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A retrospective analysis of water security benefits from the raising of Awoonga Dam

Final Report – Overview

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1 Introduction

An issue emerging from Gladstone Area Water Board's (GAWB's) current price review is the treatment of historical supply augmentation costs (specifically the raising of the Awoonga Dam wall), and how these costs are to be allocated across customers.

1.1 Background

In 2000, the Awoonga Dam had a storage capacity of 282,743ML, corresponding to a wall height of 30 metres. Based on historical inflows, losses and environmental needs, the dam was assessed at the time to be capable of delivering a "historical no failure annual yield" (HNFY) of 49,400ML per annum (defined as the maximum yield that could have been delivered without failure during the worst drought on record). To put this in perspective, the level of consumption at the time was around 42,000ML per annum, so there was only a small surplus capacity over demand and the system was vulnerable to drought.

The vulnerability of supply was demonstrated in the severe drought of 2002-03 when the level in the Awoonga Dam reached a low point of 57,800 ML in February 2003. Under arrangements at that time, restrictions were triggered as follows[1]:

- Stage 1: April 2002 - 35% reduction in supply to local government authorities and 10% reduction in supply to industrial customers; and
- Stage 2: November 2002 - 50% reduction in supply to local government authorities and 25% reduction in supply to industrial customers.

Rainfall following Cyclone Beni in February 2003 increased storage to 484,000 ML and restrictions were subsequently lifted on 13 February 2003.

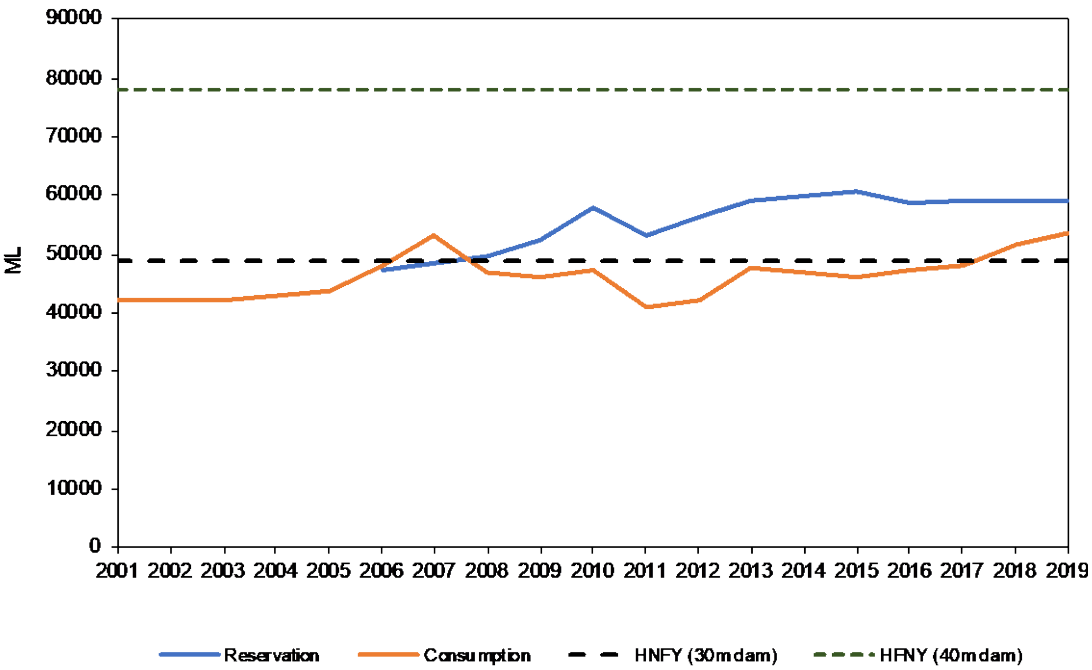
In order to improve the security of water supplies for Gladstone for existing customers, and to allow for future economic growth of the region, a decision was taken to raise Awoonga Dam by 10 metres to a wall height of 40 metres. This augmentation was completed in 2002 and resulted in storage capacity increasing from 282,743ML to 776,854ML with a corresponding increase in the then assessed HNFY from 49,400ML to 87,900ML[2]. This yield was subsequently revised downward to 78,000ML, following the severe drought of 2002-03.

[1] GAWB (2015) Drought Management Plan, November 2015

[2] GAWB (2013). Strategic Water Plan, November, p.29.

Over time, the volume of contracted demand has risen to around 59,000ML per annum (Figure 1). Therefore, the available surplus capacity over contracted demand is approximately 20,000ML. This surplus provides a security buffer for GAWB's customers, which can potentially reduce the frequency, severity and duration of supply restrictions during times of drought. Some customers contend that this surplus capacity would not have been warranted in the absence of new demand, and as such the augmentation costs should be recovered only from post-2002 customers. A counter argument to this is that all customers benefit from the water security afforded by the augmented dam height. This 'insurance' is beneficial to all customers by prolonging the onset of restrictions in times of low inflows. Accordingly, GAWB is of the view that all customers should share these costs.

Figure 1 Raising of dam to meet growth in annual demand



Data source: GAWB

1.2 This report

Synergies has been engaged by GAWB to undertake a retrospective analysis for the purpose of quantifying the water security benefits arising from the 2002 augmentation of Awoonga Dam. The analysis involves simulating the frequency, severity and duration of supply restrictions that would have occurred had the Dam not been raised to 40 metres. We examine the counterfactual scenario in which the Dam was raised by just 35 metres instead of the full 40 metres. We select 35 metres as a reference point for the analysis because the focus of the analysis is the incremental benefit of heightening the dam to the full 10 metres, instead of opting for lesser augmentation of just 35 metres. The question of interest is not whether a larger dam was justified (as clearly the 30 metre dam was incapable of reliably meeting demand even before new customers came online), but what added benefit an augmentation to 40 metres had over a marginally smaller dam.

2 Methodology and assumptions

Dam height affects water security in two ways. First, dams with a low wall are less able to meet consumption and environmental flow requirements, and this will be especially pronounced when inflows are infrequent. GAWB modelling has shown that at current consumption levels, it takes approximately 3.5 years (from a starting point where Awoonga Dam is at 100% capacity) before a Low Supply Alert is issued in accordance with the 2015 Drought Management Plan. As will be demonstrated in this study, this timeframe is considerably shorter under a smaller, 35 metre dam.

Second, a dam with a lower wall will spill more quickly after significant inflows. This reduces the volume of water that can be retained after a major inflow event for future consumption. Consequently, the period between a spill event (full dam capacity) and the triggering of restrictions is shortened considerably.

2.1 Overview of analytical approach

Our modelling procedure is as follows:

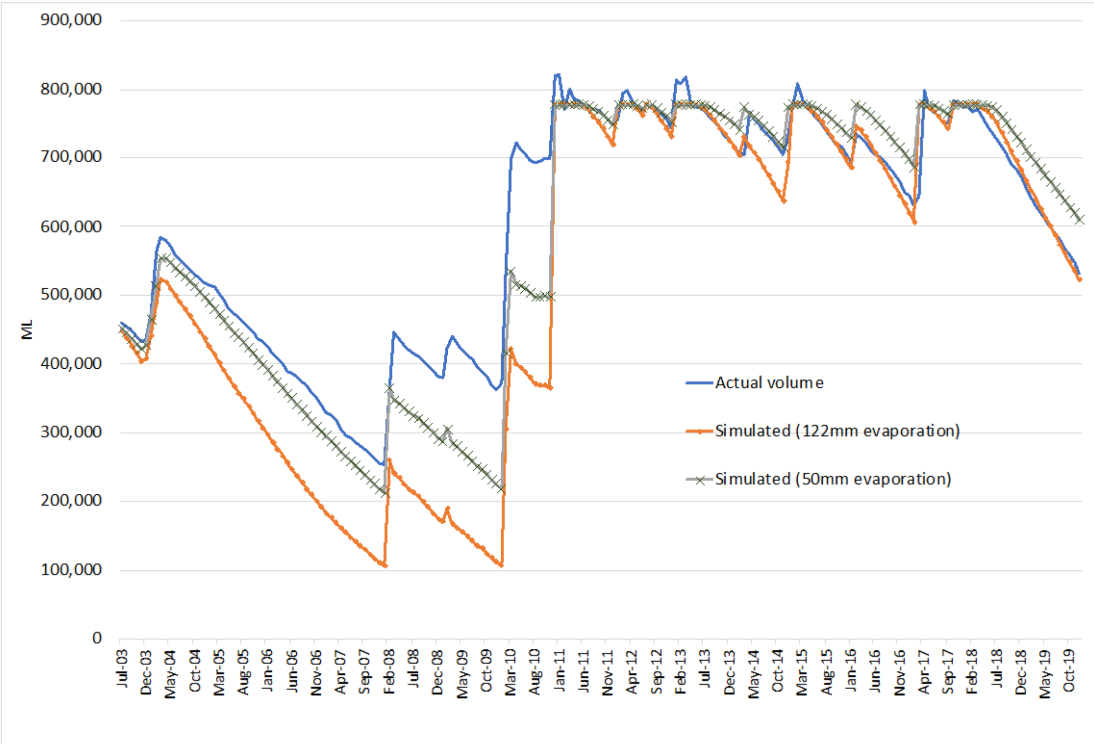
- A simple 'stock and flow' model is developed to simulate the monthly historical dam levels observed for the augmented, 40 metre (m) Awoonga Dam since 2003. The simulation uses:
  - actual inflow and consumption data;
  - actual environmental releases; and
  - estimated seepage and evaporation at different dam levels.
- For the above simulation, the number of months spent in supply restrictions at different severity levels is recorded, assuming the current restriction triggers were in place at the time and were implemented.
- Then, to evaluate the impact of the counterfactual dam height, the model is re-run for the smaller dam size – i.e. a 35m dam wall height, and the number of months spent in supply restrictions at each severity level recorded. The models for the smaller dam sizes assume the same pattern of historical inflows and consumption.
- Finally, the economic benefit derived by customers since 2003 from the added security of a larger dam is calculated by applying estimates of the economic impact experienced by particular customers as a result of restrictions of a given severity.

The remainder of this section documents further details on how the model is specified, its behaviour, and how restrictions were simulated as an output of the model.

2.2 Model specification and behaviour

The stock and flow model is capable of approximately simulating the actual levels observed for Awoonga Dam since 2003. This is shown in Figure 2.

Figure 2 Comparison of actual and simulated dam volumes



Data source: Synergies analysis

The blue line is the actual monthly levels of the 40m dam, defined in terms of percentage of full capacity. The orange line is the simulated monthly dam under loss assumptions provided by GAWB, which are:

- evaporation equalling 122 mm per month, per square metre of surface area; and
- seepage equalling 30 mm per month, per square metre of surface area.

The actual versus simulated dam levels follow the same pattern, but there is a considerable gap between the two lines, indicating that the water losses under the simulated model (using the assumptions above) appear to be larger than what actually occurred.

In order to establish a better fit between actual and simulated dam levels, Synergies decreased evaporation to 50 mm per month. This has the effect of closing the gap, as shown by the grey line. (However, we observe that the green line appears to understate losses over the most recent 18 months).

2.2.1 How the model works

Each month, the opening volume of the dam is calculated as the minimum of the closing volume at the end of the previous month, or the relevant capacity of the dam. This assumes that if the dam is above its capacity (i.e. spilling) at the end of a particular month, the dam is immediately returned to 100% capacity at the beginning of the next month.

The dam surface area in any given month is calculated based on the opening dam volume. This information is required in order to calculate monthly evaporation and seepage losses. The detail of this calculation is provided in Appendix A and the functional relationship between surface area and dam volume is presented in Appendix B.

Monthly inflow is added to the opening volume of the dam, and monthly consumption is subtracted. Industrial and residential consumption are treated separately, because these two customer categories may be subject to different restrictions.

The closing dam volume for the month is calculated as the opening dam volume plus inflows, consumption, evaporation, seepage and environmental flows. Based on the closing dam capacity, the model records whether a particular restriction is triggered. If a restriction is triggered, consumption is adjusted in the subsequent month in accordance with the specified restriction level (eg 10%, 25% or 50% cut in water use).

2.2.2 Restriction schedule

The restriction schedule for each dam size is derived from that contained in GAWB's 2015 Drought Management Plan (DMP). The restriction triggers in the DMP are set according to water levels in the 40m Awoonga Dam (expressed in terms of metres), which in turn are calculated using GAWB's monthly water balance simulation model for the dam (referred to as AWSIM-D). This model provides an estimate of how long (in months) the dam will reach a level known as 'supply failure', assuming inflows remain at historic drought volumes.

The dam is said to fail when the water level reaches 13.6m AHD[3]. The volume of water remaining in the dam below this level is referred to as 'dead storage', because it is below the level of the lowest off take and therefore cannot be used without the use of pumps or other means to extract it from the dam.

3 Australian Height Datum, which is given by the mean sea level.

The restriction triggers contained in the DMP, and corresponding time remaining till supply failure, are as follows:

- At 33.8m, a Low Supply Alert is triggered. At this point it will take 60 months (5 years) before supply failure
- At 31.0m, a 10% supply restriction is triggered. At this point it will take 48 months (4 years) or less before supply failure
- At 18.0m, emergency restrictions are triggered. At this point it is estimated that just 6 months of water will remain until supply failure. Restrictions comprise a 50% cut in supply to Gladstone Regional Council and a 100% cut in supply to all other customers.

Synergies has used data provided by GAWB[4] to redefine the DMP triggers in terms of volume of water remaining in the dam and what this translates to as percentage capacity of each dam size. This is necessary in order to develop a schedule for the 35m dam, based on the same 'months to supply failure' convention used in the DMP for the 40m dam. Table 1 illustrates the adopted triggers.

Table 1 Restriction schedules for industrial and residential customers

Restriction level	Water level in 40m dam	Corresponding volume in 40m dam	Corresponding percent capacity (40m dam)	Corresponding percent capacity (35m dam)
Low Supply Alert	33.8	439,308 ML	57%	90%
Level 1 Supply Restrictions	31.0	318,013 ML	41%	65%
Level 2 Supply Restrictions	27.0	190,181 ML	24%	39%
Emergency restrictions	22.0	75,076 ML	10%	15%

Note: (1) The 40m dam has a capacity of 776,845ML when full, while the 35m dam has a capacity of 486,002ML when full (2). Level 2 Supply Restrictions were not part of the 2015 DMP and have been assumed by Synergies. Further, for the purpose of Synergies' analysis, the level at which Emergency Restrictions are triggered has been lifted to 22m, as opposed to 18m in the DMP.

Source: Based on GAWB 2015 Drought Management Plan.

Synergies has added a Level 2 restriction to the schedule, which was not part of the 2015 DMP.

The assignment of restrictions to GAWB's industrial and residential customers is shown in Table 2 (noting that 'residential customers' are serviced by Gladstone Regional Council).

[4] These data provide the correlation between water level heights and volume, as shown in Table B1 and Appendix B.

Table 2 Restriction for industrial and residential customers

Restriction level	Capacity trigger (40m dam)	Capacity trigger (35m dam)	Industrial customers	Residential customers (Gladstone Regional Council)
Low Supply Alert	57%	90%	Voluntary demand reduction	Voluntary demand reduction
Level 1 Supply Restrictions	41%	65%	10% consumption reduction	10% consumption reduction
Level 2 Supply Restrictions	24%	39%	25% consumption reduction	25% consumption reduction
Emergency restrictions	10%	15%	Supply ceases to industrial customers	50% consumption reduction

Source: GAWB 2015 Drought Management Plan, Level 2 Supply Restrictions were not part of the DMP and have been assumed by Synergies

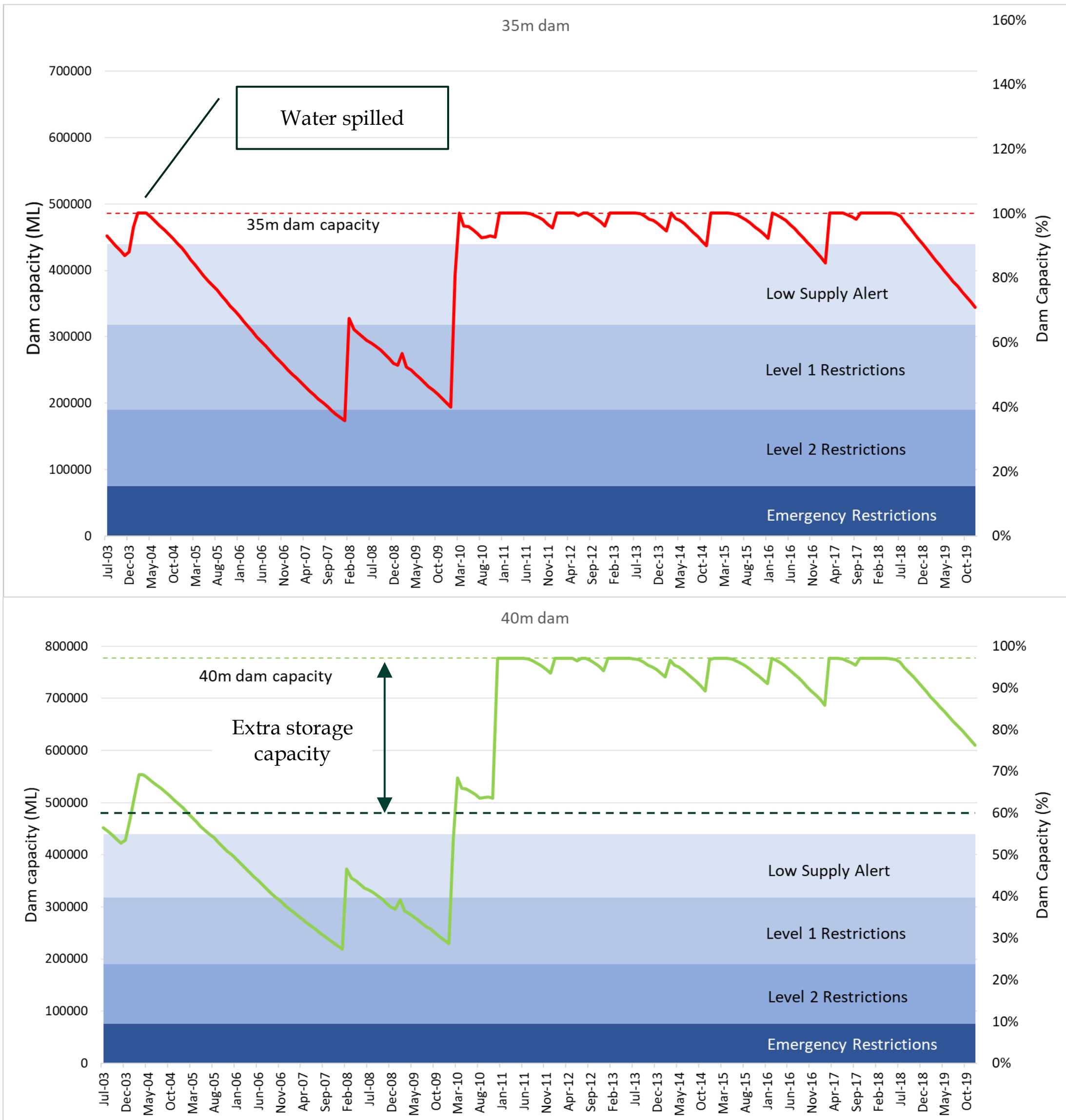
3 Results

The results of the simulation analysis are presented and discussed below.

3.1 Storage depletion under dams of different sizes

The modelling demonstrates that had the dam been raised to only 35m in 2002, customers would have incurred more severe supply restrictions during the Millennium Drought, and been in restrictions for longer (Figure 3).

Figure 3 Incidence of restrictions under different dam heights



The results show that the 40m dam was able to capture all inflows over the three month period March, April and May 2004, when inflows were high. By contrast, this water would have spilled over the 35m dam, and thus not be available for future use. This extra water in storage (estimated to be around 68 GL) was particularly valuable going into the Millennium Drought, as it provided a security buffer and deferred the triggering of restrictions (which would have applied had the 2015 DMP been in force at the time).

Under the 40m dam, the model estimates that a Low Supply Alert would have been triggered in July 2005, while under a 35m dam the Alert would have been triggered seven months earlier (in December 2004). Similarly, the extra buffering capacity of the 40m dam defers the triggering of Level 1 restrictions by seven months. And under the 35m dam, customers would have incurred Level 2 restrictions for four months, while this level of restriction is never triggered under the 40m dam.

3.2 Months spent under restrictions

Table 3 summarises the simulated number of months that customers would have incurred restrictions of particular severity under each of the dam sizes. The 35m dam would have resulted in Level 2 restrictions being imposed for four months, while the 40m dam avoids the need for Level 2 restrictions altogether. In addition to this, the 35m dam spends an extra 10 months under Level 1 restrictions compared to the 40m dam.

Table 3 Months spent under restrictions

	40m dam		35m dam	
Restriction level	**Capacity trigger**	**Duration**	**Capacity trigger**	**Duration**
Low Supply Alert	57%	28 months	90%	38 months
Level 1 Supply Restrictions	41%	32 months	65%	42 months
Level 2 Supply Restrictions	24%	0 months	39%	4 months
Emergency restrictions	10%	0 months	15%	0 months

Source: Synergies analysis

3.1 Economic implications for customers

In this section, the costs incurred by customers through the months spent under each restriction level are quantified based on Synergies' research and existing data. This data has been used to estimate the costs certain industries and production processes would incur if restrictions at 10% or 25% were imposed for a period of 12 months. The costs were estimated based on current (2019) production systems and output prices. The retrospective analysis therefore examines what impacts would have been incurred by today's customers had they been operating at 2019 levels over the historical period.

The analysis converts the annual 2019 cost estimates to monthly figures. Our water security calculations are based on the following aggregated figures:

- Monthly estimated cost of 10% restrictions: $4.90 million
- Monthly estimated cost of 25% restrictions: $90.12 million

The estimated cost of 25% restrictions is more than 18 times the estimated cost of 10% restrictions. This implies that there are significant water supply benefits from a dam scenario that mitigates the likelihood of even a brief introduction of Level 2 restrictions.

Applying these values to the months of restrictions experienced under each dam size gives the estimated costs shown in Table 4. The total cost of restrictions associated with a 40m dam is estimated to be $157 million, which is almost $410 million less than the estimated cost of restrictions under a 35m dam scenario ($566 million).

The estimated economic impacts are shown graphically in Figure 4.

Table 4 Estimated economic impact, by dam scenario

Restriction level		**40m dam**	**35m dam**
Level 1 Supply Restrictions	**Duration**	32 months	42 months
	Total cost	$156.88 million	$205.91 million
Level 2 Supply Restrictions	**Duration**	0 months	4 months
	Total cost	$0 million	$360.47 million
Total cost of Level 1 and Level 2 Supply Restrictions		**$157 million**	**$566 million**

Note: Emergency Restrictions are not reached under any of the dam scenarios that we have modelled.
Source: Synergies analysis

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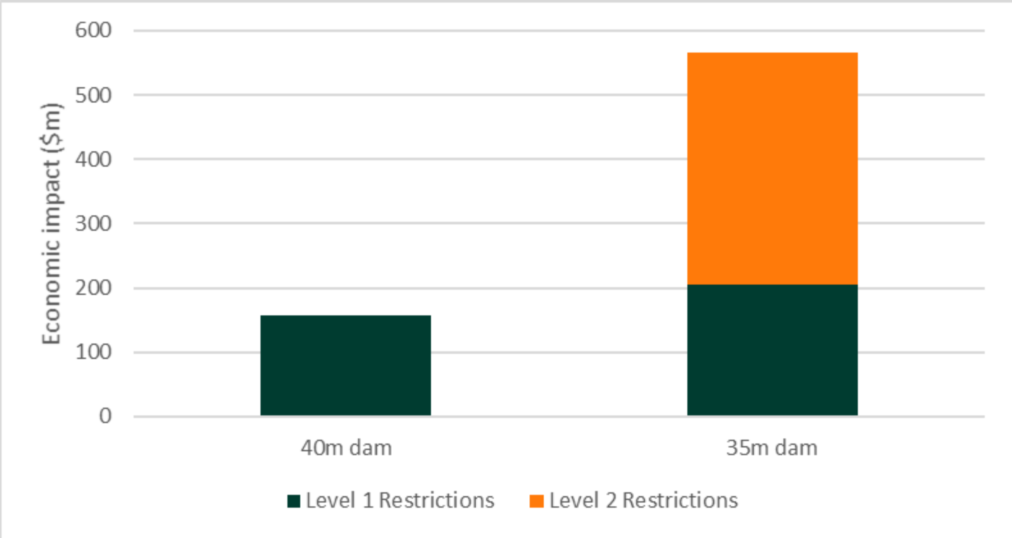
Figure 4 Split between Level 1 and Level 2 supply restriction impacts



Data source: Synergies analysis

4 Conclusion

Our analysis indicates that the raising the dam wall to 40m dam instead of just 35m has delivered an economic benefit (avoided cost) to customers of in the order of $410 million over the period from July 2003 to December 2019..

Furthermore, as this is a retrospective study it does not take into account the 'insurance value' of having a larger capacity buffer going into the current drought. Had the dam only been raised to 35m and low inflows continue, the modelling indicates that a Low Supply Alert would be triggered within 3 months. While the model has not been run past December 2019, the trend line indicates that the 40m defers the need to trigger an Alert by at least 7 months.