output every hour.[25] This constant output generator can be thought of as providing 'vanilla' or 'baseload' electricity into the system.

8.18 Generators that achieve a capture rate above 100% are (on average) providing supply when it is more beneficial to the system. The premium above 100% indicates their output is more valuable than the standard vanilla product.

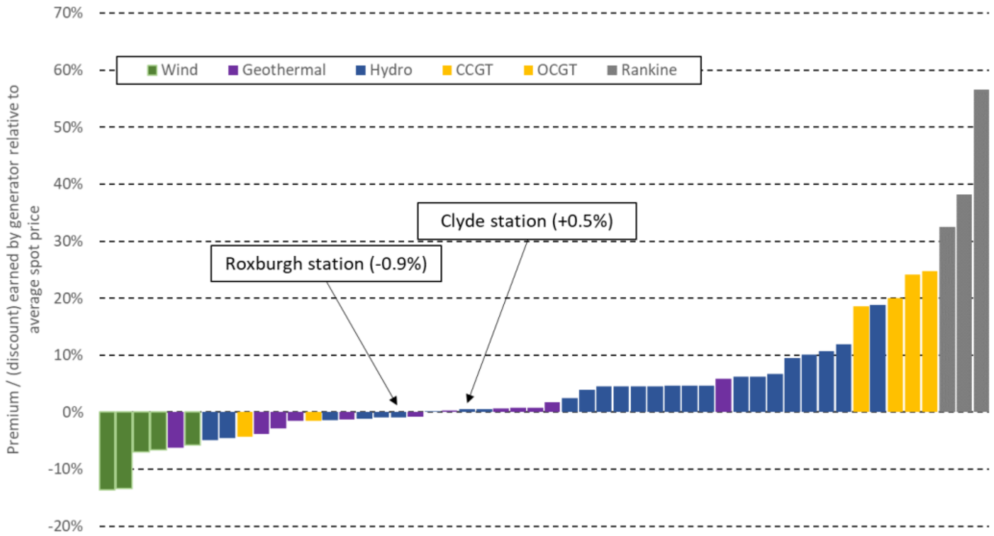
8.19 In contrast, generators with a capture rate below 100% are (on average) contributing supply at times when it has lower benefits to the system – and

[24] The Clyde wholesale price is the time-weighted average price (TWAP) for each day of the week. For simplicity I have only presented the wholesale price at the Clyde node. Prices at Roxburgh have a near identical pattern.
[25] The capture rate is also known as the GWAP/TWAP ratio where GWAP is the generation weighted average price and TWAP is the time weighted average price.

are therefore net contributors to the need for flexibility.[26] Put another way, their output is less valuable that the standard vanilla product.

8.20 Figure 15 below shows the capture rates for all major power stations in New Zealand since 2015, with the rates expressed as a premium or discount to 100% (ie the rate applicable for the 'vanilla' generator).[27]

Figure 15: Indicative flexibility premium/(discount) earned in spot market



Source: Concept analysis of Electricity Authority data

8.21 Key observations from the chart are that since 2015:

(a) the Clyde hydro station earned a small premium to the vanilla energy value – indicating that it was a net contributor to system flexibility;

(b) the Roxburgh hydro station earned a small discount to the vanilla energy value – indicating that it was a small net user of system flexibility;

(c) many stations earned a greater premium than the Clyde and Roxburgh hydro stations, with the highest premia for the combined cycle gas turbine, and open cycle gas turbine, and Rankine units.[28] However, all of these generation types currently operate on fossil-fuels, and fossil-fuel use is likely to phase down as the electricity sector decarbonises; and

[26] Investment in such generators may still be economically attractive, provided their costs are low enough to offset the reduced system benefits they provide.
[27] Rates are shown based on data for the 2015 year. Rates for individual stations vary from year to year in absolute terms, but the relativities between stations are fairly stable over time.
[28] Combined cycle gas turbines (CCGT) and open cycle gas turbines (OCGT) run on gas or diesel, and Rankine units operate on gas or coal.

(d) some stations (for example wind generators and run-of-river hydro) received a substantial discount to the vanilla price. This indicates the stations were net users of system flexibility due to their intermittent output.

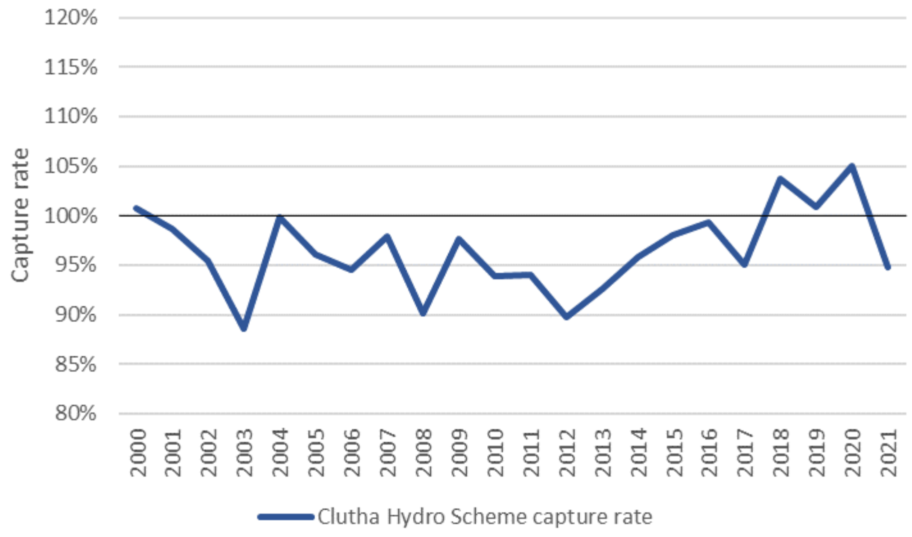
8.22 Looking more closely at the capture rates for the Clutha Hydro Scheme, Figure 16 below shows the annual capture rate for the Clutha Hydro Scheme over the past 22 years. It shows that Clutha Hydro Scheme's capture rate:

(a) has been less than 100% in most years;

(b) can change significantly from year to year; and

(c) has increased (on average) over the last decade.

Figure 16: Clutha Hydro Scheme capture rate over time



8.23 I consider that the Clutha Hydro Scheme's capture rate is less than 100% in most years because the Scheme's ability to respond to changes in demand and supply in the short-term (intraday and within week) are outweighed by its limited ability to 'save' generation for the times of the year (autumn and winter) when wholesale electricity prices are higher. However, I consider that the Clutha Hydro Scheme's capture rate is likely to increase in the future, which I discuss in paragraph 9.17 below.

Conclusion on the contribution of the Clutha Hydro Scheme to the electricity system

8.24 The Clutha Hydro Scheme plays an important role in meeting New Zealand's electricity demand. The Scheme generates about 12% of New Zealand's renewable electricity generation, roughly equivalent to the consumption of the South Island's nearly 500,000 residential electricity consumers. It also has some flexibility to respond to intraday and longer changes in electricity demand and supply due to Lake Hāwea's storage capacity. The Clutha Hydro Scheme's flexibility is expected to become even more important as the proportion of electricity generated by intermittent supply (wind and solar) increases.

9. THE ECONOMIC AND DECARBONISATON BENEFIT OF THE CLUTHA HYDRO SCHEME

9.1 The national economic and decarbonisation benefit of the Clutha Hydro Scheme's energy supply can be estimated by considering the costs (including the emissions impact) that would be incurred if the Scheme were not available to operate. The greater those costs, the greater the benefits from continued operation of the Scheme and vice versa.

9.2 Before discussing the estimates themselves, it is important to emphasise that I have compiled estimates of economic effects, that is, the economic impacts on New Zealand society as a whole. The commercial effects for the owner of the Clutha Hydro Scheme will differ from the wider economic effects for a range of reasons. It is also important to recognise that the estimates only incorporate electricity-related effects.

9.3 Returning to the estimation of the cost if the Clutha Hydro Scheme were not available to operate, it is useful to consider two timeframes: the short-term (when alternative energy resources already in existence must provide the substitute energy); and the longer-term (when permanent substitutes could be in place, noting it generally takes years to construct new power stations).

9.4 In this section I consider the:

(a) short-term cost impact if supply from the Clutha Hydro Scheme were not available;

(b) longer-term cost impact if supply from the Clutha Hydro Scheme were not available; and

(c) additional cost impact of losing the Clutha Hydro Scheme's controllable energy (ie its flexibility).[29]

Short-term cost impact if supply from Clutha Hydro Scheme not available

9.5 The electricity system normally has some unutilised plant that can operate at relatively short notice to provide so-called reserve. This reserve is largely comprised of capacity at fossil-fuelled thermal power stations. However, this type of plant has high operating costs (one of the reasons it is seldom used) and significant carbon emissions so is therefore not suitable as an ongoing substitute.

9.6 If the Clutha Hydro Scheme were not available, the most likely initial effect would be the increased operation of thermal power stations, running on gas or coal.

9.7 Table 1 sets out estimates of the costs of obtaining power from these types of generation units. The underlying fuel cost estimates are based on the historical longer-term average prices for gas and coal (prices are currently much higher) and forward projections for New Zealand carbon prices.[30]

Table 1: Initial annual costs to substitute for Clutha Hydro Scheme supply

	Gas-fired substitute	Coal-fired substitute
Cost to replace lost energy ($m/year)	$ 326	$ 625
Increase in emissions (tCO2e/year)	1,450,135	3,606,747
Emissions equivalent (number of cars)	782,615	1,946,505

Clutha hydro scheme analysis.xlsx

9.8 As shown in Table 1, it would be very costly to replace energy from the Clutha Hydro Scheme with electricity generated from thermal power stations. Even the cheapest option (gas-fired) would incur a cost of over $326m per year. Using coal-fired generation instead would almost double the cost.

9.9 It is important to note that the estimates in Table 1 assume that sufficient spare thermal plant is available to fully substitute for the Clutha Hydro

[29] The estimates of the short-term and longer-term cost impacts noted in paragraphs 9.4(a) and 9.4(b) do not make any allowance for the value of the flexibility that the Clutha Hydro Scheme provides.
[30] If current fuel costs were used, the cost estimates in Table 1 would be much higher. See https://www.commtrade.co.nz/ for the information on projected carbon prices.

Scheme. That assumption is optimistic given the large volume of energy that would be lost if the Clutha Hydro Scheme could not operate.

9.10 A more likely outcome is that thermal generation would be a partial substitute, and power rationing would be required in some periods (eg cold winter evenings) due to insufficient spare thermal capacity. In that case, the costs would be even higher than those shown in Table 1.

9.11 Table 1 also shows the expected emissions impact of replacing the renewable energy from the Clutha Hydro Scheme with output from thermal power stations. If gas-fired units were used as the source (a best case for fossil-fuelled thermal energy), emissions would rise by over 1.4 million tonnes of carbon dioxide equivalent per year. If coal-fired units were used as the source, there would be an increase of almost 3.6 million tonnes per year. To put these figures into perspective, that would be roughly equivalent to the emissions from nearly 800,000 or two million petrol light passenger vehicles respectively on the roads.[31]

Longer-term cost impact if supply from Clutha Hydro Scheme not available

9.12 If supply from the Clutha Hydro Scheme were not available on an ongoing basis, new generation sources would need to be developed as a replacement. The most likely alternatives are geothermal, solar, or wind generation, or some mix of these. On a dollar per unit of energy basis, they would have lower economic costs than the thermal plant options discussed above. However, they would all involve significant upfront capital expenditure and take some time to build. This investment in new generation sources would also be in addition to the substantial growth in renewable generation required to provide the electricity to meet New Zealand's decarbonisation goals (as discussed from paragraph 6.12 above).

9.13 Table 2 below shows my estimates of the ongoing costs to produce substitute energy if the Clutha Hydro Scheme was not available. The estimates incorporate the additional expenditure that would be required on alternative new power stations, less an allowance for avoided expenditure on the Clutha Hydro Scheme assets.[32]

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[31] These estimates are based on the average emission/km travelled of new vehicles, and assuming they each travel 10,500 km per year (the New Zealand average for 2020).
[32] This allowance roughly reflects the average reported capital expenditure for another hydro scheme that is thought to have broadly similar costs.

Table 2: Ongoing costs to substitute for Clutha Hydro Scheme supply

	Lower est.	Higher est.
Annual cost ($m/year)	$204	$260
Total over 35 years ($m)	$3,348	$4,261

Clutha hydro scheme analysis.xlsx

Source: Concept estimates. Present values have been calculated using 5% discount rate (pre-tax real) as recommended by NZ Treasury for calculating economic costs and benefits of energy projects).

9.14 Given the uncertainties in some variables, I have calculated lower and higher cost estimates for obtaining substitute energy. The overall cost impacts range from $204 to $260 million per year. These estimates are lower than the costs associated with replacing Clutha Hydro Scheme output with thermal generation but are still very substantial in annual terms.

9.15 They are even more significant when viewed over the likely lifetime of substitute energy sources such as solar or wind farms. In present value terms, the costs would be approximately $3.3 to $4.3 billion.

The cost impact if controllable energy from Clutha Hydro Scheme was not available

9.16 The cost estimates for substitute energy I have discussed so far assume that the Clutha Hydro Scheme produces vanilla or baseload energy. As noted in paragraph 7.1 the Clutha Hydro Scheme does provide short-term (intraday and within a week) flexibility.

9.17 My assessment above of the Clutha Hydro Scheme's capture rates (in paragraphs 8.16-8.23) indicates that the economic benefit of the Scheme's flexibility in the short-term has (to date) been outweighed by the cost of the Scheme's lack of flexibility over the longer-term. However, I expect that in the future the economic benefit of the Clutha Hydro Scheme's short-term flexibility will increase and that its capture rate will correspondingly increase. This is because, as noted above in paragraph 6.14(c), the proportion of intermittent generation (wind and solar) on the system is expected to increase substantially in the future (from around 6% of total supply now to about 50% in 2050). These intermittent forms of generation require flexible energy sources to firm up their output, particularly over short periods (eg within a month).

9.18 For this reason, the economic cost estimates to replace the energy from the Clutha Hydro Scheme in paragraph 9.15 are likely to be conservative (ie low).

David Thomas Hunt

23 November 2022

Appendix B

Evidence in Chief of Ms Jacqueline Nelson on behalf of Contact Energy Limited (Proposed Otago Regional Policy Statement 2021 Fresh Water Planning Instrument Hearing)

BEFORE THE HEARING COMMISSIONERS APPOINTED BY OTAGO REGIONAL COUNCIL

Under	the Resource Management Act 1991
In the matter	of the proposed Otago Regional Policy Statement 2021 (excluding provisions renotified as part of a freshwater planning instrument)

STATEMENT OF EVIDENCE OF JACQUELINE MARIE NELSON (CORPORATE OVERVIEW) ON BEHALF OF CONTACT ENERGY LIMITED

23 November 2022

BUDDLE FINDLAY

Barristers and Solicitors
Wellington

Solicitor Acting: **David Allen / Frances Wedde**
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CONTENTS

1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is **Jacqueline (Jacqui) Marie Nelson**.

1.2 I have worked for Contact Energy Limited (**Contact**) for 18 years and have extensive knowledge of Contact's electricity generation activities and operations, both in the Otago Region and throughout Aotearoa New Zealand.

1.3 My current role at Contact is Chief Development Officer. I have held this role for 12 months. In this role, I am responsible for leading Contact's renewable electricity generation (**REG**) development and demand growth activities by attracting new industrial demand for renewable electricity (ie transitioning from fossil fuels to renewable electricity), aligned with our Contact26 strategy, to lead the decarbonisation of Aotearoa New Zealand.

1.4 Prior to holding this role, I have held the following positions at Contact:

(a) Corporate Treasurer (December 2004 – Mid-2010);

(b) Land & Consenting Manager in Contact's Environmental Team (Mid-2010 – July 2013);

(c) Head of Land, Environment and Consenting (July 2013 – 2015);

(d) Head of Electricity Markets and Environment (2015 – March 2016);

(e) General Manager of Operations (April 2016 – July 2020); and

(f) Chief Generation Officer (August 2020 – September 2021). In this role I provided strategic and operational leadership to Contact's operations teams tasked with the safe and optimal operation of Contact's generation sites and management of Contact's LPG infrastructure. I was responsible for the electricity generation and trading, and sustainability functions of the business, which deliver 80% of Contact's EBITDAF,[1] and accountable for the financial management of the company's largest cost budget.

1.5 I have an BSc in chemistry from Otago University.

[1] Earnings before interest, tax, depreciation, amortisation, and changes in fair value of financial instruments.

2. SCOPE OF EVIDENCE

2.1 In preparing my evidence I have reviewed at a high-level the relevant parts of:

(a) the proposed Otago Regional Policy Statement (**proposed RPS**);

(b) Contact's submissions and further submissions;

(c) the Otago Regional Council's (**Regional Council**'s) section 42A report, including the version showing recommendations from the Regional Council's supplementary evidence and additional supplementary evidence (**section 42A report (October version)**); and

(d) the statements of evidence prepared by expert witnesses on behalf of Contact.

2.2 This evidence is corporate evidence and not expert evidence. I am authorised by Contact to provide this evidence on its behalf.

2.3 The purpose of my evidence is to provide:

(a) an overview of Contact, including its operating history, role in the energy industry and its contribution to meeting national electricity demand;

(b) an overview of Contact's continued progression toward REG and Contact's contribution to the Government's greenhouse gas emissions reduction targets;

(c) an overview of Contact's sustainability tikanga in its operations;

(d) an overview of Contact's assets in the Otago Region, being the Clutha Hydro Scheme (**CHS**), including a description of its key features, its current resource consents, its land holdings, how it operates within the broader electricity generation network; and what the future operation of the CHS might be;

(e) an overview of Contact's investigation of new REG opportunities in the region; and

(f) a discussion of the key issues and concerns that Contact has with the proposed RPS.

3. EXECUTIVE SUMMARY

3.1 Contact is the second-largest electricity generator/retailer in Aotearoa New Zealand with a flexible and largely renewable portfolio of electricity generation assets. Contact owns and operates 11 generating stations across the country, and generally produces 80-85 percent of its electricity from renewable hydro and geothermal resources.

3.2 Contact is committed to contributing to the achievement of Aotearoa New Zealand's climate change targets and assisting the New Zealand Government to meet its climate change goals. To that end, Contact's target is to reduce Scope 1 and 2 greenhouse emissions by 45% compared to a 2018 baseline; and is currently investigating new REG opportunities in the region and New Zealand more broadly.

3.3 A commitment to REG is also a core part of Contact's sustainability tikanga; which informs and guides the way we run our business.

3.4 Within the region, Contact operates the CHS, which is nationally significant infrastructure and contributes about 10 percent of Aotearoa New Zealand's overall electricity supply and on average 12 percent of Aotearoa New Zealand's REG. Contact wants to ensure that the provisions of the RPS appropriately protect and provide for this critical infrastructure now and in the future.

3.5 In terms of the proposed RPS, Contact has a number of concerns, which are addressed in detail in section 9 of this evidence. To address these concerns, Contact supports the amendments to the proposed RPS set out in the expert planning evidence of **Ms Hunter**.

4. CONTACT ENERGY LIMITED

4.1 Contact is the second-largest electricity generator/retailer in Aotearoa New Zealand with a flexible and largely renewable portfolio of electricity generation assets. Contact is listed on the New Zealand (NZX) and Australian Stock Exchanges (ASX) and has approximately 63,000 shareholders.

4.2 Contact commenced operations in early 1996 when it acquired a portfolio of electricity generation assets from the state-owned electricity generator

ECNZ (Electricity Corporation of New Zealand). These assets included gas and hydro electricity generation assets (including the CHS).

4.3 Contact owns and operates 11 generating stations across the country, and generally produces 80-85 percent of its electricity from renewable hydro and geothermal resources.

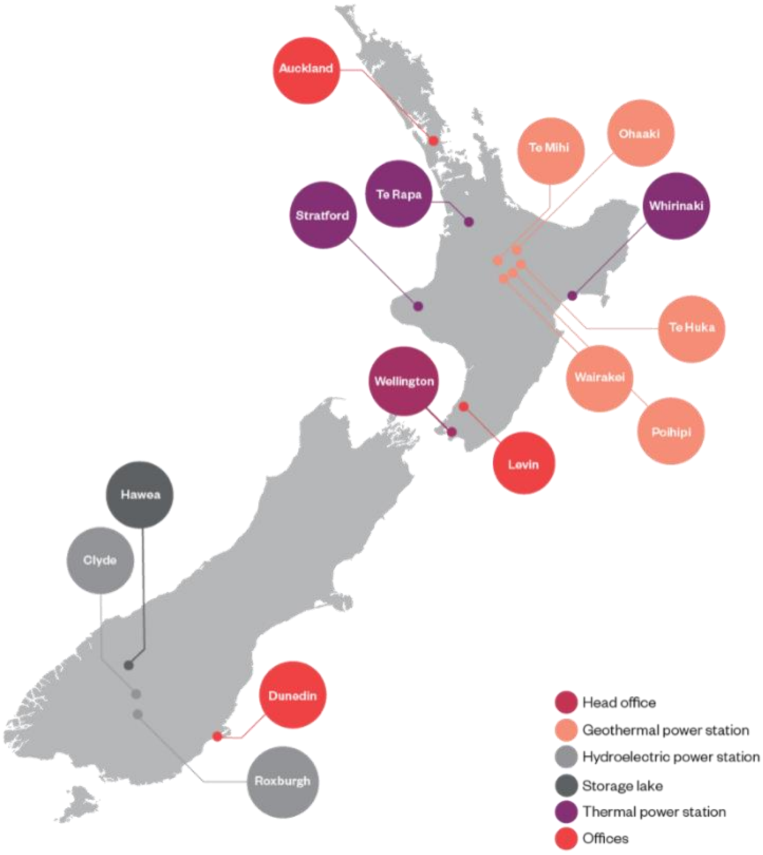

Figure 1: Location of Contact's assets and operations

4.4 Contact's contribution to New Zealand's electricity generation is critical to the health and wellbeing of New Zealanders. For example only, Contact supplies electricity to 4,428 "medically dependent" customers, which includes individuals as well as numerous hospitals, retirement villages and medical centres. Contact also supplies 14 councils with a total of 161 connections. These connections to health care and council infrastructure help to support the health and wellbeing of numerous New Zealanders by ensuring that these essential services have the electricity they need to continue to operate.

5. RENEWABLE ELECTRICITY GENERATION

5.1 In 2008, less than 55 percent of Contact's electricity generation portfolio was from renewable sources. Since then, Contact has led the substitution of almost 3 terawatt-hours (**TWh**)[2] of higher-carbon thermal generation with REG. This has led to an increase in the proportion of electricity that Contact generates from REG to well over 84 percent (81 percent in the 2021 financial year). This generation provided about 17.5 percent of Aotearoa New Zealand's total REG in 2021.

5.2 Contact is committed to contributing to the achievement of Aotearoa New Zealand's climate change targets and assisting the New Zealand Government to meet:

(a) the emissions reduction target established by the Climate Change Response Act 2002 of reducing New Zealand's greenhouse gas emissions (except biogenic methane) to net zero by 2050;[3]

(b) the targets for the energy system set out in the Emissions Reduction Plan, including the Government's aspirational target of transitioning to 100 percent REG by 2030;[4] and

(c) the increased demand for REG as a result of decarbonising Aotearoa's industries as set out in the Emissions Reduction Plan.[5]

5.3 Contact's strategy focuses on achieving its vision: "*Building a better Aotearoa / New Zealand by leading the decarbonisation of its economy.*" To do this, Contact is (amongst other things) focusing on the development of new REG assets, and the on-going decarbonisation of its current generation portfolio.

5.4 Contact's target is to reduce Scope 1 and 2 greenhouse emissions by 45% compared to a 2018 baseline.

5.5 Contact is continuing to investigate new REG development opportunities across Aotearoa New Zealand, including new wind, solar developments and the potential for green hydrogen (with its partner Meridian Energy Limited).

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[2] A terawatt-hour is a unit of energy equal to outputting one trillion watts for one hour.
[3] Climate Change Response Act 2002, s 5Q.
[4] *Aotearoa New Zealand's first emissions reduction plan*, page 220.
[5] *Aotearoa New Zealand's first emissions reduction plan*, page 218.

6. SUSTAINABILITY

6.1 Sustainability is integral to Contact, and Contact is committed to continually improving its environmental performance and reducing its impact on the environment, and the communities within which we operate.

6.2 This starts with "*Our Tikanga*" – our commitment to being a responsible organisation. *Our Tikanga* sets out a series of principles and commitments that Contact is guided by in its business, including by:

(a) striving to minimise any environmental impacts on our customers and communities;

(b) ensuring the sustainability of our business;

(c) taking care of the environment by looking after our natural and shared resources; and

(d) being a good neighbour in the communities where we operate.

6.3 We also have the Contact26 strategy, which sets out Contact's plan of action for the five years from 2021-2026, including Contact's commitment to lead the decarbonisation of Aotearoa New Zealand's economy by transitioning our generation portfolio to renewable electricity and developing new renewable electricity generation.

6.4 This strategy is grounded in a sustainable and conscious effort to lead the decarbonisation of Aotearoa / New Zealand's economy. We are committed to lowering our carbon emissions, investing in our communities, and treating our customers fairly.

6.5 As part of this strategy, we have a comprehensive set of environmental, social and governance targets to track our performance. Our environmental initiatives include:

(a) a generation portfolio that is 95% renewable by 2025;

(b) a reduction of Scope 1 and 2 carbon emissions by 45% by 2026, compared to 2018 when we first set our targets;

(c) a commitment to displace 1PJ[6] of industrial heat with electricity by 2024;

(d) planting 20,000 hectares of economically marginal land in Aotearoa New Zealand by 2024 through our partnership with Dryland Carbon. This equates to 30 million tonnes of carbon dioxide removal over the lifetime of the 40-year partnership; and

(e) planting an additional 100,000 native trees on Contact land and in partnership with others by 2024.

6.6 Contact also seeks to continuously improve its sustainability and environmental performance using the ISO14001:2015 Environmental Management System. This internationally recognised and audited system provides the framework for enabling Contact to go beyond fulfilling its compliance obligations to consider broader environmental and social objectives.

7. CONTACT ASSETS IN THE OTAGO REGION (THE CLUTHA HYDRO SCHEME)

7.1 In the Otago region, Contact owns and operates the CHS. The CHS in its entirety has a maximum output of 752 MW with an average annual output of about 3,900 GWh. As **Mr Hunt** observes, this is roughly the same scale as the total consumption of all South Island residential electricity consumers.[7]

7.2 The CHS contributes about 10 percent of Aotearoa New Zealand's overall electricity supply and on average 12 percent of Aotearoa New Zealand's REG. It is also a source of controllable energy which helps in balancing the overall electricity system (as discussed further in the evidence of **Mr Hunt**)[8] and from the perspective of Contact's generation portfolio discussed in my evidence below.

7.3 The CHS is operated as one integrated / interdependent management unit from Clyde. There are three primary structures associated with the CHS, being the Hāwea Dam (and associated Gladstone Gap Stopbank and

[6] 1PJ is approximately 277GWh. This is the equivalent of servicing 35,000 houses for 1 year and 4.5 million Tesla car charges. By way of further context, in terms of large electricity users, Alliance – Meat uses a total of 96GWh of heat per year which amounts to approximately 35% of 1PJ.
[7] Hunt EIC, para 4.6.
[8] Hunt EIC, from para 8.5.

Spillway), the Clyde Dam and the Roxburgh Dam. The relationship between these structures is described in the following paragraphs.

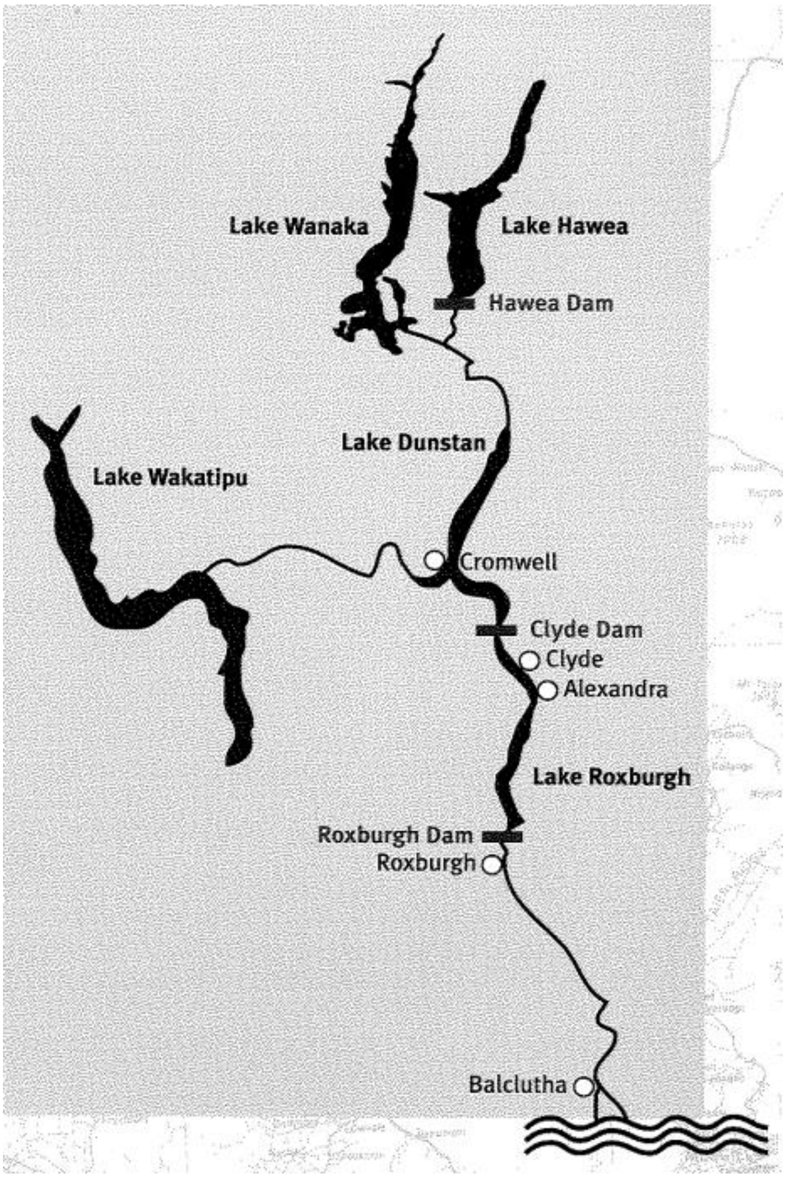

Figure 2: Location of the Clutha Hydro Scheme and key features

The Hāwea Dam Control Structure

7.4 A control structure was built at Lake Hāwea between 1954 and 1958 to coincide with the commissioning of the Roxburgh Dam. The Hāwea Dam is a 30 metre high earth-filled structure that is designed to give an effective control of the lake level over a range of 21.65m. Prior to the construction of the control structure, the mean lake level was 327.7m above sea level. Since 1960 the lake has generally operated at a level of 342.9m.

7.5 There is no electricity generation plant at Hāwea. The role of the dam is simply to control the level of Lake Hāwea and therefore provide storage for the Roxburgh and Clyde plants downstream. The dam does, however, also have a role in providing flood control downstream.

Figure 3: The Hāwea Dam

7.6 The Gladstone Gap is a natural feature that forms a low point in the moraine of the southern shoreline of Lake Hāwea. As part of the construction of the Hāwea Dam, a stop bank (shown in red at Figure 4 below) with its crest below that of the Dam was constructed across this feature. The stop bank serves to dam Lake Hāwea when the lake is at extremely high levels and to act as the only spillway for the Dam and prevent it from overtopping.

Figure 4: The Gladstone Gap Stopbank and Spillway

The Clyde Dam

7.7 The Clyde Dam was constructed by the Crown in the 1980s. Whilst its construction was completed in 1990, the filling of Te Wairere / Lake Dunstan behind it, and its commissioning were delayed until 1992 and 1993, respectively. This is because work was required to stabilise a large number of ancient landslides in the Cromwell Gorge.

7.8 The Clyde Dam is the largest concrete gravity dam in Aotearoa New Zealand. It is 100 metres high and has a 490 metre wide crest. The capacity of the Clyde Dam is 432 MW.

Figure 5: The Clyde Dam

7.9 Te Wairere / Lake Dunstan has an area of about 26 square kilometres that encompasses the Cromwell Gorge and the Kawarau and Clutha Arms. The lake has been operating at a range of one metre which effectively means that the power station largely uses the "run of the river". However, this flow is supplemented using storage at Lake Hāwea.

Figure 6: Te Wairere / Lake Dunstan

The Roxburgh Dam

7.10 The Roxburgh Dam is the oldest of the three structures that form the CHS. It was constructed in the 1950s and commissioned in 1956. It is a substantial structure with a height of about 78 metres and a crest length of 358 metres. The power station has a capacity of 320 MW.

Figure 7: The Roxburgh Dam

7.11 As a result of the dam's construction, Lake Roxburgh was formed behind the dam. It has an area of six square kilometres and extends upstream from the Roxburgh Dam to the Clyde Dam.

Figure 8: Lake Roxburgh, looking towards Alexandra

Contact's land holdings and the "operating easement"

7.12 Contact has landholdings within the catchment but they are small compared to the size of the lakes and river edges that it has rights over.

7.13 Contact owns the core CHS assets; its dams at Lake Hāwea (the control structure and Gladstone Gap), Clyde Dam and Roxburgh Dam and some land immediately adjacent to them. Contact also owns the landslide buttresses at Lake Dunstan, and pockets of land at Lowburn/Wanaka Road near Lake Dunstan, Waenga Station in the Cromwell Gorge and in and around the Manuherikia River. These land holdings amount to about 2,542 hectares (Waenga Station accounts for 2,242 hectares of this). By way of comparison Lake Dunstan covers 2,948 hectares; Lake Roxburgh covers 1,086 hectares and Lake Hāwea covers 15,600 hectares.[9]

7.14 Contact's right to store water in Lakes Dunstan, Roxburgh and Hāwea and the Hāwea River to its confluence with the Clutha River/Mata-au is created and controlled by an easement granted to it by the Crown when the power generation assets were sold to it. That right is referred to as an "Operating Easement".

[9] These are all approximate values.

7.15 The Operating Easement is a series of easements for each of the lakes and relevant sections of the Hāwea/Clutha/Kawarau Rivers. Under the easements, Contact's rights include:

(a) the right to store water on the land described;

(b) the right to install and operate electricity works from time to time on that land; and

(c) ancillary rights including the lawful ability to store sediment on the land subject to the easement.

Current resource consents

7.16 The Hāwea, Clyde and Roxburgh Dams were all established prior to the enactment of the Resource Management Act 1991 (**RMA**). In 2001, Contact lodged resource consent applications to continue operating these three structures. **Table 1** below sets out a list of the resource consents applied for and held by Contact in relation to the operation of the CHS.

Table 1: Resource consents applied for and held by Contact in relation to the operation of the CHS

Hāwea Dam	Water permit to dam (2001.383)
	Water permit to discharge (2001.389)
	Discharge permit (2001.392)
	Discharge permit (2001.395)
	Water permit to take and use (2001.399)
Gladstone Gap Stop Bank	Water permit to dam (2001.384)
Clyde Dam	Water permit to dam (2001.385)
	Water permit to divert (2001.387)
	Water permit to take and use (2001.390)
	Discharge permit (2001.393)
	Discharge permit (2001.396)
Roxburgh Dam	Water permit to dam (2001.386)
	Water permit to divert (2001.388)
	Water permit to take and use (2001.391)
	Discharge permit (2001.394)
	Discharge permit (2001.397)

	Land use consent (2001.398)

7.17 The consents were granted by independent Commissioners appointed by the Regional Council on 10 September 2003, subject to conditions. Contact, and a number of other submitters, appealed the decision to the Environment Court. In *Alexandra District Flood Action Society Inc v Otago Regional Council*,[10] the Court granted the consents, again subject to conditions. The consents have 35 year terms and expire on 23 May 2042.

7.18 Combined, these consents regulate the way in which Contact can physically operate the CHS. They are therefore integral to Contact's ability to continue to supply up to 10 percent of Aotearoa New Zealand's electricity.

7.19 The consents for Hāwea and Roxburgh Dams provide specific conditions which require Contact to provide for fish passage and habitat, including through the development and implementation of monitoring and mitigation programmes. As part of those conditions, Contact has been developing and implementing monitoring and mitigation programmes, including its "trap and transfer" system, to support the upstream and downstream passage of fish in the CHS. Contact is committed to continuously improving upstream and downstream fish passage within the CHS.

How the CHS operates within the broader electricity generation network

7.20 The CHS must be operated as an integrated part of Aotearoa New Zealand's total electricity generation.

7.21 As explained in the evidence of **Mr Hunt**, the CHS is a source of controllable energy (particularly in the short term) which helps in balancing the overall electricity system.[11] Hydro-electricity generation with storage capacity can offer flexibility and speed of response, which is not the case for wind and/or solar plants.

7.22 The demand for electricity varies over time (i.e. days and seasons) and generation (supply) must precisely match demand. Swings in demand can be large. Therefore, hydro schemes ideally need to be able to respond not only to daily changes in demand, but also to immediate fluctuations in

[10] *Alexandra District Flood Action Society Inc v Otago Regional Council* Environment Court C067, 24 May 2007. See also the first interim decision C102/2005, issued 21 July 2005 and second interim decision C34/2007, issued 29 March 2007.
[11] Hunt EIC, from para 8.5.

demand and overall system security. This is enabled through access to water storage. Therefore, water storage is a critical component of hydro-electricity schemes.

7.23 There is also an operational constraint (required by consent conditions) due to the requirement to operate the Roxburgh and Clyde Dams in conjunction with one another. For example, to ensure Lake Roxburgh's levels are within the limited consented range, roughly the same flow must pass through the dams.

7.24 Each day decisions are made as to how Contact will generate electricity to meet its current and future electricity supply commitments and market demand while complying with its consents to operate.

7.25 At the same time, Contact must manage its storage and fuel use to avoid risks associated with disruptions to supply or meeting its commitments. This means generation opportunities at CHS need to be carefully managed, particularly given the nature of its run-of-river system, and short-term storage at Lake Hāwea.

7.26 As noted in **Mr Hunt**'s evidence, the CHS plays a critical role in meeting the electricity demands of New Zealand (including through its intraday and intraweek flexibility) and therefore contributes significantly to the country's economic and social well-being.

Future operation of the CHS

7.27 The CHS forms a key component of both Contact's REG portfolio, and Aotearoa / New Zealand's at large. As an existing physical asset that contributes an average of 12 percent of the country's renewable generation, it is critical that the efficient operation of the CHS continues to be both protected and enabled.

7.28 Contact does not have any immediate plans to make significant upgrades or undertake further development of the CHS. Ongoing minor upgrading and repair work will occur and may include (for example) replacing turbines and managing the visual and recreational impacts of sediment deposition in the hydro lakes.

7.29 Programmes to improve the operability and sustainability of the system are always being considered in the light of electricity demand, the sustainable use of the natural resource and the cultural values and wāhi tapū of hapū.

For example, we are currently working with Kai Tahu and the National Institute of Water and Atmosphere to improve native fish passage along the Clutha / Mata-au and seeking resource consent to undertake works in the Bannockburn Inlet to maintain the bed profile to enable its on-going recreational use.

7.30 From a social and economic perspective, Contact employs almost 100 people at the CHS, and looks to local industry to provide ongoing maintenance support across all aspects of the system (ie. engineering, civil works, building and resource management support). Each year we invest in, and support, several local charities and events such as the Alexandra Blossom Festival and the Contact Epic Race.

8. INVESTIGATING NEW RENEWABLE ELECTRICITY GENERATION DEVELOPMENT

8.1 As I have explained above, Contact is committed to contributing to the achievement of Aotearoa New Zealand's climate change targets and assisting the New Zealand Government to meet:

(a) the emissions reduction target established by the Climate Change Response Act 2002 of reducing New Zealand's greenhouse gas emissions (except biogenic methane) to net zero by 2050;[12]

(b) the targets for the energy system set out in the Emissions Reduction Plan, including the Government's aspirational target of transitioning to 100 percent REG by 2030;[13] and

(c) the increased demand for REG as a result of decarbonising Aotearoa's industries as set out in the Emissions Reduction Plan.[14]

8.2 **Mr Hunt** has commented further on these commitments in his evidence and noted that achieving these goals will require unprecedented development of new generation.[15] Mr Hunt estimates around 1,100 GWh of new REG will be required on average every year until 2050. This is huge – as Mr Hunt notes, it is roughly equivalent to adding a new set of Clyde and Roxburgh hydro stations to the electricity system every 3.5 years until 2050. Mr Hunt

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[12] Climate Change Response Act 2002, s 5Q.
[13] *Aotearoa New Zealand's first emissions reduction plan*, page 220.
[14] *Aotearoa New Zealand's first emissions reduction plan*, page 218.
[15] Hunt EIC, para 6.15.

has also explained the increased need for flexible supply and diversity of generation sources.[16]

8.3 Contact is committed to helping the government achieve these commitments and accordingly has embarked on a significant project to investigate suitable sites for new wind and solar electricity generation throughout New Zealand. This includes investigation of several sites within the Otago region. However, if the planning framework becomes too restrictive in this region, Contact may decide to focus on alternative sites in other regions.

9. CONTACT'S KEY ISSUES AND CONCERNS WITH THE PROPOSED RPS

9.1 Contact supports the intention and purpose of the proposed RPS to promote positive sustainable change and a flourishing Otago community.

9.2 Contact’s submissions and further submissions on the proposed RPS centre around the following key concerns:

(a) providing a policy framework that appropriately recognises and prioritises REG and its role in achieving Aotearoa New Zealand's emissions reduction targets and in providing for wellbeing;

(b) recognition that new large-scale REG operations, like wind farms, will, due to functional, technical and locational constraints have unavoidable (and likely significant) impacts on the environment and will not be 'effects-free' – particularly at the local level;

(c) providing a realistic consenting pathway for new REG development and upgrades, including access to the full effects management hierarchy;

(d) protecting significant REG assets such as the CHS and ensuring that its operation, maintenance and minor upgrading is provided for;

(e) recognising that the environment of the CHS is significantly modified and cannot realistically be returned to a "natural" state; and

(f) protecting the CHS and any future REG assets from potential reverse sensitivity effects.

[16] Hunt EIC, from para 6.18.

9.3 These concerns are addressed in detail in the other evidence provided on behalf of Contact, especially by **Ms Hunter**. The key points I would like to make in relation to the proposed provisions are:

(a) the development of the CHS has had, and will continue to have over its life, a significant impact on the Clutha catchment and its environment as explained in more detail in the evidence of **Dr Keesing** and **Messrs Coombs and Foster**;

(b) these impacts are irreversible and extend well beyond the large-scale dam structures and their respective storage lakes – the CHS is of a scale that it has fundamentally altered the nature of the catchment and the development around it. Therefore, provisions that seek for waterways to be returned to a "natural" state are unlikely to be practical or sensible in respect of the Clutha and CHS;

(c) if climate change is a significant national issue (which I believe it is), and if it is an urgent issue to address (which I believe it is) then for New Zealand is to meet its climate change commitments, and decarbonise its economy, documents such as the RPS must prioritise climate change (especially greenhouse gas reductions);

(d) protecting existing, and enabling new, REG developments are key for New Zealand to reduce greenhouse gas emissions and to do its part in avoiding or reducing the effects of climate change on New Zealand (both on people and on our natural resources);

(e) Contact does not seek a 'free ride' for such activities, effects must be appropriately managed and in some cases development at a particular site may not be appropriate but what is critical is that projects can be assessed, both for their benefits and costs, through a consenting process and not prevented at a policy level as set out in **Ms Hunter's** evidence; and

(f) the proposed RPS ignores the significance of the implications of climate change to New Zealand and the region and the critical role that REG provides in reducing our emissions by failing to appropriately protect existing and enable new REG activities as explained further in **Ms Hunter's** evidence.

9.4 For all of these reasons, and the further reasons set out in the expert evidence provided on behalf of Contact, Contact prefers the amendments that Ms Hunter has recommended and set out in her evidence.

Jacqueline Marie Nelson

23 November 2022

Appendix C

Evidence in Chief of Mr Peter Foster on behalf of Contact Energy Limited

(Proposed Otago Regional Policy Statement 2021 Fresh Water Planning Instrument Hearing)

BEFORE THE HEARING COMMISSIONERS APPOINTED BY OTAGO REGIONAL COUNCIL

Under	the Resource Management Act 1991
In the matter	of the proposed Otago Regional Policy Statement 2021 (excluding provisions renotified as part of a freshwater planning instrument)

STATEMENT OF EVIDENCE OF PETER FOSTER (RIVER MORPHOLOGY AND SEDIMENTATION) ON BEHALF OF CONTACT ENERGY LIMITED

23 November 2022

BUDDLE FINDLAY

Barristers and Solicitors
Wellington

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CONTENTS

1. QUALIFICATIONS AND EXPERIENCE

1.1 My name is **Peter Francis Foster**.

1.2 I am a Principal Engineer (Dams) at Stantec New Zealand.

1.3 I have a BE (Hons) in civil engineering from the University of Canterbury. I graduated in 1976 and have worked predominately in the areas of dam engineering, and hydropower operations.

1.4 I am a Fellow of Engineering New Zealand and a Chartered Professional Engineer. I am a member of the New Zealand Society of Large Dams, the New Zealand Geotechnical Society and the New Zealand National Society of Earthquake Engineering.

1.5 From 1975 to April 2002 I was employed by the Ministry of Works and Development, Works Consultancy Services and when they were privatised, Opus International Consultants. I joined MWH New Zealand Ltd (now Stantec New Zealand) in 2002 as a Senior Civil/Hydro Engineer before becoming a Principal Engineer in 2014

1.6 I am familiar with the Clyde and Roxburgh Dams and their reservoirs and many of the operational issues associated with Contact Energy Limited's (**Contact**'s) Clutha Hydro Scheme (**CHS**). In particular:

(a) I have had a long involvement as a consultant to the New Zealand Electricity Department, then the Electricity Corporation of New Zealand (**ECNZ**) and now Contact with regard to dams, reservoirs and their operations on the Clutha River.

(b) My involvement with Clyde Dam covers the dam site investigations, dam detailed design and construction, lake filling and operational phases of its life.

(c) In addition to the physical works associated with the Clyde Dam I have worked in the following areas:

(i) concept and detailed design for the tailrace deepening downstream of the Clyde Dam - I contributed to the report, *Clyde Power Project: Environmental Impact Report on Design and Construction Proposal* (December 1977), with respect to this aspect of the project; and

(ii) predictions of sedimentation levels and hydraulic calculation of flood levels in the Kawarau Arm and Cromwell Gorge section of Te Wairere / Lake Dunstan, to assist the land purchase requirements associated with construction of the Clyde Dam.

(d) From 1986 onwards I became more involved with the landslide stability issues adjacent to what is now Te Wairere / Lake Dunstan. I ultimately held the position of Deputy Design Manager for the landslide stabilisation works. I continued to be involved by reviewing monitoring data for the landslides when Te Wairere / Lake Dunstan was initially filled1998.

(e) In the 1990s I also began to provide consulting services to ECNZ and then Contact regarding the issues of sedimentation into Lake Roxburgh and the potential flood risk at Alexandra. I project managed and contributed to a pre-feasibility study in 1993 that looked at options to alleviate the flood risk at Alexandra. After the January 1994 flood I project managed the joint study for the Otago Regional Council and ECNZ that recommended investigation and monitoring of operational procedures to encourage sediment migration and flushing in Lake Roxburgh, and flood management strategies that account for storage within Lake Hawea. In 1995 and 1996 I also project managed and contributed to a number of joint studies that Works Consultancy Services and NIWA produced that evaluated the effectiveness of lowering flood levels at Alexandra by flushing activities in Lake Roxburgh.

(f) I project managed and contributed to a number of studies prepared by Opus International Consultants as part of Contact's application for resource consents for the reconsenting of the CHS in the early 2000s.

(g) I have also provided Contact with design services related to both Clyde and Roxburgh Dams. This has included annual inspection reports in accordance with procedures recommended by the New Zealand Society of Large Dams. At Roxburgh Dam I have also been involved in reassessing the Dam foundation stability, and provided recommendations to upgrade the instrumentation at the Dam, project managed the design for the spillway strengthening works and the design for rock removal from the tailrace downstream of the Dam to lower the tailwater level.

1.7 In addition to the above, I have also provided consulting services in dam engineering and reservoir operations to clients such as Meridian Energy, Mighty River Power, Watercare Services and other dam owners in New Zealand and Seqwater and Sunwater in Queensland, Australia.

1.8 I have authored or co-authored some 13 technical papers that have appeared in New Zealand and international journals and conferences. The papers relate to either the Clyde Dam, the landslide stabilisation work adjacent to Te Wairere / Lake Dunstan, or the sediment flushing in Lake Roxburgh.

2. CODE OF CONDUCT

2.1 I have read the Environment Court's Code of Conduct for Expert Witnesses, and I agree to comply with it. My qualifications as an expert are set out above. I confirm that the issues addressed in my brief of evidence are within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

3. SCOPE OF EVIDENCE

3.1 In preparing my evidence I have reviewed relevant provisions / parts of:

(a) the proposed Otago Regional Policy Statement (**proposed RPS**);

(b) Contact's submissions and further submissions;

(c) the Regional Council's section 42A report, including the version showing recommendations from the Regional Council's supplementary evidence and additional supplementary evidence (**section 42A report (October version)**);

(d) my council-level evidence (dated October 2002) (**2002 evidence**) and Environment Court evidence (dated 2004/2005) (**Environment Court evidence**), filed as part of Contact's application for resource consents to permit the operation of the CHS;

(e) a number of technical reports, including:

(i) NIWA (2015), *Lake Dunstan Sediment Modelling*;

(ii) WSP (2020), *Lake Roxburgh Sedimentation and Backwater Analysis for 2020 Bed Survey*;

(iii) WSP (2022), *Lake Dunstan Sedimentation and Backwater Study for March 2022 Bed Survey - Kawarau Arm Update* (**WSP 2022 report**); and

(iv) *Contact Energy Clutha Flood Rules 2022*.

3.2 The purpose of my evidence is to provide:

(a) an overview of the Clutha Mata-au and the CHS;

(b) a description of the sedimentation effects of the CHS on the Clutha Mata-au and how it has changed the river morphology of this catchment (including the effects of the CHS on flood levels);

(c) an overview of how sediment (and flood levels) are managed (and could be managed in the future) in regard to the CHS; and

(d) comments on proposed provisions of the proposed RPS relevant to the above matters.

4. EXECUTIVE SUMMARY

4.1 Contact owns and operates the CHS. As part of the CHS, there are two hydroelectric generation facilities located on the Clutha Mata-au River; being the Clyde Dam at Clyde and the Roxburgh Dam located upstream of Roxburgh. These generation facilities are essentially 'run of river' hydroelectricity schemes, with a narrow operating range at Te Wairere / Lake Dunstan (upstream of Clyde Dam) and Lake Roxburgh (upstream of Roxburgh Dam).

4.2 The inflows into the Clutha Mata-au catchment can vary year to year and over periods of a few decades due to the Interdecadal Pacific Oscillation which can affect climate variability in the South Pacific. For example, at Roxburgh, the period 1978 to 2000 had approximately 13% more inflow than other periods between 1930 to 2022.

4.3 Most of the sediment transported by the Clutha Mata-au comes from the Shotover River, which is a tributary of the Kawarau River located above the Clyde and Roxburgh Dams. The sediment flow was originally interrupted by the construction of the Roxburgh Dam. However, since the Clyde Dam's construction, this sediment is now being captured within the Kawarau Arm of Te Wairere / Lake Dunstan.

4.4 Based on the data from cross-sections of Lake Roxburgh that were surveyed pre-construction of the dam and from 1961 to 1992/1993, the average rate of sediment accumulation was calculated to be in the range of 1.37 to 1.42 million cubic metres per year. This indicates that approximately 51 million cubic metres of sediment accumulated in Lake Roxburgh in the period 1956 to 1992/1993.

4.5 An effect of the sediment deposition has been the progressive increase in flood levels at Alexandra. The 1994 flood reached a level approximately 4 metres higher than the level of an equivalent flood that occurred after Lake Roxburgh was first filled.

4.6 In 1994 a partial drawdown of Lake Roxburgh during the 1994 flood was implemented and demonstrated that such a drawdown can redistribute sediment within the reservoir and flush sediment downstream. Such a procedure has been introduced into the Clutha Flood Rules as a mode of operation for Lake Roxburgh and has led to increased flood protection at Alexandra. Modelling by NIWA indicates future increased benefits can be gained and in my opinion the flood drawdown mode of operation for the Roxburgh Dam should continue.

4.7 In my 2002 evidence, I predicted that sediment from the Kawarau River would initially be deposited in the Kawarau and Dunstan Arms of Te Wairere / Lake Dunstan at an average rate of 1.2 million m^3/yr and reach Clyde Dam at year 2105. The Kawarau Arm will develop a riverine appearance as the sediment advances with medial and point bars appearing in this reach. While the character of the Kawarau Arm is much as I predicted, the average rate of sediment deposition has been 0.91 million m^3/yr from 1994 to 2022. The sediment tipping face is not as advanced into the Dunstan Arm below Cromwell as my initial prediction due to the average low deposition rate.

4.8 Letting sediment pass through the Clyde Dam turbines and over the spillway without flood drawdown, combined with use of the sluice with floods, may remain an option for sediment passage downstream of Te Wairere / Lake Dunstan heading into the next century and beyond. I envisage that flood drawdown and flushing will still be the ongoing operating procedure for Lake Roxburgh to promote sediment redistribution downstream of Roxburgh Dam

4.9 Given the significant effect of the CHS on the Clutha Mata-au, I consider that provisions in the proposed RPS that refer to the river being restored to "as natural as possible" should be approached with some caution. In my opinion, the CHS has permanently altered the character of this river, and will continue to do so in the future.

5. OVERVIEW OF CLUTHA MATAU-AU CATCHMENT AND THE CHS

5.1 An overview of the key aspects of the Clutha Mata-au catchment is provided in **Figure 1** below.

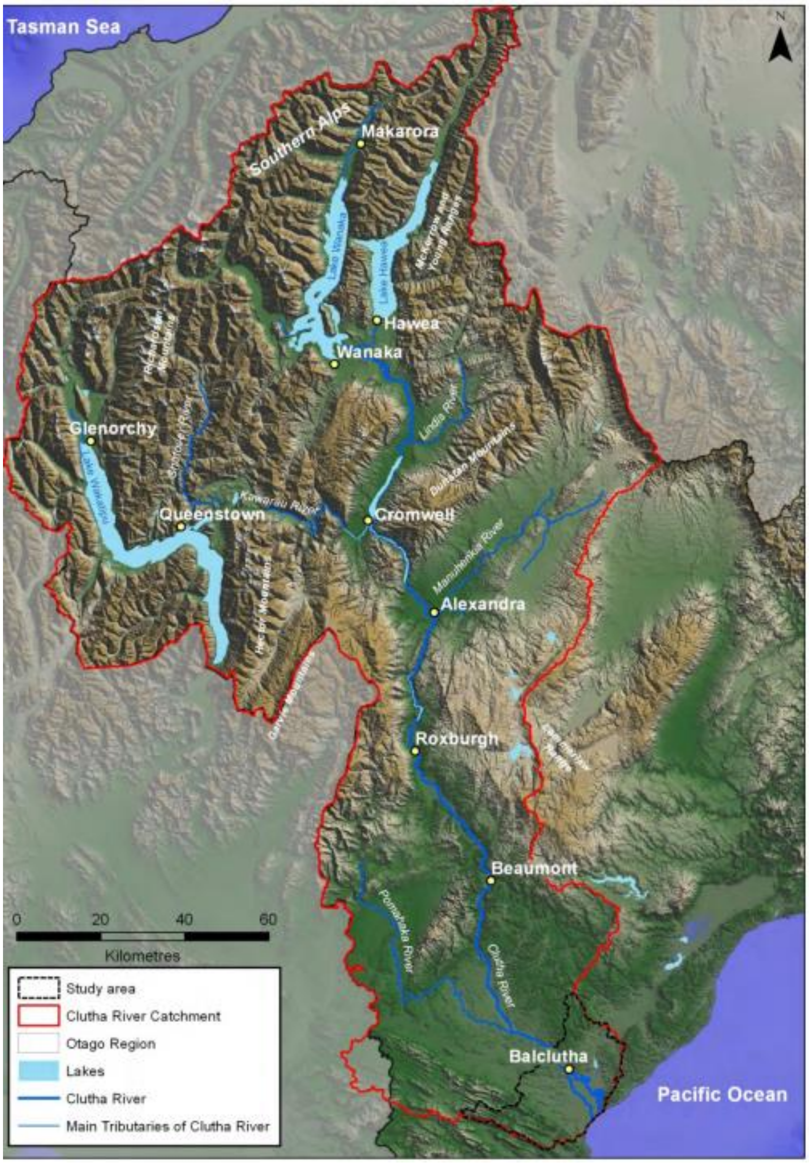


Figure 1: Overview map of Clutha Mata-au (Otago Regional Council)

5.2 Contact owns and operates the CHS. As part of the CHS, there are two hydroelectric generation facilities located on the Clutha Mata-au River; being the Clyde Dam at Clyde and the Roxburgh Dam located upstream of Roxburgh. These generation facilities are essentially 'run of river' hydroelectricity schemes, with a narrow operating range at Te Wairere / Lake Dunstan (upstream of Clyde Dam) and Lake Roxburgh (upstream of Roxburgh Dam).

5.3 Electricity generation is limited by the average inflow reaching the power stations each day. Outflows through the power stations can then be varied to match the electricity demand profiles throughout the day and night. When the power station consented flow capacity is reached, additional flows are then passed via the spillways or sluices located at the dam.

5.4 As explained further in **Mr Hunt's** evidence, the level of generation from the CHS can be controlled to a certain extent to reflect the needs of the electricity system. While the CHS is largely 'run of river' there is some storage capacity (and therefore flexibility) behind the Clyde and Roxburgh dams and in Lake Hāwea. The storage behinds Clyde and Roxburgh dams offers short-term flexibility (eg across a day); whereas the storage in Lake Hāwea offers some seasonal flexibility.

Water inflows

5.5 The inflows into the Clutha Mata-au catchment can vary year to year and over periods of a few decades due to the Interdecadal Pacific Oscillation which can affect climate variability in the South Pacific.

5.6 In my 2002 evidence, I identified the mean inflows and normalised mean flows of water relative to the period 1957 to 1977 across the Clutha Mata-au and across different time periods. I have updated these tables to include the last two decades from 2001 to 2022.[1] This is shown in **Tables 1** and **2** below.

Table 1: Mean inflows of water

	Mean Inflows (m3/s)				
	Roxburgh	Wakatipu	Wanaka	Hawea	Balclutha
1930-1956	484	154	188	62	-
1957-1977	494	171	187	63	535
1978-2000	560	204	218	71	618
2001-2021	502	162	197	60	561

[1] On request, Contact provided me with the data required in order to update **Table 1** and **Table 2**.

Table 2: Normalised mean inflows of water relative to 1957 -1977 period

	Normalised Mean Inflows based on 1957-1977 (m3/s)				
	Roxburgh	Wakatipu	Wanaka	Hawea	Balclutha
1930-1956	0.98	0.90	1.01	0.98	
1957-1977	1.00	1.00	1.00	1.00	1.00
1978-2000	1.13	1.19	1.17	1.13	1.16
2001-2021	1.02	0.95	1.05	0.95	1.05

5.7 The mean inflows and normalised mean inflows identified in **Tables 1** and **2** indicate that:

(a) the period between 1978 to 2000 had a higher average mean inflow compared to the periods between 1930 to 1956 (which was before Roxburgh Dam was completed) and 1957 to 1977; and

(b) in 2001 to 2021 the inflows are similar to those from 1930 to 1957.

5.8 From 1978 to 2000, three of the largest floods at Roxburgh Dam (since 1957) occurred in the period between 1994 to 1999.

Sediment inflow

5.9 Sediment inflow into Te Wairere / Lake Dunstan (and prior to the construction of the Clyde Dam, into Lake Roxburgh) is not at a constant rate but relates to flood activity. The large floods can move higher concentrations of bed load and suspended sediment and result in periods of above average sediment deposition. I discuss the sedimentation characteristics of the Clutha Mata-au, including the effects of the CHS on these characteristics, further below.

6. SEDIMENTATION CHARACTERISTICS OF THE CLUTHA MATA-AU

Overview

6.1 Most of the sediment transported by the Clutha Mata-au comes from the Shotover River, which is a tributary of the Kawarau River located above the Clyde and Roxburgh Dams. The sediment flow was originally interrupted by the construction of the Roxburgh Dam. However, since the Clyde Dam's construction, this sediment is now being captured within the Kawarau Arm of Te Wairere / Lake Dunstan.

6.2 The sedimentation characteristics at the Clutha Mata-Au have developed over time as a result of the impacts of the Roxburgh and Clyde Dams. Generally, sediment flows through waterways, however, where there are structures such as dams, this creates a build-up of sediment in their reservoirs over time. This build-up of sediment increases the bed levels of lakes, and ultimately can result in upstream flood levels if not managed appropriately.

6.3 In this section of my evidence I discuss:

(a) The sedimentation characteristics of Lake Roxburgh, including the effects of this sedimentation on flood levels at Alexandra; and

(b) The sedimentation characteristics of the areas upstream of the Clyde Dam (ie the Kawarau and upstream of Te Wairere / Lake Dunstan), including the effects of this sedimentation on flood levels.

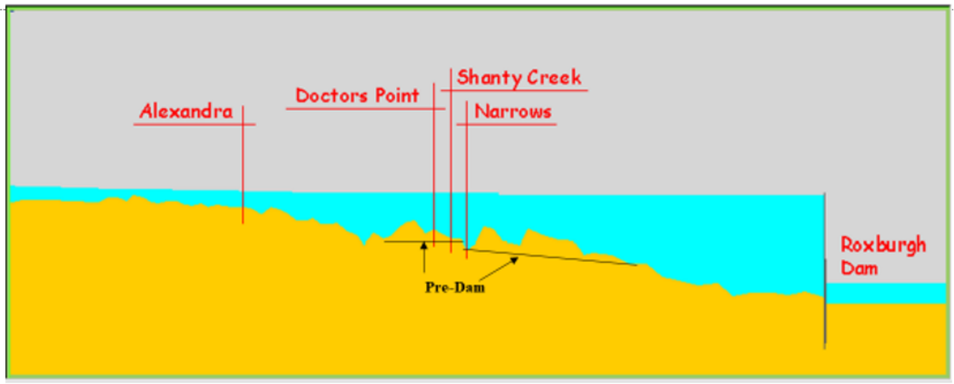
Lake Roxburgh sedimentation

6.4 Lake Roxburgh is a long narrow reservoir within the Roxburgh Gorge. Lake Roxburgh commenced filling in 1956 following the construction of the Roxburgh Dam. It progressively filled with sediment until Te Wairere / Lake Dunstan began filling in 1992 following the construction of the Clyde Dam. After that the sediment supply at Lake Roxburgh was significantly reduced.

6.5 Based on the data from cross-sections of Lake Roxburgh that were surveyed pre-construction of the dam and from 1961 to 1994, the average rate of sediment accumulation was calculated to be in the range of 1.37 to 1.42 million cubic metres per year. This indicates that approximately 51 million cubic metres of sediment accumulated in Lake Roxburgh in the period 1956 to 1992/1993.

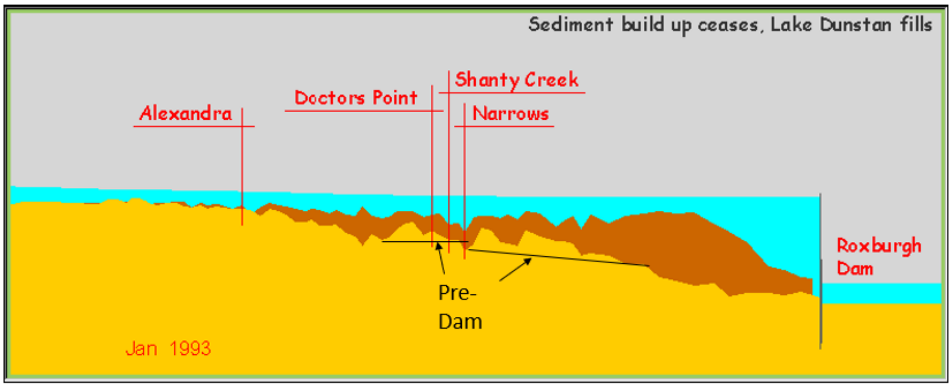
6.6 **Figures 2** and **3** below show the thalweg[2] bed level along the reservoir taken from an initial survey in 1961, and a composite survey from 1992 to 1994, at locations between the Roxburgh and Clyde Dams. The black lines indicate the approximate bed level pre-construction of the Roxburgh Dam. The yellow colour indicates the bed level in 1961; with dark brown representing the bed level in 1992-1994 and blue being the level of water behind the dam.

[2] The thalweg is a line connecting the lowest points of successive cross-sections along the course of a valley or river.



Roxburgh Bed Profile 1961

Figure 2: Bed Profile 1961



Roxburgh Bed Profile 1992-1994

Figure 3: Bed Profile 1992 -1994

6.7 **Figures 2** and **3** show that the sediment tipping front (or tipping face, being the place where most of the bed load and suspended sediment is being deposited) has progressed down the reservoir over time. This would not be seen by an observer on the foreshore of the reservoir, however, has been revealed by the survey of cross-sections described above.

6.8 The sediment and water volumes at the reservoir from the period between 1961 and a survey completed in February 1994 are shown in **Table 3** below. This table shows that the volume of sediment has been increasing, with the reservoir volume concurrently reducing over this period.

Table 3: Lake Survey Dates, Reservoir Volume and Sediment Volume

Survey Date	Reservoir Volume (million cubic metres)	Sediment Volume (million cubic metres)
July 1961	101	0
July 1970	87	14
July 1974	82	19
July 1978	78	23
February 1979	76	25
February 1984	67	34
November 1989	59	42
February 1994	57	44

6.9 The tipping face would have progressed further towards the Roxburgh Dam if the Clyde Dam had not been constructed. However, since the construction of Clyde Dam, the vast majority of sediment that previously accumulated behind the Roxburgh Dam is now being trapped upstream of the Clyde Dam. Some sediment is still coming into Lake Roxburgh via the Fraser and Manuherikia catchments. This would have resulted in further sediment accumulation if the practice of lake drawdown ahead of floods had not been introduced in January 1994 (as I describe below).

6.10 Eventually, if Clyde Dam had not been built, the 'trap efficiency' of the Roxburgh reservoir would have reduced to the point where most incoming sediment would pass through the turbines or over the spillway. The term 'trap efficiency' relates to the amount of sediment that settles out relative to the total amount of sediment input. In my experience from observing reported reservoir sedimentation at some Chinese hydro schemes, a state of equilibrium can be reached after 70-90 percent of the reservoir capacity is lost, whereby the volume of sediment stabilises and stops increasing.

6.11 The effect of sediment accumulation is that it reduces the flow area at each section along the reservoir and increases the velocity of water flow at sections where there has been sediment accumulation. The velocity increase causes a rise in reservoir water levels that can result in flooding, which has been an issue at Alexandra.

Flood management and its effect on sedimentation of Lake Roxburgh

6.12 I began advising ECNZ and then Contact on options to reduce the flood risk at Alexandra in 1992.

6.13 I was involved in studies in 1994 for the Regional Council and ECNZ. In these studies, we found that the sediment accumulation at Lake Roxburgh had caused water levels to rise by 3.4 metres from the first filling in 1956. In my 2002 evidence and Environment Court evidence I produced flood level data for the 1994 flood and included a peak data point for the 1957 flood, which had a slightly higher peak flow than the 1994 flood. I expressed my opinion that a repeat of the 1957 flood would have caused flood levels to rise by 3.9 metres if it had occurred in 1994, based on a peak flow estimate of 2570 m^3/s. The current data is discussed in paragraphs 6.25 and 6.26 below.

6.14 In February 1993 I was involved in a prefeasibility study into options to alleviate the flood risk at Alexandra. The possible options we identified included:

(a) do nothing;

(b) stop bank protection at Alexandra;

(c) dredging with land disposal;

(d) dredging with lake disposal; and

(e) flushing material from the lake.

6.15 Our feasibility study noted that "*…limited or substantial drawdown of the reservoir through upgraded sluices is a viable option for flushing sediment from the lake…Flood reduction gains may be realised in 10-30 years if operating procedures are modified*."

6.16 The options were then shortlisted down to flushing during floods or as a seasonal drawdown such as from 1 November to 31 January when flood activity was more likely. Sedimentation transport studies completed by NIWA around that time indicated that flushing during floods was the preferred option, and this is now Contact's current practice.

6.17 When flows exceeded 850 m^3/s in November and December 1994, ECNZ partially lowered the lake at Roxburgh Dam using the powerhouse and spillway. ECNZ found they could go lower than 127.4 metres and could operate at an extreme minimum operating level of 125.75 metres. This represents a drawdown of 6.25 metres from normal maximum operating level.

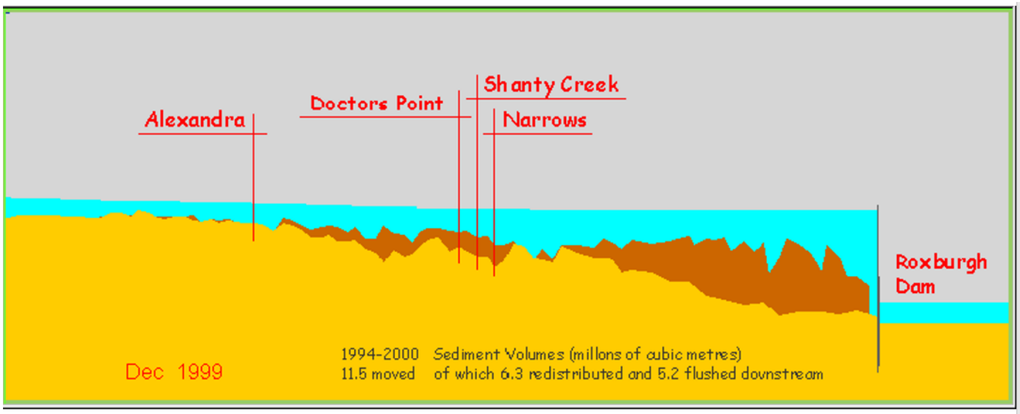
6.18 Since then the lake has been drawn down during floods on numerous occasions. The figure at **Appendix PF.1** shows the lake levels at Roxburgh Dam for the period from 1992 through to March 2022.

6.19 The first trial of a flood drawdown happened in January 1994 and flood drawdown has continued to the present day when flood flows are expected to exceed the trigger levels, provided for in consent conditions for drawdown and operation. The frequency of drawdown was highest in the period of 1994 to 2000 due to greater flood frequency compared to the period from 2000 to 2022.

6.20 **Appendix PF.2** shows the Lake Roxburgh inflows for the period from 1992 through to 2022. The floods in 1994 and 1999 are notable in the period up to 2000, with nothing approaching the size of these floods since 2000.

6.21 The 1994 flood had a peak inflow (3 hourly) of 2343 m^3/s into Lake Roxburgh. The 1995 flood had a peak 3 hourly inflow of 3213 m^3/s and the 1999 flood had a peak 3 hourly inflow of 3623 m^3/s. The 1999 flood and the 1995 flood are ranked 2nd and 3rd respectively as the highest floods at Alexandra since 1878.

6.22 Flooding events affect the bed profile, as I describe below. **Figure 4** below shows the Roxburgh bed profile surveyed after the 1999 flood.



Roxburgh Bed Profile December 1999

Figure 4: Roxburgh Bed Profile December 1999

6.23 In the period between 1994 to 1999 the flushing events had mobilised some 1.5 million cubic metres of sediment, of which 6.3 million cubic metres was redeposited in the reservoir closer to the dam, and 5.2 million cubic metres was flushed downstream of Roxburgh Dam over the spillway and through the turbines.

6.24 **Appendix PF.3** shows a plot provided by Eliot Sinclair of the lake bed profiles from Alexandra to Roxburgh Dam from surveys in 1994, 1999, 2007 and March 2020. This shows that bed levels have been reasonably stable since 1999 with the current sediment flushing regime. There has been a small advance of the tipping face downstream (four sections closest to Roxburgh Dam).

6.25 **Appendix PF.4** shows the 3 hourly measured water levels at Alexandra Bridge and the corresponding Roxburgh inflows in January 1994, November to December 1995 and November to December 1999. It also shows the peak flood levels for the 1957, 1978 and 1987 floods.

6.26 **Appendix PF.4** shows the same data points that I presented in my 2002 evidence, however this now includes peak flood data from floods since 2002 and shows rating curves produced by others that indicate the current situation and predictions of future rating curves if the flushing regime is continued.

6.27 As a result of flushing and lake lowering, the 1999 flood water level at Alexandra was approximately 1.4 metres lower than the 1994 event at a flow equivalent to the peak of the 1994 flood (2343 m^3/s). **Appendix PF.4** also shows a data point for measurements made since the 1999 flood.

6.28 **Appendix PF.4** shows a March 2020 rating curve that is marginally lower than the 1999 flood data for flows <1500 m^3/s, but the WSP 2022 report[3] states that if the 1999 peak flow were to occur now then it would peak with a similar level to the peak in 1999, which is contained now by the stop banks built after 1999. The WSP 2022 report also reported predictions by NIWA as to the rating curves that could occur, projecting out to 2029 and 2059. The accuracy of these projections will depend on the actual flood activity but they do signal that the flushing procedures at Roxburgh should continue into the future to maximise potential flood protection at Alexandra.

[3] WSP (2022), *Lake Dunstan Sedimentation and Backwater Study for March 2022 Bed Survey - Kawarau Arm Update*.

6.29 In addition to the rating curve at Alexandra, Contact's consent conditions require flood maps to be produced for a 1 in 500 AEP flood and the Probable Maximum Flood (PMF). These maps are given in **Appendix PF.5** and **Appendix PF.6**

Te Wairere / Lake Dunstan sedimentation

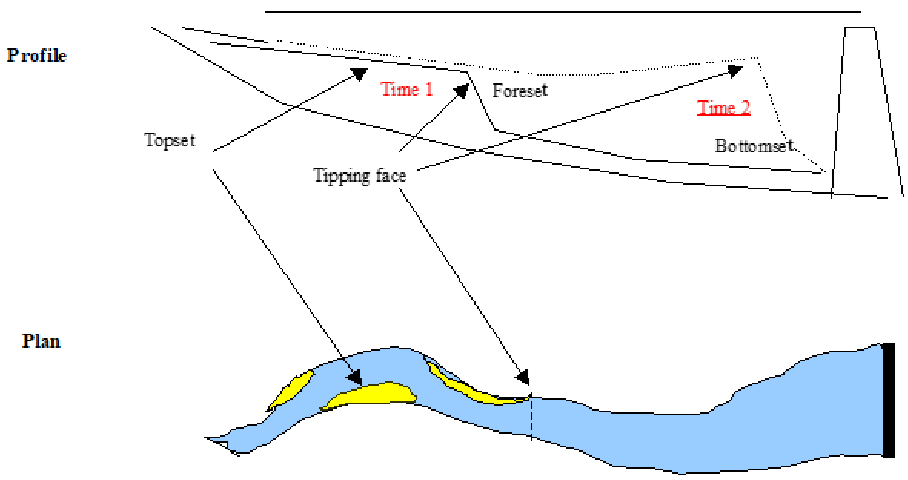
6.30 I started my engineering career in 1976 as an assistant engineer with the Ministry of Works and Development in a team developing concept layouts for a dam in the Cromwell Gorge, initially at Gibraltar Rock (DG7 site) and later at Clyde (DG3 site). By 1978 I was aware of the following from other studies done within the Ministry:

(a) That the accumulation of large quantities of sediment in the proposed Lake Dunstan is inevitable, as has occurred in Lake Roxburgh; and

(b) That by 1977 the bed of Lake Roxburgh had been surveyed in 1960/61, 1970 and 1974 and it had been deduced that between 1956 and 1976 some 34 million cubic metres of sediment had settled in the headpond. It was also known that the volume of Lake Roxburgh was reducing at an average rate of 1.45 million cubic metres per year due to sediment deposition.

6.31 As noted above, most of the sediment entering the Clutha / Mata-au catchment is sourced from erosion within the slopes of the Shotover catchment, which feeds into the Kawarau River. That sediment is now being captured in Te Wairere / Lake Dunstan.

6.32 A stylised pattern of sedimentation into a reservoir that is similar to the Kawarau Arm and Cromwell to Clyde Dam reach of Te Wairere / Lake Dunstan is shown in **Figure 5** below.



Idealised plan and profile of an elongate reservoir receiving sediment (after US Dept of the Interior, Bureau of Reclamation, 1974).

Figure 5: Idealised plan and profile of an elongate reservoir receiving sediment

6.33 The velocity of the water entering the top end of the lake reduces compared to the velocity in the river upstream of the lake. This causes the sand and gravel materials that roll and bounce along the riverbed to settle out and form a delta. The finer suspended sediment also begins to fall from suspension and forms an apron type deposit on the reservoir bed. **Figure 5** shows an initial advance of the delta into the reservoir at 'Time 1' and the establishment of a tipping face.

6.34 As explained above, by 1994, Lake Roxburgh had filled with sediment and reached a similar situation to 'Time 2' as shown above in 'Profile' view in **Figure 5**.

6.35 The Kawarau Arm of Te Wairere / Lake Dunstan has (consistent with the stylised pattern demonstrated in **Figure 5**) transitioned to a morphology more like that of an alluvial river, with 'point bars' growing off the inside of bends and possible 'medial' bars or islands growing mid-stream if the channel is wide enough. This can create a meandering or semi-braided channel pattern. **Figure 5** shows some of these bars in the 'Plan' view of the reservoir.

6.36 The bars can grow higher with raised water levels in floods and emerge to become beaches or islands when floods recede, and the reservoir then reverts back to being a lake. With time, the raised beaches and islands will accumulate finer sediment as "overbank" material and will tend to vegetate as they grow in elevation and are swept by floods less frequently. The beaches and islands will eventually grow above the level of the main channel.

6.37 Over time, the tipping face in the Kawarau and Cromwell to Clyde Dam reach is expected to advance to the dam in a similar manner as for Lake Roxburgh (and as shown in concept at 'Time 2' in **Figure 5**).

6.38 **Photos 1 and 2** below show evidence of Te Wairere / Lake Dunstan evolving in a pattern of sedimentation similar to **Figure 5** expectations. **Photo 1** shows the head of the lake where flow exits from the Kawarau Gorge in 2005.[4] It shows that sand bars were beginning to appear in the lake at that time. **Photo 2** shows the same area in 2010, and shows that these sand bars had developed further.[5]

Photo 1: Sand bars at Te Wairere / Lake Dunstan (2005) (photo courtesy Peter Silvester)

[4] This photo was taken during a helicopter flight over the head of Lake Dunstan that I attended together with Peter Silvester from Contact.
[5] This photo was taken from a helicopter flight over the area by Peter Silvester.

Photo 2: Sand bars at Te Wairere / Lake Dunstan (2010) (photo courtesy Peter Silvester)

Earlier predictions about sedimentation in the Kawarau Arm and Cromwell to Clyde Dam reach of Te Wairere / Lake Dunstan

6.39 In 2002, I made an estimate with NIWA of the likely average rate of sediment accumulation in the Kawarau Arm and Cromwell to Clyde Dam reach of Te Wairere / Lake Dunstan. This estimate was made on the following basis:

Sediment sources/types	Estimate (million cubic metres/yr)
Long term rate into Lake Roxburgh	1.42
Less Upper Clutha sediment	- 0.17
Less other downstream sources	- 0.05
Total	**1.20**

6.40 In my 2002 evidence I noted my opinion that an average sedimentation accumulation rate of 1.3 million cubic metres per year in the Kawarau Arm to Clyde Dam was a long-term upper bound. This higher figure allows for a potentially higher trap efficiency in Te Wairere / Lake Dunstan relative to Lake Roxburgh.

6.41 Not all the sediment entering the Te Wairere / Lake Dunstan reservoir is trapped. The finer sediment is still able to remain in suspension and pass through the lake via the penstocks and spillway at Clyde Dam, particularly in flood conditions when sediment inflow pulses occur and the velocities in the reservoir are higher. **Photo 3** below shows sediment-laden water discharging from the Clyde Dam spillway during the November 1999 flood.

Photo 3: Clyde Dam spillway in 1999 flood

6.42 In the Opus report *Lake Dunstan Sedimentation Report* (June 2001) we set out our predictions as to how the sediment accumulation will develop in time in the Kawarau Arm and Cromwell to Clyde Dam reach of Te Wairere / Lake Dunstan. These predictions are provided in the figure at **Appendix PF.7**. I comment below on what this figure shows, also drawing from additional data that was available in 2002.

6.43 The lower half of the figure at **Appendix PF.7** shows how the bed profile is expected to develop with time. Data in 2002 was available from the completion of filling Te Wairere / Lake Dunstan in 1994 through to February 2000 to show how the delta and tipping face was developing. By that time the tipping face had advanced down to about the Bannockburn Bridge, and the finer apron materials were extending down towards the confluence at Cromwell.

6.44 **Appendix PF.7** also shows the tipping face reaching the confluence at about 2010 and then advancing down the Cromwell to Clyde Dam reach of the reservoir. In 2002 I predicted that the tipping face would be getting close to Clyde Dam at about 2105, some 100 years into the future from when the prediction was made based on an annual average accumulation of 1.2 million m^3 per year.

More recent surveys generally confirm my earlier predictions

6.45 More recent surveys by Eliot Sinclair show the bed profile in July 2007 and March 2022 as shown **in Appendix PF.8**.

6.46 **Appendix PF.8** shows that the tipping face has now reached the confluence at Cromwell. In 2002 I predicted it could be approximately 3 km further downstream by 2020. The data is showing that the tipping face is developing much as expected, but suggests the sediment deposition rate has been lower than my average projection of 1.2 million m^3/yr.

6.47 **Table 4** below is taken from the WSP 2022 report[6] and presents the sediment deposition for surveys from April 1994 to March 2022.

[6] WSP (2022), *Lake Dunstan Sedimentation and Backwater Study for March 2022 Bed Survey - Kawarau Arm Update*

Table 4: Sediment deposition April 1994 to March 2022

Table 3-1: Cumulative sediment deposition volumes and average rates in Kawarau Arm.

Survey date	Sediment deposition since April 1994 (Mm^3)	Average annual rate of Sediment deposition since April 1994 ($Mm^3/yr.$)	Sediment deposition since previous survey (Mm^3)	Rate of sediment deposition since previous survey ($Mm^3/yr.$)
September 1999	5.69	1.05	1.8	0.51
February 2000	8.48	1.45	2.79	6.67
December 2004	14.96	1.40	6.48	1.34
July 2007	16.25	1.23	1.28	0.50
July 2009	17.56	1.15	1.31	0.65
October 2011	18.81	1.07	1.25	0.56
February 2014 (to cross-section 73)	20.52	1.03	1.71	0.73
February 2014 (Kawarau Arm incl. cross-sections 35-38 and 73 in the Dunstan Arm)	21.6	1.08	1.97 *	0.79 *
March 2016 (to cross-section 73)	21.47	0.98	0.95	0.46
March 2016 (Kawarau Arm incl. cross-sections 35-38 and 73 in the Dunstan Arm)	22.6	1.03	1.07	0.54
March 2018 (to cross-section 73)	22.30	0.93	0.83	0.41
March 2018 (Kawarau Arm incl. cross-sections 35-38 and 73 in the Dunstan Arm)	23.6	0.98	1.01	0.5
March 2020 (to cross-section 73)	22.88	0.88	0.59	0.29
March 2020 (Kawarau Arm incl. cross-sections 35-38 and 73 in the Dunstan Arm)	-	-	-	-
March 2022 (to cross-section 73)	23.68	0.85	0.80	0.40
March 2022 (Kawarau Arm incl. cross-sections 35-38 and 73 in the Dunstan Arm)	25.34	0.91	1.74 (2018-2022)	0.44 (2018-2022)

* Note: For these sediment deposition volumes, it has been assumed that the date of the lake-bed survey of the Dunstan Arm occurred at the same time as the lake-bed survey of the Kawarau Arm.

6.48 **Table 4** indicates that the average deposition rate has been 0.91 million m^3/yr for the 28 years since 1994. However, in the 22 years since February 2000 the average sediment deposition rate was lower at 0.77 million m^3/yr.

6.49 Through the Cromwell to Clyde Dam reach I expect the advancing tipping face to be less visible compared to the Kawarau Arm. This is because the larger combined flow from the Kawarau and Upper Clutha will allow a greater flow area, which still produces sufficient velocity to keep sediment moving. The width of the lake is also narrower than in the Kawarau arm immediately upstream of the confluence. These factors combined cause a drop in bed level. For this reason, medial bars and islands are unlikely to appear. Lake Roxburgh is an example of a similar situation where the narrowness of the reservoir prevented medial islands forming.

6.50 In the Upper Clutha arm at the head of Te Wairere / Lake Dunstan a braided delta has built up (ie the river is braided upstream of the Lake and the braided channel now extends further into the head of the Lake). I expect that this braided delta will advance with a similar form by approximately 4 km over the next 100 years, from sediment sourced from the Lindis and Cardrona tributaries downstream of Lake Wanaka and Hāwea. This relatively slow rate of advance, combined with relatively small sediment inputs (compared to the Kawarau Arm) should result in colonisation by vegetation (willows) and a reasonably stable pattern of channels. I expect to see a braided channel pattern, with several channels passing between stable, vegetated islands. **Photo 4** below shows upstream of Te Wairere / Lake Dunstan in the Upper Clutha arm in 2010, with evidence of the braided delta pattern starting to develop.

Photo 4: Upper Clutha sediment deposition (2010) (photo courtesy of Peter Silvester)

6.51 Further modelling of the sediment deposition and flood level predictions was completed by NIWA in 2015.[7] A schematic of the NIWA model is shown in **Figure 6** below.

[7] NIWA (2015), *Lake Dunstan Sediment Modelling*.

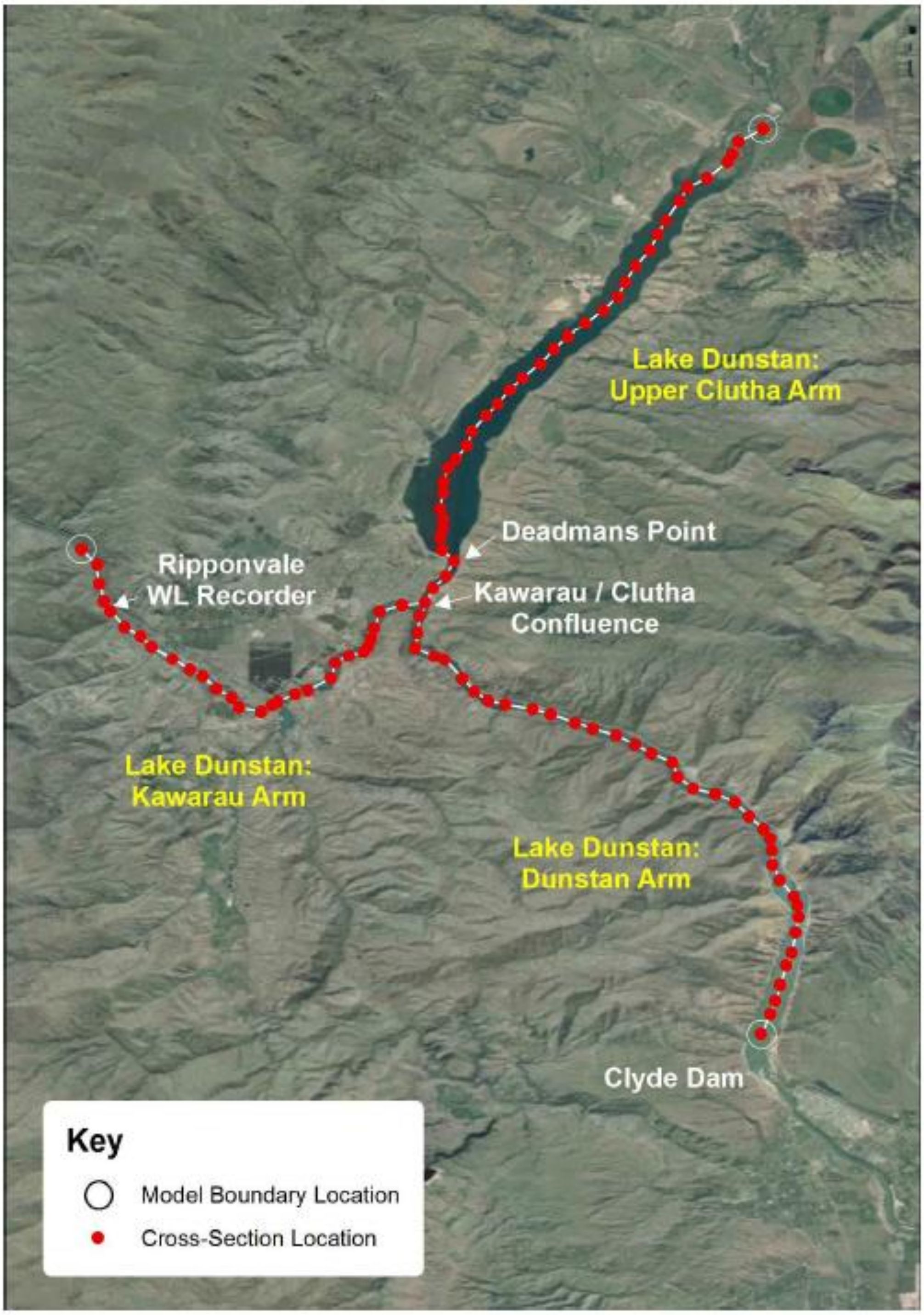


Figure 6: NIWA schematic model representation (NIWA)

6.52 The sediment transport model was calibrated by NIWA using data from the 18-year period between March 1996 to February 2014. NIWA calculated that the average annual deposition in Kawarau arm for the 18-year calibration period was 0.91 million m^3/yr and that the trap efficiency for sediment inflows to the Kawarau Arm was 93%, ie 7% of the sediment was passed downstream of Clyde Dam.

6.53 **Appendix PF.9** shows the NIWA predictions of the sediment bed levels for the Kawarau and Dunstan arms of Lake Dunstan for years 0, 20, 40, 60, 80 and 100 from February 2014. In year 2114 the tipping face is still 3km upstream of Clyde Dam with the thalweg level at a similar level to the intakes at Clyde Dam.

6.54 NIWA predicts the sediment outflow from Te Wairere / Lake Dunstan to increase over time from 168kt/yr for years 0 to 20 to 518 kt/yr for years 80 to 100, with a corresponding reduction on trap efficiency from 91% for year 0-20 to 72% for year 80-100.

7. SEDIMENT AND FLOOD MANAGEMENT NOW AND IN THE FUTURE

7.1 As discussed above, the management of sediment at Lake Roxburgh has been occurring for some time through the flushing regime to address the associated flood risks at Alexandra

7.2 The management of sedimentation into Te Wairere / Lake Dunstan commenced at the design stage of the Clyde Dam. The dam was designed with the penstock intakes set low at an elevation of 169 metres, and a high flow capacity low-level sluice was constructed as well. **Figures 7** and **8** below show those sections at the Clyde Dam.

7.3 **Figure 7** shows that the intakes for the penstocks are set some 25 metres below lake level. I was on the design team for the Clyde Dam and one of the reasons we set the intakes this low (and we could have set them higher) was to limit the eventual height at which sediment could build up in the vicinity of the dam.

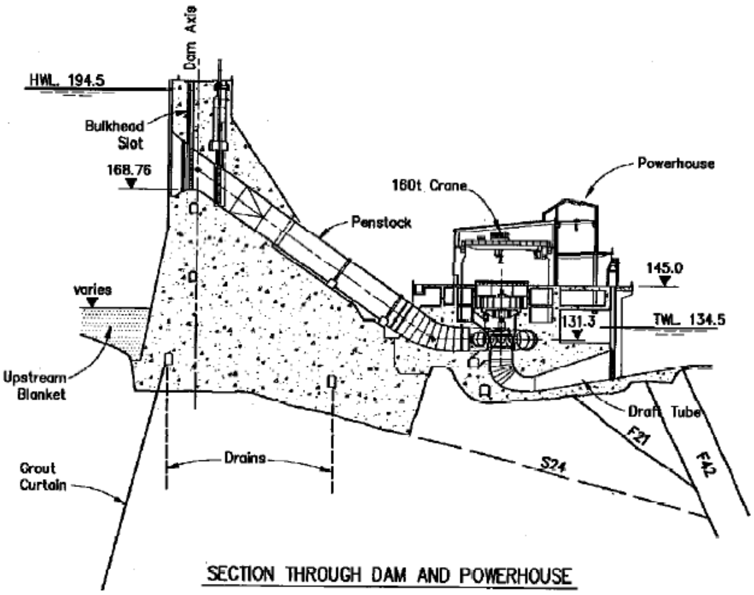


Figure 7: Intake section at Clyde Dam

7.4 **Figure 8** shows the low-level sluice that exists between the intakes and spillway at Clyde Dam. The base of the sluice is set 53 metres below the lake level. The sluice allows the opportunity to locally draw down the sediment levels further and pass this small amount of additional sediment downstream of the dam. Unless the sluice is used to draw the lake well down, such that the river can cut down into upstream sediment beds, the sluice will have only a limited effect on accumulated sediment immediately upstream of the sluice opening.

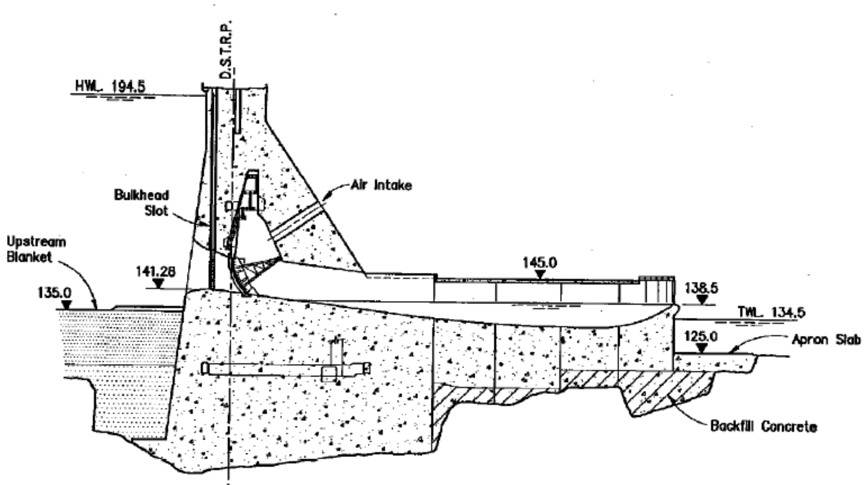


Figure 8: Sluice section at Clyde Dam

7.5 The penstock intakes and low level sluice also allow for the option of sediment flushing to pass sediment downstream of Clyde Dam.

7.6 I also consider it important to recognise that Te Wairere / Lake Dunstan's primary purpose is as the headpond to allow for hydropower generation. The normal operating range is only 1.0 metre. Loss of reservoir capacity at Te Wairere / Lake Dunstan, with sediment going into the dead storage zone below the intakes, is not critical to efficient or sustained energy production in the long term extending into the next century. Excluding the storage at Lake Hawea, the Clutha is a run of river scheme and power generation is a function of flow in the river and the height between reservoir level and tailwater level at the power station, not the water volume in Lake Roxburgh or Dunstan. The sediment accumulation in Te Wairere / Lake Dunstan will affect upstream flood levels, but not power production.

7.7 The approach taken in the past to purchase land around Te Wairere / Lake Dunstan recognises that sediment accumulating in the lake will, with time, give rise to higher flood levels. The land purchased in the Kawarau arm is generally at an elevation of about 220 metres and is well above the 3200 m^3/s flood levels predicted to occur in 100 years time (except for possibly a small area of one property and a small section of road at the Bannockburn inlet).

7.8 In the remainder of Te Wairere / Lake Dunstan, at the confluence and the Upper Clutha, predictions of flood reservoir levels were based on simulations made in 2002. The WSP 2022 report used the March 2022 profile in backwater calculations to update the flood levels in the Kawarau Arm for a flow of 3200 m3/s at Clyde dam as shown in **Appendix PF.10.**

7.9 **Appendix PF.10** also shows a projected flood line out to year 2040 based on the confluence level expected in 2042. As the tipping face progresses further down the Dunstan Arm I expect the backwater model will need to be re-calibrated as surface roughness will be changing due to the bed level rise with sediment. Once the model is re-calibrated for higher flows then further projections for flows as high as 3200 m^3/s can be made.

7.10 Letting sediment pass through the Clyde Dam turbines and over the spillway without flood drawdown, combined with use of the sluice with floods, may remain an option for sediment passage downstream of Te Wairere / Lake Dunstan heading into the next century and beyond. I envisage that flood drawdown and flushing will still be the ongoing operating procedure for Lake Roxburgh to promote sediment redistribution downstream of Roxburgh Dam

7.11 However, if sediment flushing was introduced at Te Wairere / Lake Dunstan now it would not, in my opinion, reduce the sediment accumulation rate. The Kawarau arm bed may deepen a little, but due to the width of the lake, point bars are likely to still form and be unaffected in the long-term. Sediment would still be deposited further down the lake and not necessarily flushed downstream.

7.12 The Clyde Dam has been designed to allow sediment to build up to the level of the intakes. However, it would be desirable to utilise the low-level sluice more frequently in usual flood operations so as to limit sediment build-up near the sluice, as the sluice flow capacity is required for extreme flood passage at Clyde Dam.

7.13 Once sediment starts passing downstream from Te Wairere / Lake Dunstan it will be important to continue the flood flushing regime available under the Flood Rules for Lake Roxburgh in order to maintain the flood level benefits at Alexandra that have been gained since 1994.

7.14 In conclusion, I consider it would be appropriate, over at least the next 80 plus years, to allow sediment to accumulate in Te Wairere / Lake Dunstan without changing any of the operating rules for the reservoir. The opportunity exists to monitor and review the situation every 10 years as sediment accumulates and new measurements are made of the lakebed profile, with updated calculated water levels about the reservoir under flood conditions. Rises in flood level predictions may give rise to further land purchases or flood easements in the Upper Clutha arm of Te Wairere / Lake Dunstan.

8. COMMENTS ON THE PROVISIONS OF THE PROPOSED RPS

8.1 With the above background in mind, I have been asked to consider the following provisions of the proposed RPS (section 42A report (October version):

(a) LF-VM-O2 (noting that this provision has been renotified to go through the freshwater planning process, however, it is useful context to the other provisions that I discuss as set out below);

(b) LF-FW-P13; and

(c) LF-FW-P14.

8.2 These provisions all make reference to the "natural form and function" of the river in some way.

8.3 LF-VM-O2 sets an objective that in the Dunstan, Manuherekia and Roxburgh rohe, flows in water bodies sustain and, wherever possible, restore the natural form and function of main stems and tributaries to support Kai Tahu values and practices. It also sets an objective that in the Lower Clutha rohe, there is no further modification of the shape and behaviour of the water bodies and opportunities to restore the natural form and function of water bodies are promoted wherever possible.

8.4 This objective is echoed in the following policies which related to natural character:

(a) LF-FW-P13 is a policy to preserve natural character. It states that the natural character of lakes and rivers and their beds and margins is to be preserved by wherever possible, sustaining the form and function of a water body that reflects its natural behaviours; and preventing modification that would reduce the braided character of a river; and controlling the use of water and land that would adversely affect the natural character of the water body.

(b) LF-FW-P14 is a policy to restore natural character. It states that where the natural character of lakes and rivers and their margins has been reduced or lost, actions are to be promoted that restore a form and function that reflect the natural behaviours of the water body. Improve water quality or quantity where it is degraded.

8.5 As set out in my evidence above, the CHS has significantly and irrevocably changed the character of the Clutha / Mata-au through the creation of the dams; and Lakes Dunstan / Roxburgh; and the various sedimentation/flooding issues associated with this as I have described. I am therefore not sure how these policies could practically be implemented in relation to this river system.

8.6 If it were considered practicable or possible to remove the dams, consideration must also be given as to how to remove 66 years of sediment stored behind Roxburgh and Clyde Dams and to transport this out of the river system and into the ocean without significant adverse effects to the environment.

8.7 **Ms Hunter** has recommended amendments to these provisions to reflect that sustaining or restoring the natural form and function of the Clutha River is not practical or sensible in the context of the CHS;[8] and I agree with her recommendations in this respect.

Peter Foster

23 November 2022

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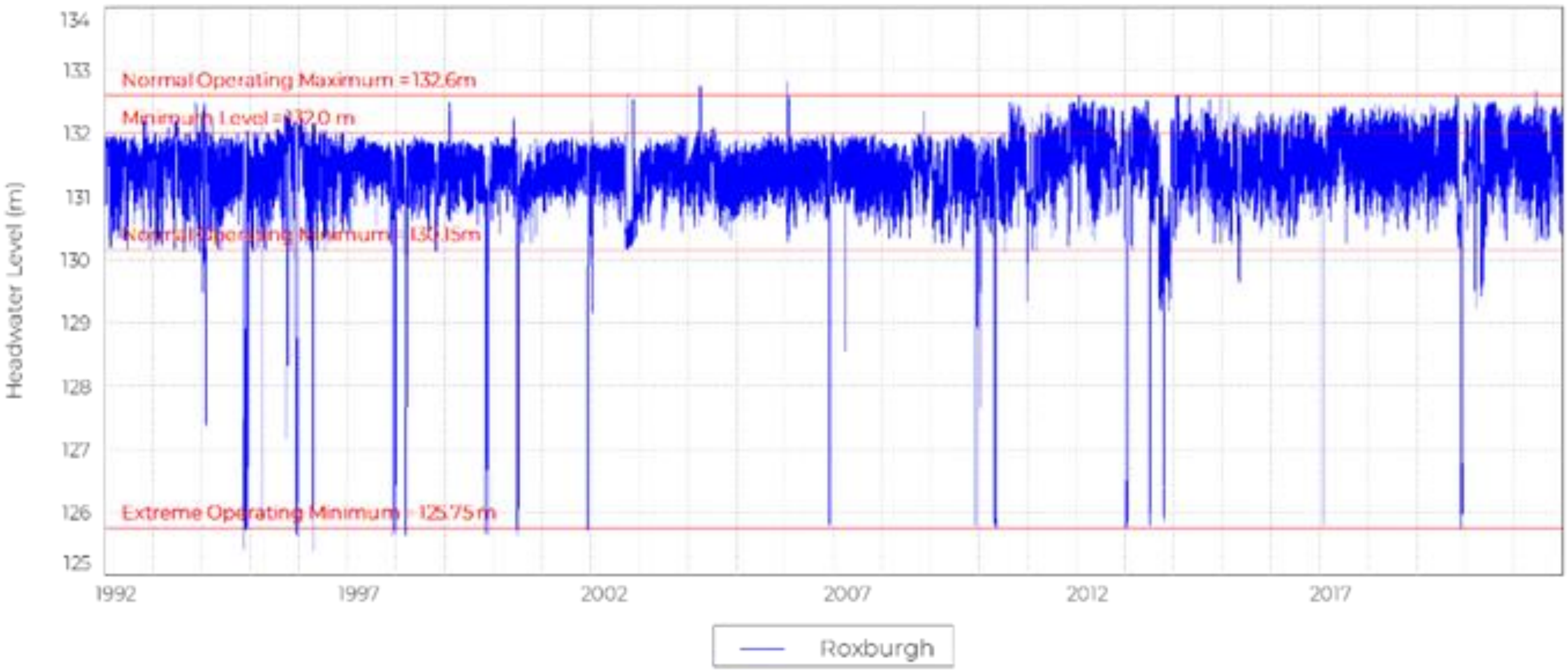
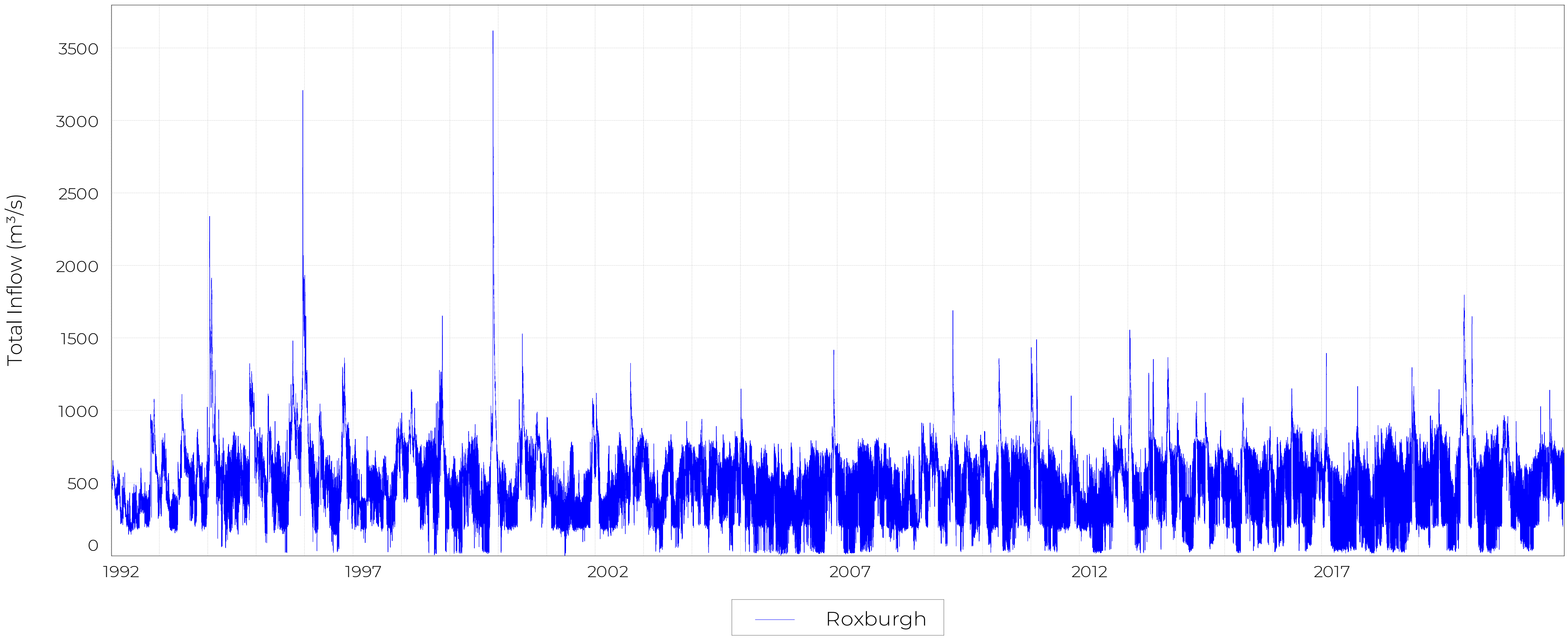
[8] Hunter EIC, section 9.

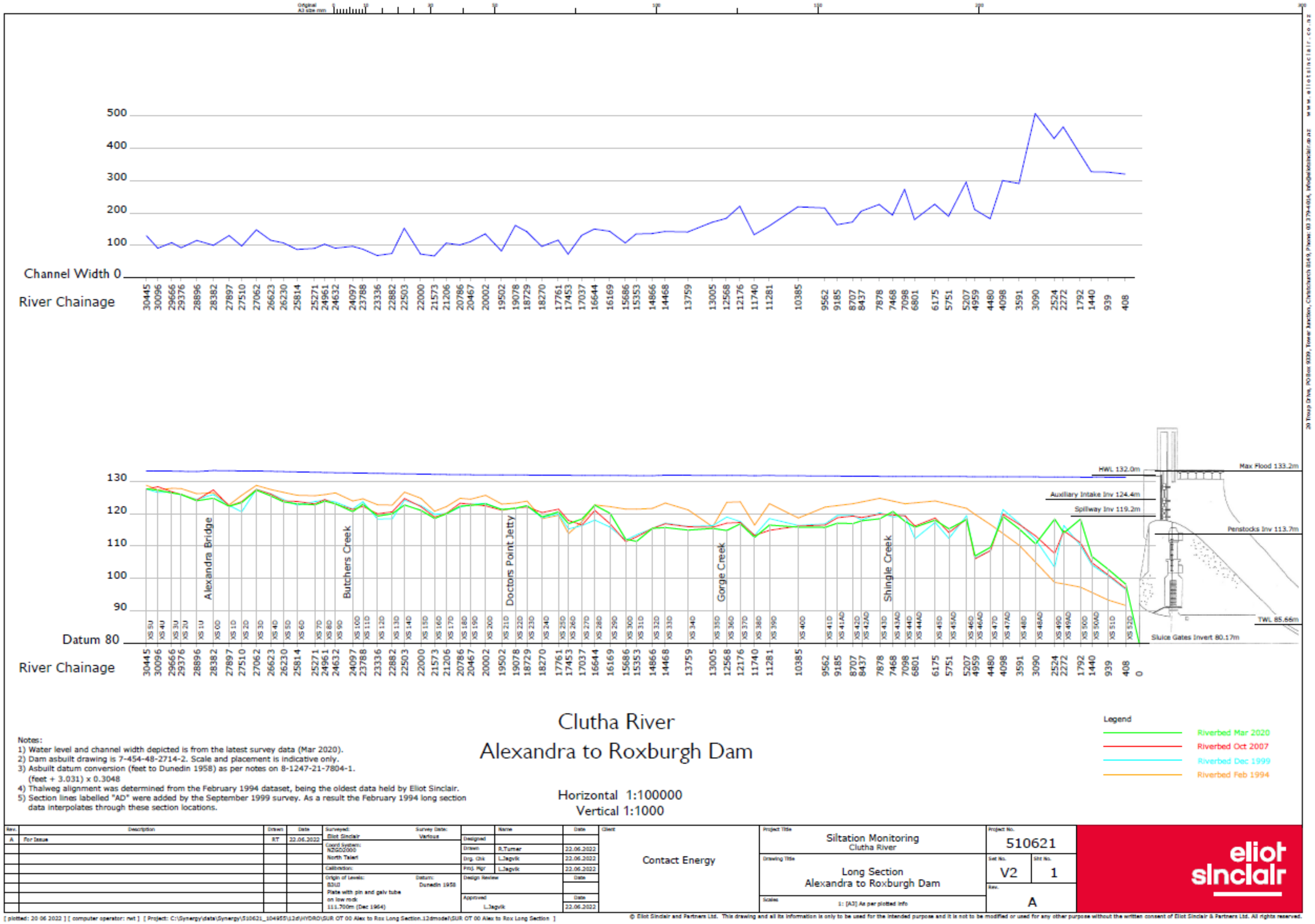
APPENDIX PF.1 – Roxburgh Reservoir Levels 1992 to 2022



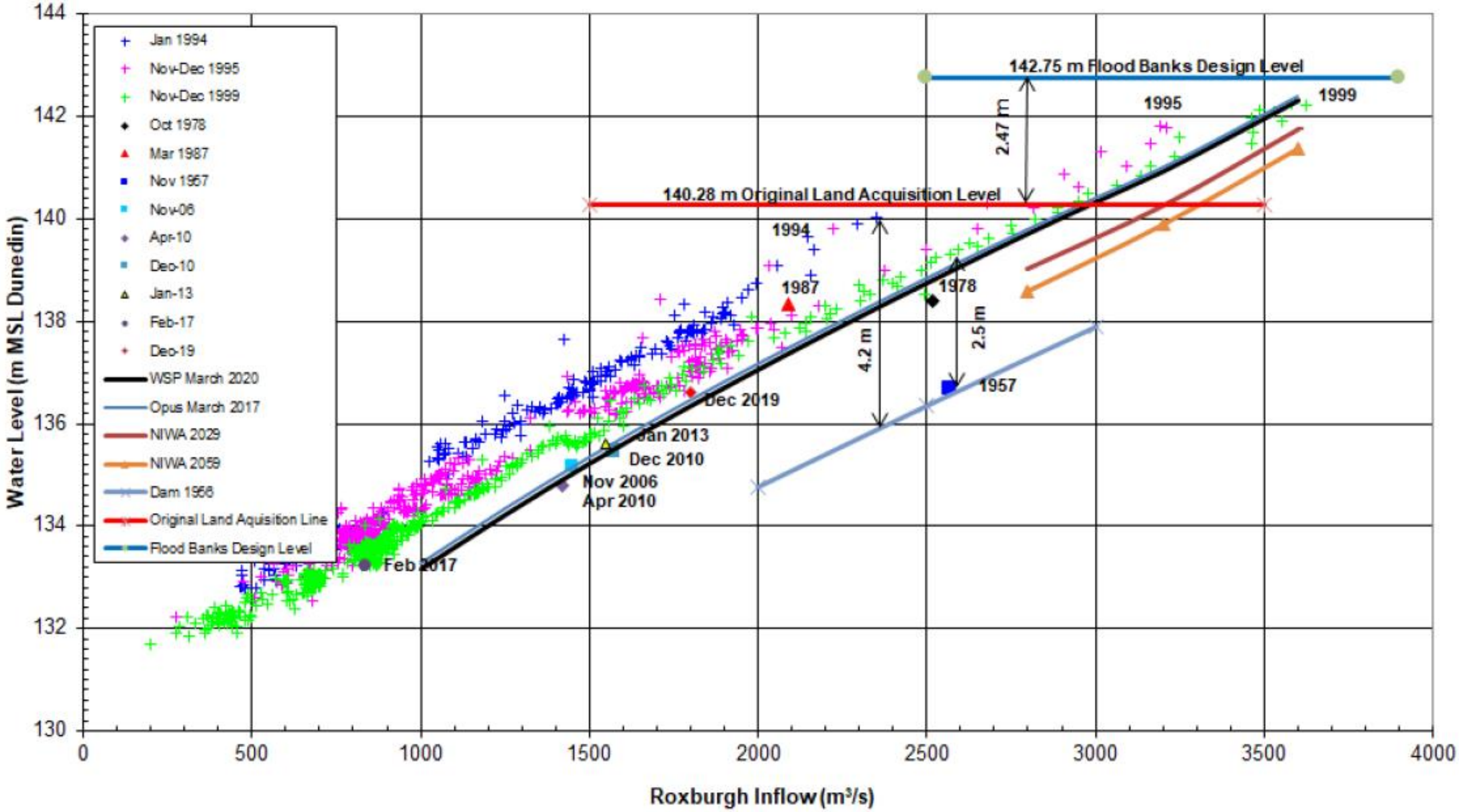
APPENDIX PF.2 – Roxburgh Inflows 1992 to 2022



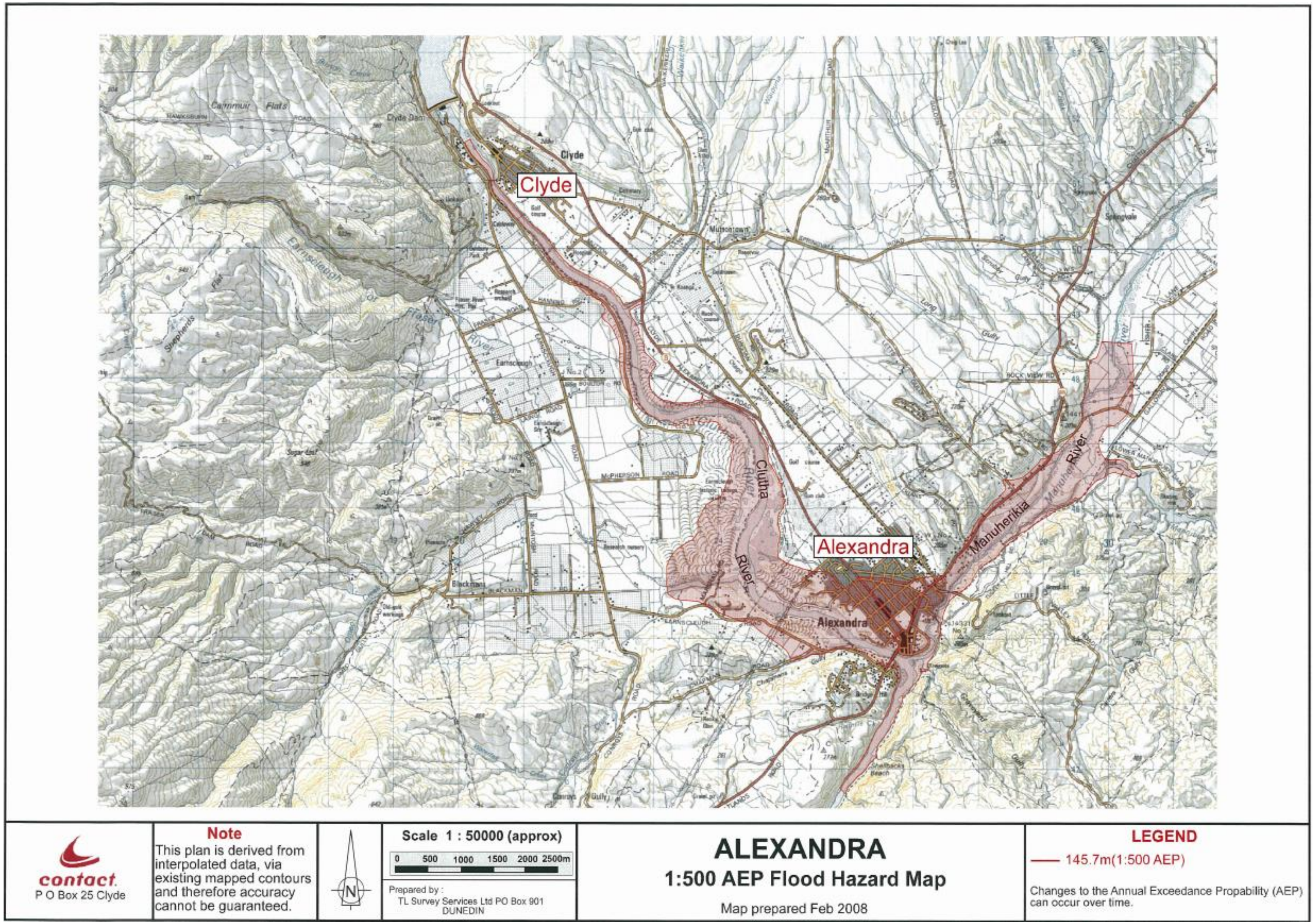
APPENDIX PF.3 – Lake Roxburgh Bed Profiles 1994, 1999, 2007 and March 2020



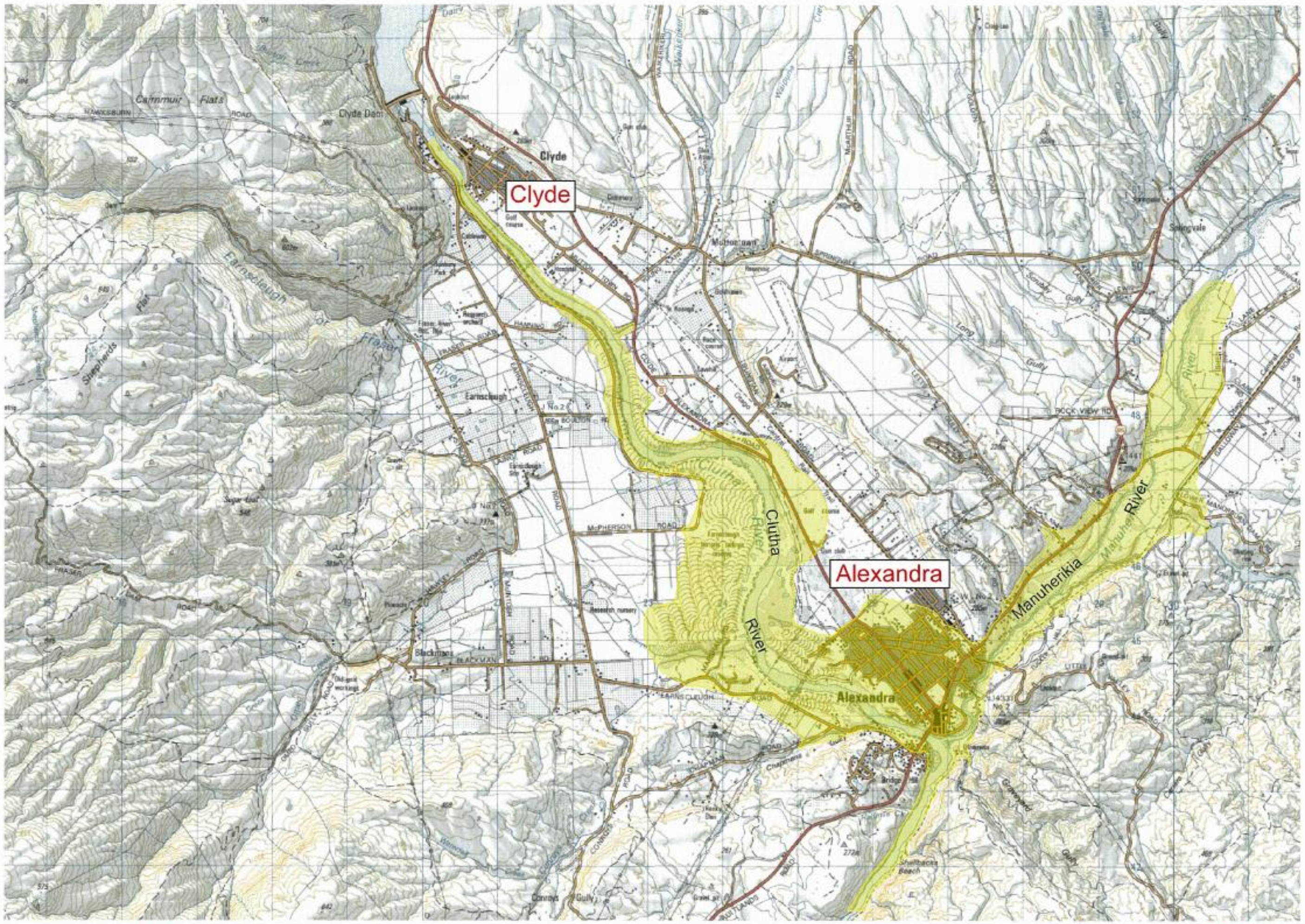
APPENDIX PF.4 – Alexandra Bridge Rating Curve



APPENDIX PF.5 – Alexandra 1 in 500 AEP Flood Hazard Map



APPENDIX PF.6 – Alexandra PMF Flood Hazard Map



contact.
P O Box 25 Clyde

Note
This plan is derived from interpolated data, via existing mapped contours and therefore accuracy can not be guaranteed.

N

Scale 1 : 50000 (approx)
0 500 1000 1500 2000 2500m

Prepared by :
TL Survey Services Ltd PO Box 901
DUNEDIN

ALEXANDRA
PMF Flood Hazard Map
Map prepared Feb 2008

LEGEND
151.8 (PMF)
Changes to the propable Maximum Flood (PMF) can occur over time.

APPENDIX PF.7 – Sediment Profiles Te Wairere / Lake Dunstan 2000 and Projected to 2105

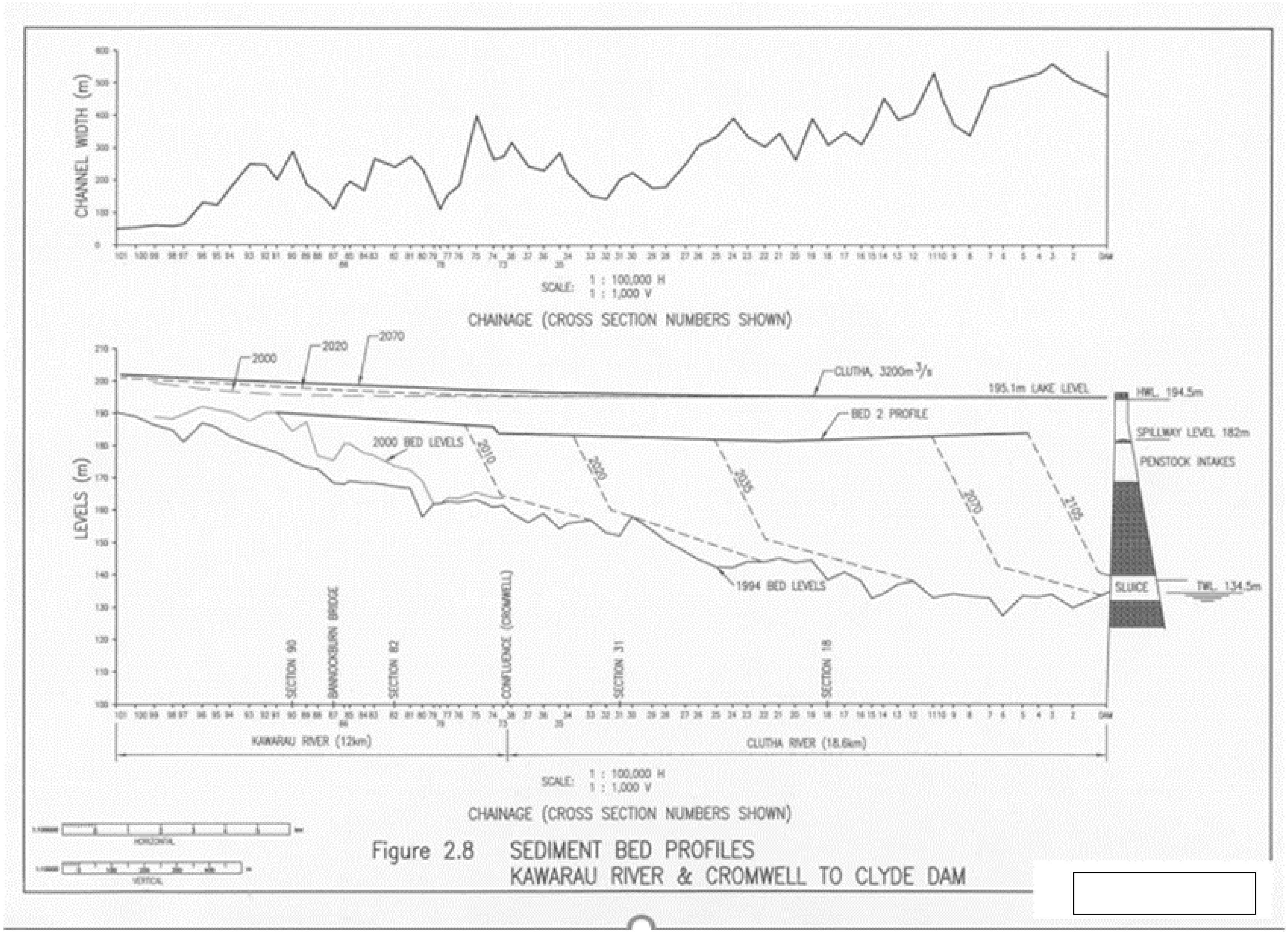
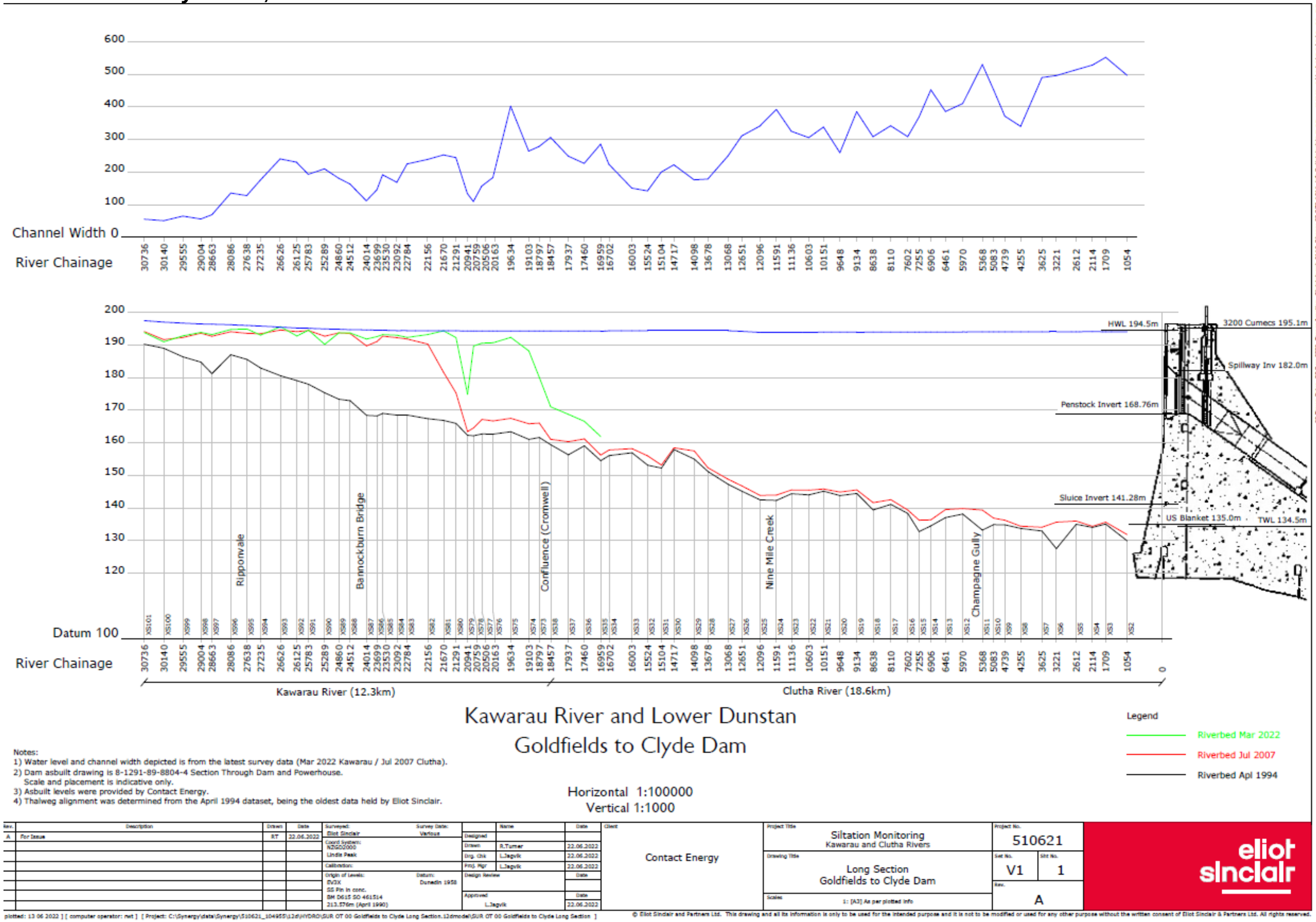
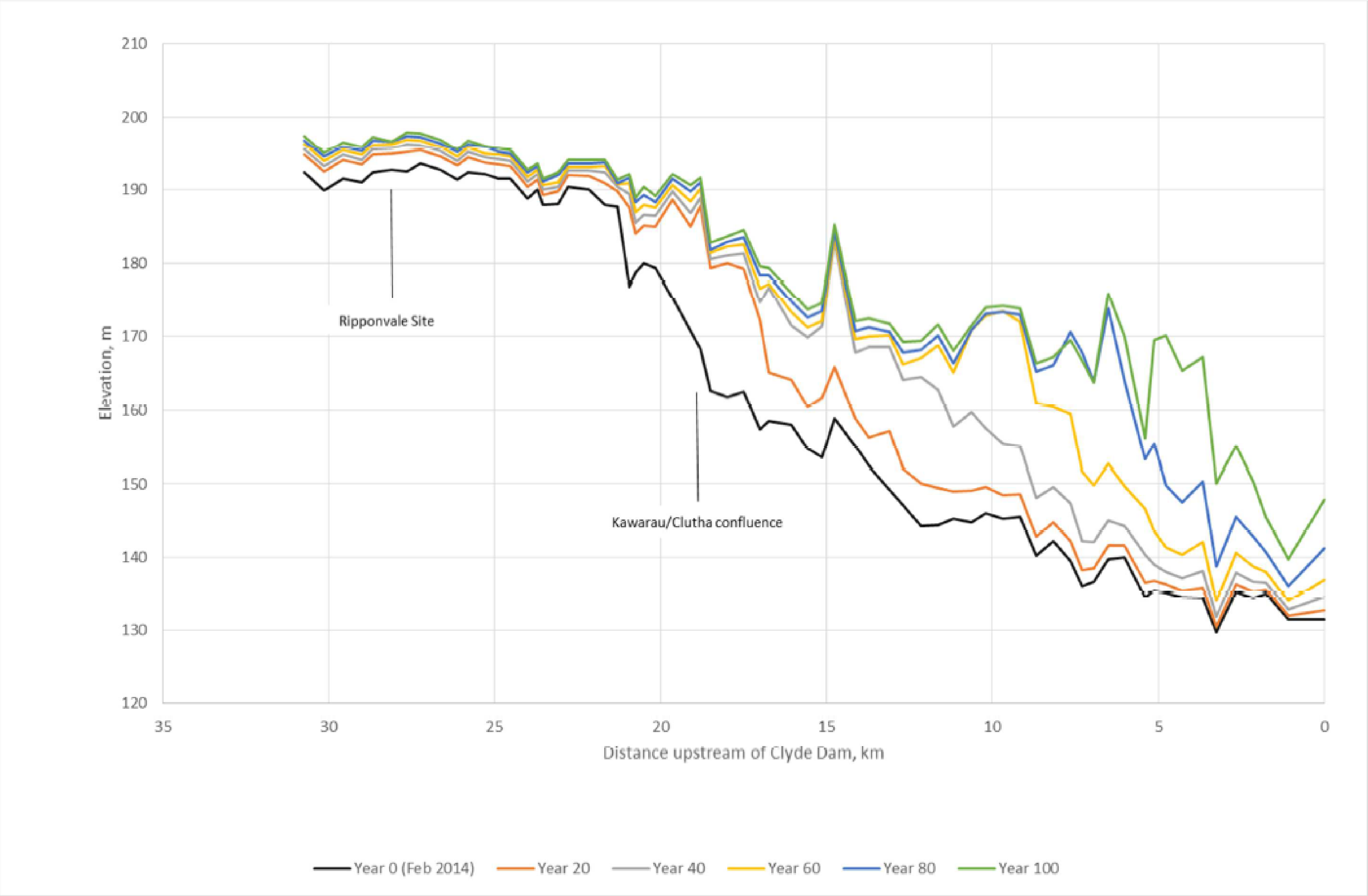


Figure 2.8 SEDIMENT BED PROFILES
KAWARAU RIVER & CROMWELL TO CLYDE DAM

APPENDIX PF.8 – Bed Surveys 1994, 2007 and 2020



APPENDIX PF.9 – NIWA predicted thalweg bed levels Kawarau and Dunstan Arms at years 0, 20, 40, 60 and 80 from February 2014



APPENDIX PF.10 – Kawarau Arm Flood Level Projections

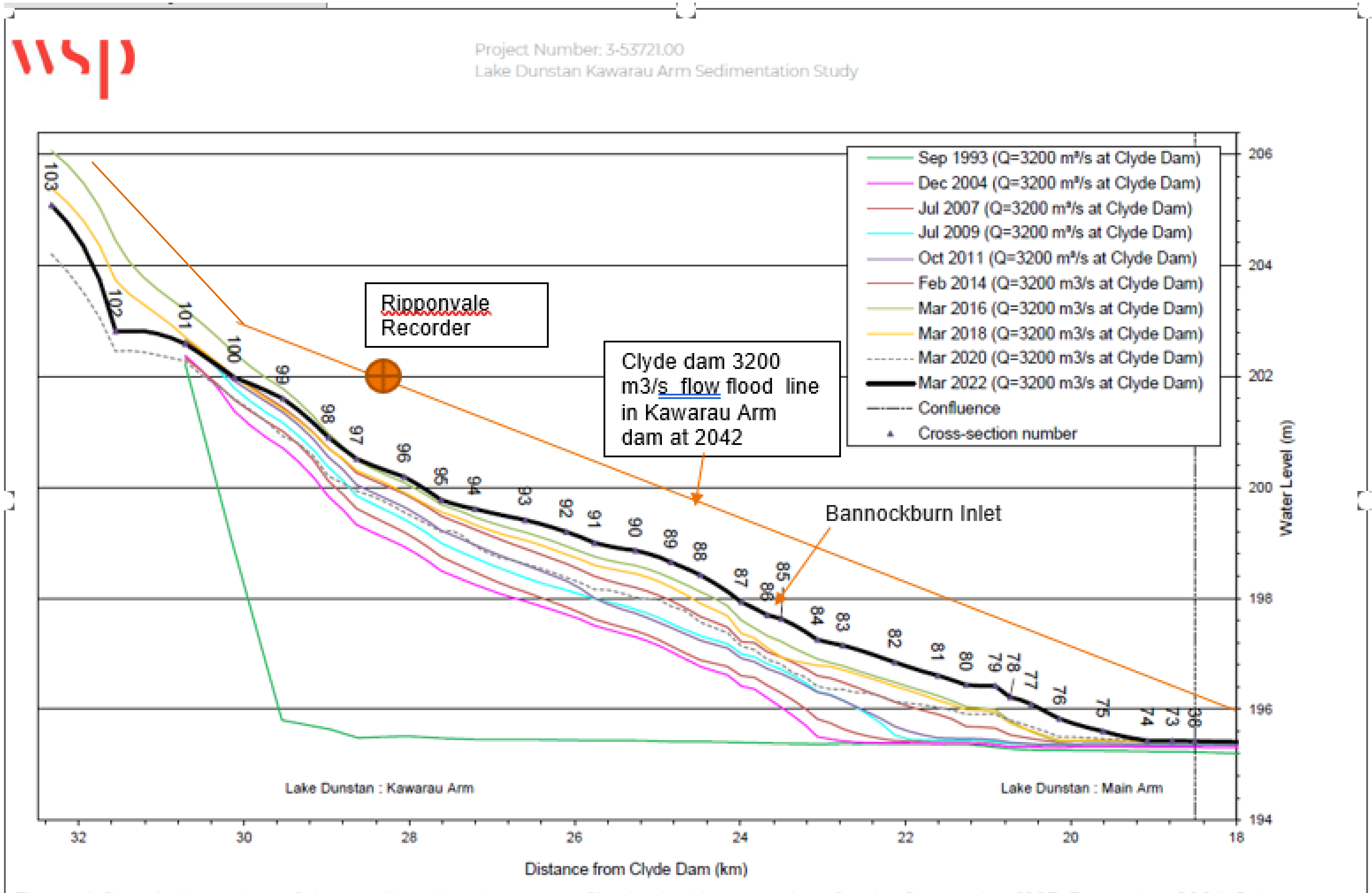


Figure 4-6b: A closer view of the predicted backwater profiles in the Kawarau Arm for the September 1993, December 2004, July 2007, July 2009, October 2011, February 2014, March 2016, March 2018, March 2020 and March 2022 lake-bed profiles, based on a flow of 3200m³/s at the Clyde Dam.