Drought Security - Maitai Dam

Nelson City Council

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1 Background

Over the past year Landmark Lile Ltd. have applied for resource consents on behalf of Nelson City Council to replace the expiring consents for the Maitai Dam, the reservoir, and water abstraction for municipal use. The application was publicly notified with a small number of submissions received. These submissions have all been resolved without the need for a hearing. Therefore, Landmark Lile Ltd. have now progressed to discussing specific conditions, and are attempting to agree on a full suite of resource consent conditions.

After several rounds of discussion, agreement has been reached on most conditions. On 21 June 2017 Landmark Lile Ltd. received a final set of conditions from the consent authority (i.e. Nelson City Council). Two conditions have been problematic:

- Condition 9(a & b) to establish winter and summer minimum flows. The applicant has sought that these minimum flows be subject to reduction, or cessation, to ensure that sufficient water remains in the dam to supply Nelson City during extreme drought conditions (i.e. the 60-year ARI event). The reporting officer for the consent authority has queried the implications of this. Landmark Lile Ltd. agree that this is a fair question, and that it should be answered to provide more certainty for both the consent authority and the consent holder.
- Condition 12 requires the release of surplus summer water, and makes reference to an operating diagram (Maitai Dam operating parameters from Water Supply Asset Management Plan, 2006). The diagram allows for (but does not require) water to be released from the reservoir if the level of the reservoir is above a drawdown threshold. Advice has been obtained from Cawthron staff that this may not be the best practice with regard to achieving ecological outcomes. Therefore it is considered that this "release" needs reviewing.

It is considered, with regard to Conditions 9(a & b) and 12, that more information and advice from suitably qualified professionals is required. Landmark Lile Ltd have also requested recommendations regarding dam management during periods of low inflows to ensure appropriate drought security of the water supply to Nelson City.

A hydrological model was developed in 1996 to assist with providing information relating to drought security of the Maitai Dam. This model has been updated to reflect the new consent conditions, the longer flow series now available for the Roding River and South Branch of the Maitai River, population projections for the duration of the consents (i.e. 35 years), and the actual total monthly water demand.

An earlier report (Opus, 2007) discussed the issues of water supply and storage during drought conditions; considering the resource consent conditions and demand scenarios at that time. The report concluded that a 1-in-60 year drought capacity was available out to 2055, and provided a range of options for improving drought storage and resilience. The current report updates those findings, using the latest suite of consent conditions, updated per capita water demand, and recent population projections.

1.1 Additional scenarios

Following some initial modelling, but prior to the finalisation of this report, additional modelling scenarios were requested by NCC. The results of these are included in a series of addenda.

A total of 18 scenarios have now been run on both the mean and maxima per capita demand discussed in Section 2.3. Scenarios run using the mean per capita demand are denoted (a), while scenarios using the maximum per capita demand are donated with (b). Table 1.1 lists all the scenarios modelled; including those reported here, and those in the subsequent addenda.

Table 1.1: The various scenarios modelled (see Section 2.3) and structure of reports.

Scenario	Description	Report
1a	Landmark Lile Population projections for 2028 -mean	Report
1b	Landmark Lile Population projections for 2028 - max	Report

2a	Landmark Lile Population projections for 2053 -mean	Report
2b	Landmark Lile Population projections for 2053 - max	Report
3a	Landmark Lile Population projections for 2100 -mean	Report
3b	Landmark Lile Population projections for 2100 - max	Report
4	LL populations using old consent conditions - max	Report
5a	Landmark Lile Population projections for 2028 + 2500m³/day - mean	Addendum 1
5b	Landmark Lile Population projections for 2028 + 2500m³/day - max	Addendum 1
6a	Landmark Lile Population projections for 2028 + 7500m³/day - mean	Addendum 1
6b	Landmark Lile Population projections for 2028 + 7500 m³/day - max	Addendum 1
7a	Landmark Lile Population projections for 2053 + 2500 m³/day - mean	Addendum 1
7b	Landmark Lile Population projections for 2053 + 2500 m³/day - max	Addendum 1
8a	Landmark Lile Population projections for 2053 + 7500m³/day - mean	Addendum 1
8b	Landmark Lile Population projections for 2053 + 7500m³/day - max	Addendum 1
9a	Landmark Lile Population projections for 2100 + 2500m³/day - mean	Addendum 1
9b	Landmark Lile Population projections for 2100 + 2500m³/day - max	Addendum 1
10a	Landmark Lile Population projections for 2100 + 7500 m³/day - mean	Addendum 1
10b	Landmark Lile Population projections for 2100 + 7500 m³/day - max	Addendum 1
11a	NCC Population projections for 2028 -mean	Addendum 2
11b	NCC Population projections for 2028 - max	Addendum 2
12a	NCC Population projections for 2053 -mean	Addendum 2
12b	NCC Population projections for 2053 - max	Addendum 2
13a	NCC Population projections for 2100 -mean	Addendum 2
13b	NCC Population projections for 2100 - max	Addendum 2
14a	NCC Population projections for 2028 + 2500m³/day - mean	Addendum 3
14b	NCC Population projections for 2028 + 2500m³/day - max	Addendum 3
15a	NCC Population projections for 2028 + 7500m³/day - mean	Addendum 3
15b	NCC Population projections for 2028 + 7500m³/day - max	Addendum 3
16a	NCC Population projections for 2053 + 2500 m³/day - mean	Addendum 3
16b	NCC Population projections for 2053 + 2500 m³/day - max	Addendum 3
17a	NCC Population projections for 2053 + 7500 m³/day - mean	Addendum 3
17b	NCC Population projections for 2053 + 7500 m³/day - max	Addendum 3
18a	NCC Population projections for 2100 + 2500 m³/day - mean	Addendum 3
18b	NCC Population projections for 2100 + 2500 m³/day - max	Addendum 3
19a	NCC Population projections for 2100 + 7500 m³/day - mean	Addendum 3
19b	NCC Population projections for 2100 + 7500 m³/day - max	Addendum 3
Discussed in this report		

2 Supply Scheme

The Maitai Dam was built in 1986, and has a total usable storage volume of 4,200,000m³ (i.e. 4.2Mm³) above RL 139.30. This is the minimum level at which water can be extracted from the dam into the supply pipeline.

2.1 Supply capacity

The dry weather capacity of the Maitai Dam has previously been assessed at 50,000m³/day[1]. The storage capacity of the dam therefore allows for a notional 84 days' supply, assuming no inflow.

[1] Nelson City Council Water Supply Asset Management Plan 2001

2.2 Population estimates

Population forecasts for the Nelson community supplied by the dam have been provided by Landmark Lile. Population projections were calculated using the Statistics NZ medium series projections as a base, plus an adjustment to the underlying net migration assumption. It is assumed that future average net migration each year will be the same as Nelson has experienced over the 10 years from 2006 to 2016. The Statistics NZ medium projections assume net migration of 300 a year, compared to the average from 2006 to 2016 of 450.

Nelson – population trends

- Nelson's population is expected to grow by 5,000 residents over the next ten years, to 56,800 in 2028, at an average annual growth rate of 0.9 percent.
- Population growth is expected to slow down over time, based on the assumptions that; deaths will increase, births will decrease slightly, and that migration remains constant.
- Nelson's population is likely to grow by a further 6,300 over the 20 years between 2028 and 2048, to 63,100 in 2048, at an average annual growth rate of 0.5 percent.

The Statistics NZ population projections end at 2043. Therefore, projections to 2048 were extrapolated using the growth rate over the five years ending 2043 (i.e. from 2038 to 2043). This aligns with Nelson City Council's 30-year Infrastructure Strategy, and with the long-term timeframe required by the National Policy Statement for Urban Development Capacity (2018-2048).

Landmark Lile have requested that volume demand forecasts out to 2100 also be provided. Subsequently, based on the anticipated growth rate of 0.5% per year from 2048, the projected population of Nelson will be 81,800 by 2100.

Projections, however, are not predictions. Consequently, they should be used only as an indication of the overall trend, rather than as exact forecasts.

Table 2.1: Population and household projections for Nelson (medium plus adjusted net migration).

Month	2018	2028	2048	2053	2100
Population	51,800	56,800	63,100	64,700	81,800*

**** Assuming a population growth of 0.5% from 2048.***

2.3 Demand

Previous studies relating to the drought security of the Maitai Dam have assumed the monthly water demand as set out in Tonkin & Taylor (1986, Section 3.2) and in NCC (August 1995) (Table 2.2).

Table 2.2: Monthly peak 1-day water demand for Nelson City (Tonkin & Taylor, 1986).

Month	Cubic metres
January	48,000
February	50,000
March	50,000
April	48,000
May	40,000
June	32,000
July	29,000
August	29,000
September	32,000
October	38,000
November	44,000
December	46,000

Total daily abstraction, and the volume of water supplied to Nelson and Stoke, have been provided by NCC for the period July 2007- February 2017 (Figure 2.1). Of particular interest is the apparent decrease in the volume of water supplied over the period for which data are available (Figure 2.2). Since the population has increased over this period, these data show a significant improvement in water use efficiency, and a reduction in per capita consumption.

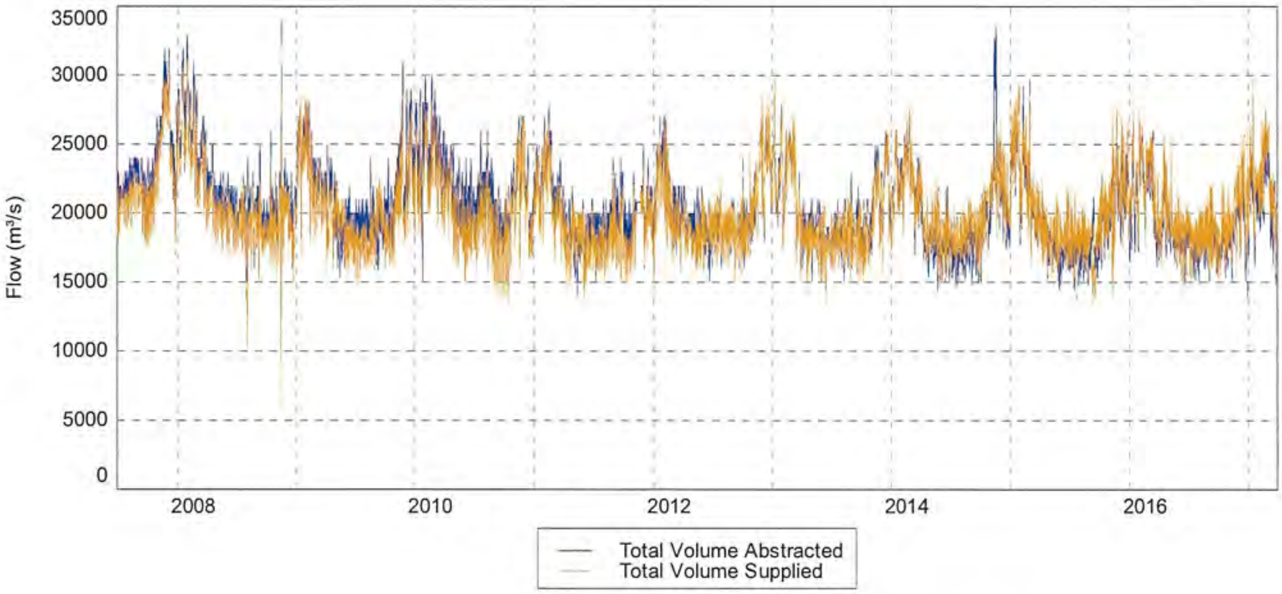


Figure 2.1: Total daily volume of both water supply and abstraction; July 2007–Feb 2017. Data provided by NCC.

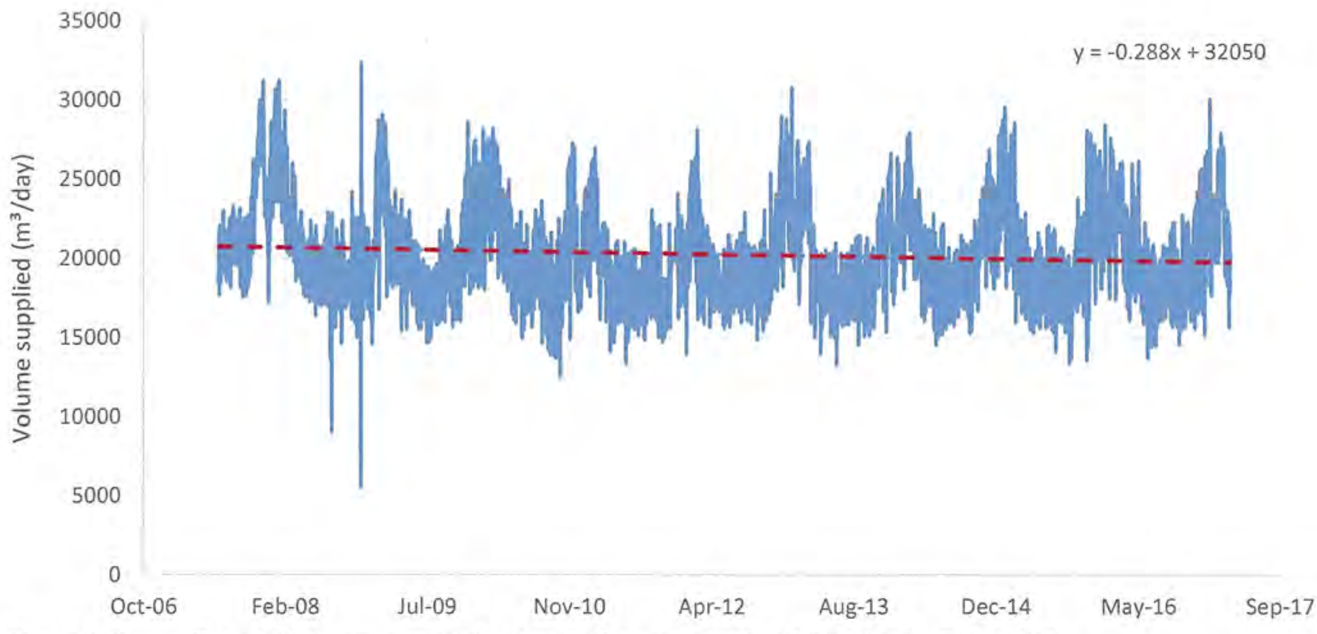


Figure 2.2: Trend of decreasing total volume of water supplied (July 2007 - Feb 2017).

The total daily volume of water supplied to the Nelson community was used to derive an average, and maximum, monthly per capita demand. This has then been applied to population forecasts for 2053 (i.e. the expected duration of the resource consent), and 2100 (to facilitate the development of a long term water supply and demand strategy). The subsequent demand projections were rounded up to the nearest 100m^3 to provide some conservatism (Table 2.3).

It should be noted that future demand forecasts for 2053 and 2100, under average conditions, are lower than those provided by T&T (1986). In July 1999 universal metering was installed, and as a result the demand has dropped by 37% over the summer period. Consequently, the timing of the peak demand has shifted. This shift in the period of peak demand has been exacerbated by the water restrictions which have been put in place over recent dry summers.

Table 2.3: Monthly peak 1-day water demand for Nelson City (m^3).

Month	T&T (1984)	2028		2053		2100	
		Mean	Maximum	Mean	Maximum	Mean	Maximum
January	48,000	32,800	37,500	37,400	42,700	47,200	54,000*
February	50,000	32,200	35,400	36,600	40,300	46,300	51,000*
March	50,000	29,600	32,400	33,700	36,900	42,600	46,600
April	48,000	26,600	29,400	30,300	33,500	38,300	42,300
May	40,000	25,900	29,200	29,500	33,300	37,200	42,000
June	32,000	25,100	27,100	28,600	30,800	36,100	39,000
July	29,000	25,100	27,900	28,600	31,700	36,200	40,100
August	29,000	25,700	28,300	29,200	32,200	36,900	40,700
September	32,000	25,600	28,000	29,100	31,900	36,800	40,300
October	38,000	26,900	31,700	30,700	36,200	38,700	45,700
November	44,000	31,300	38,700	35,700	44,000	45,100	55,600*
December	46,000	31,100	37,800	35,500	43,000	44,800	54,400*

* ***Demand exceeds current infrastructure capacity to abstract water at a rate of 50,000m³/day.***

The Maitai Scheme was designed initially to meet a peak demand of 37,000m³/day through a 75-year design drought, but with the capacity to abstract water at a rate of up to 50,000m³/day. As seen in Table 2.3, peak demand during the larger population and maximum monthly demand scenarios exceed this capacity.

3 Water Permits and Controls

The model uses the revised water permit conditions which will come into effect in Jan 2018.

3.1 Minimum flow requirements

As currently drafted, the resource consent conditions contain the following conditions with regard to the maintenance of minimum flows.

The following minimum flows shall be maintained in the river immediately below the Forks:

(a) From 1 May to 31 October [Winter] the flow in the South Branch shall be measured at the existing water level recording station and:

(i) When the South Branch instantaneous flow exceeds 140 litres/sec, the minimum instantaneous flow at the Forks shall be 300 litres/sec; and

(ii) When the South Branch instantaneous flow is less than or equal to 140 litres/sec, the minimum instantaneous flow at the Forks shall be 230 litres/sec. This minimum flow shall remain effective until the South Branch flow exceeds 140 litres/sec, and the water level in the Maitai Reservoir exceeds the level shown in Figure 3.1.

(b) From 1 November to 30 April a minimum instantaneous flow of no less than 230 litres/sec shall be maintained a the Forks recorder site.

(c) The minimum flow in (a) and (b) above shall be subject to maintaining 1-in-60 year drought security within the Maitai Dam at all times.

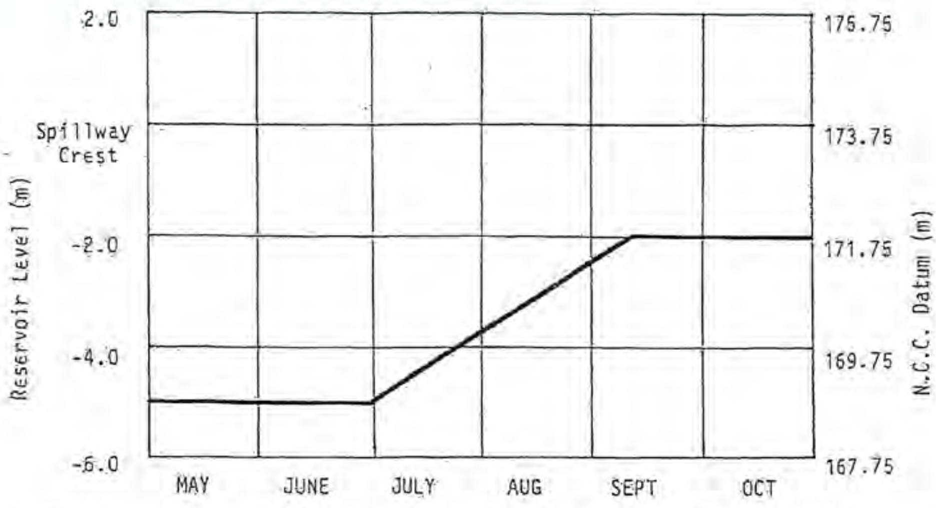


Figure 3.1: Maitai Dam reservoir level for the minimum flow condition.

It is noted that the above consent conditions refer to 'instantaneous flows'. If these are adopted, they are likely to prove problematic with respect to compliance monitoring; especially when flows approach 140L/s. This is because flow measurements are essentially estimates, and even using industry best practice, the uncertainty of these estimates is generally assumed to be ±8%. Therefore, even if flow is held constant, measurements are likely to 'bounce' above and below the actual flow. With the current wording of the consent conditions, any measurement below 140L/s would be considered a technical 'non-compliance'.

It is suggested that the consent conditions should be reworded to describe the flow thresholds in terms of 'mean daily flows', rather than 'instantaneous flows'. This would largely avoid the issue regarding consent compliance discussed above.

In reality, during periods of low flow, the difference between the mean daily flow and estimates of instantaneous flow (irrespective of the sampling time frame) is very small. Any difference in the way 'flow' is defined would pose no threat to the environment or aquatic ecosystem. Therefore, while still achieving the same environmental outcomes, the use of the mean daily flow would simplify compliance monitoring.

3.1.2 Roding River residual flows

The model uses two scenarios for the residual flow requirements set out in the current resource consent RM165239):

- The current requirement is to leave a residual flow of 150 litres/sec in the river opposite the caretaker's house, or the natural flow of the river if this is less than 150 litres/sec. As the intake location is upstream of the Caretaker flow site, this results in leaving a residual flow of at least 144 litres/sec in the Roding River, as provided by Nelson City Council; and
- Residual flow review. During the 10th year following the commencement of this consent, the NCC may review the residual flows for the purpose of assessing whether the minimum flow during February and March should be adjusted based on any effects on the aquatic environment.

3.2 Condition 12

This condition requires the release of 'surplus' summer water, and makes reference to an ecological flow operating diagram (Maitai Dam operating parameters from Water Supply Asset Management Plan, 2006). The diagram allows for, but does not require, water to be released from the reservoir if the level of the reservoir is above particular thresholds.

Advice has recently been obtained from staff at Cawthron that this may not be the best practice for ecological outcomes. Consequently, there is a need to revise this diagram. The results of the subsequent modelling will be used to inform whether this diagram remains appropriate, or whether it could be reviewed to provide better operational guidance for NCC.

4 Model

The model used to calculate the drought security of the Maitai dam considers the inflows, outflows, and changes in storage of the reservoir at a daily timescale. The volume of water within the Maitai reservoir is determined from the water level and a level-volume storage curve. The inflow is derived from flow records for the North Branch of the Maitai River and the Roding River, and considers the effect of any consent conditions relating to residual flows. While water from the Roding River does not enter the Maitai reservoir, it reduces the demand that must be met from the reservoir. Water from the Roding River can therefore be considered an 'indirect' input. Outflow is calculated from the daily water demand of the Nelson community, adjusted by per capita demand and population estimates at various dates in the future, and the residual flow requirements for the Maitai River below Forks; based on the recorded flow in the South Branch of the Maitai River.

Using the above information, the Maitai model essentially runs a daily water balance for the reservoir, determining a running total of storage in the reservoir after considering the various inputs and outputs.

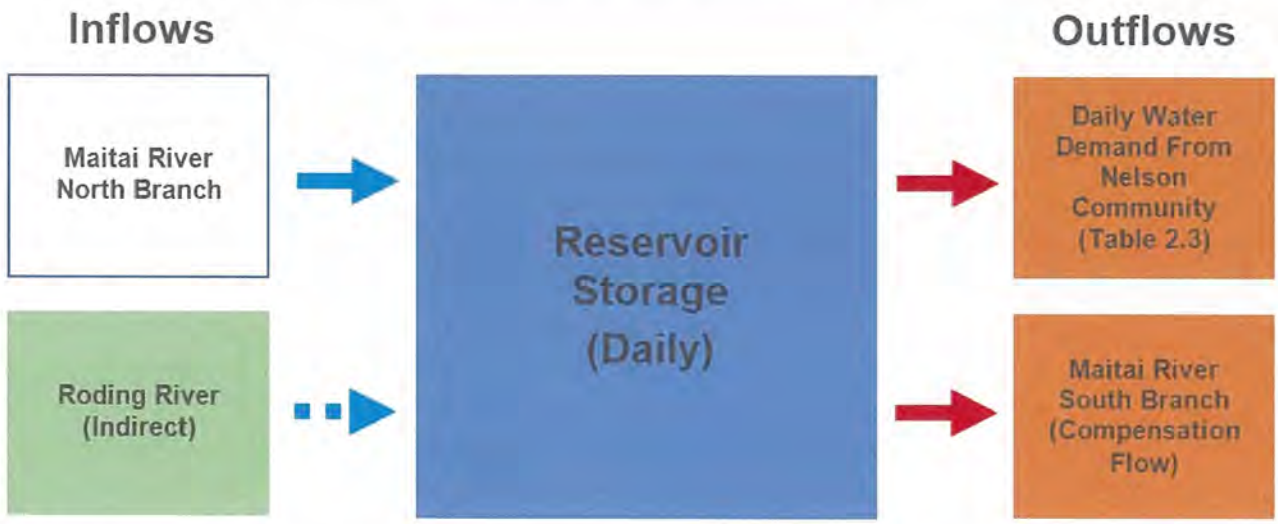


Figure 4.1: Conceptual model of the inflows and outflows from the Maitai reservoir.

5 Flow Data

The model requires flow data from the Roding River, the Maitai North Branch, and the Maitai South Branch. Roding River data are required to calculate the inflows diverted from this river to the water supply (Figure 5.1). The North Branch represents the inflows to the dam, and the South Branch of the Maitai is used to determine the compensation flow required from the dam.

WCS (1996) explains the details of how the synthetic flow data were created for the 1958-96 period for each of these datasets. In this study, we have extended these flow records using the actual data where available, or synthetic data using the same correlations as used in WCS (1996).

The model therefore now considers 60-years of daily flow data (i.e. 1957-2017). The assumption is that these data provide a realistic surrogate for the flow regimes of these rivers at the end of the two periods considered i.e. 2053 (the end of the current consent period) and 2100 (the end of a reasonable planning timeframe for new large infrastructure projects).

It should be noted that the period of record is now the same length as the specific design drought i.e. the 1-in-60 year event. This means that estimates of the magnitude and severity of this event can be defined in a robust manner. Also, it is generally accepted that the magnitudes of design events can be extrapolated out to twice the length of record. Consequently, the use of 60-year's data in the model allows reliable estimates for all events out to at least the 1-in-100 year, or 1% AEP, event.

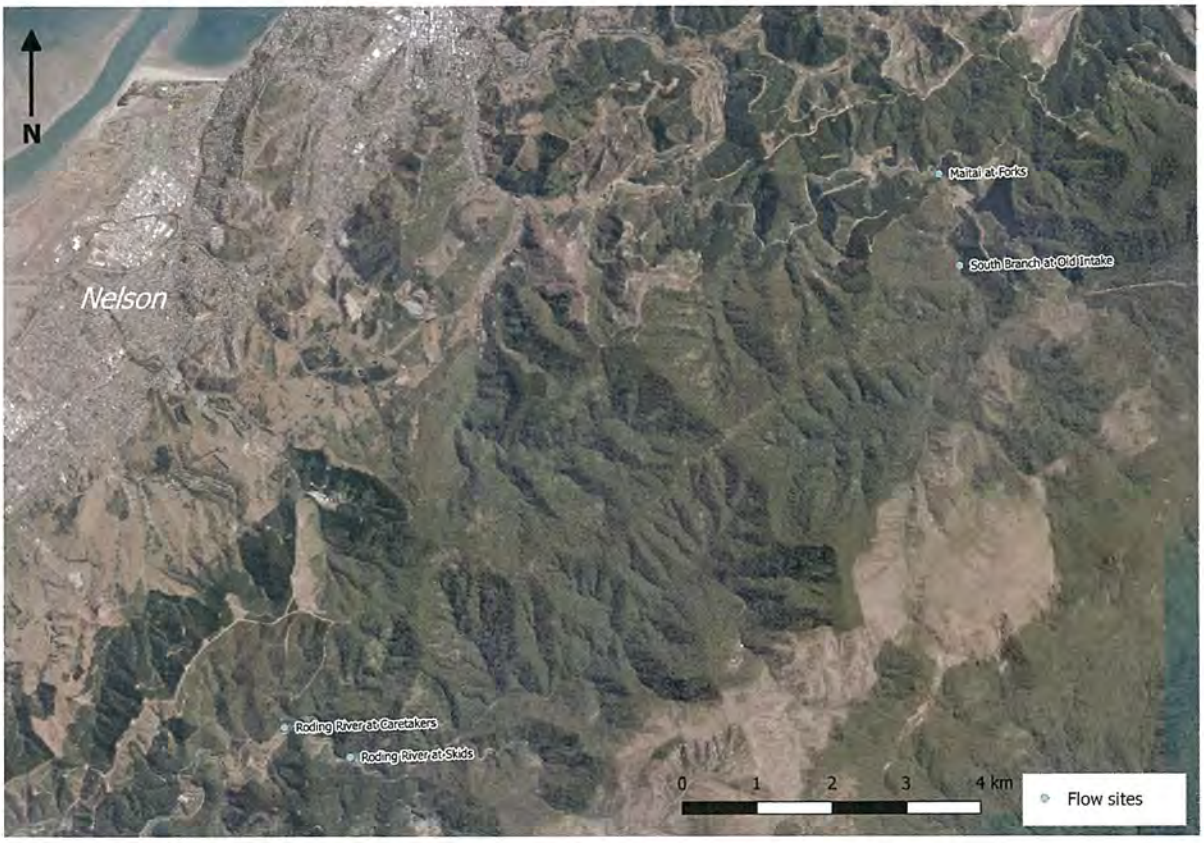


Figure 5.1: Location of the Maitai Dam and various flow recording sites.

5.1 Maitai North Branch

The data for the North Branch of the Maitai was derived using the same correlation with the Wairoa River at Irvines flow site (site 57521), as was used in previous studies. The correlation is:

$$\textit{Maitai North Flow} = 0.03141 \times \textit{Wairoa}^{1.0124} + 29$$

Data from 2003 to 2017 was appended to the previously derived flow record for the Maitai to ensure consistency between the various drought model simulations.

Table 5.1 compares the summary statistics for both the previous and extended flow series for the North Branch of the Maitai River. The summary statistics of both periods of record are very similar. The mean flow of the extended series is approximately 20L/s lower. This is because of the moderating effect the extended record has had on the higher flows experienced during the early to mid-1980s. Over the more recent years, there has been a slight decrease in flows coming into the dam. However, no trend analysis has been carried out, and this relatively small change does not suggest a significant reduction in flows within the catchment.

Table 5.1: Maitai North Branch flow summary statistics comparison.

Date	Minimum flow (l/s)	Mean flow (l/s)	Maximum (l/s)
Nov 1957 to Oct 2003	67	634	33217
Nov 1957 to Nov 2017	67	615	33217

Figure 5.2 shows the entire flow series, including both the new data and that which had been previously synthesised for the North Branch of the Maitai River. The consistency of the data over the entire period of record is apparent.

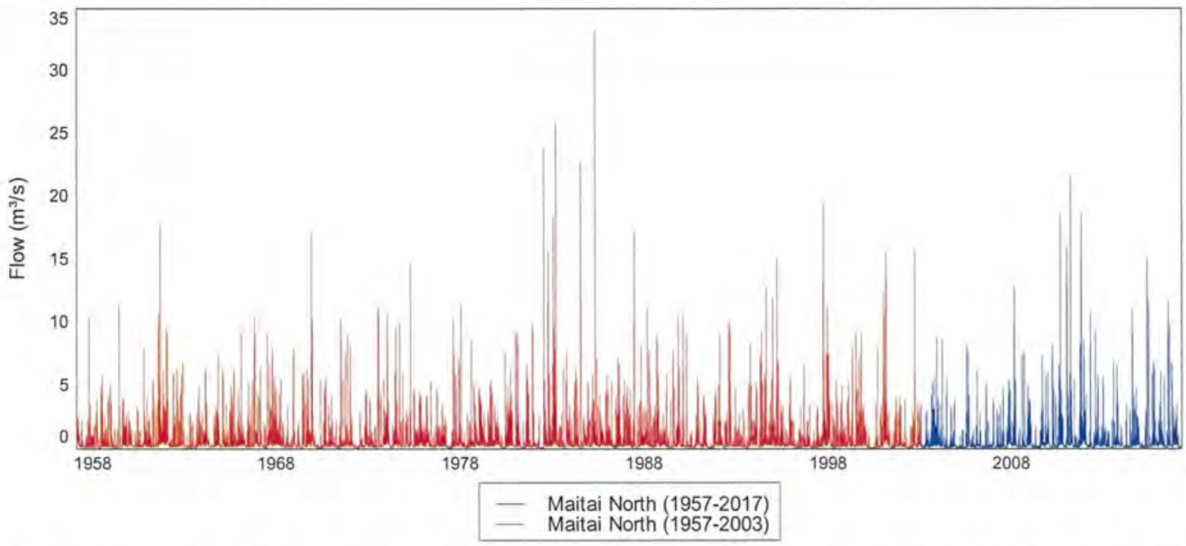


Figure 5.2: *Maitai North Branch flow data used in previous drought simulations (red) and the additional flow series derived for this study (blue).*

5.2 Maitai South Branch

Flow data from the Maitai South Branch was extended using the actual flow record from the Maitai South above Old Intake site (site no. 57807). Gaps in the flow data were filled using the following correlation with the flow data from the Wairoa River at Irvines (site 57521):

$$\text{Maitai South Flow} = 0.03699 \times \text{Wairoa}^{1.0154} + 70$$

Six gaps were identified in the record prior to 1993 and these were filled using the above methodology (WCS, 1996). No new gaps were identified in the extended record. Data from 2003 to 2017 was appended on to the previous flow record for the Maitai South Branch to ensure consistency between the various model simulations.

Figure 5.3 shows the entire flow series, including both the new data and that which had been used previously for the South Branch of the Maitai River. The consistency of the data over the entire period of record is also apparent.

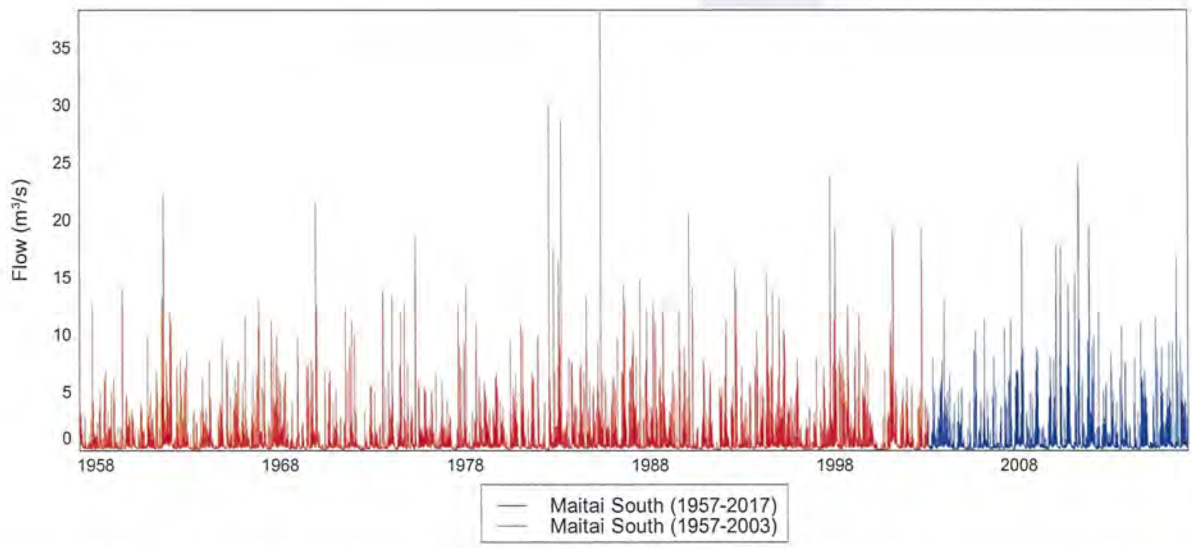


Figure 5.3: *Maitai South Branch flow data used in previous drought simulations (red) and the additional flow series derived for this study (blue).*

Table 5.2 compares summary statistics for both the previous and the extended flow series for the South Branch of the Maitai River. The extended flow series has almost identical summary statistics as the previous shorter series i.e. the mean flow differs by only 3L/s or 0.4%. This suggests that the flow regime of the South Branch has remained essentially the same since the previous studies.

Table 5.2: Maitai South Branch flow summary statistics comparison.

Date	Minimum flow (l/s)	Mean flow (l/s)	Maximum (l/s)
Nov 1957 to Oct 2003	0	812	38402
Nov 1657 to Nov 2017	0	815	38402

5.3 Roding River

The flow series for the Roding River was derived using a combination of data from the previous flow site, Roding at Weir (site no. 57503), and the current Roding at Skid Site (site no. 57522). Further details of the synthesized flow series between the two sites is detailed in WCS (1996). Gaps in the flow series were filled using the following correlation with the flow data from the Wairoa River at Irvines (site 57521)

Roding = 0.107 x Wairoa + 24

Twelve gaps were identified in the Roding flow series, five of which were identified in the most recent data. These were filled using the above methodology. Data from 2003 to 2017 was appended to the previous flow record for the Roding River to ensure consistency between the various model simulations.

Figure 5.4 shows the new data that was used to extend the previously derived flow series for the Roding River and which was used subsequently in the current model.

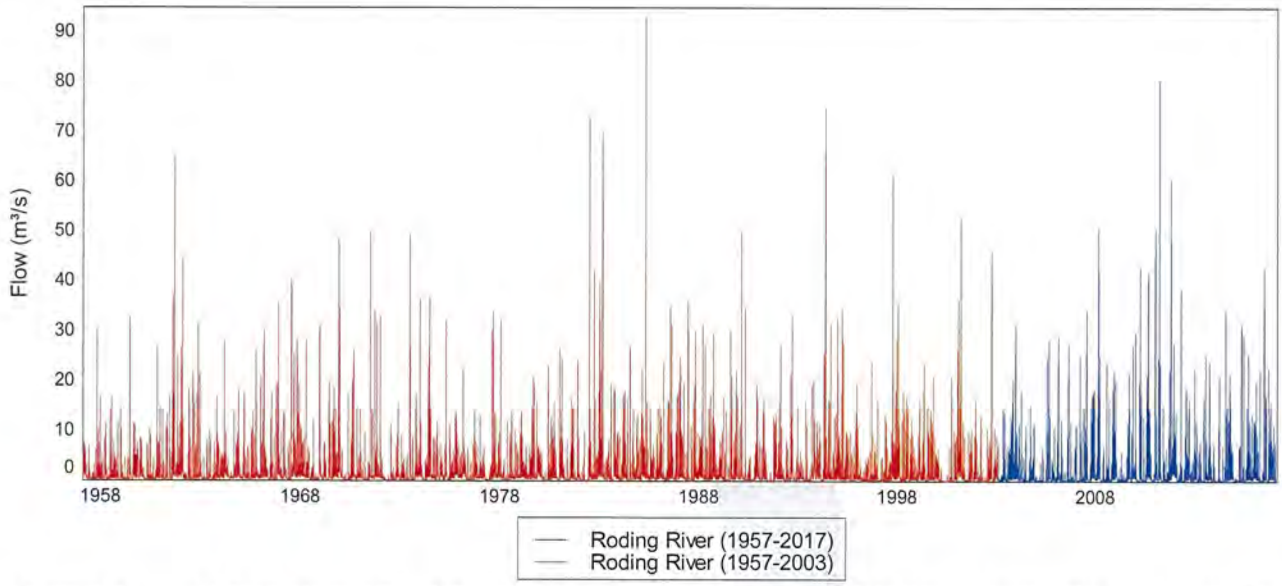


Figure 5.4: Roding River flow data used in previous drought simulations (red) and the new input flow series for this study (blue).

Table 5.3 compares the summary statistics for both the previous and the extended flow series for the Roding River. The summary statistics of both periods of record are very similar. The mean flow of the extended series is approximately 36L/s lower. This is because of the moderating effect the extended record has on the higher flows experienced during the early to mid-1980s. This indicates that over the more recent years there has been a slight decrease in flows in the Roding River i.e. ~2%. However, no trend analysis has been carried out, and this relatively small change does not suggest a significant reduction in flows within the catchment.

Table 5.3: Roding River flow statistics summary comparison.

Date	Minimum flow (l/s)	Mean flow (l/s)	Maximum (l/s)
Nov 1957 to Oct 2003	125	1797	93103
Nov 1957 to Nov 2017	125	1761	93103

6 Model Runs and Results

6.1 Modelling assumptions

In addition to the required flow inputs outlined in Section 5, other modelling assumptions are detailed below:

- The model considers 60-years of historic daily average flow data. The assumption is that these historic flows represent the future flow regime accurately, at either 2053 or 2100 depending on the particular scenario;
- The model was run on a daily time step;
- The model considers total demand and does not split the demand between Nelson City and the Stoke/Tahuna areas as done previously;
- The Maitai Dam was assumed full at the start of the simulation (i.e. 4.2Mm³);
- Total abstraction from the dam is limited to 50,000m³/day (i.e. the current infrastructure capacity);
- The existing upper limit of the Roding River weir supply is restricted to 22,000m³/day. (It would appear that the sustained yield from the Roding weir may actually be 20,664m³/day (Fulton Hogan, 2016);
- The model runs in an unconstrained fashion, i.e. it does not take into account demand restrictions on a daily or weekly basis; except where the effects of restrictions are represented in the actual supply volumes which were used to represent demand. The monthly demand figures detailed in Table 2.2 have been used; and
- The total live storage of the Matai reservoir is 4.2Mm³. This deviates from previous drought simulations where the live storage was only 3.3Mm³ (3.1Mm³ available storage and a 0.2Mm³ drought security margin). The remaining 0.9Mm³ was dead storage, restricted by the invert level of the intake pipe. This limitation has subsequently been resolved by installing a new intake pipe, providing access to the full capacity of the dam.

6.2 Model runs

Seven scenarios were modelled:

- Scenario 1a: All the conditions as stated in Section 3, using the 2028 mean monthly demand, rounded up to the nearest 100m³;
- Scenario 1b: All the conditions as stated in Section 3, using the 2028 maximum monthly demand, rounded up to the nearest 100m³;
- Scenario 2a: All the conditions as stated in Section 3, using the 2053 mean monthly demand, rounded up to the nearest 100m³;
- Scenario 2b: All the conditions as stated in Section 3, using the 2053 maximum monthly demand, rounded up to the nearest 100m³;
- Scenario 3a: All the conditions as stated in Section 3, using the 2100 mean monthly demand, rounded up to the nearest 100m³;
- Scenario 3b: All the conditions as stated in Section 3, using the 2100 maximum monthly demand, rounded up to the nearest 100m³; and
- Scenario 4: Using the previous conditions that were effective until January 2018, but using the 2053 maximum monthly demand rounded up to the nearest 100m³. These conditions had lower residual flows for the Maitai at Forks and the Roding River.

Scenarios 1a, 2a and 3a represent the 'average' expected water demand from the Nelson community which must be met from the Maitai Dam; including flow from the Roding River. Scenarios 1b, 2b and 3b reflect the more extreme water demand (i.e. the maximum monthly demand) from the Maitai Dam (including flow from the Roding River) and the resulting impact on water supply security.

Scenario 4 shows how the newly implemented consent conditions impact the security of the water supply compared to the previous conditions; under the maximum 2053 monthly demand scenario. This provides information on how best to manage water releases from the Maitai Dam (including flow from the Roding River) to maintain residual flows, while keeping security of supply at the 1-in-60 year design level.

6.3 Results

The seven scenarios described in Section 6.2 to model storage in the Maitai reservoir are displayed in Figure 6.1 through to Figure 6.4. These results show the daily storage based on the 60-year historic flow series, on the assumption that these flows are also representative of those during each scenario. While this has implications for the security of supply, it does not model the actual security of supply which can be affected by demand management. Of the seven scenarios modelled, four predict at least one period when storage would reach zero i.e. there is insufficient water in the Maitai Dam to meet the demand from the Nelson community.

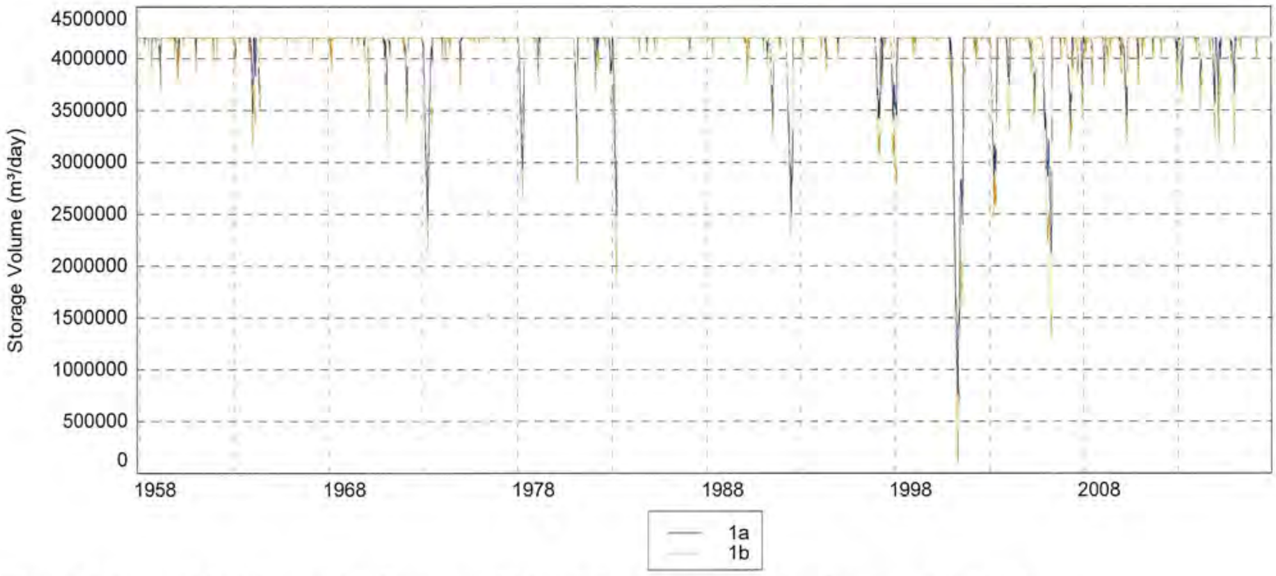


Figure 6.1: Model outputs of predicted Maitai dam storage under Scenarios 1a & 1b.

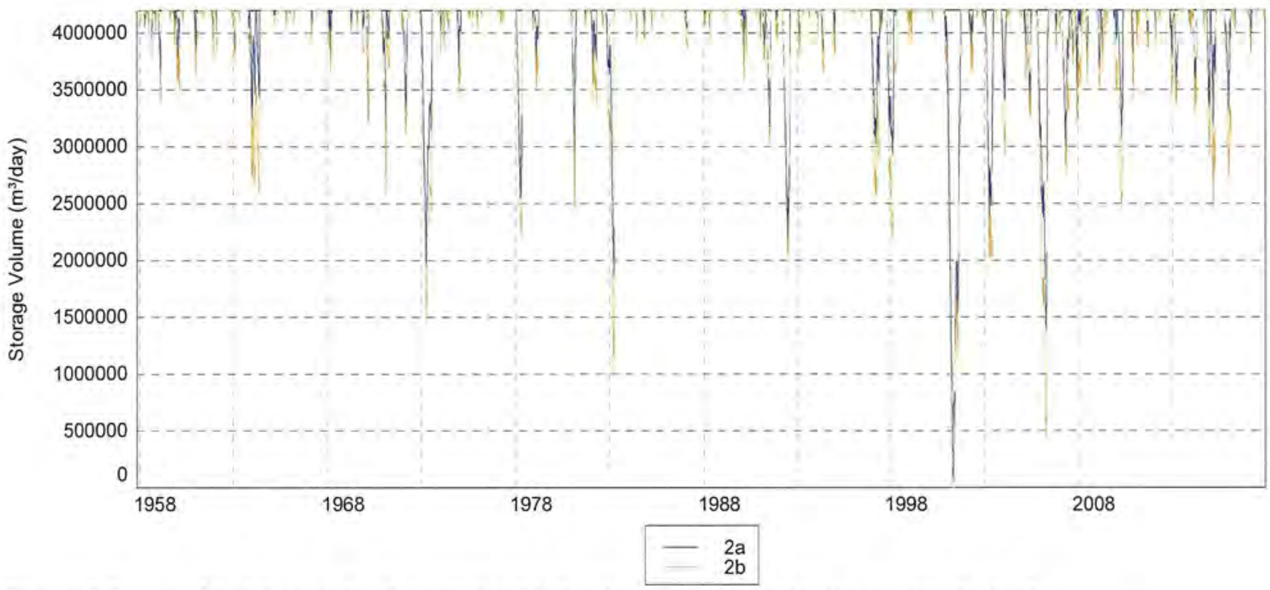


Figure 6.2: Model outputs of predicted Maitai dam storage under Scenarios 2a & 2b.

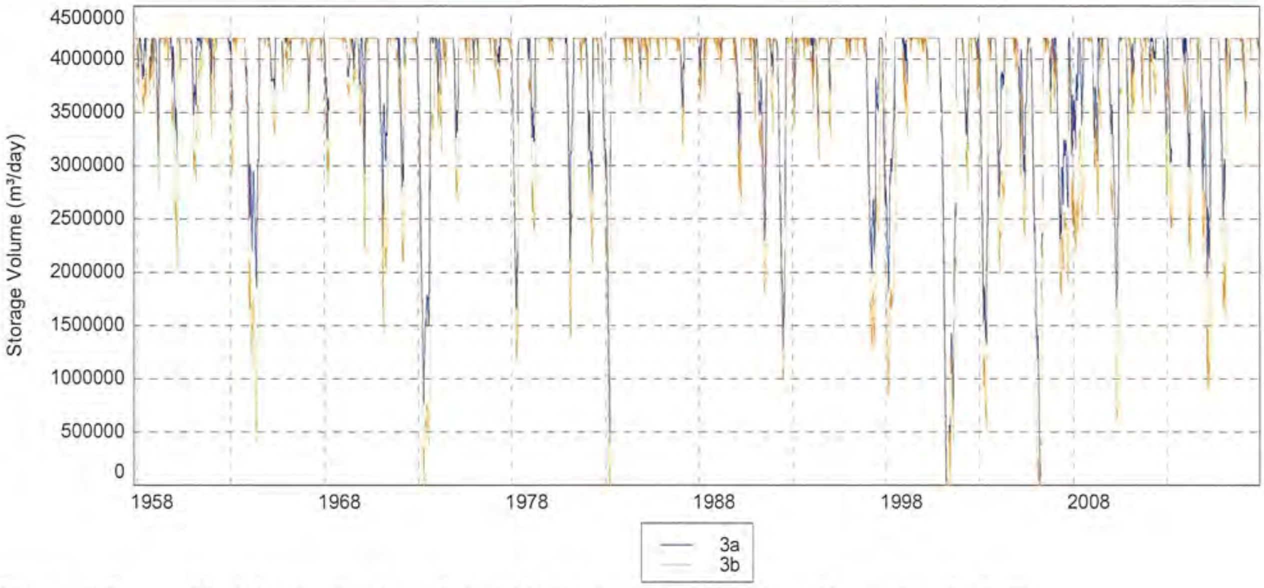


Figure 6.3: Model outputs of predicted Maitai dam storage under Scenarios 3a & 3b.

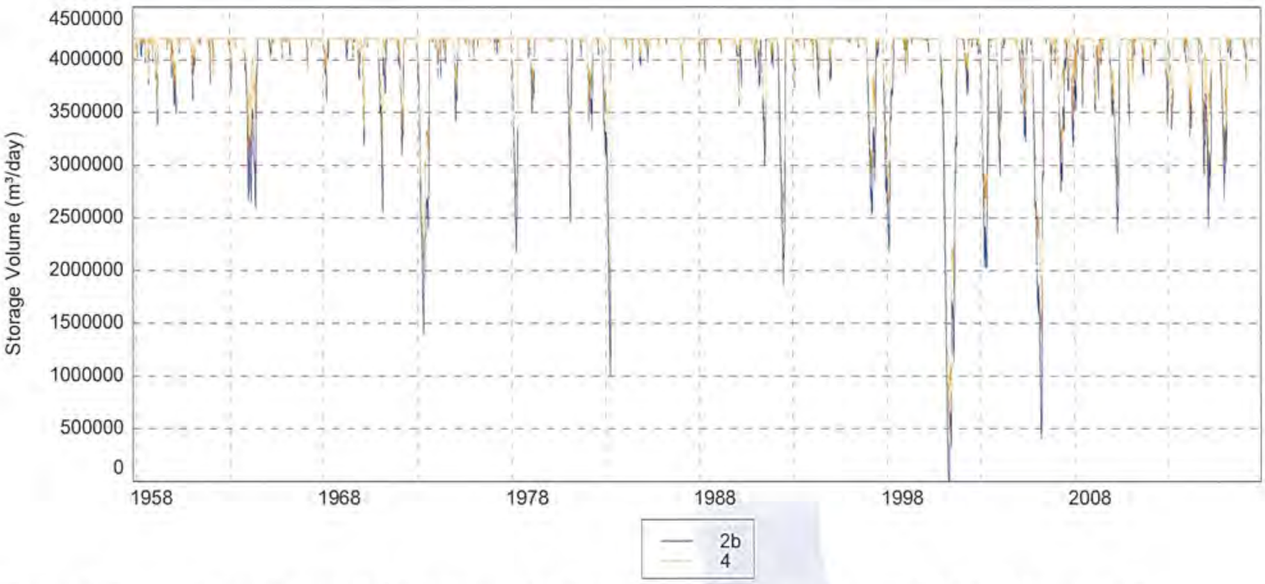


Figure 6.4: Model outputs of predicted Maitai dam storage under Scenario 2b and Scenario 4.

As expected, using the higher monthly water demand requires a greater volume of water, and consequently draws the Maitai reservoir down to a lower level e.g. Figure 6.1 comparing Scenario 1a & 1b. Also, because of population growth, there is greater demand for water, and consequently lower reservoir levels, when comparing Figure 6.1 and Figure 6.2. Finally, the increased residual flows under the currently proposed consent conditions also reduce drought security. This is because, although the demand for water does not increase, the availability of water decreases (Figure 6.4). The increased residual flows have a particularly significant effect on drought security beyond 2053.

It should be noted that these increased residual flows serve an important environmental purpose, and reduce the potential stress caused by the abstraction of water on the aquatic environment. The potential effects of the increased residual flows will need to be 'offset' by a new water demand management philosophy. This could involve various phases or levels of restriction including, for example:

- Advise the community that restrictions are likely, and that they should conserve water;
- A sprinkler ban, allowing hand held hoses only, including no watering of non-productive gardens; and
- Commercial and industrial restrictions.

The aim of each phase is to delay or defer the introduction of subsequent phases, and allow more time for rain to arrive, which it will eventually.

Should these restrictions not be sufficient to prolong the water supply, then the drought management programme could include a gradual reduction in the residual environmental flows. This, however, would be a last resort, adopted only once all other options had been implemented.

Figure 6.5 shows the longest duration when the Maitai Dam would be empty under the scenarios modelled. This would occur under flow conditions similar to those experienced from March to May 2001, but with the demand scenarios predicted to occur in 2053 and 2100 i.e. it is the conditions rather than the dates which are relevant. It should be noted, however, that this was a very extreme event; certainly significantly more extreme than a 1-in-60 year drought.

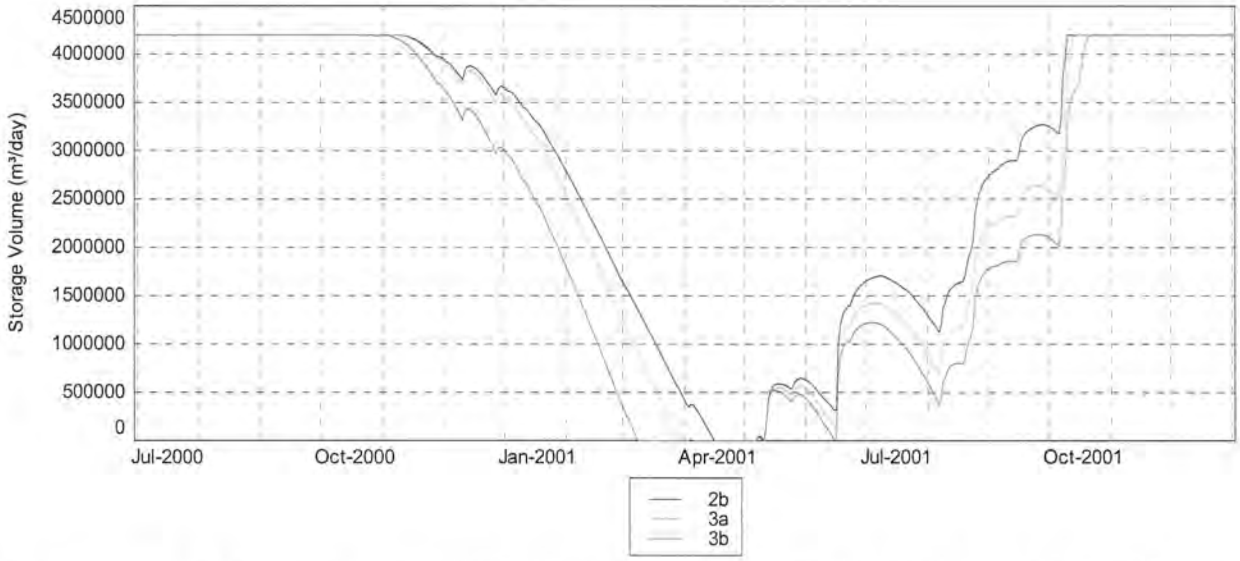


Figure 6.5: Period of longest consecutive days of zero storage in the Maitai dam for all three modelled scenarios where storage reached zero. ***Note: this assumes that inflow conditions are as experienced in 2001 but with the demand scenarios out to 2028, 2053 and 2100 i.e. the actual dates on the axis are not relevant.***

The number of days where storage reached zero for each scenario are displayed in Table 6.1. Under the newly proposed consent conditions, the maximum monthly demand based on population projections out to 2100 (Scenario 3b) resulted in the greatest number of days of zero storage; as expected. Scenarios 1a, 1b and 2a all had no days where storage hit zero. Scenario 4, the scenario which included the previous residual flow conditions also had zero days with zero storage. This highlights that the new residual flow conditions for the Roding and Maitai Forks will have a significant influence on the supply security of the Maitai Dam out past 2053. As discussed, the effect of the increased residual flows could be offset by reducing demand, introducing water restrictions, increasing storage within the Maitai reservoir by raising the dam spillway, or locating an additional water source to augment supply from the Maitai reservoir during prolonged drought conditions.

Table 6.1: Total days where storage was at zero under each modelled scenario. ***Note that this was during conditions similar to 2001, which were very extreme, but assuming the various scenarios.***

Scenario						
1a	1b	2a	2b	3a	3b	4
0 days	0 days	0 days	21 days	49 days	123 days	0 days

The increased residual flows means that less water is available within the dam, which is exacerbated further by the increase associated with population growth and the demand for water. The reservoir would only go 'dry' under the 2053 - 2100 population scenarios during environmental conditions similar to those experienced in 2001 (i.e. a 27-year rainfall event). Extreme drought conditions would also be experienced under environmental conditions similar to those experienced in 1973. With respect to reservoir storage (rather than just rainfall), both of these 'events' were well in excess of the 1-in-60 year drought.

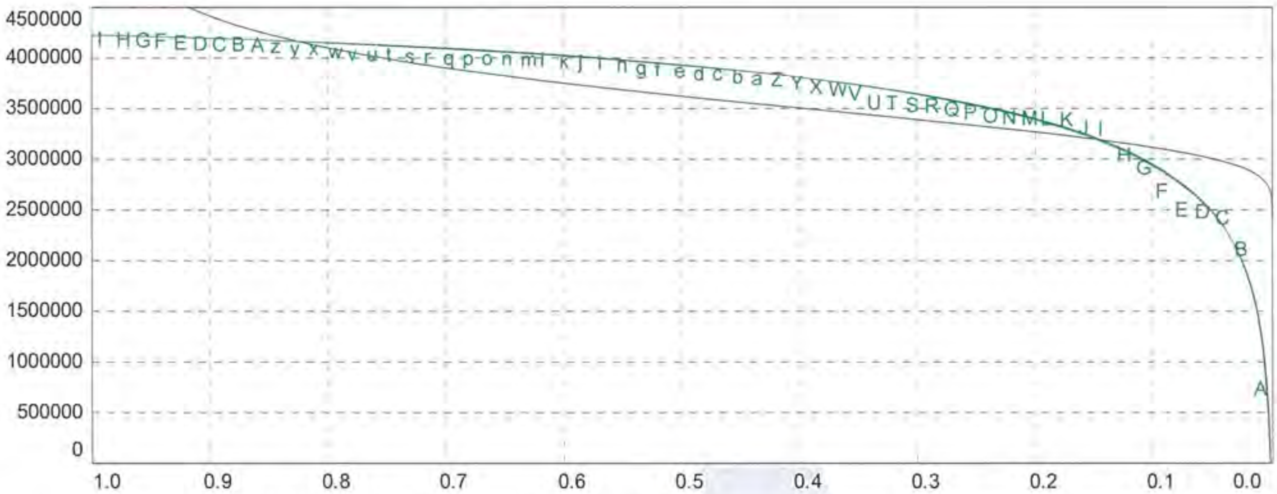
6.4 Frequency analysis

The previous section considered the actual 60-year flow series, and assumed that this will be similar to that experienced in 2028, 2053 or 2100. This section attempts to define the 1-in-60 year drought; the design standard for the level of service provided by the Maitai dam, and therefore the minimum storage required.

A frequency analysis was undertaken of the annual storage minima series for each of the scenarios. Three types of statistical distribution were assessed for how well they modelled the actual annual storage minimum series (i.e. Gumbel, Pearson 3 (PE3) and GEV). The distribution which provided the best fit to the annual minimum series was then used to estimate the frequency and magnitude of various annual minimum storage events, i.e. droughts, of specific annual exceedance probabilities (i.e. AEPs) or average recurrence intervals (i.e. ARIs).

As is standard practice, the frequency analyses were performed on a 12-month partition. That is, only the lowest storage volume in each complete year was plotted, and the most appropriate statistical distribution fitted to those annual values. The frequency distribution of the minimum annual storages for Scenario 1a is shown in Figure 6.6. The minimum storage each year is denoted by the letters, with the best-fit curve over plotted.

The PE3 statistical distribution, which is almost identical to the GEV distribution, provided the best fit for all seven scenarios; with their respective monthly water demands and residual flow conditions. As shown, the Gumbel distribution provides a very poor fit to the annual minima series.



Gumbel Distribution: Location = 3.43e+006 Scale = 4.21e+005
GEV Distribution: Location = 3.72e+006 Scale = 5.61e+005 Shape = 1.21
Pearson3 Distribution: Location = 3.67e+006 Scale = 6.18e+005 Shape = -2.47

Figure 6.6: Frequency distribution of the minimum storage volume of the Maitai Dam assuming the same daily flows as experienced from 1958-2016 but the Scenario 1a water demand and population.

Assuming that future annual minima will also approximate a PE3 distribution allows the minimum storage required to provide security against various design drought events (i.e. events with a particular magnitude and frequency) to be estimated. As the storage volume cannot decrease below 0, i.e. have a negative storage, the volumes displayed are the amount of water that is required to be stored in the Maitai Dam for events with the specified annual exceedance probabilities (i.e. AEPs) to prevent any water shortage (Table 6.2).

Table 6.2: Required storage for the Maitai Dam under the various scenarios and associated annual exceedance probabilities (AEPs) in Mm³.

Storage Scenario	AEP (%)						
	50 (i.e. 2-year)	20 (i.e. 5-year)	10 (i.e. 10-year)	5 (i.e. 20-year)	2 (i.e. 50-year)	1.6 (i.e. 60-year)	1 (i.e. 100-year)
Scenario 1a	0.4	0.9	1.3	1.8	2.4	2.6	2.9
Scenario 1b	0.6	1.2	1.7	2.3	3.1	3.2	3.6
Scenario 2a	0.6	1.2	1.7	2.3	3.0	3.2	3.6
Scenario 2b	0.9	1.6	2.2	2.9	3.7	3.9	4.4
Scenario 3a	1.2	2.0	2.7	3.4	4.3	4.5	4.9
Scenario 3b	1.8	2.7	3.4	4.1	4.9	5.1	5.5
Scenario 4	0.7	1.2	1.7	2.2	2.9	3.0	3.4

Under the new residual flow regimes for Maitai Forks and the Roding River, and using the monthly demands based on population growth out to the year 2100, the dam can meet neither the mean or maximum monthly demands during a 1-in-60 storage event. New storage, or a new water source, will therefore be required to provide the existing 1-in-60 year drought security.

Under Scenario 4, which assumes the previous consent conditions and population growth projections over the next 35 years, the dam could meet the storage requirements for drought security for a 1-in-60 year event i.e. 3.0Mm³. This is less than the maximum storage capacity of the dam. In fact, under Scenario 4 the existing dam has sufficient storage for a drought event with an average recurrence interval (ARI) greater than 200 years, (i.e. 0.5% AEP).

The ARI of a drought event when demand exceeds the Maitai Dam storage capacity are presented in Table 6.3.

Table 6.3: Average recurrence interval of a drought event when demand exceeds the Maitai Dam storage capacity.

Demand Scenario	ARI (years).
Scenario 1a	>500
Scenario 1b	~200
Scenario 2a	~200
Scenario 2b	~84
Scenario 3a	~47
Scenario 3b	~23
Scenario 4	>200

7 Rainfall Analysis

To manage water security efficiently requires an understanding of when water levels are expected to decrease within the reservoir, and the need to impose restrictions to conserve storage. Analysing rainfall records can assist with this, as rainfall ultimately 'drives' inflows to the reservoir, demand from the community, and the need to augment residual flows. Determining when the reservoir may go dry in relation to rainfall patterns can therefore help with the development of strategies to help mitigate the potential effect of such events.

Of particular interest are those climatic conditions which occurred from March through to May 2001. Under some of the modelled abstraction scenarios (i.e. Scenario 3a&b), storage in the Maitai reservoir is predicted to reduce to zero under such conditions. Therefore, rainfall over this period was analysed to determine its magnitude, frequency and characteristics.

7.1 Rainfall data

There are two rain gauges in close proximity to the Maitai dam; Maitai at Forks, and Brook at Third House. These records are described in Table 7.1. The closest site to the dam is Maitai at Forks, approximately 1.5km from the dam compared to just over 5.6km for the Brook at Third House. However, the former site has a shorter record, with a significant gap in the middle.

Table 7.1: Summary of available rainfall records in the vicinity of Maitai Dam.

Site name	Start date	End date	Length of record	Resolution	No. of gaps
Maitai at Forks	Nov-1999	Jan-2018	~19 years	15 min	1 (1.85 years)
Brook at Third House	Sep-1991	Jan-2018	~26 years	15 min	1 (8.9 days)

When the two rainfall records are compared, it is apparent that there is a strong relationship between the rainfall experienced at both sites; i.e. 92% of the variation in daily rainfall at one gauge can be explained by variation at the other (Figure 7.1). This means that longer record from the Brook site can be used to represent the rainfall over the wider area.

The Brook gauge is at a higher elevation than that at Maitai Forks, and is therefore expected to receive higher rainfall as a result of orographic enhancement. This is confirmed by Figure 7.1 which indicates that on average the Brook gauge receives about 15% more rainfall than the gauge at Maitai Forks. Because of its higher elevation, the Brook gauge is more likely to reflect the rainfall over the upper Maitai catchment, and consequently inflows to the dam; particularly during extended dry periods.

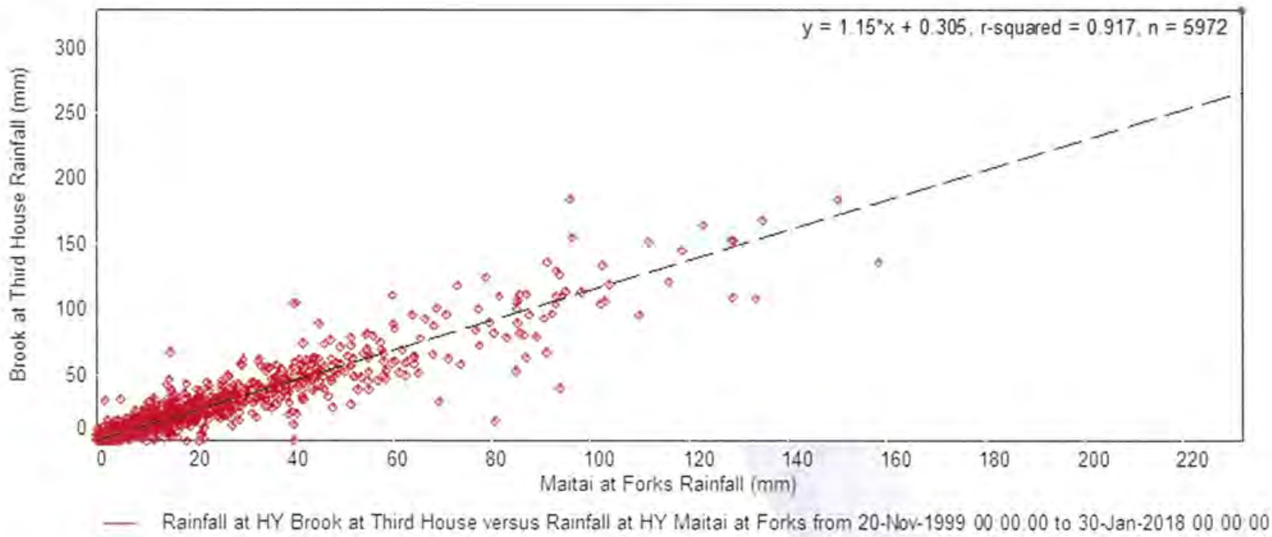


Figure 7.1: Correlation between daily rainfall at Brook at Third House and Maitai at Forks (1999-2018).

Using the Brook at Third House rainfall record, a series of analyses were carried out to determine the characteristics of dry periods, and how these relate to the modelled periods of low storage within the Maitai Dam. Of particular importance is the modelled zero storage of the Maitai Dam during periods with similar climatic conditions to those experienced from the end of March to mid-May in 2001.

Comparison of the total rainfall during each water year (i.e. from the 1 July to the 30 June the following year) shows that 2000/2001 had the lowest rainfall over the past ~26 years i.e. it was a particularly dry year. Rainfall over the water year was compared, rather than the calendar year, to capture the entire summer period; rather than splitting this across two years. Low rainfall typically occurs over the summer months.

Table 7.2: Annual Rainfall for each water year (1st July to 30th June) for Brook at Third House rainfall record (complete years only).

Water Year	Annual Rainfall total (mm)
1992/93	2246
1993/94	1605
1994/95	2344
1995/96	2091
1996/97	1680
1997/98	1612
1998/99	3001
1999/00	2302
2000/01	1218
2001/02	2592
2002/03	1540
2003/04	1796
2004/05	1608
2005/06	1485
2006/07	1387
2007/08	1625
2008/09	2246
2009/10	1850
2010/11	2594
2011/12	2384
2012/13	2375
2013/14	2031
2014/15	1551
2015/16	1840
2016/17	2188
Mean	1968
Minimum	1218
Maximum	3001

A frequency analysis of the rainfalls experienced over the different water years indicates that 2000/2001, in which 1218mm of rain fell, was a 3.7% AEP, or 1-in-27 year ARI event (Table 7.3)

Table 7.3: Frequency analysis of water year rainfall minima.

AEP (%)	ARI (years)	Water Year Rainfall (mm)
43	2.3	1745
20	5	1496
10	10	1358
5	20	1256
2	50	1153
1	100	1090

Analysing the rainfall on a monthly basis, further demonstrates the consistently low rainfall throughout the 2000/2001 water year (Table 7.4). Although none of the months during the 2000/2001 water year recorded the lowest monthly rainfall for the site, all months were consistently below the mean; with the exception of June 2001. The June rainfall was above average and this coincided with the reservoir starting to fill.

Table 7.4: Comparison of the monthly statistics for Brook at Third House with the monthly rainfalls experienced during the 2000/2001 water year.

Month	Minimum	Mean	Maximum	Year 2000/2001
July	11	151	593	147
August	21	149	298	136
September	50	173	324	127
October	48	194	615	163
November	23	137	370	53
December	26	204	903	86
January	28	152	354	34
February	9	118	360	10
March	30	140	386	37
April	11	164	366	58
May	15	165	520	140
June	36	196	352	230

The lack of rainfall during the 2000/2001 water year is also highlighted by analysing the duration of periods without rain, and the number of days when no rainfall was recorded (Table 7.5). The 2000/2001 water year did not have a particularly long period of consecutive days with no rainfall (i.e. 18 days), which is the average across all years. However, this period did have the second highest total number of days on which no rainfall was experienced i.e. 239. Coupled with having the lowest total rainfall, those days on which rain was experienced did little to increase inflows to the dam and increase storage in the Maitai reservoir.

Table 7.5: Consecutive, and total number, of days with no rainfall for each water year at Brook at Third House.

Water Year	Longest consecutive no rain days	Total no. of no rain days
1992/93	17	196
1993/94	16	229
1994/95	10	216
1995/96	13	212
1996/97	15	219
1997/98	14	226
1998/99	20	231
1999/00	22	208
2000/01	18	239
2001/02	20	208
2002/03	24	246
2003/04	15	218
2004/05	18	226
2005/06	13	223
2006/07	16	235
2007/08	20	232
2008/09	20	219
2009/10	15	211
2010/11	17	205
2011/12	17	229
2012/13	39	226
2013/14	19	217
2014/15	15	237
2015/16	24	237
2016/17	15	221

The lack of rain days, and particularly the low total rainfall over the 2000/2001 water year, led to a decline in available storage in the Maitai reservoir between March 2001 and May 2001 (Figure 7.2). The lack of significant rainfall from December 2000 resulted in the dam not recharging, as the outflows from the model exceeded the inflows, and any diversion from the Roding River.

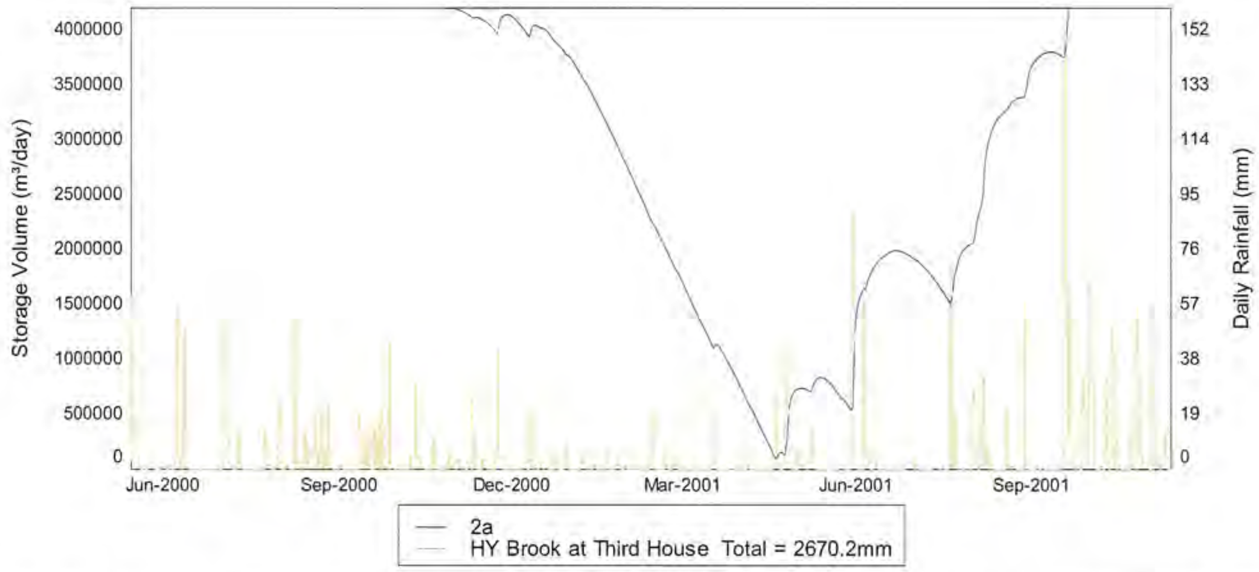


Figure 7.2: Comparison of daily rainfall at Brook at Third House and modelled Maitai Dam storage using the average monthly water use demands and population growth projected out to 2053 i.e. the best case scenario.

Generally, significant rainfall i.e. >30mm in one day, results in a corresponding increase in storage within the Maitai reservoir. However, this increase can be of short duration if there is no further rainfall to sustain inflows and augment storage.

8 Conclusions

Modelling storage in the Maitai Dam, using the extended flow series for the various rivers, population projections, and a range of consent conditions, allows the following conclusions:

- 2.55Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, and using the projected 2028 mean monthly water demand for the Nelson community;
- 3.22Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, and using the projected 2028 maximum monthly water demand for the Nelson community;
- 3.19Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, and using the projected 2053 mean monthly water demand for the Nelson community;
- 3.92Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, and using the projected 2053 maximum monthly water demand for the Nelson community;
- 4.47Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, and using the projected 2100 mean monthly water demand of the Nelson community;
- 5.11Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, and using the projected 2100 maximum monthly water demand for the Nelson community;
- 3.03Mm³ storage is required for 1.6% AEP drought event (1-in-60 year) assuming the present flow regime, the previous conditions regarding residual flows, and using the projected 2053 maximum monthly water demand for the Nelson community;
- Under the proposed residual flow conditions, and the projected 2028 mean monthly water demand, there is sufficient storage for a drought event with an AEP greater than 0.2%, the equivalent of a 1-in-500year drought event;

- Under the proposed residual flow conditions, and the projected 2028 maximum monthly water demand, there is sufficient storage for a 0.5% AEP event, the equivalent of a 1-in-200 year drought event;
- Under the proposed residual flow conditions, and the projected 2053 mean monthly water demand, there is sufficient storage for a 0.5% AEP event, the equivalent of a 1-in-200 year drought event;
- Under the proposed residual flow conditions, and the projected 2053 maximum monthly water demand, there is sufficient storage for a 1.2% AEP event, the equivalent of a 1-in-84 year drought event;
- Under the proposed residual flow conditions, and the projected 2100 mean monthly water demand, there is sufficient storage for a 2.1% AEP event, the equivalent of a 1-in-47 year drought event;
- Under the proposed residual flow conditions, and the projected 2100 maximum monthly water demand, there is sufficient storage for a 4.4% AEP event, the equivalent of a 1-in-23 year drought event; and
- Using the previously consented residual flow conditions, and the projected 2053 maximum monthly water demand, there is sufficient storage for a drought event with an AEP less than 0.5%, the equivalent of a 1-in-200 year drought event.

The change to the residual flows in the Roding River and the Maitai Rivers has had a measurable impact on the volume of water that can be abstracted from the Roding River, and increased the compensation flow that must be provided from the dam to the Maitai River. This will result in less water being stored in the Maitai Dam for community supply.

It should be noted that these increased residual flows serve an important environmental purpose, and reduce the potential stress that the abstraction of water places on the aquatic environment. The potential effects of the increased residual flows will need to be 'offset' by a new water demand management philosophy. This could involve various phases, or levels, of restriction including, for example:

- Advise the community that restrictions are likely, and that they should conserve water;
- A sprinkler ban, allowing hand held hoses only, including no watering of non-productive gardens; and
- Commercial and industrial restrictions.

The aim of each phase is to delay or defer the introduction of subsequent phases, and allow more time for rain to arrive, which it will eventually.

Should these restrictions not be sufficient to prolong the water supply, then the drought management programme could include a gradual reduction in the residual environmental flows. This, however, would be a last resort, adopted only once all other options had been implemented.

Alternatively, additional storage could be provided within the Maitai reservoir by raising the level of the spillway of the dam, or a new water source, to augment the potable supply during extreme conditions, could be investigated.

Opus (2007) identified the following possible sources of additional water to help meet any shortfall that may arise:

- The proposed Waimea Dam at the Lee Valley in the Tasman District. The design of this scheme has allowed 22,000m^3/day for future regional demand that the Nelson community could potentially access. To access this water, Opus (2007) identified the need for Nelson City to contribute to the construction costs of the dam, and separately arrange for the installation of pipe reticulation and treatment.
- Additional Roding Dam. An additional dam on the Roding River was investigated in concept by Tonkin and Taylor (1986). We understand that some work has recently been commissioned by Council to update the likely costs of this proposal.
- Increased storage in the Maitai Dam. Some additional storage capacity could be achieved in the Maitai Dam by modifying the spillway to raise the dam level by one metre. This option would require further detailed investigations and design to confirm the scope of changes required to the existing dam construction.

Subsequently, we understand that Council has also looked at the possibility of re-use of wastewater from the Nelson Regional Sewerage Business Unit (NRSBU) wastewater treatment plant on Bell Island. We understand that a return pipeline from Bell Island to Monaco has already been installed for this purpose as part of recent pipeline duplication works by the NRSBU. However, utilisation of water from this source would still require treatment, pumping, reticulation and storage reservoirs.

The increase in available storage in the Maitai Dam, from 3.3Mm³ to 4.2Mm³, as a result of the new intake and pipeline, provides sufficient storage to meet the water security of a 1-in-60 year event under the newly introduced residual flow regime and projected population increase; assuming the average monthly water demand from the Nelson community over the anticipated life of the consent (i.e. out to 2053).

The underlying assumption in these analyses is that the flow regimes over the past 60-year for the various rivers which supply water to the Nelson community remain characteristic over the various timeframes considered.

9 Discussion

As part of Condition 12, NCC are required to use 'surplus' summer water from the Maitai Dam to supplement flows for ecological reasons. Currently, an ecological flow operating diagram is used to set these flows (Figure 9.1). The diagram allows for, but does not require, water to be released from the reservoir if the level of the reservoir is above particular levels.

Advice has recently been obtained from staff at Cawthron that this may not be the best practice to achieve the desired ecological outcomes. Consequently, there is a need to revise this diagram.

The preceding analysis shows that the increased residual flow requirements now restricts the volume of water available for environmental enhancement releases during summer. Any increased flow release is likely to compromise the 1-in-60 year drought security provided by the dam.

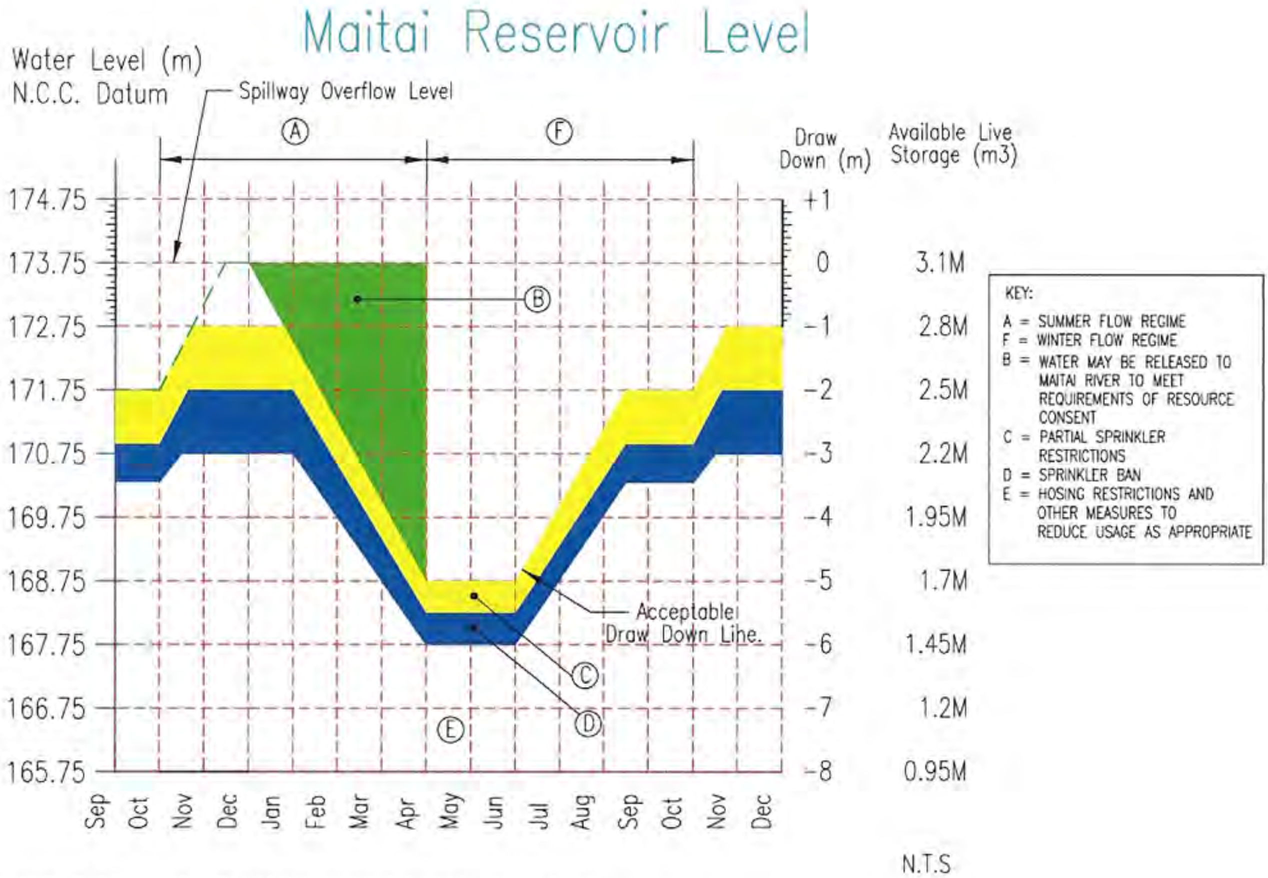


Figure 9.1: Maitai Dam operational parameters.

In an attempt to provide a simpler decision-making tool to assist with the management of the Maitai Dam, the daily storage time series, assuming Scenario 2b, was converted to an equivalent reservoir level series using the level-storage curve shown in Figure 9.2. A frequency distribution was then derived of the annual minima water level series to show the percentage of time the reservoir was at different levels (Figure 9.3). It is apparent that for over 90% of the time, the Maitai reservoir maintains a relatively constant water level i.e. within about 2m (from ~171-173m RL).

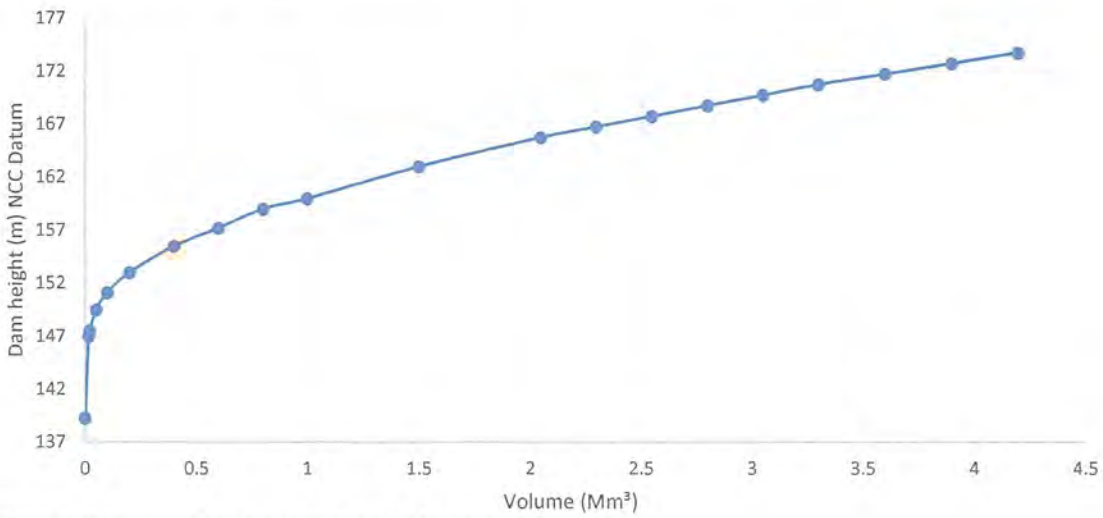


Figure 9.2: Maitai Dam area/volume curve.

To provide greater resolution over the range where the reservoir level varies significantly, only the lower 10% of levels are plotted in Figure 9.4. Five potential trigger levels are indicated where different phases of a demand management strategy could be considered (Table 9.1). As discussed, the aim of these phases would be to delay or defer the introduction of subsequent phases, and allow more time for rain to arrive and replenish the reservoir.

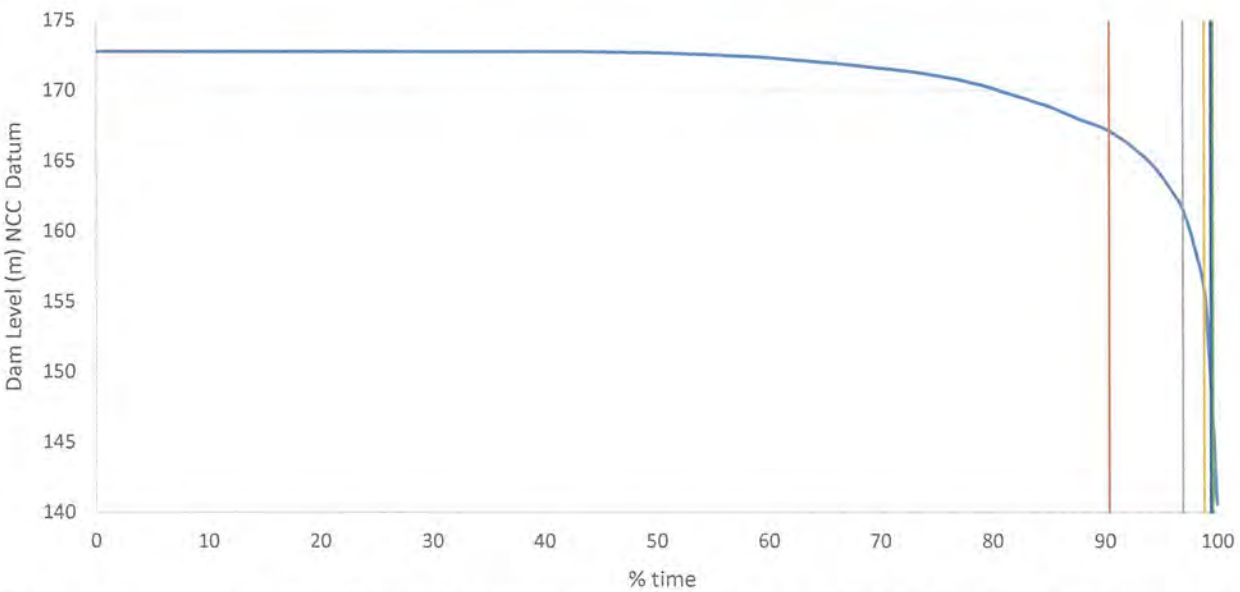


Figure 9.3: Distribution of reservoir levels based on the modelled storage volumes, assuming Scenario 3b, and some possible trigger levels for considering water conservation actions.

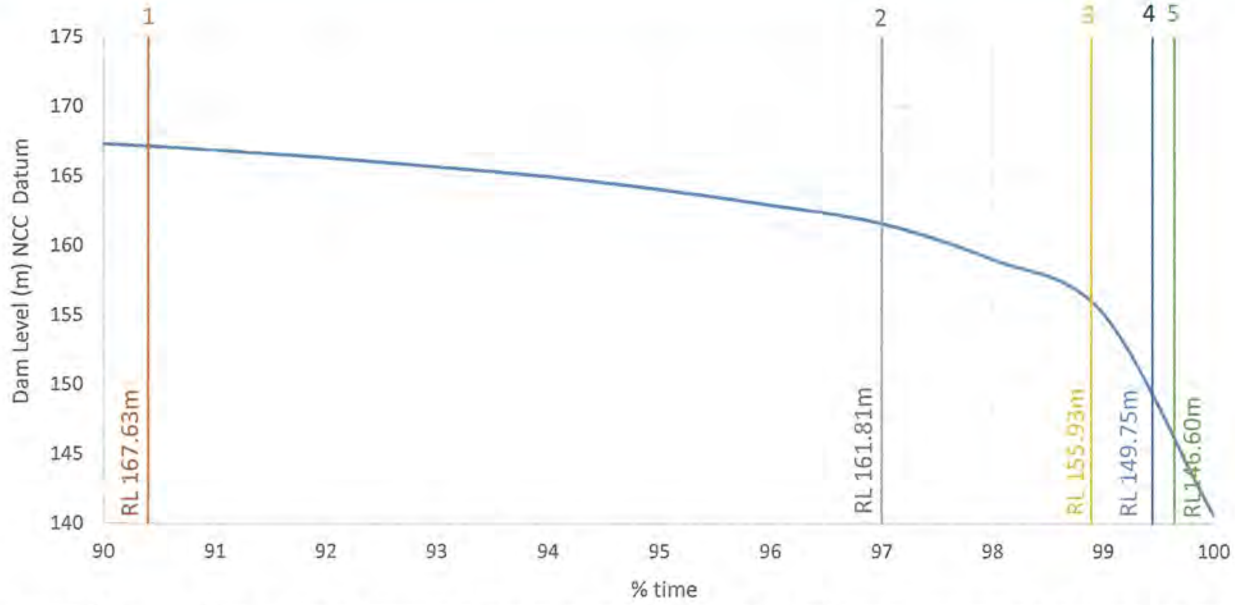


Figure 9.4: *Distribution of reservoir levels, over the lower 10% of levels, based on the modelled storage volumes, assuming Scenario 3b, and some possible trigger levels for considering water conservation actions.*

Table 9.1: *Possible trigger levels, actions, percentage of time exceeded, and return periods (based on the annual reservoir water level minima series).*

Phase	Action	Level (m) NCC Datum	% time exceeded	Return period (years)*
1	Advertise drought condition – save water	167.6	<10	2
2	Sprinkler ban	161.8	<3	5
3	Hose ban, industrial and commercial restrictions	155.9	<2	10
4	Reduce compensation flow to 200l/s	149.8	<1	20
5	Reduce compensation flow to 180l/s	146.6	<1	30

**** Based on a frequency analysis of the annual minima flow series.***

Should these restrictions not be sufficient to prolong the water supply, then the drought management programme could include a gradual reduction in the residual environmental enhancement flows. This, however, would be a last resort, adopted only once all other options had been implemented.

As indicated in Table 9.1, these various phases of a demand management plan would come into effect with different frequencies to reflect their differing magnitudes. For example, using the triggers indicated would result in:

- An 'advertising campaign' to reduce water usage, about every second year;
- A sprinkler ban, about once every 5 years;
- A hosing ban with industrial and commercial restrictions, about once every 10 years;
- A reduction in the residual environmental flow from 230 to 200L/s, about once every 20 years; and
- A reduction in the residual environmental flow from 200 to 180L/s, about once every 30 years.

It should also be noted that these different phases would be cumulative i.e. by the time Phase 4 is implemented Phases 1-3 would all be in effect.

10 Recommendations

This study has used the model, and many of the assumptions, adopted in WCS (1996). While the model has been updated to reflect the new consent conditions, and estimates of population growth, a number of the original inputs have not been tested. Given the sensitivity of the model to these parameters, it is suggested that:

- The reservoir be surveyed to either confirm, or update, the level-volume curve;
- The relationships used to derive the synthetic inflow series be reviewed, and either confirmed or updated; and
- The level of the Maitai Dam be recorded, ideally in a manner consistent with NEMS (i.e. National Environmental Monitoring Standards) for water level measurement and monitoring.

11 References

Fulton Hogan. 2016: Roding RW Capacity Report. Report No. 44552.

Tonkin & Taylor. 1986: Maitai Water Supply Project Design. Report prepared for Nelson City Council, Report No. 5574.

Opus. 2007: Maitai Pipeline and Alternative Water Sources Addendum: Maitai Dam Drought Storage Study for 2055. Prepared for Nelson City Council, Reference 3-AW513.00.

Works Consultancy Service. 1996: Drought Security of the Maitai Dam – Reassessment of the Drought Security for Varying Levels of Water Supply Demand. Report Prepared for the Nelson City Council: Reference 5-G894A.00

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Memorandum

To	Phil Ruffell
From	Jack McConchie & Samwell Warren
Office	Wellington Environmental Office
Date	13 March 2018
File	3-53417.00
Subject	Addendum 1 – Medium growth, high net migration, and additional demand scenarios

1. Background

Following Opus (2018), NCC requested the running of additional scenarios relating to drought security of the Maitai Dam assuming different potential water demands. These include, that:

- NCC supplies an additional 2500m^3/day of water to the south Nelson residential and industrial areas. These are areas supplied currently by Tasman District Council; and
- NCC also supplies additional water to Richmond. This scenario models the possibility that in an extremely dry year Tasman District will run short of water if the Waimea Dam is not constructed. Combined with Scenario 1 above, this would add 7,500m^3/day to the total water demand from the Maitai.

Each scenario was run on both the mean (a) and maximum (b) monthly peak 1-day demand for the Nelson community (Table 1.1). Consequently, there are 12 scenarios summarised in Table 1.1.

Table 1.1: Monthly peak 1-day water demand for the Nelson community (additional design Scenarios) (m^3).

Month	Scenario											
	5		6		7		8		9		10	
	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
January	35300	40000	40300	45000	39900	45200	44900	50200	49700	56500	54700	61500
February	34700	37900	39700	42900	39100	42800	44100	47800	48800	53500	53800	58500
March	32100	34900	37100	39900	36200	39400	41200	44400	45100	49100	50100	54100
April	29100	31900	34100	36900	32800	36000	37800	41000	40800	44800	45800	49800
May	28400	31700	33400	36700	32000	35800	37000	40800	39700	44500	44700	49500
June	27600	29600	32600	34600	31100	33300	36100	38300	38600	41500	43600	46500
July	27600	30400	32600	35400	31100	34200	36100	39200	38700	42600	43700	47600
August	28200	30800	33200	35800	31700	34700	36700	39700	39400	43200	44400	48200
September	28100	30500	33100	35500	31600	34400	36600	39400	39300	42800	44300	47800
October	29400	34200	34400	39200	33200	38700	38200	43700	41200	48200	46200	53200
November	33800	41200	38800	46200	38200	46500	43200	51500	47600	58100	52600	63100
December	33600	40300	38600	45300	38000	45500	43000	50500	47300	56900	52300	61900

1.1. Additional scenario architecture

The methodology used to derive these peak demand estimates can be found in Opus, (2018). As with Opus (2018), this addendum reports on model results based on population forecasts provided by Landmark Lile. Additional addenda report on results from population forecasts provided by Nelson City Council (NCC). Table 1.2 lists all the scenarios modelled; including those reported here, and those in the subsequent addenda.

Table 1.2: The various scenarios modelled (see Section 2.3 Opus, (2018) and reporting architecture.

Scenario	Description	Report
1a	Landmark Lile Population projections for 2028 -mean	Report
1b	Landmark Lile Population projections for 2028 - max	Report
2a	Landmark Lile Population projections for 2053 -mean	Report
2b	Landmark Lile Population projections for 2053 - max	Report
3a	Landmark Lile Population projections for 2100 -mean	Report
3c	Landmark Lile Population projections for 2100 - max	Report
4	LL populations using old consent conditions - max	Report
5a	Landmark Lile Population projections for 2028 + 2500m^3/day - mean	Addendum 1
5b	Landmark Lile Population projections for 2028 + 2500m^3/day - max	Addendum 1
6a	Landmark Lile Population projections for 2028 + 7500m^3/day - mean	Addendum 1
6b	Landmark Lile Population projections for 2028 + 7500 m^3/day - max	Addendum 1
7a	Landmark Lile Population projections for 2053 + 2500 m^3/day - mean	Addendum 1
7b	Landmark Lile Population projections for 2053 + 2500 m^3/day - max	Addendum 1
8a	Landmark Lile Population projections for 2053 + 7500m^3/day - mean	Addendum 1
8b	Landmark Lile Population projections for 2053 + 7500m^3/day - max	Addendum 1
9a	Landmark Lile Population projections for 2100 + 2500m^3/day - mean	Addendum 1
9b	Landmark Lile Population projections for 2100 + 2500m^3/day - max	Addendum 1
10a	Landmark Lile Population projections for 2100 + 7500 m^3/day - mean	Addendum 1
10b	Landmark Lile Population projections for 2100 + 7500 m^3/day - max	Addendum 1
11a	NCC Population projections for 2028 -mean	Addendum 2
11b	NCC Population projections for 2028 - max	Addendum 2
12a	NCC Population projections for 2053 -mean	Addendum 2
12b	NCC Population projections for 2053 - max	Addendum 2
13a	NCC Population projections for 2100 -mean	Addendum 2
13b	NCC Population projections for 2100 - max	Addendum 2
14a	NCC Population projections for 2028 + 2500m^3/day - mean	Addendum 3
14b	NCC Population projections for 2028 + 2500m^3/day - max	Addendum 3
15a	NCC Population projections for 2028 + 7500m^3/day - mean	Addendum 3
15b	NCC Population projections for 2028 + 7500m^3/day - max	Addendum 3
16a	NCC Population projections for 2053 + 2500 m^3/day - mean	Addendum 3
16b	NCC Population projections for 2053 + 2500 m^3/day - max	Addendum 3
17a	NCC Population projections for 2053 + 7500 m^3/day - mean	Addendum 3
17b	NCC Population projections for 2053 + 7500 m^3/day - max	Addendum 3
18a	NCC Population projections for 2100 + 2500 m^3/day - mean	Addendum 3
18b	NCC Population projections for 2100 + 2500 m^3/day - max	Addendum 3
19a	NCC Population projections for 2100 + 7500 m^3/day - mean	Addendum 3
19b	NCC Population projections for 2100 + 7500 m^3/day - max	Addendum 3
Discussed in this report		

- Scenario 5a: All the conditions as stated in Section 3 of Opus (2018), but using the 2028 mean monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 2500m³/day;
- Scenario 5b: All the conditions as stated in Section 3 of Opus (2018), but using the 2028 maxima monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 2500m³/day;
- Scenario 6a: All the conditions as stated in Section 3 of Opus (2018), but using the 2028 mean monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 7500m³/day;
- Scenario 6b: All the conditions as stated in Section 3 of Opus (2018), but using the 2028 maxima monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 7500m³/day;
- Scenario 7a: All the conditions as stated in Section 3 of Opus (2018), but using the 2053 mean monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 2500m³/day;
- Scenario 7b: All the conditions as stated in Section 3 of Opus (2018), but using the 2053 maxima monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 2500m³/day;
- Scenario 8a: All the conditions as stated in Section 3 of Opus (2018), but using the 2053 mean monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 7500m³/day;
- Scenario 8b: All the conditions as stated in Section 3 of Opus (2018), but using the 2053 maxima monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 7500m³/day;
- Scenario 9a: All the conditions as stated in Section 3 of Opus (2018), but using the 2100 mean monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 2500m³/day;
- Scenario 9b: All the conditions as stated in Section 3 of Opus (2018), but using the 2100 maxima monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 2500m³/day;
- Scenario 10a:All the conditions as stated in Section 3 of Opus (2018), but using the 2100 mean monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 7500m³/day; and
- Scenario 10b:All the conditions as stated in Section 3 of Opus (2018), but using the 2100 maxima monthly demand, rounded up to the nearest 100m³, together with an increase in demand of 7500m³/day.

2. Results

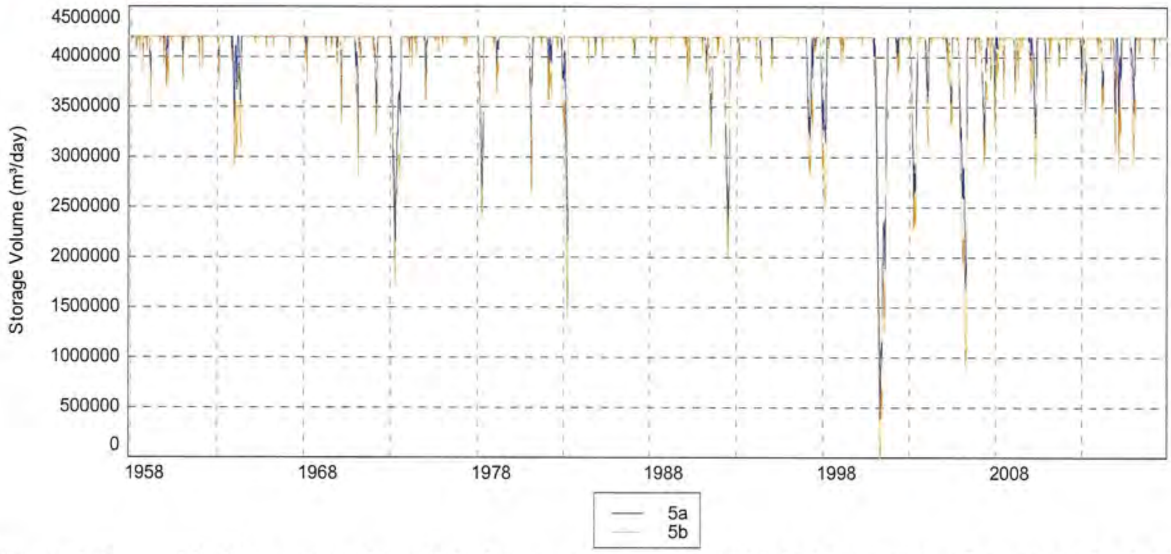

Figure 2.1: Model outputs of predicted storage remaining in Maitai Dam under Scenarios 5a & 5b.

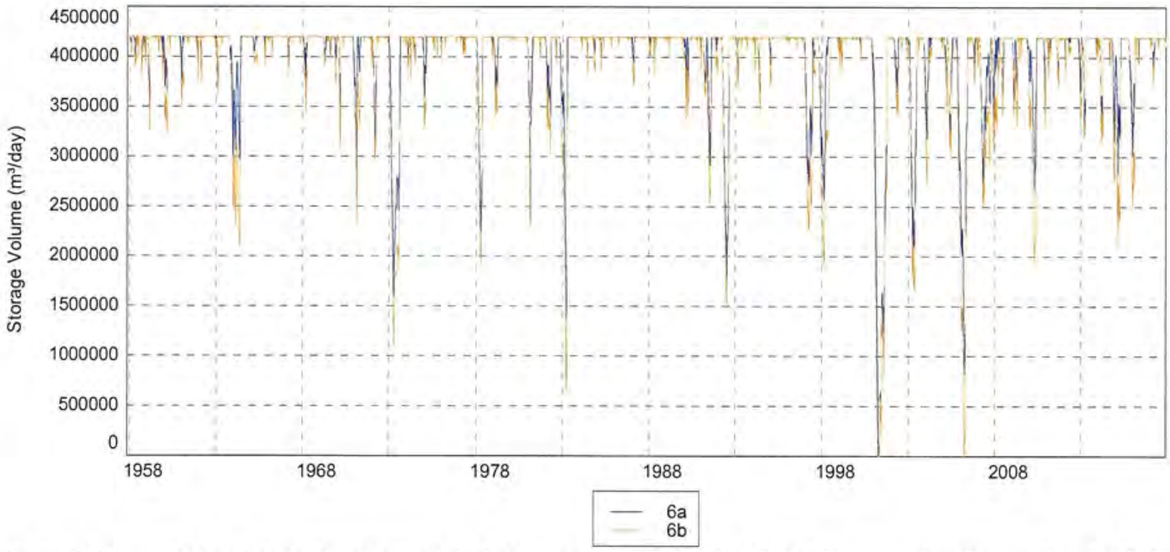

Figure 2.2: Model outputs of predicted storage remaining in Maitai Dam under Scenarios 6a & 6b.

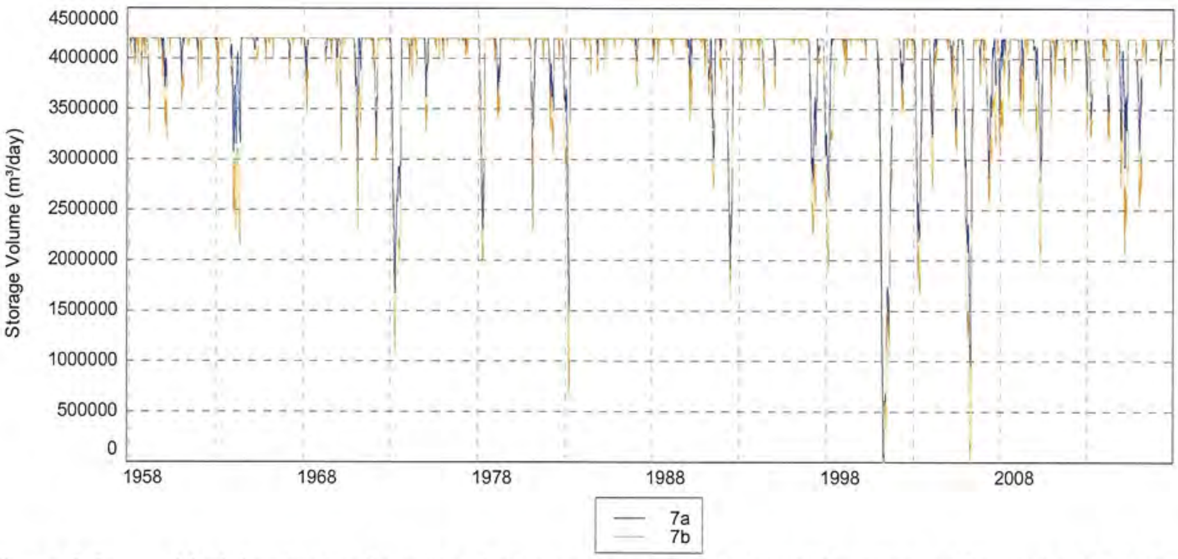

Figure 2.3: Model outputs of predicted storage remaining in Maitai Dam under Scenarios 7a & 7b.

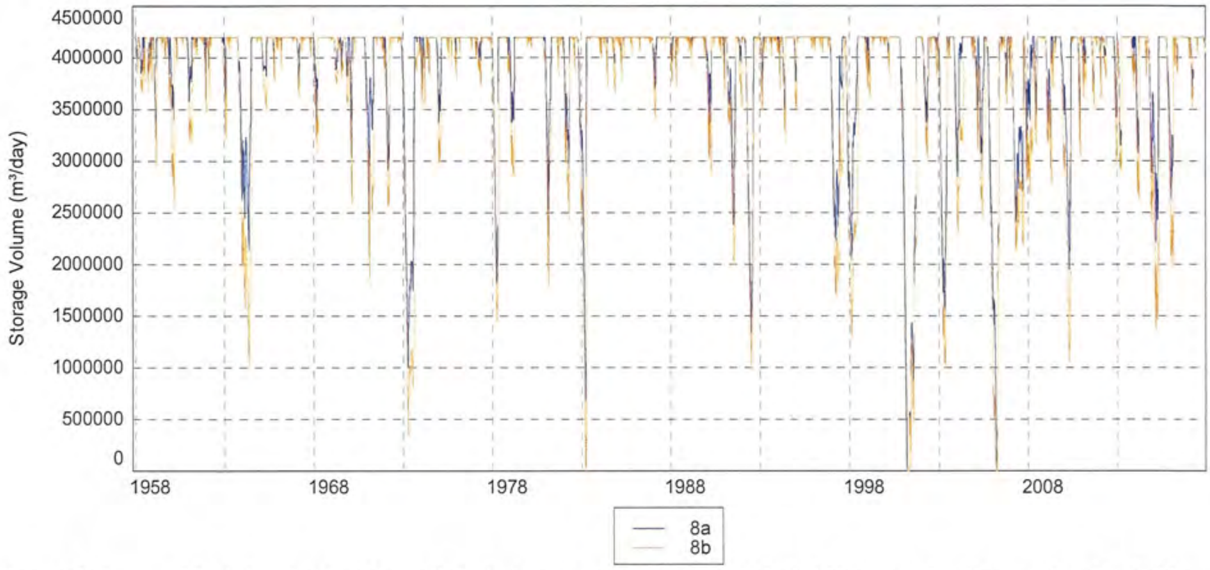

Figure 2.4: *Model outputs of predicted storage remaining in Maitai Dam under Scenarios 8a & 8b.*

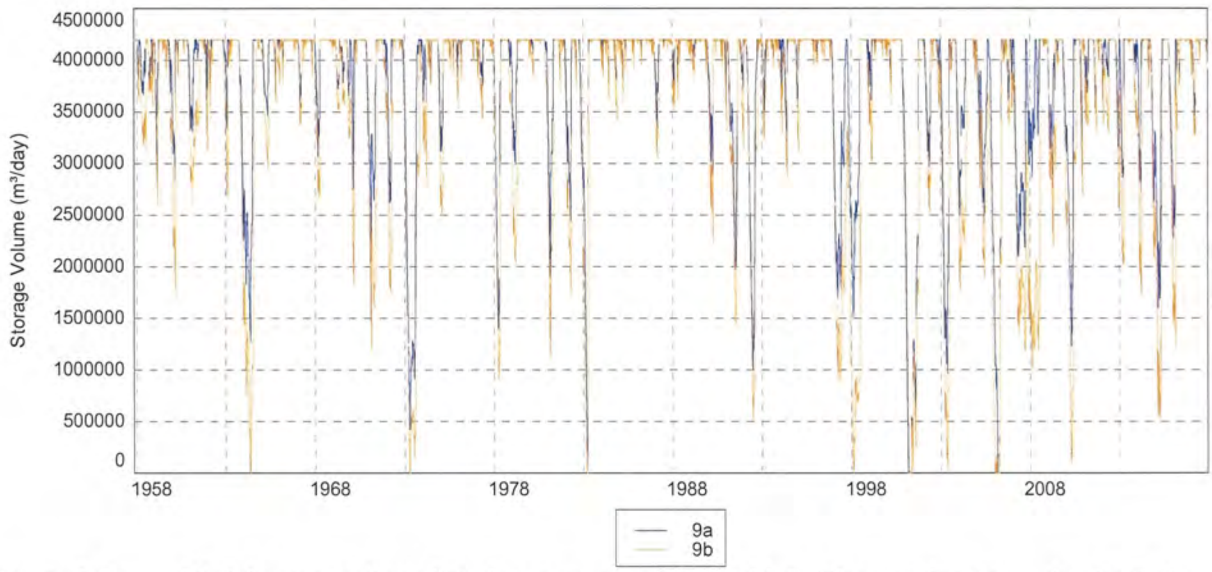

Figure 2.5: *Model outputs of predicted storage remaining in Maitai Dam under Scenarios 9a & 9b.*

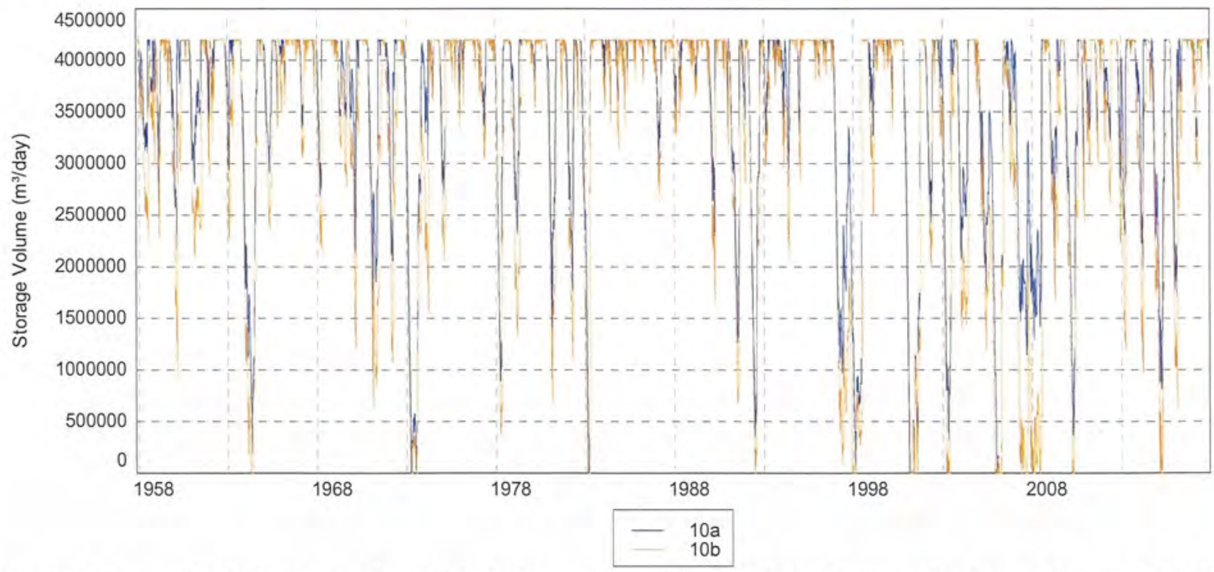

Figure 2.6: *Model outputs of predicted storage remaining in Maitai Dam under Scenarios 10a & 10b.*

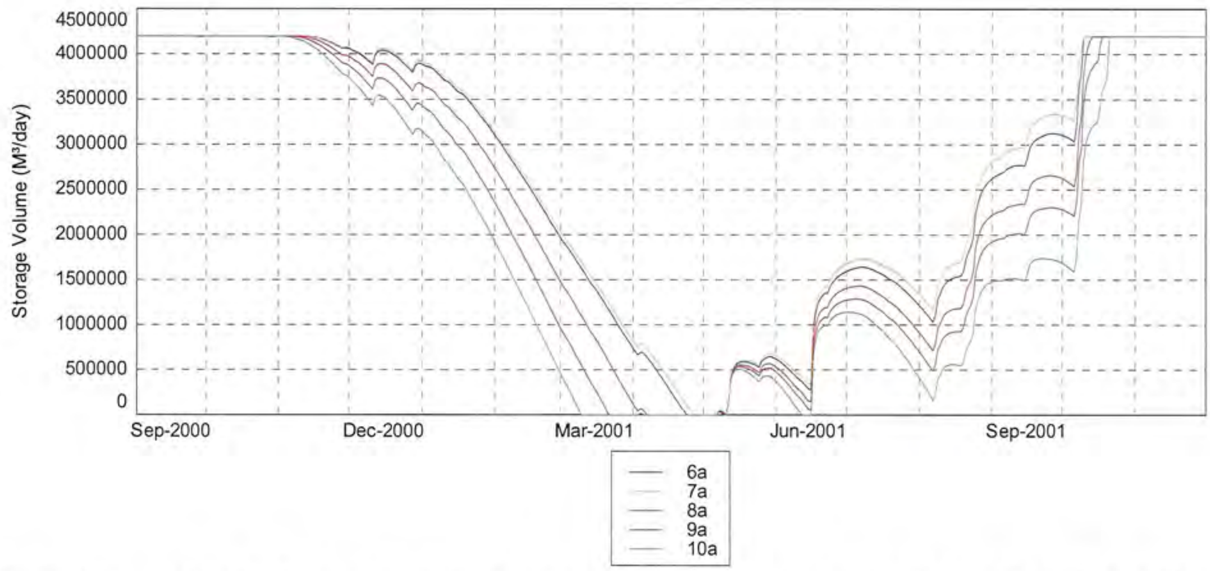

Figure 2.7: *Period of longest consecutive days of zero storage in the Maitai Dam for the five additional modelled scenarios (mean) where zero storage occurs. Note: this assumes that inflow conditions are as experienced in 2001, but with the demand scenarios out to 2053.*

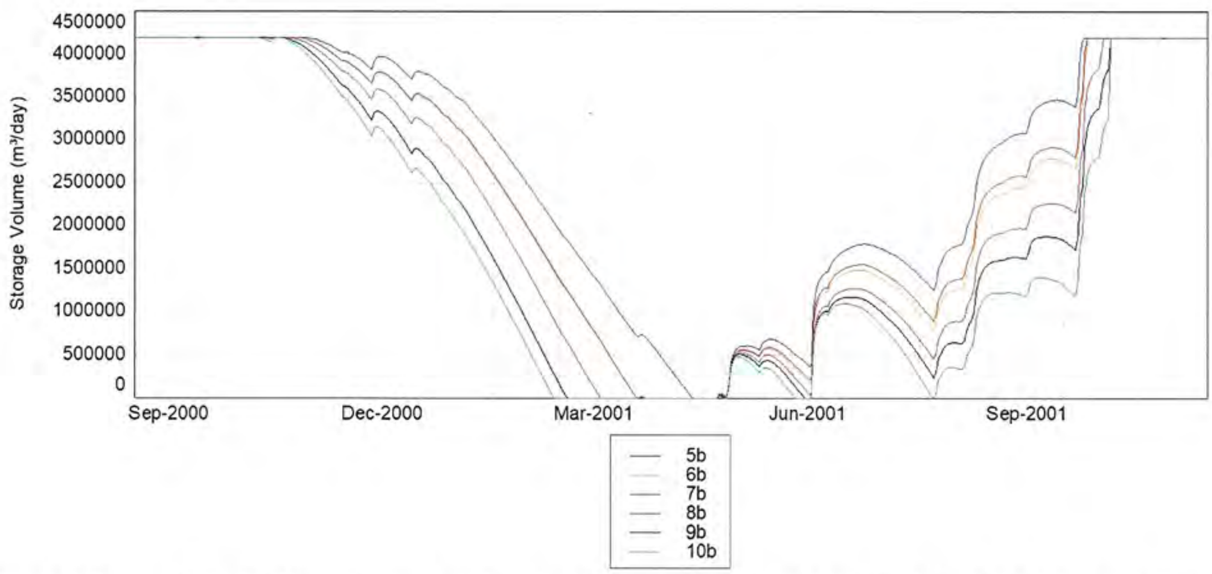

Figure 2.8: *Period of longest consecutive days of zero storage in the Maitai Dam for the six additional modelled scenarios (maxima) where zero storage occurs. Note: this assumes that inflow conditions are as experienced in 2001, but with the demand scenarios out to 2053.*

Table 2.1: *Total days where storage was at zero under each of the four additional modelled scenarios. Note that this was during conditions similar to 2001, which were extreme, but assuming the various scenarios.*

Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 9		Scenario 10	
Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
0	10	12	39	9	38	32	82	68	187	149	488

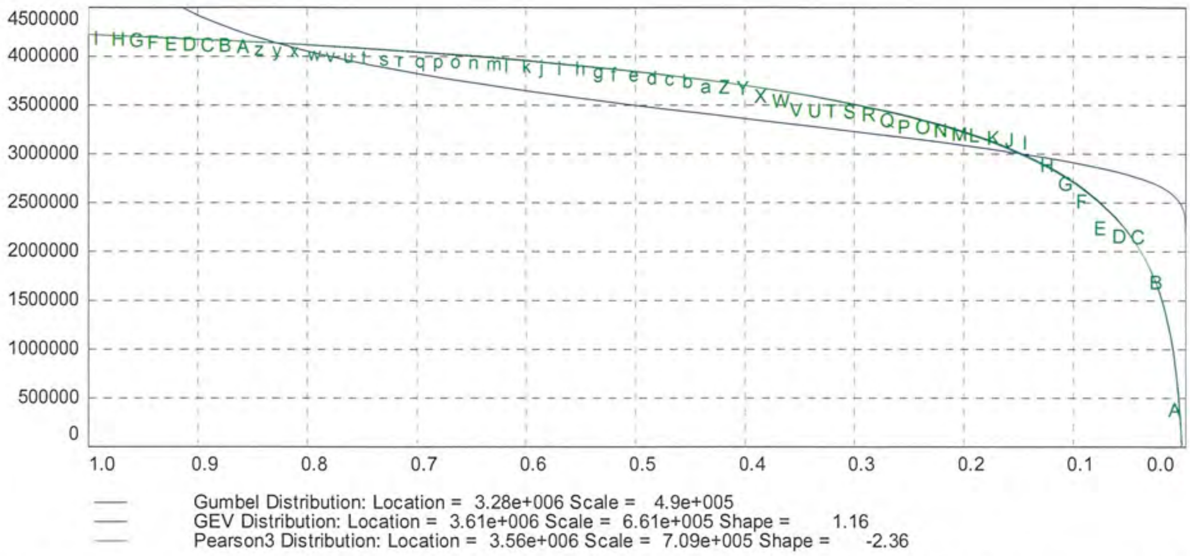

Figure 2.9: Frequency distribution of the minimum storage volume of the Maitai Dam assuming the same daily flows as experienced from 1958-2016 for Scenario 5a.

Table 2.2: Required storage needed under the various scenarios and associated annual exceedance probabilities (AEPs) in Mm³. Note that Maitai Dam currently holds a maximum of 4.2Mm³.

Demand Scenario	AEP (%)							Current capacity (AEP %)
	50 (i.e. 2-year)	20 (i.e. 5-year)	10 (i.e. 10-year)	5 (i.e. 20-year)	2 (i.e. 50-year)	1.6 (i.e. 60-year)	1 (i.e. 100-year)	
Scenario 5a	0.5	1.0	1.5	2.1	2.8	2.9	3.3	0.5%
Scenario 5b	0.7	1.4	2.0	2.6	3.4	3.6	4.0	0.8%
Scenario 6a	0.7	1.4	2.0	2.6	3.5	3.7	4.1	0.9%
Scenario 6b	1.1	1.9	2.6	3.2	4.1	4.3	4.8	1.8%
Scenario 7a	0.7	1.4	2.0	2.6	3.4	3.6	4.0	0.8%
Scenario 7b	1.1	1.8	2.5	3.2	4.1	4.3	4.7	1.8%
Scenario 8a	1.0	1.8	2.5	3.2	4.1	4.3	4.8	1.8%
Scenario 8b	1.5	2.4	3.1	3.8	4.6	4.9	5.3	3.2%
Scenario 9a	*1.4*	*2.3*	*3.0*	*3.7*	*4.6*	*4.8*	*5.2*	*2.9%*
Scenario 9b	*2.2*	*3.1*	*3.8*	*4.4*	*5.2*	*5.4*	*5.7*	*6.4%*
Scenario 10a	*2.0*	*2.9*	*3.7*	*4.6*	*5.1*	*5.4*	*5.7*	*5.7%*
Scenario 10b	*2.7*	*3.6*	*4.2*	*4.6*	*5.1*	*5.3*	*5.5*	*9.6%*

It should be noted that, because of constraints relating to both plant infrastructure and the hydrology of the Maitai and Roding catchments, the frequency analyses run on the more extreme demand scenarios become 'unstable'. The annual minima for the more extreme events form a 'stepped' rather than a 'smooth' distribution. This explains the variable storage values for different AEP events; particularly for Scenarios 9a through 10b (Figure 2.10).

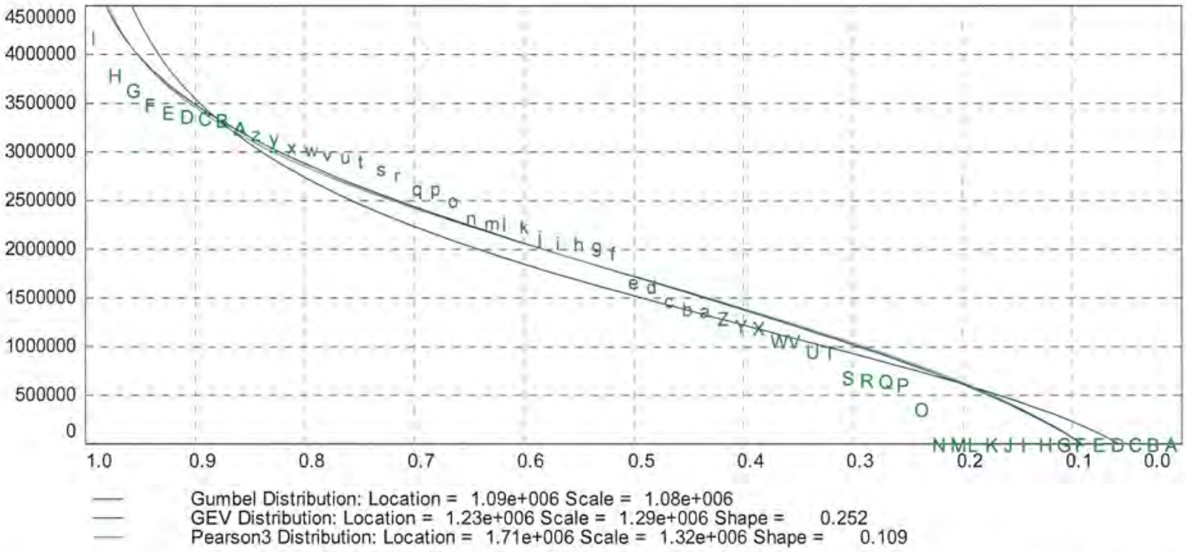

Figure 2.10: Frequency distribution of the minimum storage volume of the Maitai Dam assuming the same daily flows as experienced from 1958-2016 for Scenario 10b.

Table 2.3: Average recurrence interval of a drought event when demand exceeds the Maitai Dam storage capacity.

Demand Scenario	ARI (years)
Scenario 5a	>200
Scenario 5b	~124
Scenario 6a	~114
Scenario 6b	~55
Scenario 7a	~130
Scenario 7b	~57
Scenario 8a	~56
Scenario 8b	~31
Scenario 9a	~35
Scenario 9b	~16
Scenario 10a	~18
Scenario 10b	~11

3. Conclusions

Modelling the storage required in the Maitai Dam, using the extended flow series for the various rivers, population projections, a range of consent conditions, and additional demand allows the following conclusions:

- 2.93Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2028 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 3.58Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2028 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 3.66Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2028 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas;

- $4.32Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2028 maximum monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas;
- $3.58Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2053 mean monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas;
- $4.26Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2053 maximum monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas;
- $4.32Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2053 mean monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas;
- $4.85Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2053 maximum monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas;
- $4.79Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2100 mean monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas;
- $5.37Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2100 maximum monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas;
- $5.38Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the projected 2100 mean monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas;
- $5.29Mm^3$ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime the projected 2100 maximum monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas;
- Under the proposed residual flow conditions, the projected 2028 mean monthly water demand water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 0.5% AEP event (the equivalent of a 1-in-200 year drought event);
- Under the proposed residual flow conditions, the projected 2028 maximum monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 0.8% AEP event (the equivalent of a 1-in-124 year drought event);
- Under the proposed residual flow conditions, the projected 2028 mean monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 0.9% AEP event (the equivalent of a 1-in-114 year drought event);
- Under the proposed residual flow conditions, the projected 2028 maximum monthly water demand for the Nelson community, and an additional $7500m^3$/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 1.8% AEP event (the equivalent of a 1-in-55 year drought event);
- Under the proposed residual flow conditions, the projected 2053 mean monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 0.8% AEP event (the equivalent of a 1-in-130 year drought event);
- Under the proposed residual flow conditions, the projected 2053 maximum monthly water demand for the Nelson community, and an additional $2500m^3$/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 1.8% AEP event (the equivalent of a 1-in-57 year drought event);

- Under the proposed residual flow conditions, the projected 2053 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 1.8% AEP event (the equivalent of a 1-in-56 year drought event);
- Under the proposed residual flow conditions, the projected 2053 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 3.2% AEP event (the equivalent of a 1-in-31 year drought event);
- Under the proposed residual flow conditions, the projected 2100 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 2.9% AEP event (the equivalent of a 1-in-35 year drought event);
- Under the proposed residual flow conditions, the projected 2100 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 6.4% AEP event (the equivalent of a 1-in-16 year drought event);
- Under the proposed residual flow conditions, the projected 2100 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 5.7% AEP event (the equivalent of a 1-in-18 year drought event); and
- Under the proposed residual flow conditions, the projected 2100 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 9.6% AEP event (the equivalent of a 1-in-11 year drought event).

OPUS

Memorandum

To	Phil Ruffell
From	Jack McConchie, Samwell Warren & Lizzie Fox
Office	Wellington Environmental Office
Date	13 March 2018
File	3-53417.00
Subject	Addendum 2: Drought security of the Maitai Dam – NCC Revised Population Scenarios

1. Background

NCC have requested that the water storage model for the Maitai Dam be run assuming a 'high growth' population scenario for the first 10 years (out to 2028), before reverting to the 'medium growth' rate forecast provided by Landmark Lile out to 2100 (i.e. 0.5%/yr.) (Figure 1.1 & Table 1.1).

Table 1.1: Additional 'high growth' population projections provided by NCC.

Year	Population projections
2018	52,100
2028	58,200
2053	65,929
2100	83,345

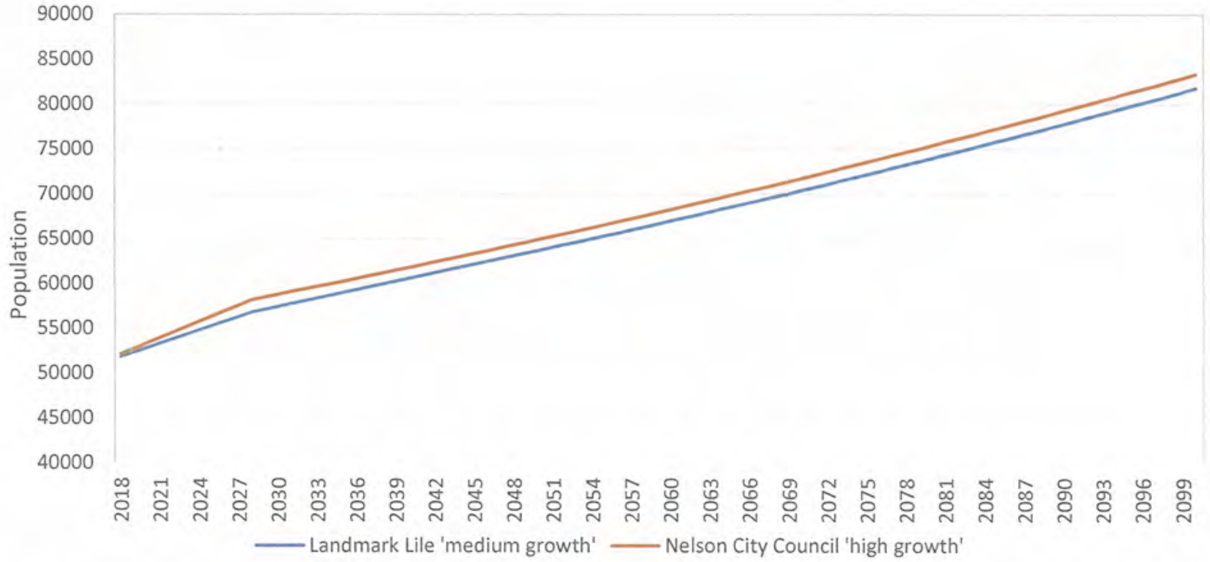

Figure 1.1: Comparison between Landmark Lile 'medium growth' and Nelson City Council 'high growth' population forecasts modelled.

The scenario was run on both the mean (a) and maximum (b) peak 1-day water demand for the Nelson community. Consequently, there are six scenarios summarised in Table 1.2

Table 1.2: Monthly peak 1-day water demand for Nelson community ('high growth' scenario) (m^3).

Month	Scenario 11 (a&b)		Scenario 12 (a&b)		Scenario 13 (a&b)	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
January	33600	38400	38100	43500	48100	55000
February	33000	36300	37300	41100	47200	51900
March	30300	33200	34300	37600	43400	47500
April	27300	30100	30900	34100	39000	43100
May	26500	29900	30000	33900	37900	42800
June	25700	27700	29100	31400	36800	39700
July	25800	28500	29200	32300	36900	40800
August	26300	28900	29800	32800	37600	41400
September	26200	28700	29700	32500	37500	41100
October	27600	32500	31200	36800	39500	46600
November	32100	39600	36400	44900	46000	56700
December	31900	38700	36100	43800	45700	55400

1.1. Additional scenario architecture

The methodology used to derive these peak demand estimates can be found in Opus, (2018). This addendum reports on the model results based on population forecasts provided by Nelson City Council under a 'high growth' population scenario for the first 10 years (out to 2028), before reverting to the 'medium growth' rate forecast provided by Landmark Lile. Table 1.3 lists all the scenarios modelled under this project, including: those reported here; those referenced in Opus (2018); and those reported in the other addenda.

Table 1.3: The various scenarios modelled (see Section 2.3 Opus, (2018) and reporting architecture.

Scenario	Description	Report
1a	Landmark Lile Population projections for 2028 -mean	Report
1b	Landmark Lile Population projections for 2028 - max	Report
2a	Landmark Lile Population projections for 2053 -mean	Report
2b	Landmark Lile Population projections for 2053 - max	Report
3a	Landmark Lile Population projections for 2100 -mean	Report
3c	Landmark Lile Population projections for 2100 - max	Report
4	LL populations using old consent conditions - max	Report
5a	Landmark Lile Population projections for 2028 + 2500m^3/day - mean	Addendum 1
5b	Landmark Lile Population projections for 2028 + 2500m^3/day - max	Addendum 1
6a	Landmark Lile Population projections for 2028 + 7500m^3/day - mean	Addendum 1
6b	Landmark Lile Population projections for 2028 + 7500 m^3/day - max	Addendum 1
7a	Landmark Lile Population projections for 2053 + 2500 m^3/day - mean	Addendum 1
7b	Landmark Lile Population projections for 2053 + 2500 m^3/day - max	Addendum 1
8a	Landmark Lile Population projections for 2053 + 7500m^3/day - mean	Addendum 1
8b	Landmark Lile Population projections for 2053 + 7500m^3/day - max	Addendum 1
9a	Landmark Lile Population projections for 2100 + 2500m^3/day - mean	Addendum 1
9b	Landmark Lile Population projections for 2100 + 2500m^3/day - max	Addendum 1
10a	Landmark Lile Population projections for 2100 + 7500 m^3/day - mean	Addendum 1
10b	Landmark Lile Population projections for 2100 + 7500 m^3/day - max	Addendum 1
11a	NCC Population projections for 2028 -mean	Addendum 2
11b	NCC Population projections for 2028 - max	Addendum 2

12a	NCC Population projections for 2053 -mean	Addendum 2
12b	NCC Population projections for 2053 - max	Addendum 2
13a	NCC Population projections for 2100 -mean	Addendum 2
13b	NCC Population projections for 2100 - max	Addendum 2
14a	NCC Population projections for 2028 + 2500m^3/day - mean	Addendum 3
14b	NCC Population projections for 2028 + 2500m^3/day - max	Addendum 3
15a	NCC Population projections for 2028 + 7500m^3/day - mean	Addendum 3
15b	NCC Population projections for 2028 + 7500m^3/day - max	Addendum 3
16a	NCC Population projections for 2053 + 2500 m^3/day - mean	Addendum 3
16b	NCC Population projections for 2053 + 2500 m^3/day - max	Addendum 3
17a	NCC Population projections for 2053 + 7500 m^3/day - mean	Addendum 3
17b	NCC Population projections for 2053 + 7500 m^3/day - max	Addendum 3
18a	NCC Population projections for 2100 + 2500 m^3/day - mean	Addendum 3
18b	NCC Population projections for 2100 + 2500 m^3/day - max	Addendum 3
19a	NCC Population projections for 2100 + 7500 m^3/day - mean	Addendum 3
19b	NCC Population projections for 2100 + 7500 m^3/day - max	Addendum 3
Discussed in this report		

- Scenario 11a: All the conditions as stated in Section 3 of Opus 2018(a), but using the mean monthly demand, adjusted for the new 'high growth' NCC population projections out to 2028, rounded up to the nearest 100m^3;
- Scenario 11b: All the conditions as stated in Section 3 Opus 2018(a), using the maximum monthly demand, adjusted for the new 'high growth' NCC population projections out to 2028, rounded up to the nearest 100m^3;
- Scenario 12a: All the conditions as stated in Section 3 of Opus 2018(a), but using the mean monthly demand, adjusted for the new 'high growth' NCC population projections out to 2053, rounded up to the nearest 100m^3;
- Scenario 12b: All the conditions as stated in Section 3 Opus 2018(a), using the maximum monthly demand, adjusted for the new 'high growth' NCC population projections out to 2053, rounded up to the nearest 100m^3;
- Scenario 13a: All the conditions as stated in Section 3 of Opus 2018(a), but using the mean monthly demand, adjusted for the new 'high growth' NCC population projections out to 2100, rounded up to the nearest 100m^3; and
- Scenario 13b: All the conditions as stated in Section 3 Opus 2018(a), using the maximum monthly demand, adjusted for the new 'high growth' NCC population projections out to 2100, rounded up to the nearest 100m^3.

2. Results

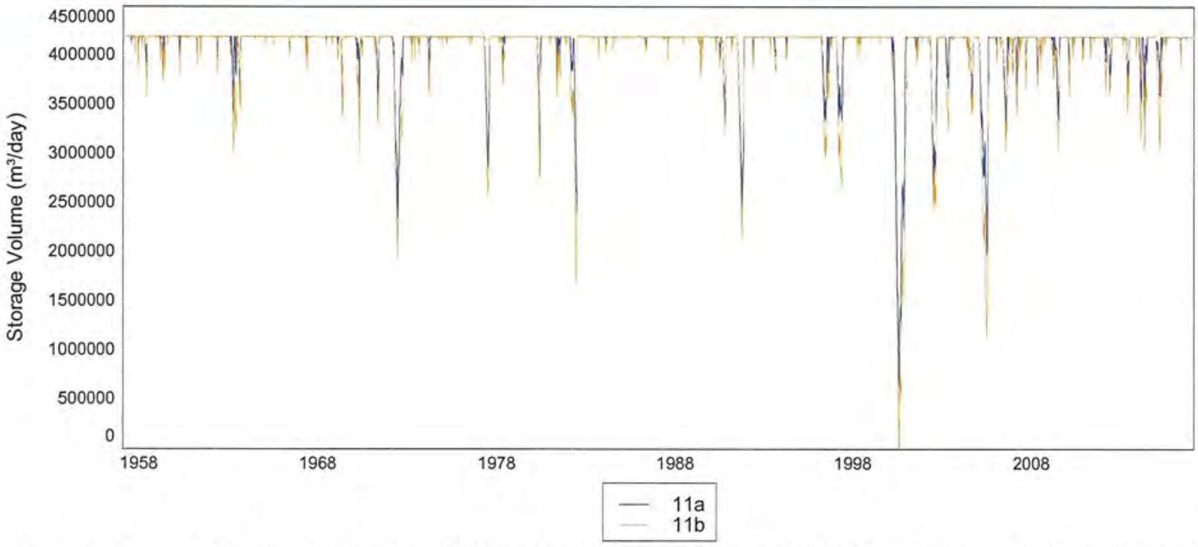

Figure 2.1: *Model outputs of predicted storage remaining in the Maitai Dam under Scenarios 11a & 11b.*

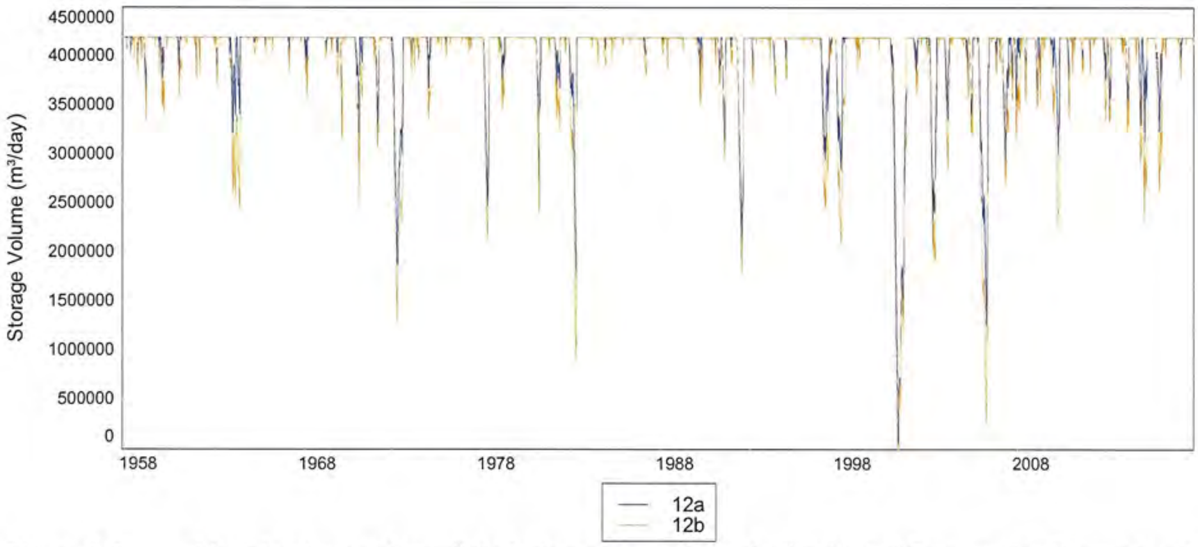

Figure 2.2: *Model outputs of predicted storage remaining in the Maitai Dam under Scenarios 12a & 12b.*

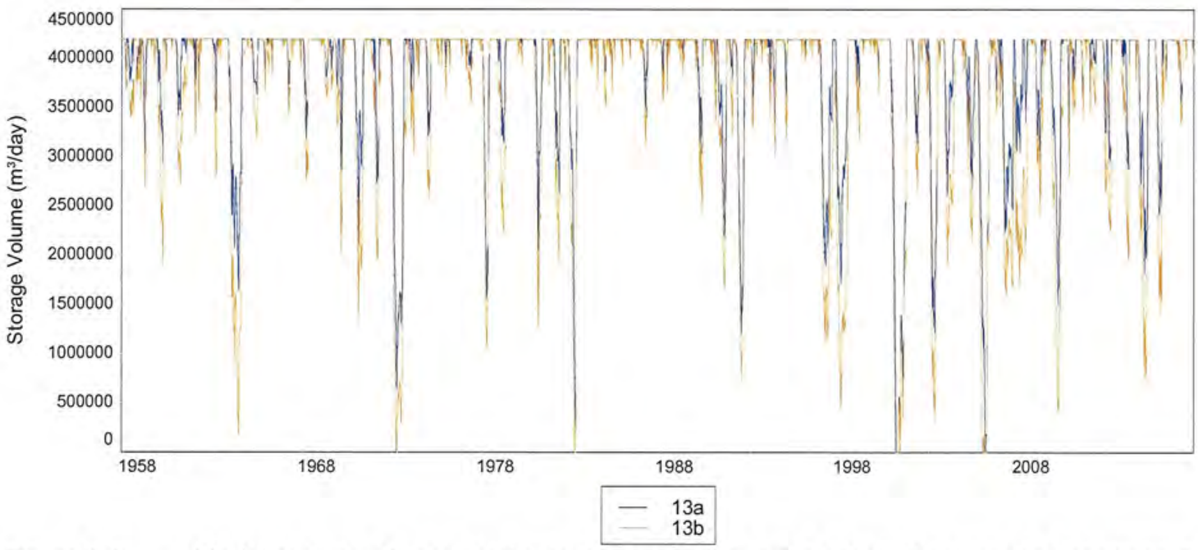

Figure 2.3: *Model outputs of predicted storage remaining in the Maitai Dam under Scenarios 13a & 13b.*

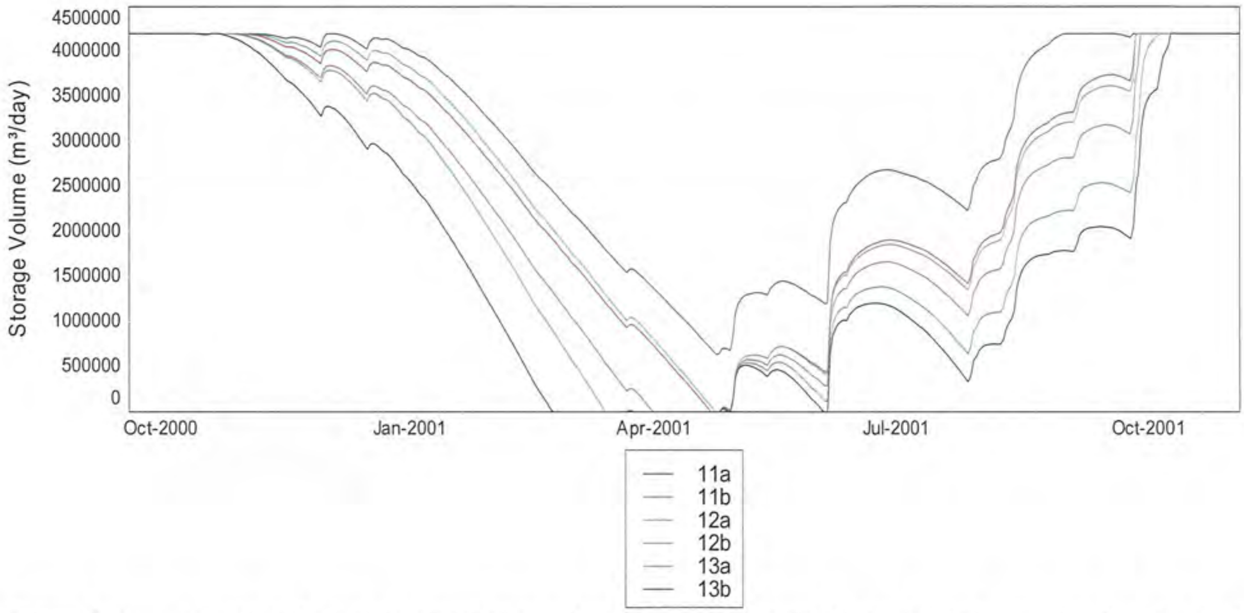

Figure 2.4: *Period of longest consecutive days of zero storage in the Maitai dam for the six 'high growth' modelled scenarios. Note: this assumes the inflow conditions experienced in 2001, but with the demand scenarios out to 2100.*

Table 2.1: *Total days where storage was at zero under each of the six 'high growth' modelled scenarios. Note that this was during conditions similar to 2001, which were very extreme, but assuming the various scenarios.*

Scenario 11 (a&b)		Scenario 12 (a&b)		Scenario 13 (a&b)	
Mean	Maximum	Mean	Maximum	Mean	Maximum
0	2	1	24	55	142

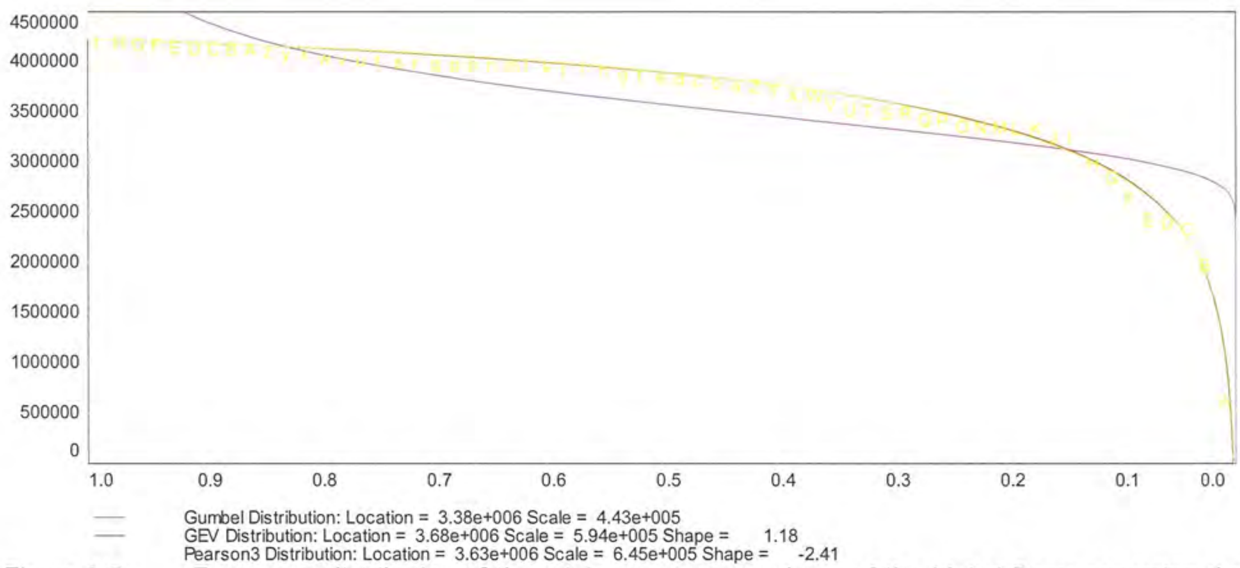

Figure 2.5: *Frequency distribution of the minimum storage volume of the Maitai Dam; assuming the same daily flows as experienced from 1958-2016 for Scenario 11a.*

Table 2.2: Required storage needed under the various scenarios and associated annual exceedance probabilities (AEP)'s in Mm³. Note that Matai Dam currently holds a maximum of 4.2Mm³.

Storage Scenario	AEP (%)							Current capacity (AEP %)
	50 (i.e. 2-year)	20 (i.e. 5-year)	10 (i.e. 10-year)	5 (i.e. 20-year)	2 (i.e. 50-year)	1.6 (i.e. 60-year)	1 (i.e. 100-year)	
Scenario 11a	0.4	0.9	1.4	1.9	2.5	2.7	3.0	<0.5%
Scenario 11b	0.6	1.3	1.8	2.4	3.2	3.4	3.8	0.6%
Scenario 12a	0.6	1.2	1.8	2.4	3.1	3.3	3.7	0.6%
Scenario 12b	0.9	1.7	2.3	3.0	3.8	4.0	4.5	1.4%
Scenario 13a	1.3	2.1	2.8	3.5	4.4	4.6	5.0	2.4%
Scenario 13b	2.0	2.9	3.6	4.2	5.0	5.2	5.5	5.1%

Table 2.3: Average recurrence interval of a drought event when demand exceeds the Maitai Dam storage capacity.

Demand Scenario	ARI (years)
Scenario 11a	>200
Scenario 11b	162
Scenario 12a	169
Scenario 12b	74
Scenario 13a	42
Scenario 13b	20

3. Conclusions

Modelling the storage required in the Maitai Dam, using the extended flow series for the various rivers, Nelson City Council 'high growth' population projections, and a range of consent conditions, allows the following conclusions:

- 2.66Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the 'high growth' population projections, and the 2028 mean monthly water demand for the Nelson community;
- 3.37Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the 'high growth' population projections, and the 2028 maximum monthly water demand for the Nelson community;
- 3.29Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the 'high growth' population projections, and the 2053 mean monthly water demand for the Nelson community;
- 4.03Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the 'high growth' population projections, and the 2053 maximum monthly water demand for the Nelson community;
- 4.57Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the 'high growth' population projections, and the 2100 mean monthly water demand for the Nelson community; and
- 5.17Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, the 'high growth' population projections, and the 2100 maximum monthly water demand for the Nelson community;

- Under the proposed residual flow conditions, the 'high growth' population projections, and the 2028 mean monthly water demand for the Nelson community, there is sufficient storage for a <0.5% AEP event, the equivalent of greater than a 1-in-200 year drought event;
- Under the proposed residual flow conditions, the 'high growth' population projections, and the 2028 maximum monthly water demand for the Nelson community, there is sufficient storage for a 0.62% AEP event, the equivalent of a 1-in-162 year drought event.
- Under the proposed residual flow conditions, the 'high growth' population projections, and the 2053 mean monthly water demand for the Nelson community, there is sufficient storage for a for a 0.59% AEP event, the equivalent of a 1-in-169 year drought event;
- Under the proposed residual flow conditions, the 'high growth' population projections, and the 2053 maximum monthly water demand for the Nelson community, there is sufficient storage for a 1.36% AEP event, the equivalent of a 1-in-74 year drought event.
- Under the proposed residual flow conditions, the 'high growth' population projections, and the 2100 mean monthly water demand for the Nelson community, there is sufficient storage for a for a 2.38% AEP event, the equivalent of a 1-in-42 year drought event; and
- Under the proposed residual flow conditions, the 'high growth' population projections, and the 2100 maximum monthly water demand for the Nelson community, there is sufficient storage for a 5.1% AEP event, the equivalent of a 1-in-20 year drought event.

4. References

Opus. 2018(a): *Drought Security-Maitai Dam. Report prepared for Nelson City Council. Ref* 3-53417.00.

Memorandum

To	Phil Ruffell
From	Jack McConchie & Samwell Warren
Office	Wellington Environmental Office
Date	13 March 2018
File	3-53417.00
Subject	Addendum 3 - High growth, with additional demand scenarios

1. Background

Following Opus (2018), NCC requested the running of additional scenarios relating to the drought security of the Maitai Dam. These scenarios were to assume the "high growth" projection reported on in Addendum 2, but assuming two additional potential water demands. These include, that:

- NCC supplies an additional 2500m³/day of water to the south Nelson residential and industrial areas. These are areas supplied currently by Tasman District Council; and
- NCC also supplies additional water to Richmond. This scenario models the possibility that in an extremely dry year Tasman District will run short of water, if the Waimea Dam is not constructed. Combined with Scenario 1 above, this would add 7,500m³/day to the total water demand from the Maitai reservoir.

Each scenario was run on both the mean (a) and maximum (b) monthly peak 1-day demand for the Nelson community. Consequently, there are 12 scenarios summarised in Table 1.1.

Table 1.1: Monthly peak 1-day water demand for Nelson community (additional design Scenarios) (m³).

Month	Scenario											
	14 (a&b)		15 (a&b)		16 (a&b)		17 (a&b)		18 (a&b)		19 (a&b)	
	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
January	36100	40900	41100	45900	40600	46000	45600	51000	50600	57500	55600	62500
February	35500	38800	40500	43800	39800	43600	44800	48600	49700	54400	54700	59400
March	32800	35700	37800	40700	36800	40100	41800	45100	45900	50000	50900	55000
April	29800	32600	34800	37600	33400	36600	38400	41600	41500	45600	46500	50600
May	29000	32400	34000	37400	32500	36400	37500	41400	40400	45300	45400	50300
June	28200	30200	33200	35200	31600	33900	36600	38900	39300	42200	44300	47200
July	28300	31000	33300	36000	31700	34800	36700	39800	39400	43300	44400	48300
August	28800	31400	33800	36400	32300	35300	37300	40300	40100	43900	45100	48900
September	28700	31200	33700	36200	32200	35000	37200	40000	40000	43600	45000	48600
October	30100	35000	35100	40000	33700	39300	38700	44300	42000	49100	47000	54100
November	34600	42100	39600	47100	38900	47400	43900	52400	48500	59200	53500	64200
December	34400	41200	39400	46200	38600	46300	43600	51300	48200	57900	53200	62900

1.1. Additional scenario architecture

The methodology used to derive these peak demand estimates can be found in Opus, (2018). This addendum reports on the model results based on population forecasts provided by Nelson City Council under a 'high growth' population scenario. Table 1.2 lists all the scenarios modelled under this project, including: those reported here; those referenced in Opus (2018); and those reported in the other addenda.

Table 1.2: The various scenarios modelled (see Section 2.3 Opus, (2018) and reporting architecture.

Scenario	Description	Report
1a	Landmark Lile Population projections for 2028 -mean	Report
1b	Landmark Lile Population projections for 2028 - max	Report
2a	Landmark Lile Population projections for 2053 -mean	Report
2b	Landmark Lile Population projections for 2053 - max	Report
3a	Landmark Lile Population projections for 2100 -mean	Report
3c	Landmark Lile Population projections for 2100 - max	Report
4	LL populations using old consent conditions - max	Report
5a	Landmark Lile Population projections for 2028 + 2500m^3/day - mean	Addendum 1
5b	Landmark Lile Population projections for 2028 + 2500m^3/day - max	Addendum 1
6a	Landmark Lile Population projections for 2028 + 7500m^3/day - mean	Addendum 1
6b	Landmark Lile Population projections for 2028 + 7500 m^3/day - max	Addendum 1
7a	Landmark Lile Population projections for 2053 + 2500 m^3/day - mean	Addendum 1
7b	Landmark Lile Population projections for 2053 + 2500 m^3/day - max	Addendum 1
8a	Landmark Lile Population projections for 2053 + 7500m^3/day - mean	Addendum 1
8b	Landmark Lile Population projections for 2053 + 7500m^3/day - max	Addendum 1
9a	Landmark Lile Population projections for 2100 + 2500m^3/day - mean	Addendum 1
9b	Landmark Lile Population projections for 2100 + 2500m^3/day - max	Addendum 1
10a	Landmark Lile Population projections for 2100 + 7500 m^3/day - mean	Addendum 1
10b	Landmark Lile Population projections for 2100 + 7500 m^3/day - max	Addendum 1
11a	NCC Population projections for 2028 -mean	Addendum 2
11b	NCC Population projections for 2028 - max	Addendum 2
12a	NCC Population projections for 2053 -mean	Addendum 2
12b	NCC Population projections for 2053 - max	Addendum 2
13a	NCC Population projections for 2100 -mean	Addendum 2
13b	NCC Population projections for 2100 - max	Addendum 2
14a	NCC Population projections for 2028 + 2500m^3/day - mean	Addendum 3
14b	NCC Population projections for 2028 + 2500m^3/day - max	Addendum 3
15a	NCC Population projections for 2028 + 7500m^3/day - mean	Addendum 3
15b	NCC Population projections for 2028 + 7500m^3/day - max	Addendum 3
16a	NCC Population projections for 2053 + 2500 m^3/day - mean	Addendum 3
16b	NCC Population projections for 2053 + 2500 m^3/day - max	Addendum 3
17a	NCC Population projections for 2053 + 7500 m^3/day - mean	Addendum 3
17b	NCC Population projections for 2053 + 7500 m^3/day - max	Addendum 3
18a	NCC Population projections for 2100 + 2500 m^3/day - mean	Addendum 3
18b	NCC Population projections for 2100 + 2500 m^3/day - max	Addendum 3
19a	NCC Population projections for 2100 + 7500 m^3/day - mean	Addendum 3
19b	NCC Population projections for 2100 + 7500 m^3/day - max	Addendum 3
Discussed in this report		

- Scenario 14a: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2028 mean monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $2500m^3$/day;
- Scenario 14b: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2028 maximum monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $2500m^3$/day;
- Scenario 15a: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2028 mean monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $7500m^3$/day;
- Scenario 15b: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2028 maximum monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $7500m^3$/day;
- Scenario 16a: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2053 mean monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $2500m^3$/day;
- Scenario 16b: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2053 maximum monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $2500m^3$/day;
- Scenario 17a: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2053 mean monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $7500m^3$/day;
- Scenario 17b: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2053 maximum monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $7500m^3$/day;
- Scenario 18a: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2100 mean monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $2500m^3$/day;
- Scenario 18b: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2100 maximum monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $2500m^3$/day;
- Scenario 19a: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2100 mean monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $7500m^3$/day; and
- Scenario 19b: All the conditions as stated in Section 3 of Opus (2018a), but using the ‘high population’ 2100 maximum monthly demand, rounded up to the nearest $100m^3$, together with an increase in demand of $7500m^3$/day.

2. Results

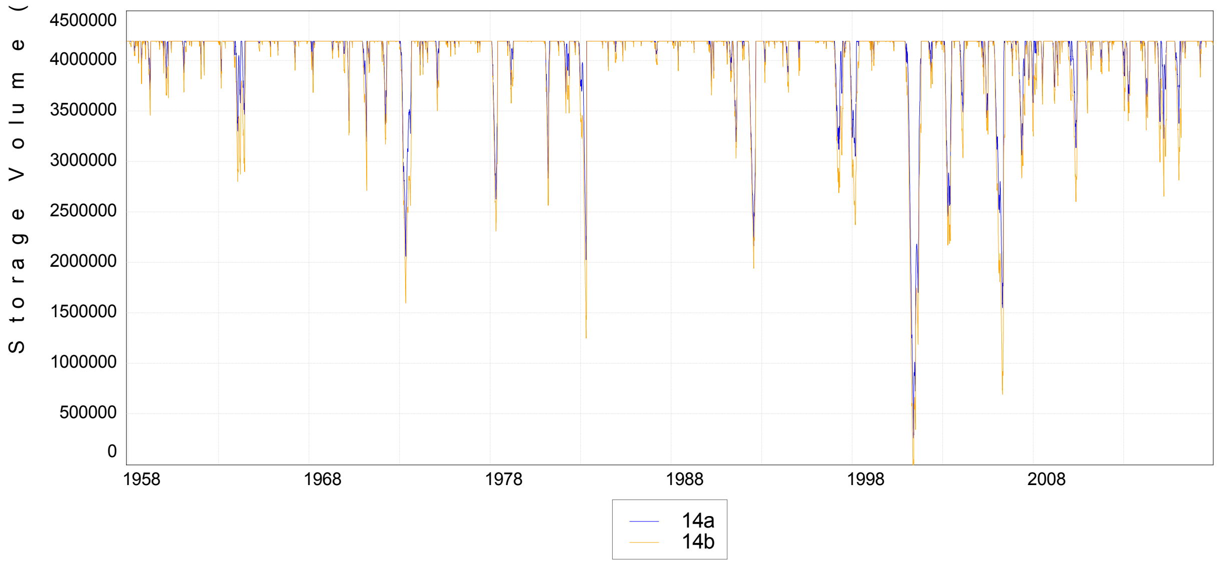

Figure 2.1: Model outputs of predicted storage remaining in Maitai dam under Scenarios 14a & 14b.

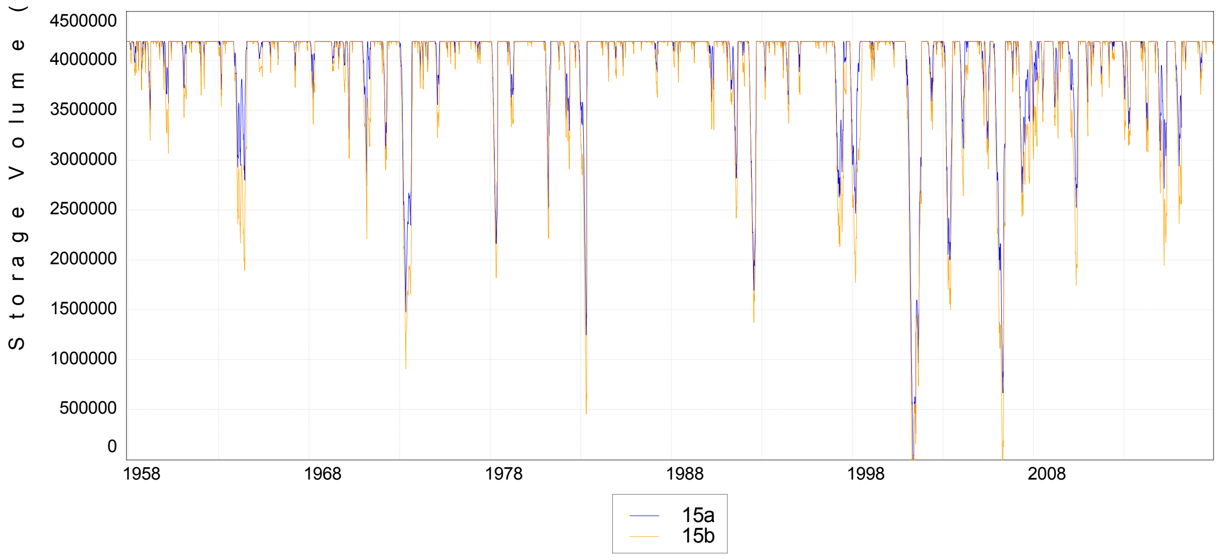

Figure 2.2: Model outputs of predicted storage remaining in Maitai dam under Scenarios 15a & 15b.

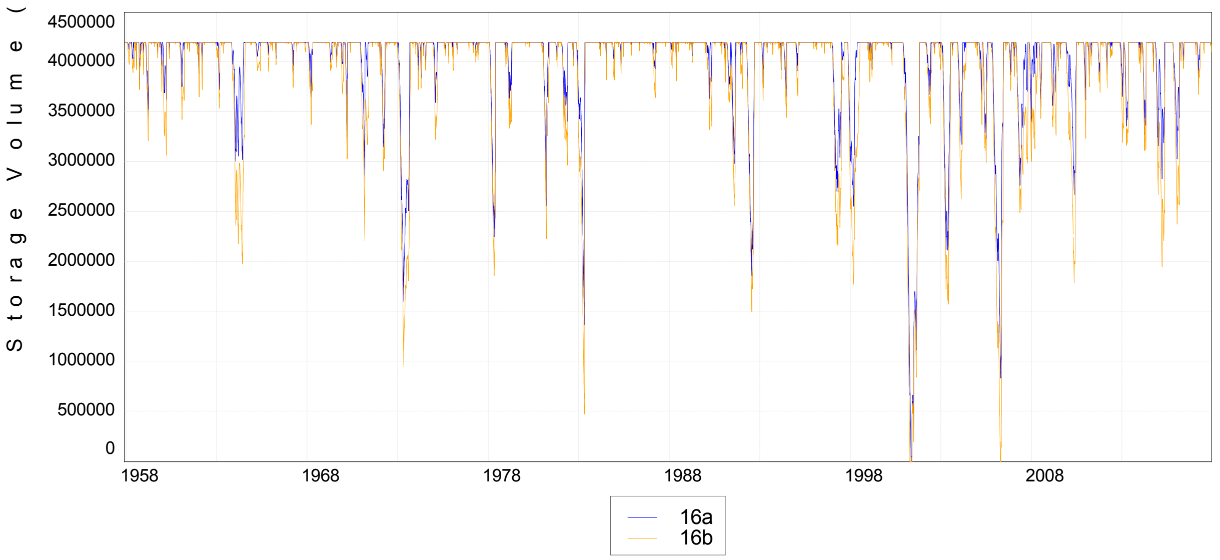

Figure 2.3: Model outputs of predicted storage remaining in Maitai dam under Scenarios 16a & 16b.

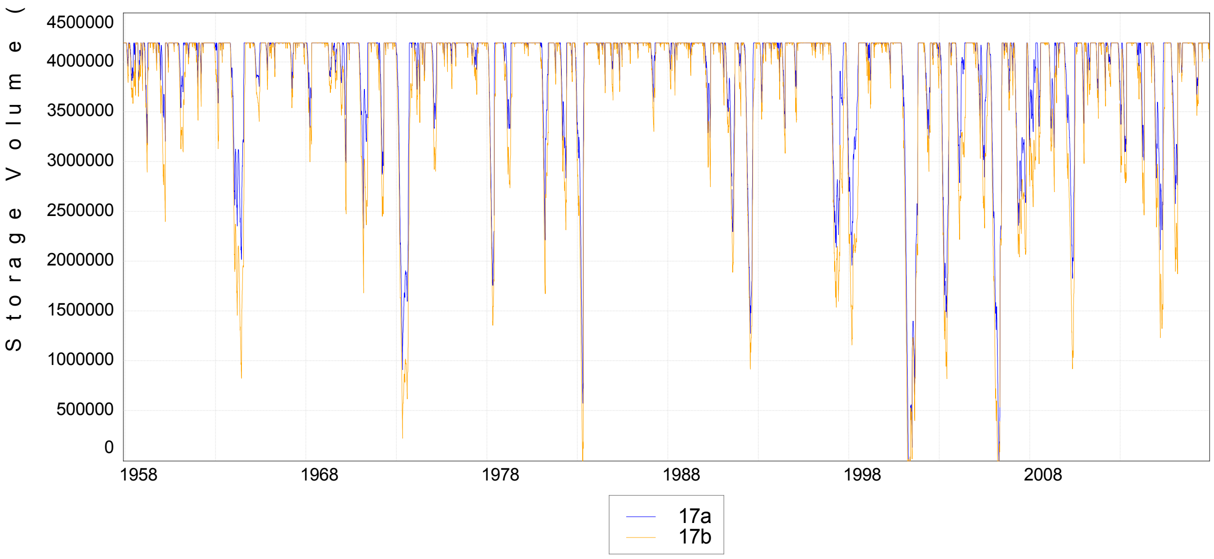

Figure 2.4: Model outputs of predicted storage remaining in Maitai dam under Scenarios 17a & 17b.

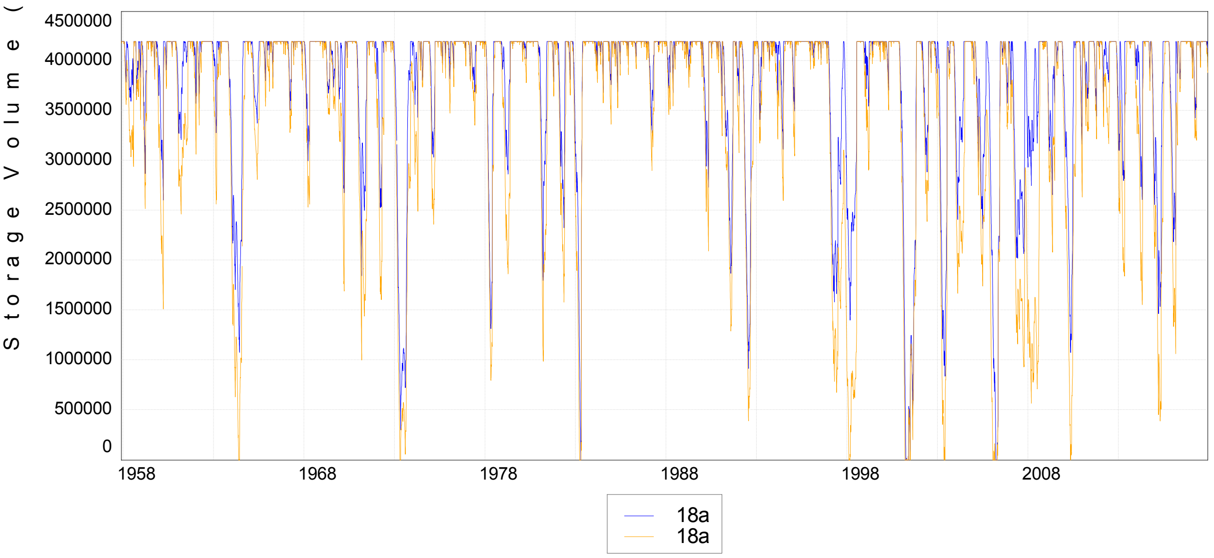

Figure 2.5: Model outputs of predicted storage remaining in Maitai dam under Scenarios 18a & 18b.

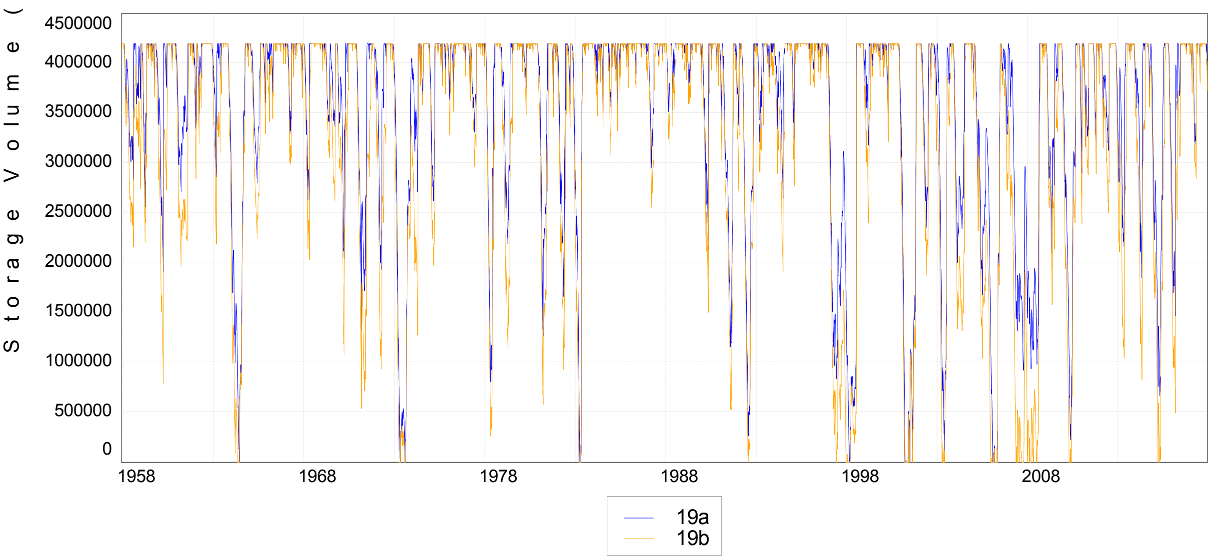

Figure 2.6: Model outputs of predicted storage remaining in Maitai dam under Scenarios 19a & 19b.

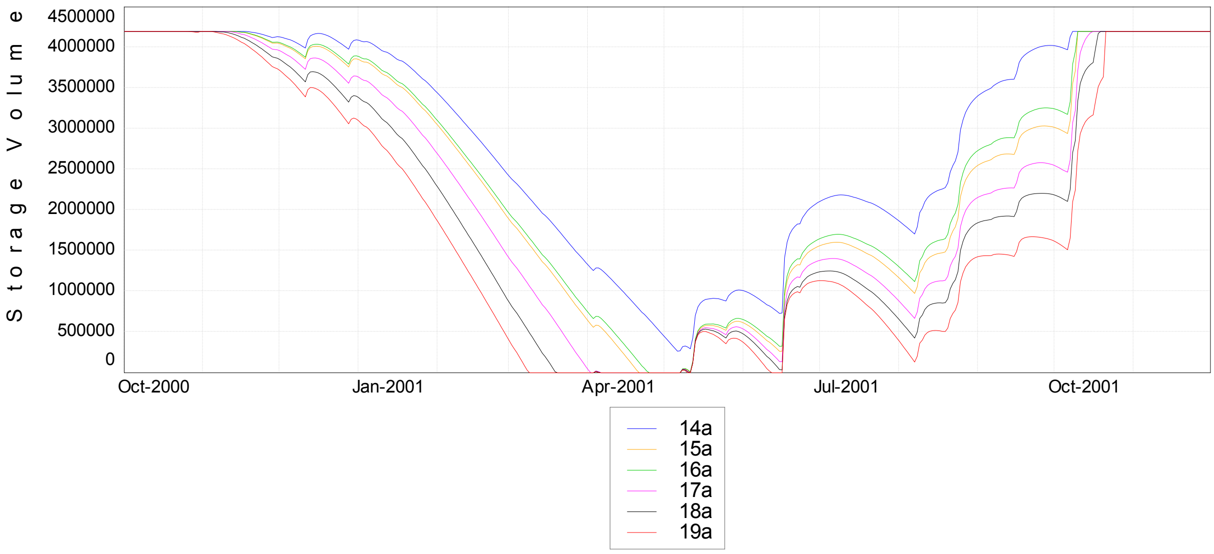

Figure 2.7: *Period of longest consecutive days of zero storage in the Maitai dam for the six additional modelled scenarios (mean). Note: this assumes inflow conditions as experienced in 2001, but with the demand scenarios out to 2100, and including the additional demand.*

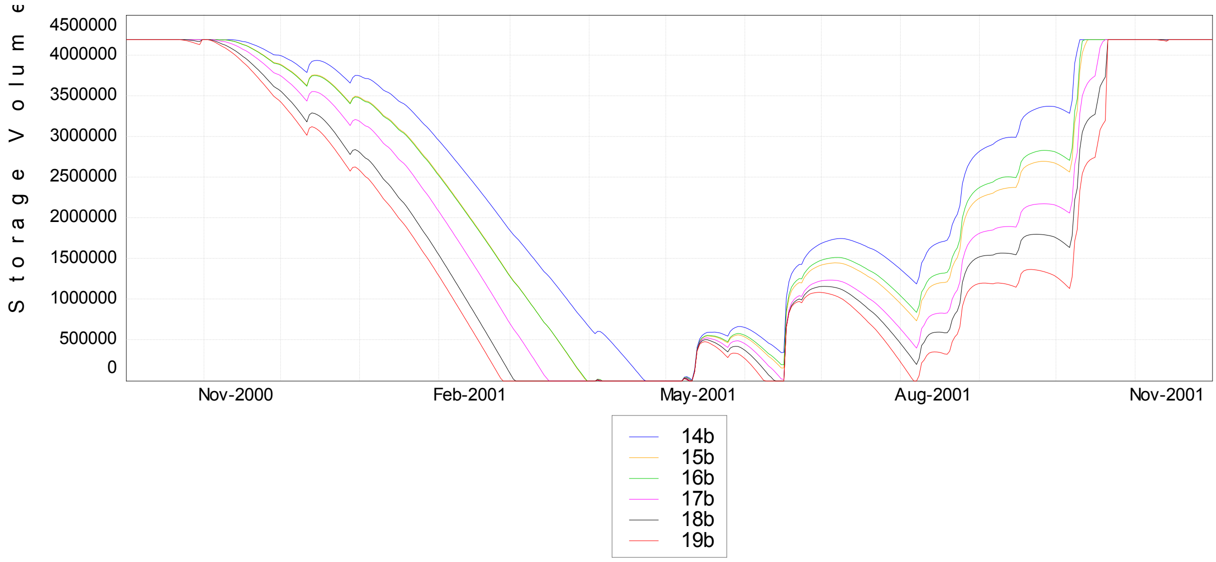

Figure 2.8: *Period of longest consecutive days of zero storage in the Maitai dam for the six additional modelled scenarios (maxima). Note: this assumes inflow conditions as experienced in 2001, but with the demand scenarios out to 2100, and including the additional demand.*

Table 2.1: *Total days where storage was at zero under each of the six additional modelled scenarios. Note that this was during conditions similar to 2001, which were very extreme, but assuming the various scenarios.*

Scenario											
14 (a&b)		15 (a&b)		16 (a&b)		17 (a&b)		18 (a&b)		19 (a&b)	
Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
0	14	17	46	12	45	41	91	77	233	179	545

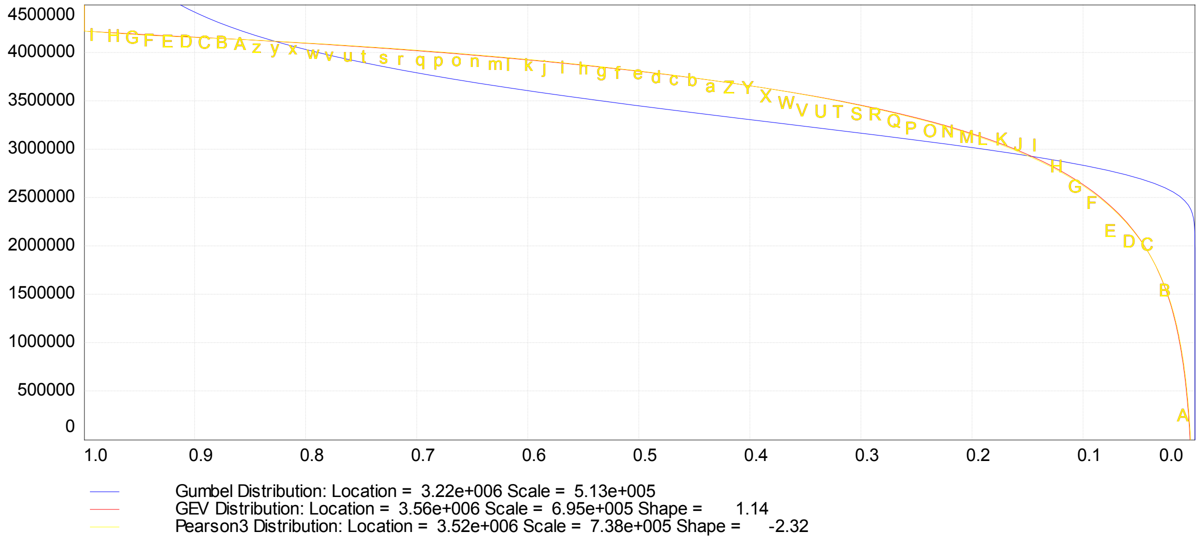

Figure 2.9: Frequency distribution of the minimum storage volume of the Maitai Dam assuming the same daily flows as experienced from 1958-2016 for Scenario 14a.

Table 2.2: Required storage needed under the various scenario and associated annual exceedance probabilities (AEPs in Mm³. Note that Maitai Dam currently holds a maximum of 4.2Mm³.

Demand Scenario	AEP (%)							
	50 (i.e. 2-year)	20 (i.e. 5-year)	10 (i.e. 10-year)	5 (i.e. 20-year)	2 (i.e. 50-year)	1.6 (i.e. 60-year)	1 (i.e. 100-year)	Current dam capacity (AEP %)
Scenario 14a	0.5	1.1	1.6	2.2	2.9	3.1	3.5	<0.5%
Scenario 14b	0.8	1.5	2.1	2.7	3.5	3.7	4.1	0.9%
Scenario 15a	0.8	1.5	2.1	2.7	3.6	3.8	4.2	1.0%
Scenario 15b	1.1	2.0	2.7	3.3	4.2	4.4	4.9	2.0%
Scenario 16a	0.7	1.4	2.0	2.6	3.4	3.6	4.1	0.9%
Scenario 16b	1.1	1.9	2.6	3.3	4.2	4.4	4.8	1.9%
Scenario 17a	1.1	1.9	2.6	3.3	4.2	4.4	4.8	1.9%
Scenario 17b	1.6	2.5	3.2	3.9	4.7	4.9	5.3	3.5%
Scenario 18a	*1.5*	*2.4*	*3.1*	*3.8*	*4.6*	4.9	*5.3*	*3.2%*
Scenario 18b	*2.3*	*3.2*	*3.9*	*4.5*	*5.2*	5.4	*5.7*	*7.0%*
Scenario 19a	*2.1*	*3.1*	*3.8*	*4.4*	*5.2*	5.4	*5.7*	*6.3%*
Scenario 19b	*2.8*	*3.7*	*4.2*	*4.6*	*5.1*	5.2	*5.4*	*9.9%*

It should be noted that, because of constraints relating to both plant infrastructure and the hydrology of the Maitai and Roding catchments, the frequency analyses run on the more extreme demand scenarios become 'unstable'. The annual minima for the more extreme events form a 'stepped' rather than a 'smooth' distribution. This explains the variable storage values for different AEP events; particularly for Scenarios 18a through 19b (Figure 2.10).

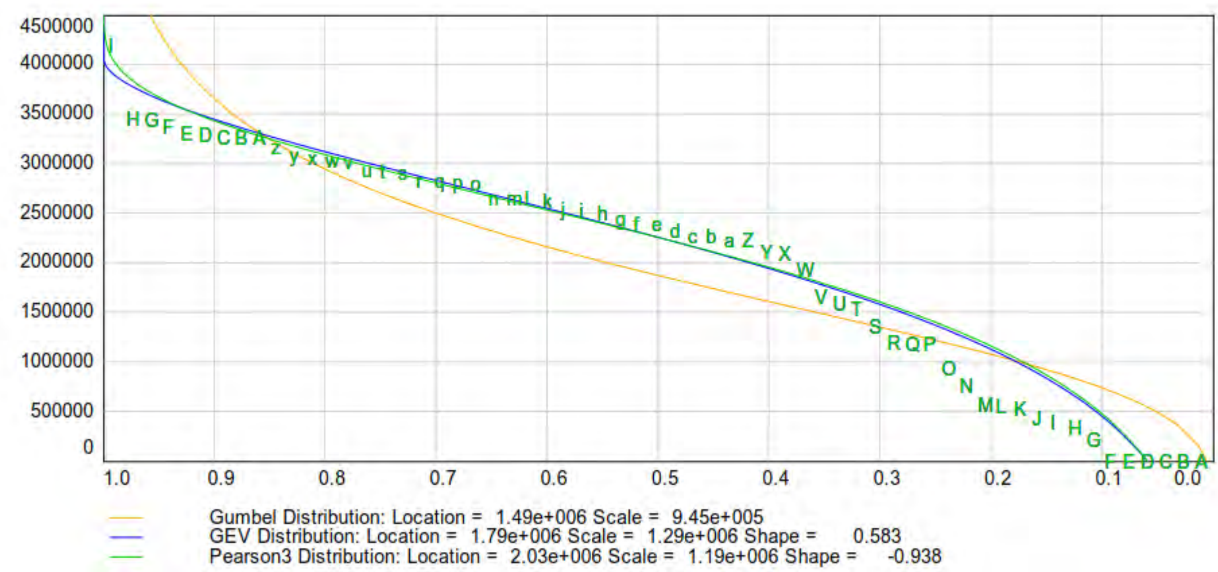

Figure 2.10: Frequency distribution of the minimum storage volume of the Maitai Dam assuming the same daily flows as experienced from 1958-2016 for scenario 19b

Table 2.3: Average recurrence interval of a drought event when demand exceeds the Maitai Dam storage capacity.

Demand Scenario	ARI (years).
Scenario 14a	>200
Scenario 14b	107
Scenario 15a	96
Scenario 15b	49
Scenario 16a	116
Scenario 16b	52
Scenario 17a	51
Scenario 17b	28
Scenario 18a	31
Scenario 18b	14
Scenario 19a	16
Scenario 19b	10

3. Conclusions

Modelling the storage required in the Maitai Dam, using the extended flow series for the various rivers, population projections, and a range of consent conditions, allows the following conclusions:

- 3.09Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2028 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 3.68Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2028 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 3.76Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2028 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond;

- 4.43Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2028 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond;
- 3.62Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2053 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 4.37Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2053 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 4.37Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2053 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond;
- 4.91Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2053 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond;
- 4.85Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2100 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 5.39Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2100 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas;
- 5.38Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2100 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond;
- 5.24Mm³ storage is required for 1.6% AEP drought event (1-in-60 year), assuming the present flow regime, using the 'high population' projected 2100 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond;
- Under the proposed residual flow conditions, the 'high population' projected 2028 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a drought event with an AEP less than 0.5%, the equivalent of a 1-in-200 year drought event;
- Under the proposed residual flow conditions, the 'high population' projected 2028 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 0.9% AEP event, the equivalent of a 1-in-107 year drought event;
- Under the proposed residual flow conditions, the 'high population' projected 2028 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 1.0% AEP event, the equivalent of a 1-in-96 year drought event;
- Under the proposed residual flow conditions, the 'high population' projected 2028 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 2.0% AEP event, the equivalent of a 1-in-49 year drought event;
- Under the proposed residual flow conditions, the 'high population' projected 2053 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson

residential and industrial areas, there is sufficient storage in the Maitai Dam for a 0.9% AEP event, the equivalent of a 1-in-116 year drought event;

- Under the proposed residual flow conditions, the ‘high population’ projected 2053 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 1.9% AEP event, the equivalent of a 1-in-52 year drought event;
- Under the proposed residual flow conditions, the ‘high population’ projected 2053 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 1.9% AEP event, the equivalent of a 1-in-51 year drought event;
- Under the proposed residual flow conditions, the ‘high population’ projected 2053 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas, there is sufficient storage in the Maitai Dam for a 3.5% AEP event, the equivalent of a 1-in-28 year drought event;
- Under the proposed residual flow conditions, the ‘high population’ projected 2100 mean monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 3.2% AEP event, the equivalent of a 1-in-31 year drought event;
- Under the proposed residual flow conditions, the ‘high population’ projected 2100 maximum monthly water demand for the Nelson community, and an additional 2500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 7.0% AEP event, the equivalent of a 1-in-14 year drought event.
- Under the proposed residual flow conditions, the ‘high population’ projected 2100 mean monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 6.3% AEP event, the equivalent of a 1-in-16 year drought event;
- Under the proposed residual flow conditions, the ‘high population’ projected 2100 maximum monthly water demand for the Nelson community, and an additional 7500m³/day to supply the south Nelson residential and industrial areas and Richmond, there is sufficient storage for a for a 9.9% AEP event, the equivalent of a 1-in-10 year drought event.

WSP OPUS

Memorandum

To	Phil Ruffell
Copy	
From	Lizzie Fox & Jack McConchie
Office	Wellington Office
Date	13 March 2018
File	3-53417.00
Subject	Addendum 4 – Reduced demand and minimum flow scenarios

1. Background

Under the resource consent as drafted currently, the Maitai Dam can provide for a 1-in-60 year drought under Scenarios 1a, 1b, 2a and 2b as described in Opus (2018). However, for populations projected out to 2100, the Maitai Dam will not provide a 1-in-60-year drought security under Scenario 3a. The reservoir would be approximately 0.3Mm³ short of the required storage during such an event.

Therefore, mitigation strategies will be required to reduce water demand from the dam. This could be achieved through reduced community demand, a reduction in residual flow requirements, or a combination of both, when the reservoir reaches a specified level.

Assuming the 3a Scenario, which includes the draft consent conditions and the 2100 mean monthly water demand (rounded up to the nearest 100m³), the threshold water level of the reservoir when either water demand or residual flows need to be reduced to maintain drought security could be determined.

The following additional scenarios, named 'Reduction Scenarios' (RS), were modelled:

- RS1: Assumes no reduction in water demand but a reduction in residual flows;
  - RS1A: reduced residual flows to achieve 200l/s at Maitai at Forks using a single water level threshold; and
  - RS1B: reduced residual flows using a two-step sequence. Flows were reduced to 200l/s at the first threshold, and subsequently down to 180l/s at Maitai at Forks if a second lower water level threshold was crossed.

  This gives the option of using either a one, or a two-step reduction strategy. A one step approach would require the threshold to be set higher, whereas a two-step reduction would allow the thresholds to be set at a lower level i.e. they would not be triggered as often.

- RS2: Assumes a 5% reduction in water demand and then a reduction in residual flows; and
- RS3: Assumes a 10% reduction in water demand and then a reduction in residual flows.

The reductions in water demand were derived using the per capita consumption and population projections provided by NCC (Table 1.1).

A total of four different Flow Reduction Scenarios were therefore modelled.

Table 1.1: Monthly demands under the various additional Flow Reduction Scenarios.

Month	Scenario		
	RS1	RS2	RS3
January	47200	44800	42500
February	46300	44000	41700
March	42600	40400	38300
April	38300	36400	34500
May	37200	35400	33500
June	36100	34300	32500
July	36200	34400	32600
August	36900	35100	33200
September	36800	35000	33100
October	38700	36800	34900
November	45100	42900	40600
December	44800	42600	40300

2. Results

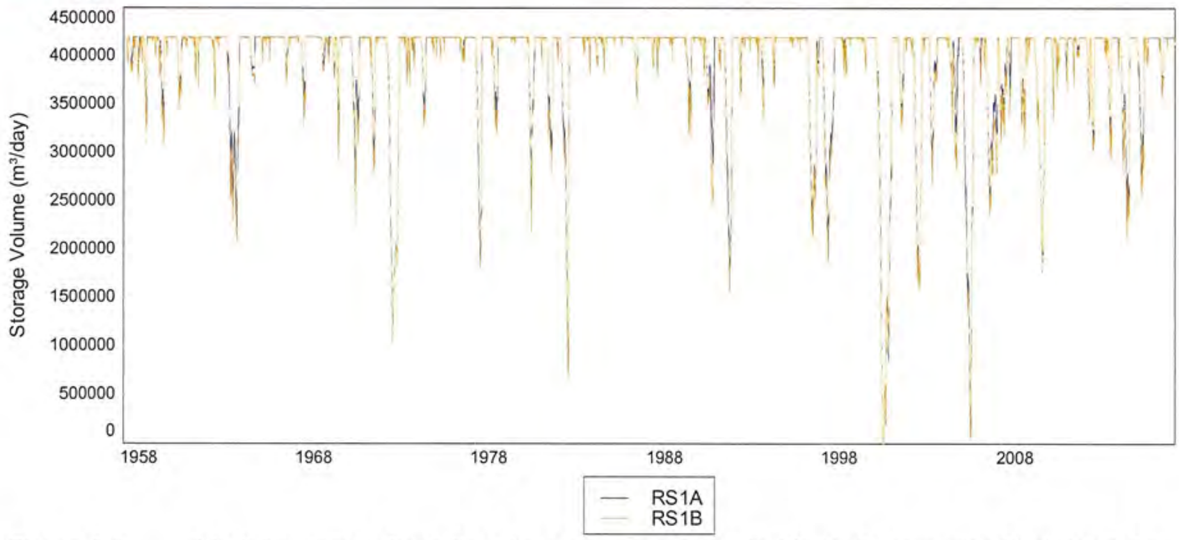

Figure 2.1: Model outputs of predicted storage remaining in Maitai Dam under Reduction Scenarios 1A and 1B.

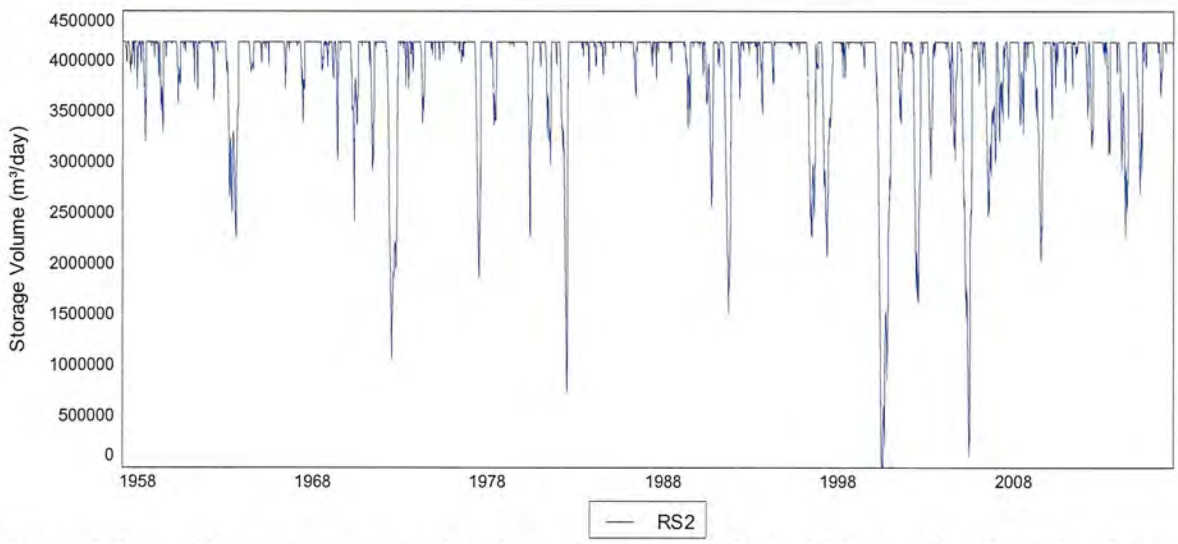

Figure 2.2: Model outputs of predicted storage remaining in Maitai Dam under Reduction Scenario 2.

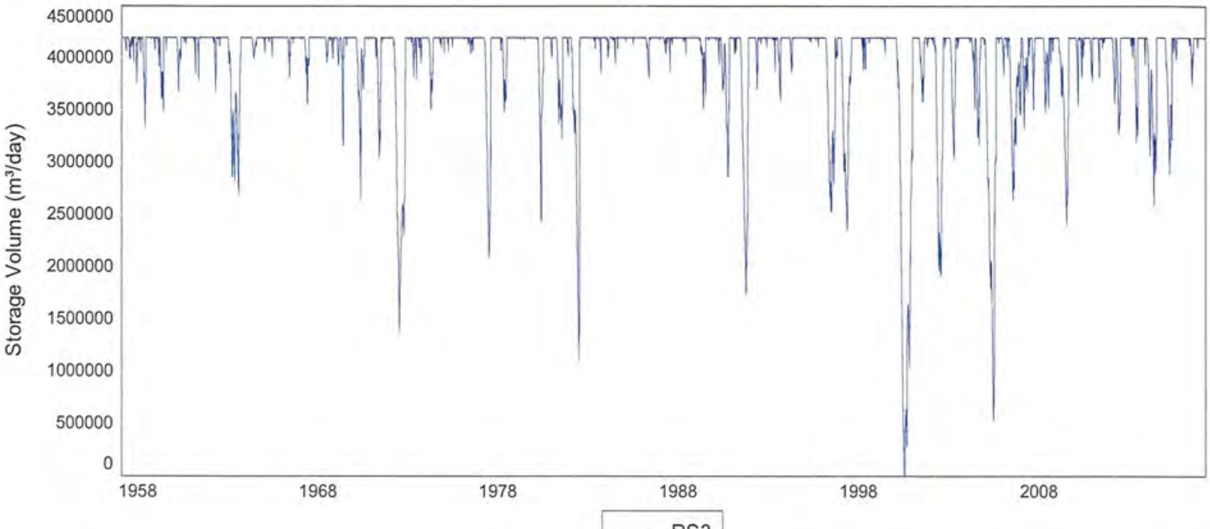

Figure 2.3: Model outputs of predicted storage remaining in Maitai Dam under Reduction Scenario 3.

All four of these additional reduction scenarios show a period of zero storage during the March to May 2001 period (Figure 2.4 & Table 2.1). As discussed in Opus (2018), this was a period of extreme drought conditions, when reservoir storage was well in excess of a 1-in-60-year drought.

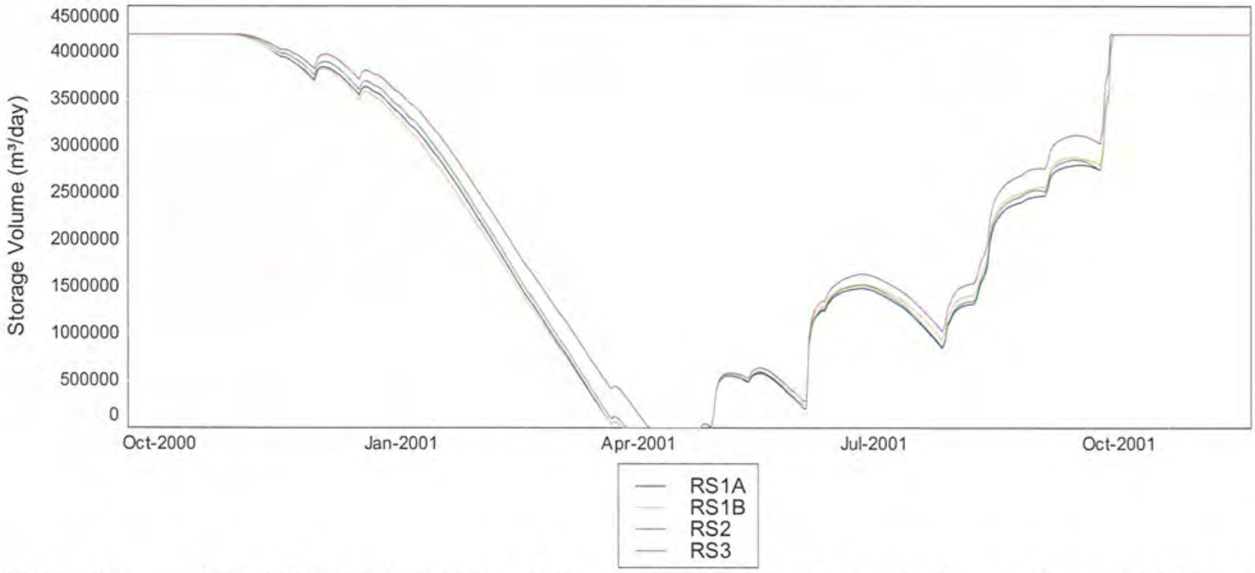

Figure 2.4: Period of longest consecutive days of zero storage in the Maitai Dam for the four additional Reduction Scenarios. Note: this assumes inflow conditions as experienced in 2001, but with the various demands out to 2100.

Table 2.1: Total days where storage was at zero under each of the 4 additional Reduction Scenarios. Note this was during March to May 2001, a particularly dry period in the record.

RS1A	RS1B	RS2	RS3
30	30	30	19

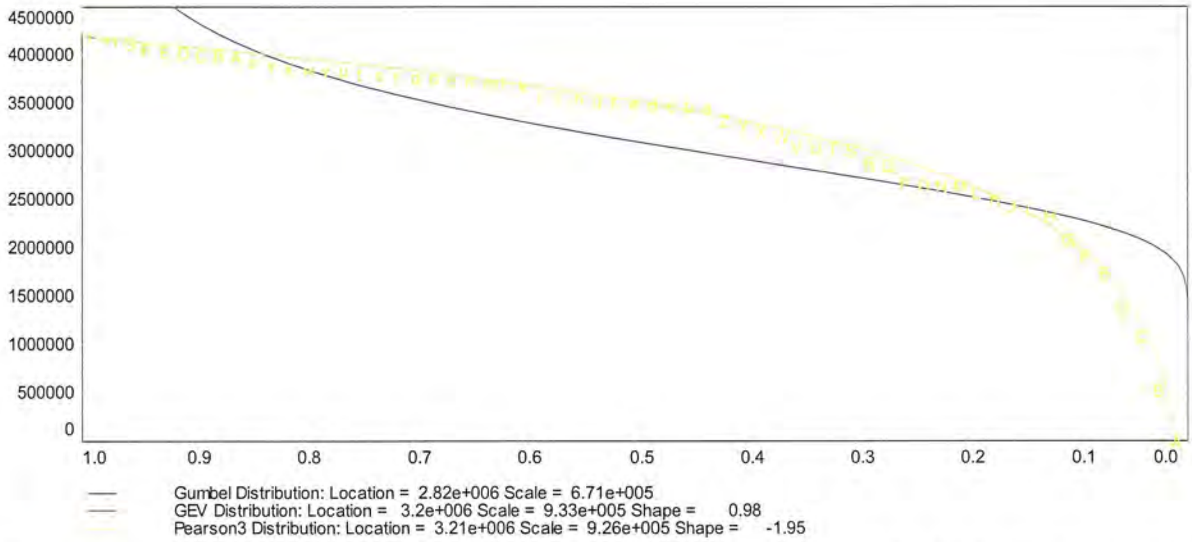

Figure 2.5: *Frequency distribution of the minimum storage volume of the Maitai Dam assuming the same daily flows as experienced from 1958-2016 for Reduction Scenario 3.*

Table 2.2: *Storage required under the various scenarios, in Mm³, and associated annual exceedance probabilities (AEPs). Note that Maitai Dam currently has a maximum capacity of 4.2Mm³.*

Demand Scenario	AEP (%)							Current capacity (AEP %)
	50 (i.e. 2-year)	20 (i.e. 5-year)	10 (i.e. 10-year)	5 (i.e. 20-year)	2 (i.e. 50-year)	1.6 (i.e. 60-year)	1 (i.e. 100-year)	
RS1A	1.1	1.8	2.5	3.2	4	4.2	4.7	1.6
RS1B	1.2	1.9	2.6	3.2	4	4.2	4.6	1.6
RS2	1	1.8	2.5	3.1	4	4.2	4.7	1.6
RS3	0.9	1.6	2.2	2.8	3.7	3.9	4.3	1.1

The proposed reservoir level thresholds for RS1A and RS1B are displayed in Table 2.3; with their respective levels and annual exceedance probabilities (AEP). When the water level drops below the first threshold, the residual flow reduces to 200l/s. For RS1A, this would occur 47% of the time over the entire record, with a greater than 50% AEP of the water level dropping below 172.6m. This is a common occurrence in the Maitai Dam at present.

Under the RS1B, the flow would reduce to 200l/s for 16% of the time at 169.1m. This has a 50% AEP of occurring i.e. it is also common in the Maitai Dam record. For 12% of the time the augmentation flow would reduce to 180l/s; at the second threshold level of 167.9m. This has a 45% AEP of occurring in any given year.

Therefore, RS1A has a longer period with augmentation flows at 200l/s, but RS1B also has flows of 180l/s for 11% of time. Both scenarios would require the augmentation flows to be reduced up to 50% of the time in any given year. This is because of the high monthly demand projected out to 2100.

Table 2.3: *Water level thresholds under Reduction Scenario 1A and 1B*

Reduction Scenario	Water Level (m)		AEP (%)	
	Threshold 1 – 200l/s	Threshold 2 – 180l/s	Threshold 1 – 200l/s	Threshold 2 – 180l/s
RS1A	172.6		>50%	
RS1B	169.1	167.9	50%	45%

3. Conclusion

Modelling the storage required in the Maitai reservoir, using the extended flow series for the various rivers, population projections, current draft consent conditions, and a variation of both the demand and residual flows, allows the following conclusions:

- 4.2Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year) using the 'mean population' projected 2100, 'mean monthly water demand' for the Nelson community, the current draft consent conditions, no restrictions of water use, but reducing the residual flow to 200l/s when the Maitai reservoir drops below 172.6m. This scenario would meet the required 1-in-60-year drought security. The probability of the water level dropping below 172.6m has a >50% AEP;
- 4.2Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year) using the 'mean population' projected 2100, 'mean monthly water demand' for the Nelson community, the current draft consent conditions, no restrictions of water use, but reducing the residual flow to 200l/s when the reservoir drops below 169.1m, and a further reduction in flow to 180l/s below 167.9m. This scenario would meet the required 1-in-60-year drought security. The water level dropping below 169.1m has a 50% AEP, and 167.9m a 45% AEP;
- 4.2Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year) using a 5% decrease in the 'mean population' (projected to 2100), the 'mean monthly' water demand for the Nelson community, the current draft consent conditions, and no reduction to the residual flows;
- 3.9Mm³ of storage is required for 1.6% AEP drought event (1-in-60 year) using a 10% decrease in the 'mean population" (projected to 2100), the 'mean monthly' water demand for the Nelson community, the current draft consent conditions, and no reduction to the residual flows;
- With a 5% decrease in the 'mean population (projected to 2100) mean monthly water demand' for the Nelson community, the current draft consent conditions, and no reduction to the residual flows, there is sufficient storage in the Maitai reservoir for a 1.6% AEP event, the equivalent of a 1-in-60-year drought event;
- With a 10% decrease in the 'mean population (projected to 2100) mean monthly water demand' for the Nelson community, the current draft consent conditions, and no reduction to the residual flows, there is sufficient storage in the Maitai reservoir for a 1.1% AEP event, the equivalent of a 1-in-89-year drought event; and
- The results suggest that the required 1-in-60-year drought security can be achieved by reducing projected water demand by 5%, without the need to also reduce the residual flows from the Maitai Dam. A further reduction in demand up to a total of 10% would ensure that there is enough storage for a less frequent drought event.