

## **Appendix C**

C1 Impact of the M2G on flow in the  
Murrumbidgee River and Burra Creek

C2 Response to public comments



**March 2009, Updated June 2009**

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## 1 EXECUTIVE SUMMARY

- The average supply rate from Angle Crossing to Googong is expected to be 8-10 GL/year without Tantangara and 10-15 GL/year with Tantangara. However, this rate will change significantly from year to year, to the point where the M2G could operate virtually all year or not at all.
- It is unclear in what time of year the M2G will operate most frequently. The demand for water is typically highest in the first half of the year, however recent years have contained low Murrumbidgee flows during this period. If this trend occurs, the M2G may be used more frequently during the second half of the year.
- The M2G will decrease flow downstream of Angle Crossing by approximately 5-10%. However, the impact on median flows is more significant at around 10-30%. The release of water from Tantangara Dam will reduce this impact.
- The impact on total flow leaving the ACT is smaller (due to increased average spills from ACT storages) with an average flow reduction of less than 1% and a median flow reduction of approximately 3%. However, average outflow will increase if Tantangara Dam releases are added to the system, albeit with a reduction in median outflow.
- Burra Creek flows will clearly be increased very significantly by the M2G. However, reasonably frequent periods of very low or zero flow will continue to occur in Burra Creek after the M2G is operational.
- The M2G is expected to increase median Burra Creek depth and velocity by 200% to 500%, depending upon the location in the creek, climate scenario and use of releases from Tantangara Dam.
- The M2G is expected to decrease median Murrumbidgee River height and velocity by 8% to 17% immediately downstream of Angle Crossing. This change is reduced to a 3% to 7% decrease if Tantangara Dam releases are included.
- The NSW Department of Water and Energy (DWE) produced a number of questions in response to the information provided in this report. These questions and responses to them are provided in an Appendix to this report.



## 2 AIM

### 2.1 Required Outputs

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A summary of the key hydrological impacts of the Murrumbidgee to Googong (M2G) transfer project is required for input to the M2G Ecological Assessment (EA) and Environmental Impact Statement (EIS). This report addresses the impacts of the M2G on flow, height and velocity in the Murrumbidgee River and Burra Creek. Specific outputs supplied include:

#### **How much will be transferred to Burra Creek?**

- Average volume per year.
- Estimate of average volume for each calendar month.
- Frequency of various flow rates through the pipeline.

#### **How often will the M2G operate?**

- Probability distribution of months per year.
- Probability distribution of days per month.
- Probability distribution of days per year.
- Probability distribution of continuous pumping durations.

#### **How will the M2G change natural flows?**

- Impact on high and low flows in the Murrumbidgee River downstream of Angle Crossing.
- Impact on flows in Burra Creek.
- Impact on flow leaving the ACT.

#### **How will the M2G change depth and velocity?**

- Seasonal depth and velocity impact at Angle Crossing.
- Seasonal depth and velocity impact downstream of Angle Crossing near Gigerline.
- Seasonal depth and velocity impact in Burra Creek.



## 2.2 Scenarios

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Three infrastructure scenarios have been modelled to assess these impacts:

- Base case (no M2G, existing system plus Enlarged Cotter Dam, Murrumbidgee Pump Station at Cotter capacity 150 ML/day)
- Base case plus M2G
- M2G plus Tantangara

Two climate scenarios have been modelled:

- The last ten years climate continually repeating (daily timestep analysis)
- Stochastic data based around the CSIRO projections of ACT 2030 climate (monthly timestep analysis)

## 3 METHOD AND ASSUMPTIONS

The REALM model of the ACT water supply network maintained by ActewAGL Infrastructure Development Branch has been used to model the three infrastructure options listed above for both climate scenarios. An Excel spreadsheet has also been developed specifically for the M2G pump station to perform the daily timestep analysis.

### Inflow and Demand

The 10,000 years of 2030 climate stochastic inflow and demand data are divided into 200 replicates of 50 years duration.

The last ten years of data have been divided into ten repeating sequences, as listed below, where the historical order is maintained except when the end of the sequence is reached:

1. February 1999 to January 2009, then February 1999 etc.
2. February 2000 to January 2009, then February 1999 etc.
3. February 2001 to January 2009, then February 1999 etc.
4. February 2002 to January 2009, then February 1999 etc.
5. February 2003 to January 2009, then February 1999 etc.
6. February 2004 to January 2009, then February 1999 etc.
7. February 2005 to January 2009, then February 1999 etc.
8. February 2006 to January 2009, then February 1999 etc.
9. February 2007 to January 2009, then February 1999 etc.
10. February 2008 to January 2009, then February 1999 etc.



### Infrastructure and Initial Conditions

Each run begins on 1<sup>st</sup> February 2009, whether using stochastic data or data from the last ten years, with the initial storage set by the actual storage at this date.

Infrastructure is added at the current estimated completion dates:

- Cotter Dam built over the period January 2010 to December 2011, with staged filling allowed during the construction period
- Murrumbidgee Pump Station at Cotter increased to 150 ML/day in January 2010
- M2G operation commences in January 2011
- Tantangara releases commence in January 2011

### Operating Rules for M2G Pump Station

The M2G is operated when all of the following conditions are met:

- Googong Dam is less than 80% full.
- The flow left in the Murrumbidgee at Angle Crossing is not less than the required environmental flow (this rule does not apply if releasing from Tantangara Dam).
- The Burra Creek flow is below the 1 in 2 year level. This is estimated as between 20 and 40 m<sup>3</sup>/s (1728 to 3456 ML/day)<sup>1</sup>. Note that this rule has not been applied in the monthly timestep analysis and has no effect on the analysis using data from the last ten years because Burra Creek is below the 1 in 2 year flood level throughout this period.

It has been assumed that water quality will always be acceptable.

### Operating Rules for Tantangara Dam Releases

Water is released from Tantangara Dam when all of the following conditions are met:

- Googong Dam is less than 80% full.
- The natural flow in the Murrumbidgee at Angle Crossing is less than the environmental flow requirement plus the maximum pump rate.
- Release up to 10.45 GL/year high security water, subject to high security water allocation being available (allocation is estimated from the last two years' Murrumbidgee flow in the model run)

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<sup>1</sup> GHD, *M2G17 - Burra Creek Hydrology and Hydraulics: Discharge flow Impacts on Burra Creek*, November 2008



### Environmental Flows

Environmental flows are modelled as per the current *Licence to Take Water*<sup>2</sup>, with the following exceptions:

- The environmental flow in the Murrumbidgee at the Cotter Pump Station is set to 20 ML/day in any level of water restrictions and the 80<sup>th</sup> or 90<sup>th</sup> percentile flow when water restrictions do not apply. The Licence proposes a lower flow requirement in unrestricted conditions, but it is believed that this more lenient rule may not be maintained in later Licences.
- The environmental flow in the Murrumbidgee at Angle Crossing is not specified in the Licence because Angle Crossing is not currently subject to any abstractions. The environmental flow has been modelled as the 80<sup>th</sup> percentile flow between November and May and the 90<sup>th</sup> percentile flow between June and October. No reduction is applied in drought conditions.

### Rating Tables

Depth and velocity cumulative probability curves have been constructed by comparing generated flow duration curves with rating tables showing the depth and velocity upstream and downstream of Angle Crossing (Table 1), and in a riffle and pool in Burra Creek (Table 2). These rating tables were generated for the Bulk Water Alliance by GHD using HEC-RAS models of Burra Creek and the Murrumbidgee immediately upstream and downstream of Angle Crossing.

Linear interpolation is used where a flow is between those shown in the rating tables. To avoid extrapolating above the values in the rating tables, flow rates greater than the 1<sup>st</sup> percentile of monthly flows are not included in the analysis.

*Table 1 – Rating Table for the Murrumbidgee River around Angle Crossing<sup>3</sup>*

| Flow<br>(ML/day) | Upstream Angle |               | Downstream Angle |               |
|------------------|----------------|---------------|------------------|---------------|
|                  | Depth(m)       | Velocity(m/s) | Depth(m)         | Velocity(m/s) |
| 0                | 1              | 0             | 0                | 0             |
| 20               | 1.01           | 0.01          | 0.12             | 0.18          |
| 41               | 1.02           | 0.02          | 0.13             | 0.21          |
| 58               | 1.035          | 0.03          | 0.14             | 0.24          |
| 105              | 1.067          | 0.05          | 0.18             | 0.33          |
| 165              | 1.1            | 0.1           | 0.23             | 0.41          |
| 516              | 1.17           | 0.21          | 0.36             | 0.63          |
| 929              | 1.22           | 0.31          | 0.48             | 0.78          |
| 1477             | 1.3            | 0.42          | 0.6              | 0.88          |
| 1788             | 1.34           | 0.47          | 0.66             | 0.9           |
| 2195             | 1.37           | 0.54          | 0.72             | 0.95          |
| 3370             | 1.49           | 0.7           | 0.89             | 1.05          |
| 5711             | 1.75           | 0.8           | 1.18             | 1.12          |

<sup>2</sup> ACT Government Territory and Municipal Services, *Licence to Take Water Under the Water Resources Act 2007*, 2<sup>nd</sup> December 2008

<sup>3</sup> GHD (Ian Hampton), *Draft Report – Computed hydraulic conditions in vicinity of Angle Crossing*, February 2009



Table 2 – Rating Table for Burra Creek<sup>4</sup>

| Flow<br>(ML/day) | Riffle Flows |               | Pool Flows |               |
|------------------|--------------|---------------|------------|---------------|
|                  | Depth(m)     | Velocity(m/s) | Depth(m)   | Velocity(m/s) |
| 0.0              | 0.0          | 0.0           | 0.0        | 0.0           |
| 5.0              | 0.1          | 0.5           | 0.2        | 0.1           |
| 50.0             | 0.3          | 0.8           | 0.5        | 0.3           |
| 100.0            | 0.5          | 0.8           | 0.6        | 0.4           |
| 950.4            | 1.4          | 1.2           | 1.6        | 1.0           |
| 1054.1           | 1.5          | 1.3           | 1.7        | 1.0           |
| 3110.4           | 2.3          | 1.7           | 2.5        | 1.5           |
| 3214.1           | 2.4          | 1.7           | 2.5        | 1.5           |

## 4 RESULTS

### 4.1 How much Water will be Transferred to Burra Creek?

#### Average Volume per Year

Figure 1 and Figure 2 show the average annual supply from the M2G to Googong generated using the 2030 climate stochastic data and data from the last ten years respectively. Note that both these figures represent averages, and individual years may be much higher or lower than these values.

The data from the last ten years produce a higher average M2G flow rate. This occurs because Googong Dam inflows are higher on average in the 2030 climate stochastic inflow set than the last ten years and Googong Dam therefore requires less water from the Murrumbidgee in the stochastic data modelling. Both data sets produce relatively constant average supply rates across the ten year period.

<sup>4</sup> GHD (Ian Hampton), *Changes in Hydraulic Conditions in Burra Creek Resulting from Pumped Discharges of 50 and 100 ML/d*, November 2008



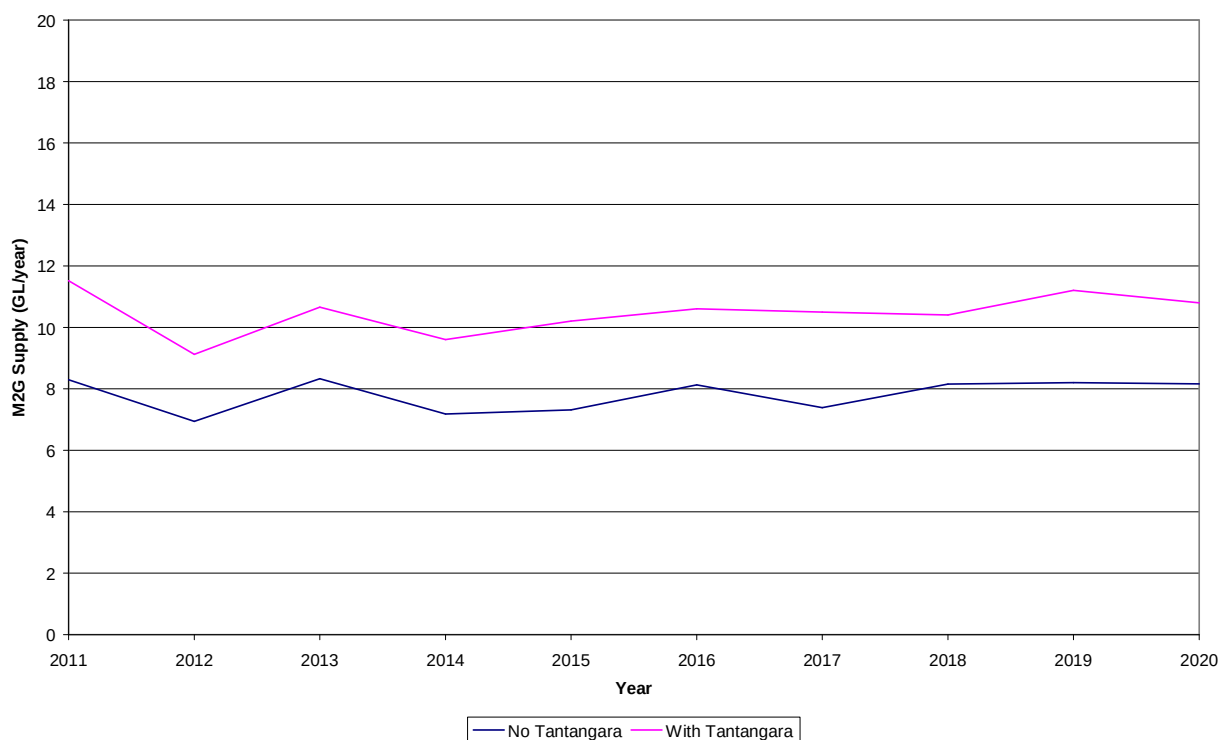


*Figure 1 – Annual Average Volume through M2G, Generated with Stochastic Data*

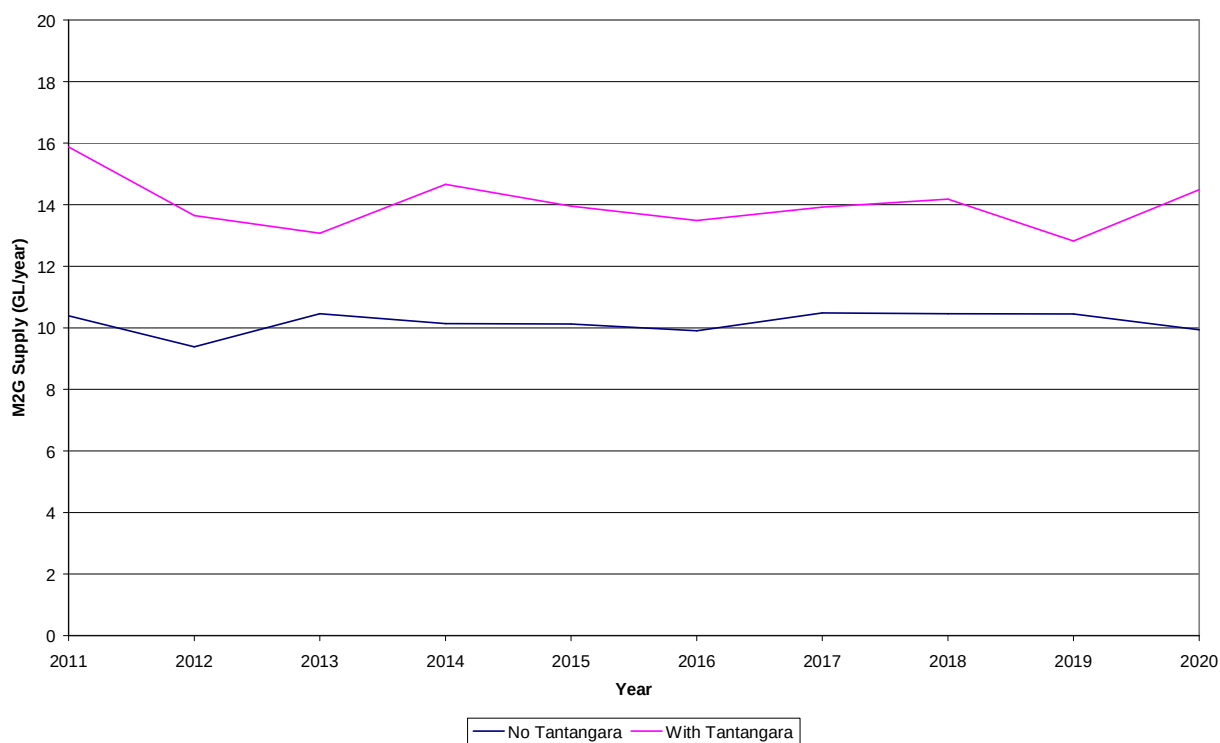


*Figure 2 – Annual Average Volume through M2G, Generated with Data from the last ten Years*



Figure 3 and Figure 4 demonstrate the range of M2G supply that could be expected in any given calendar year. The range is very large, between no operation and over 30 GL/year (almost continuous operation).

It is clear that there is more chance of using the M2G if the climate experienced during the last ten years continues to repeat than in the stochastic data sequence. The amount of years when the M2G is not used at all is reduced by a factor of three, approximately from 3 in 10 to 1 in 10. As mentioned above, this occurs because Googong Dam has a higher demand for water when using data from the last ten years. The curve produced using data from the last ten years uses a much smaller data set and is therefore not representative of the extremes that could occur.

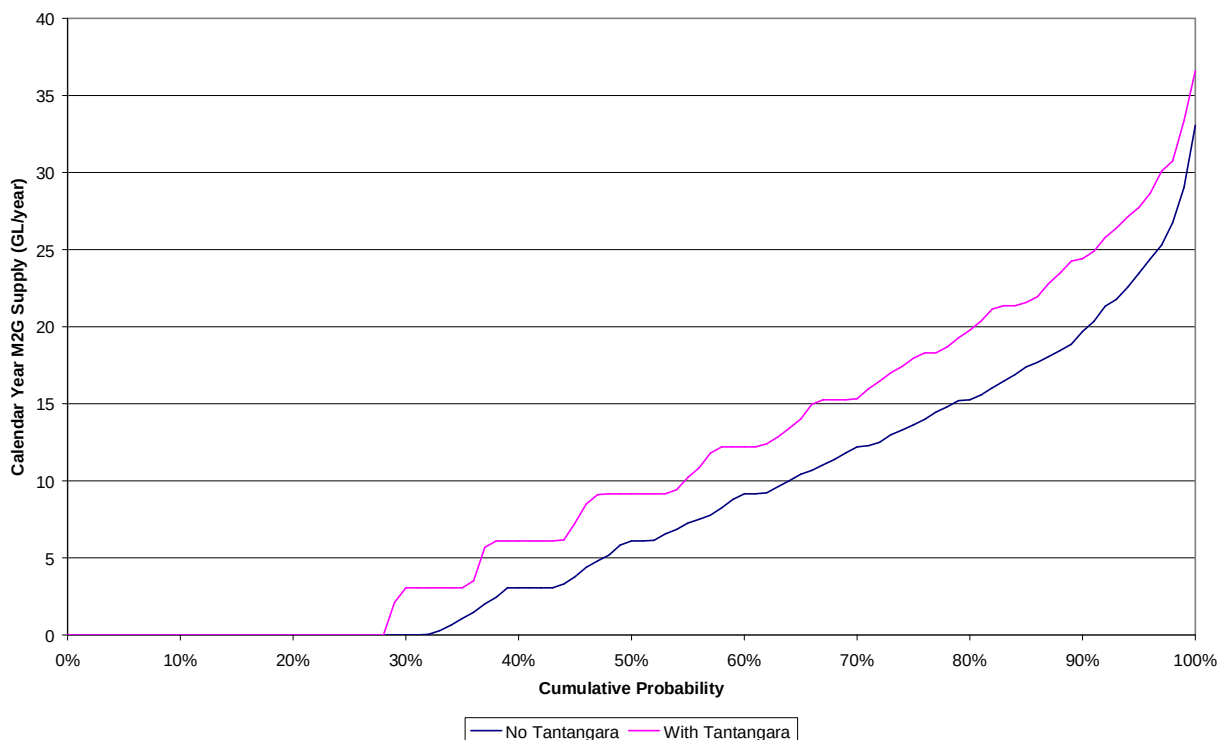


*Figure 3 – Cumulative Probability Chart of Annual Supply from M2G, Generated with Stochastic Data*



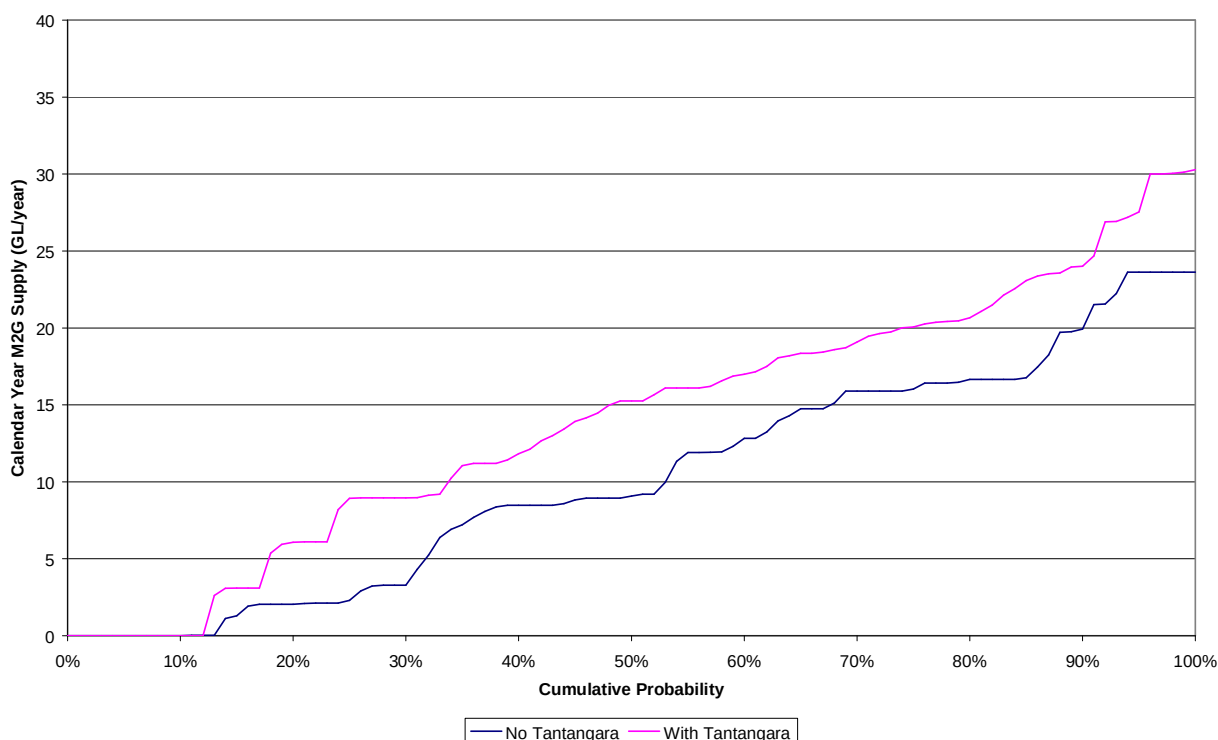


*Figure 4 – Cumulative Probability Chart of Annual Supply from M2G, Generated with Data from the last ten Years*

#### Average Volume per Calendar Month

Figure 5 and Figure 6 show the estimated monthly breakdown of M2G supply. These results are presented without releases from Tantangara because the time of year for releases is yet to be determined and could significantly influence results.

There is a clear difference between the two graphs – the last ten years model results supply much more water in the second half of the year than the stochastic results. This occurs because the last ten years have shown a marked decline in autumn rainfall and runoff that is not present in the stochastic data, resulting in insufficient Murrumbidgee flows to meet Googong demands.

In this scenario, the Murrumbidgee supply is frequently only sufficient from July to December. The stochastic data favours supply in the first half of the year – this mirrors Googong Dam’s typical seasonal cycle where storage is lowest at the end of summer.



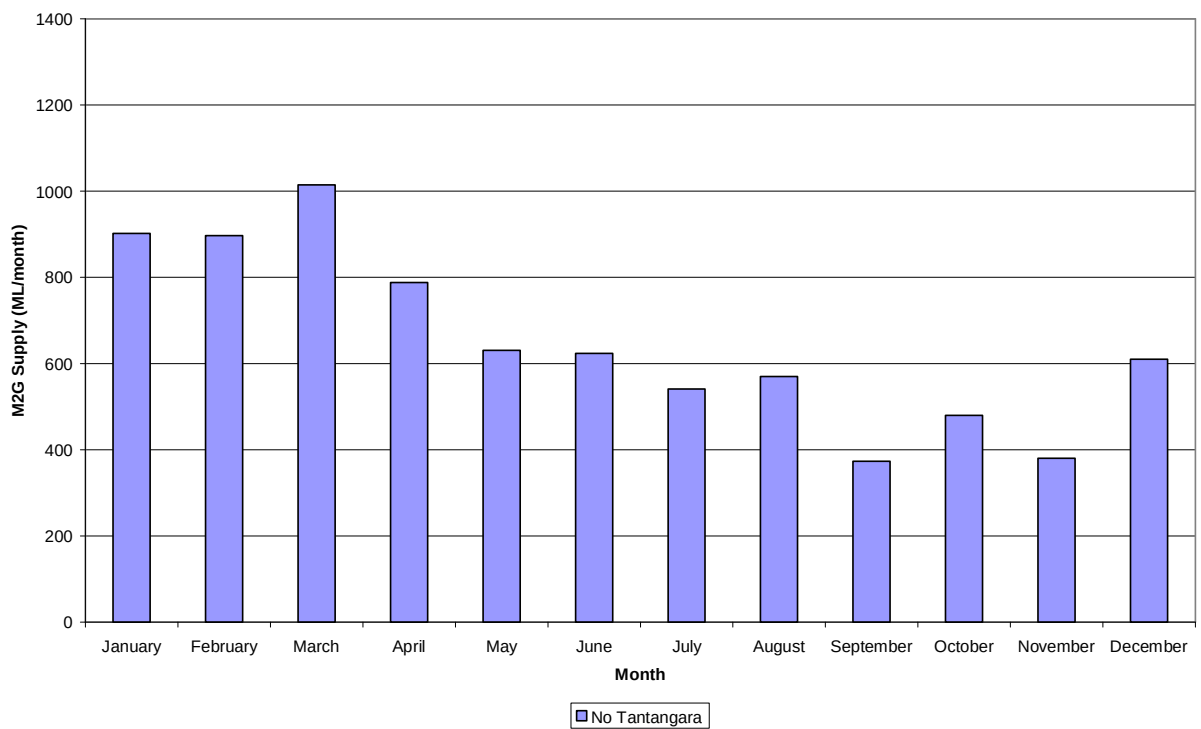


*Figure 5 – Estimated Average Monthly M2G Supply, Generated with Stochastic Data*

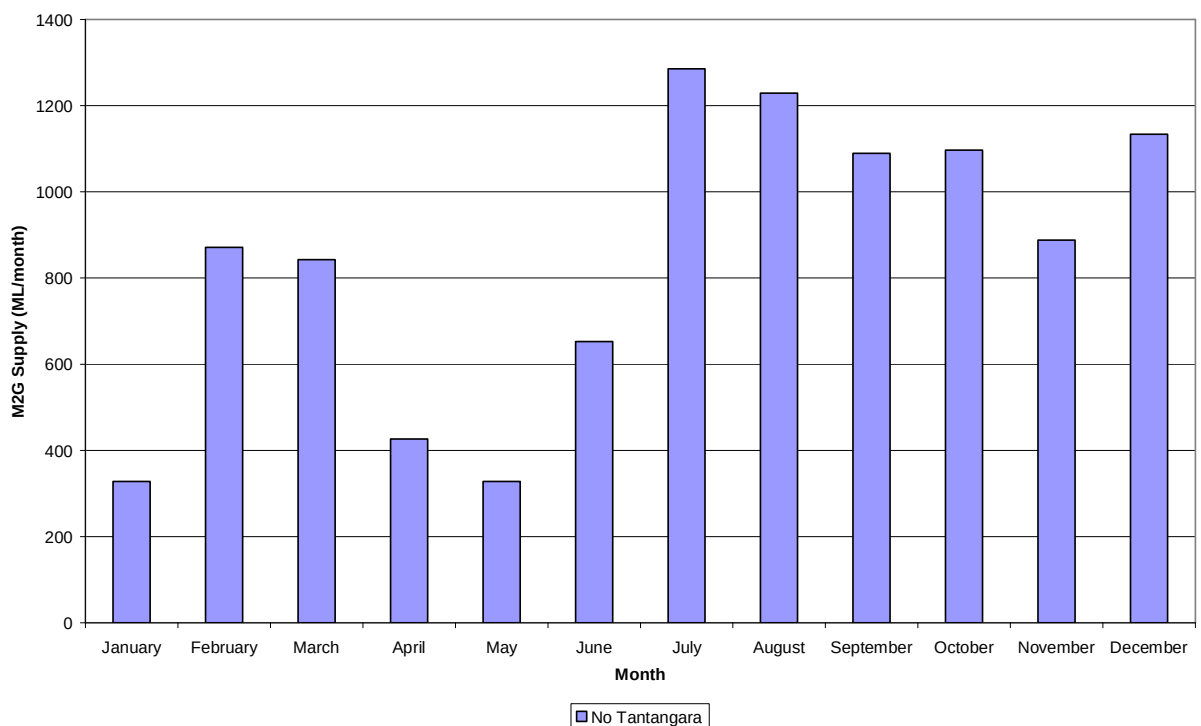


*Figure 6 – Estimated Average Monthly M2G Supply, Generated with Data from the last ten Years*



### Frequency of Different Flow Rates Through the Pipeline

Figure 7 shows the distribution of time the M2G operates at various flow rates, and the percentage of time it does not run. This graph has not been prepared using the stochastic data because a daily timestep analysis is required.

These results assume ideal flow capture (all flow above the environmental flow can be supplied). While this is not realistic, the results still provide a good indication of the flow ranges that the M2G will operate in.

The results indicate that the inclusion of Tantangara Dam will clearly increase the amount of time when the assumed maximum supply rate of 100 ML/day can be provided.

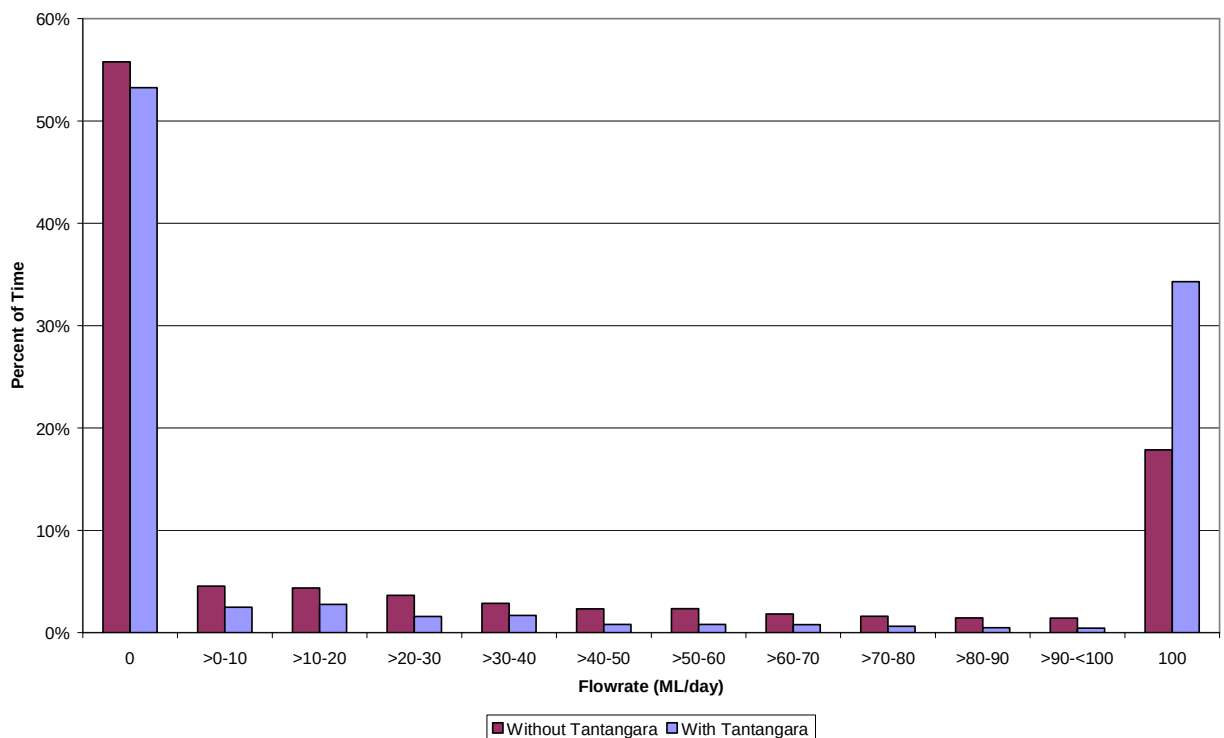


*Figure 7 – Amount of Time M2G Operates at Different Flow Rates, Generated with Data from the last ten Years*

## **4.2 How often will the M2G operate?**

### Months per Year

Figure 8 and Figure 9 show the likelihood of the M2G operating a given number of months per year. Any supply during the month is counted as use in that month. The results indicate that the M2G is more likely to run in a large number of months of the year if the last ten years of climate continue than in the stochastic scenario.



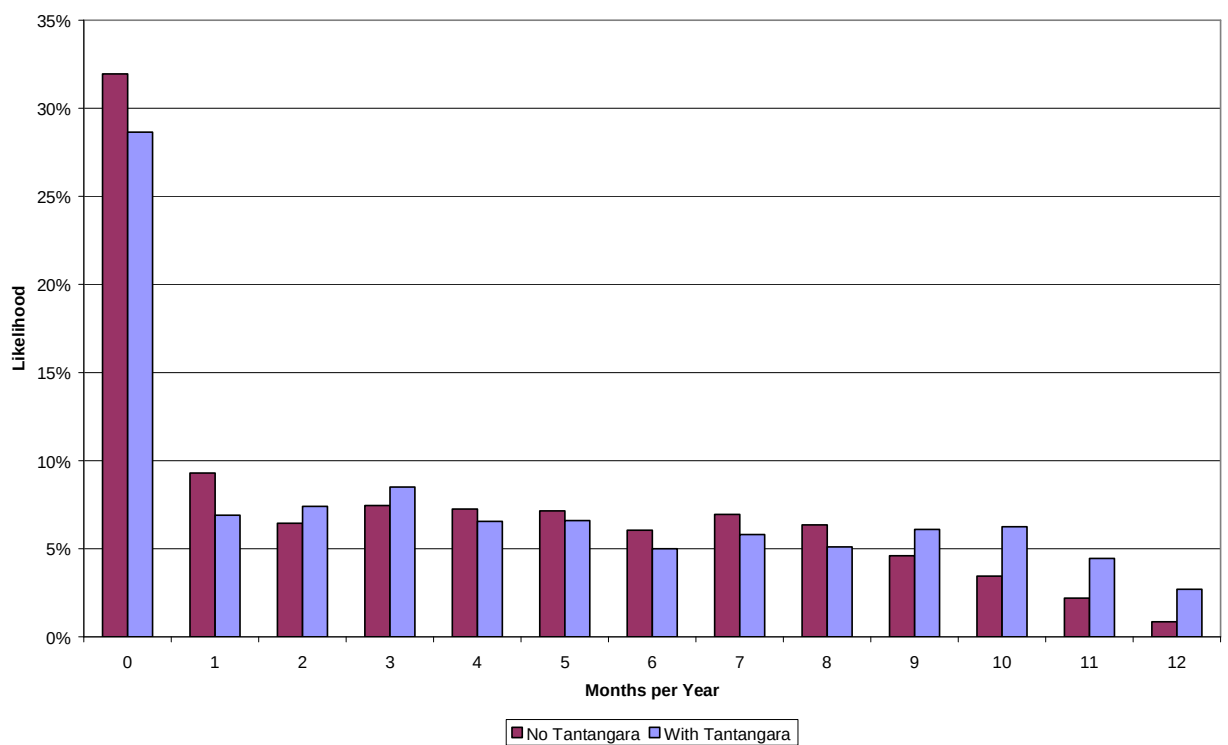


Figure 8 – Number of Months per Year M2G is Likely to Operate, Generated with Stochastic Data

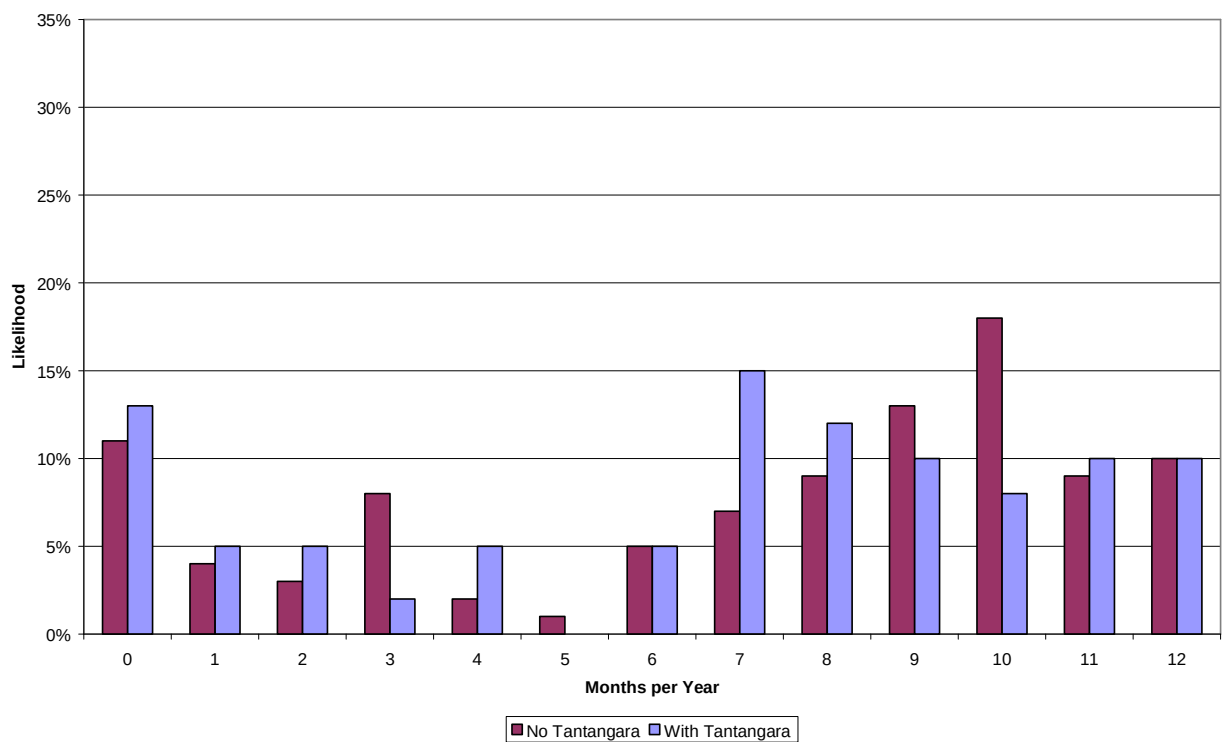


Figure 9 – Number of Months per Year M2G is Likely to Operate, Generated with Data from the last ten Years



### Days per Month

Figure 10 shows the number of days per month that the M2G may operate. This graph has not been prepared using the stochastic data because a daily timestep analysis is required.

The release of Tantangara Dam water clearly improves the ability to pump at the full flow rate throughout the month. The modelling results indicate that many months in the last ten years do not have enough flow to pump throughout the month.

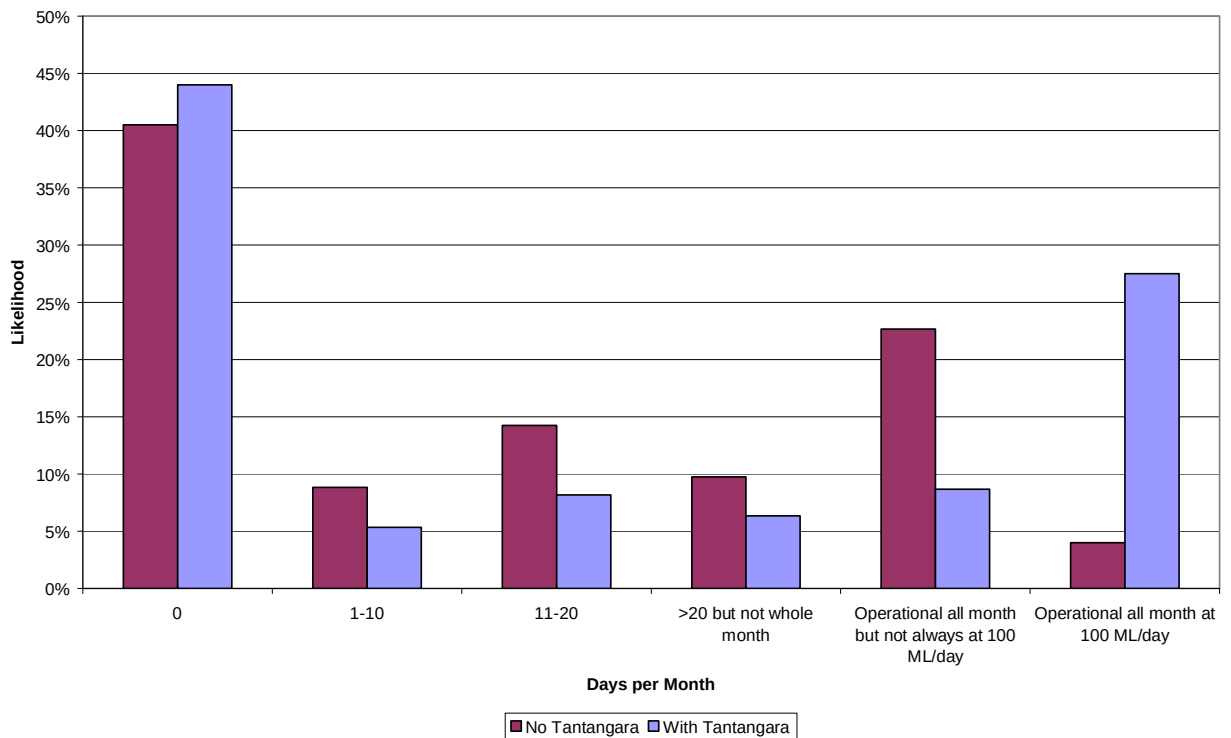


*Figure 10 – Number of Days per Month M2G is Likely to Operate, Generated with Data from the last ten Years*

### Days per Year

Figure 11 shows a probability distribution of the number of days per year that the M2G could operate. The results indicate that Tantangara releases do not greatly influence this parameter, although there is increased likelihood of using the pump station for about 100 days, which is the assumed length of release from Tantangara.

When considering data from the last ten years, there is about a 10% chance of not operating the pump station and also a 10% chance of operating the pump station for more than 300 days in a calendar year.



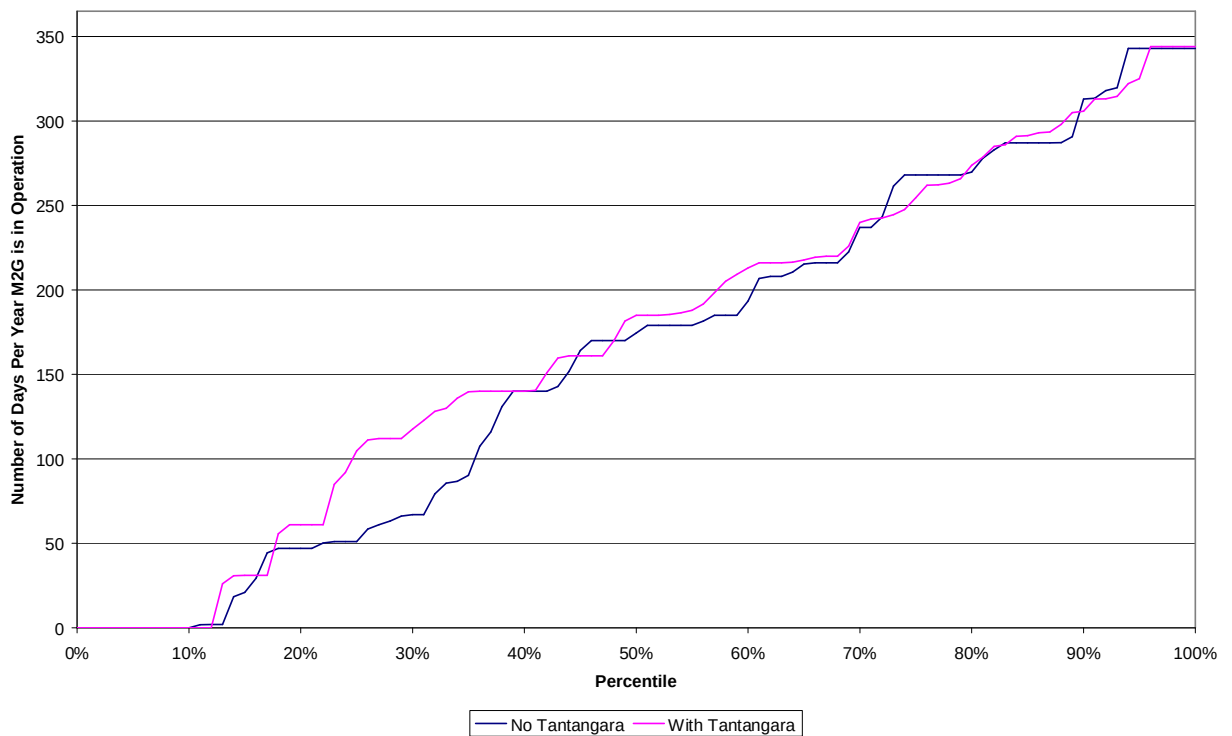


*Figure 11 – Cumulative Probability Distribution of Number of Days per Year M2G Operates, Generated with Data from the last ten Years*

### Continuous Operation

Figure 12 and Figure 13 show the probability of continuously running the M2G. The different timesteps in the two analyses lead to different definitions of continuously operating – the stochastic analysis counts any month were the pump station operates as continuing the operating event while the daily timestep analysis ends the event on any day when the pump station does not operate.

Using the last ten years daily timestep analysis, the median duration of continuous pumping is around 11 days without Tantangara and 24 days with Tantangara.



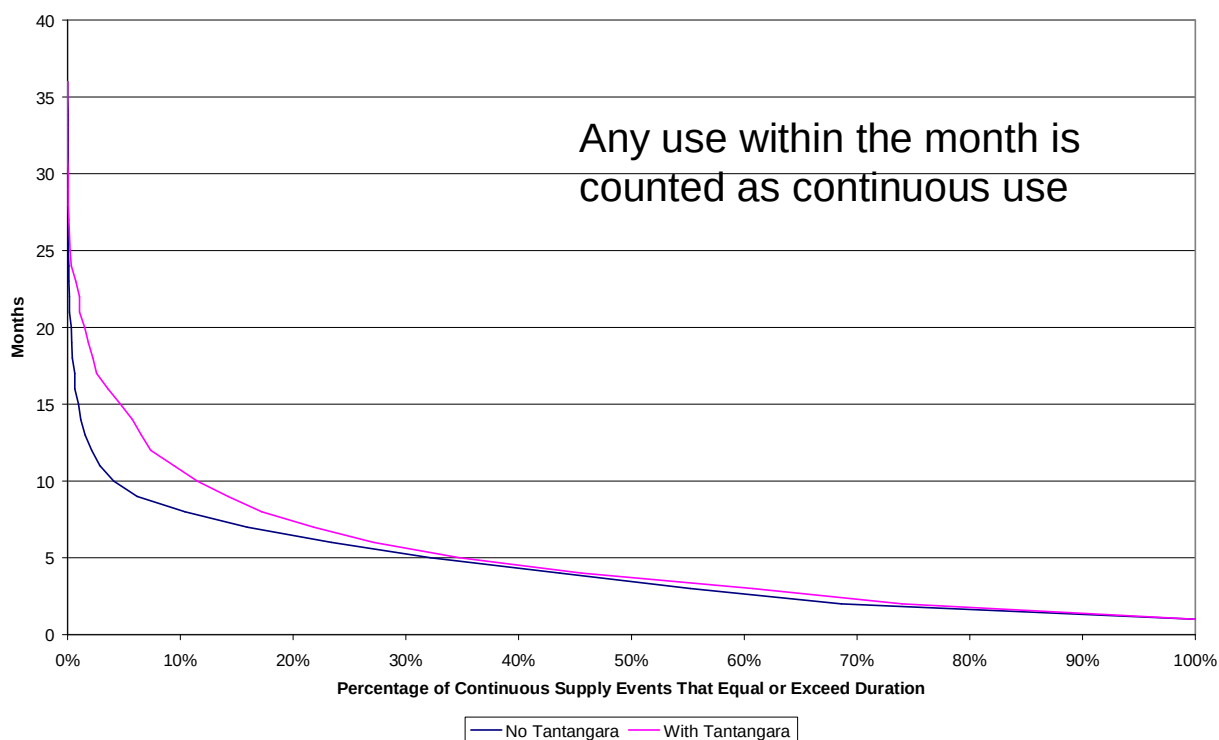


Figure 12 – Probability of M2G Operating Continuously for a Given Duration, Generated with Stochastic Data

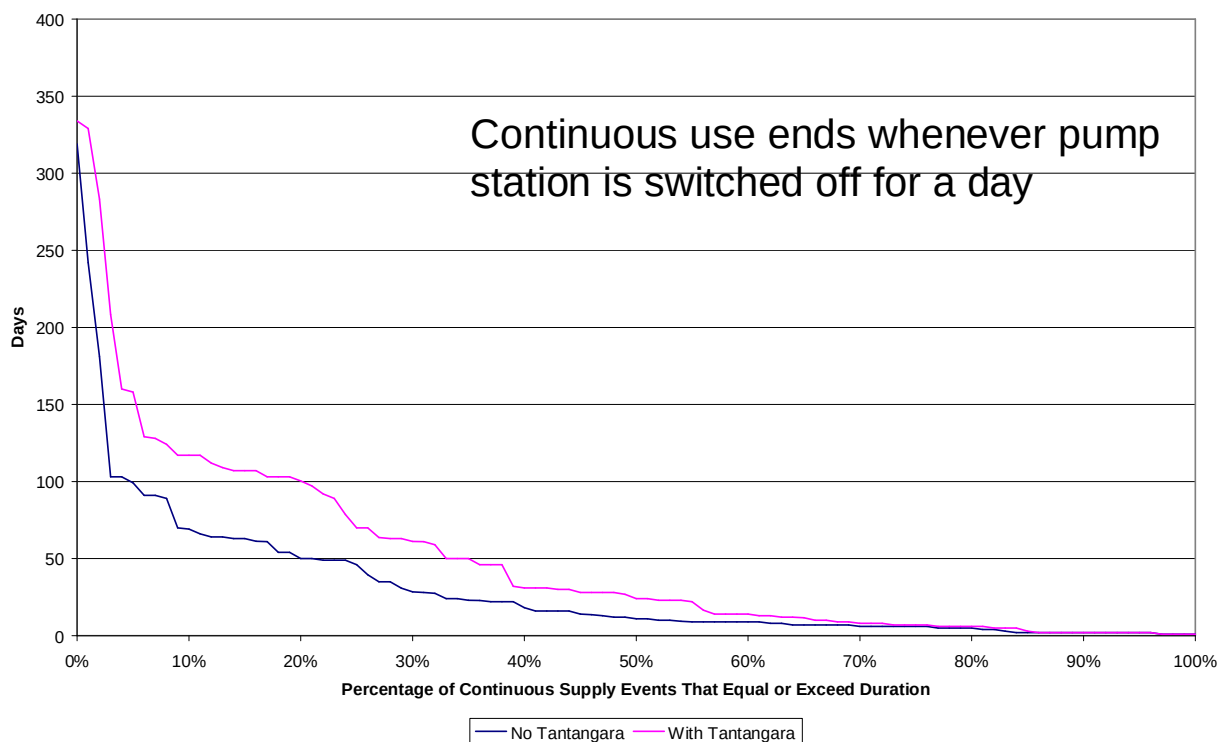


Figure 13 – Probability of M2G Operating Continuously for a Given Duration, Generated with Data from the last ten Years



### 4.3 How will the M2G change natural flows?

#### Downstream of Angle Crossing

Table 3 and Table 4 list the modelled impact of the M2G on flows downstream of Angle Crossing, with the two climate scenarios and with and without Tantangara releases. Flow duration curves are also provided in Figure 14 and Figure 15.

Tantangara releases clearly reduce the impact downstream of the M2G, as well as increasing the flow in the river upstream of Angle Crossing. The percentage impact upon median flows is clearly larger than the impact on average flows in both climate scenarios. This is logical, as the M2G pump rate is a relatively low proportion of the flow in the Murrumbidgee during high volume events.

*Table 3 – Murrumbidgee Flow at Angle Crossing (ML/month), Generated with Stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 14,477                | 13,826             | -4.5%    | 13,966               | -3.5%    |
| Median Flow     | 5,127                 | 4,400              | -14.2%   | 4,797                | -6.4%    |
| 5th Percentile  | 49,382                | 47,874             | -3.1%    | 48,578               | -1.6%    |
| 95th Percentile | 789                   | 642                | -18.6%   | 694                  | -12.0%   |

*Table 4 – Murrumbidgee Flow at Angle Crossing (ML/day), Generated with Data from the last ten Years*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 271                   | 243                | -10.3%   | 252                  | -7.0%    |
| Median Flow     | 122                   | 85                 | -30.4%   | 105                  | -13.7%   |
| 5th Percentile  | 834                   | 768                | -7.8%    | 775                  | -7.0%    |
| 95th Percentile | 9                     | 9                  | 0.0%     | 9                    | 0.0%     |



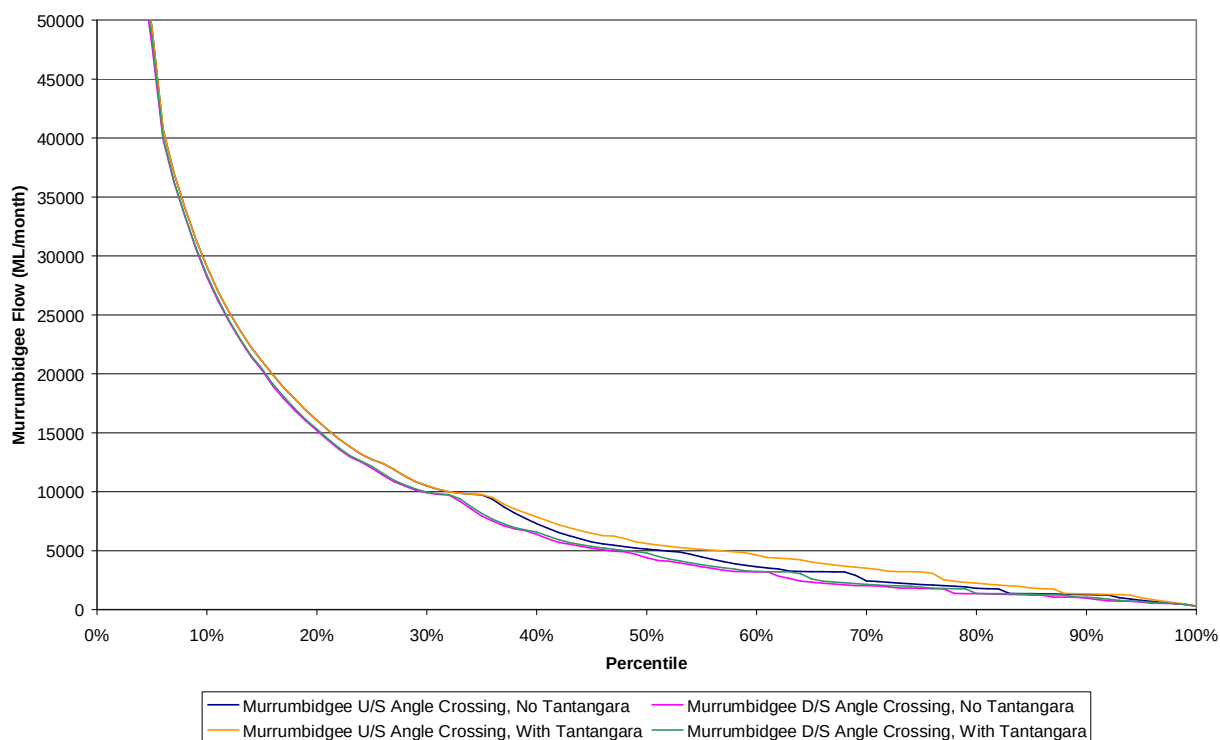


*Figure 14 – Murrumbidgee at Angle Crossing Flow Duration Curve, Generated with Stochastic Data*

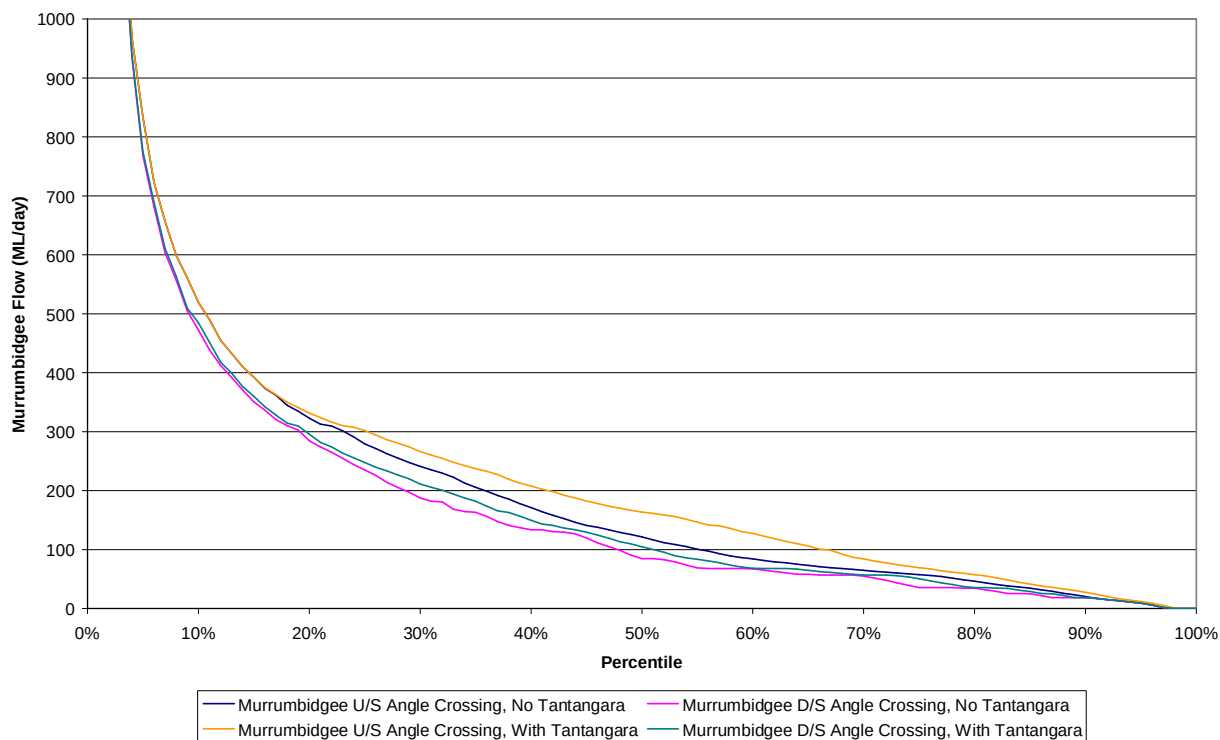


*Figure 15 – Murrumbidgee at Angle Crossing Flow Duration Curve, Generated with Data from the last ten Years*



### Burra Creek

Table 5 and Table 6 show the impact of the M2G on Burra Creek flow, while Figure 16 and Figure 17 provide this information in graphical form. The M2G will clearly cause a very significant increase in average and median flows in Burra Creek.

However, periods of very low or zero flow will continue to occur when the M2G is not operating. The frequency of very large flows in Burra Creek will not be influenced by the M2G because the M2G pump rate is small relative to these flow rates. The M2G can also be switched off in these conditions if necessary.

*Table 5 – Burra Creek Flow (ML/month), Generated with Stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 273                   | 924                | 238.5%   | 1,145                | 319.5%   |
| Median Flow     | 42                    | 171                | 306.3%   | 239                  | 467.8%   |
| 5th Percentile  | 881                   | 3224               | 266.1%   | 3,264                | 270.6%   |
| 95th Percentile | 0                     | 0                  | 0.0%     | 0                    | 0.0%     |

*Table 6 – Burra Creek Flow (ML/day), Generated with Data from the last ten Years*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 4.7                   | 32.5               | 598.6%   | 43.0                 | 824.5%   |
| Median Flow     | 1.0                   | 6.7                | 545.2%   | 7.8                  | 653.6%   |
| 5th Percentile  | 8.8                   | 103.3              | 1,072.5% | 104.8                | 1089.1%  |
| 95th Percentile | 0.0                   | 0.0                | 0.0%     | 0.0                  | 0.0%     |



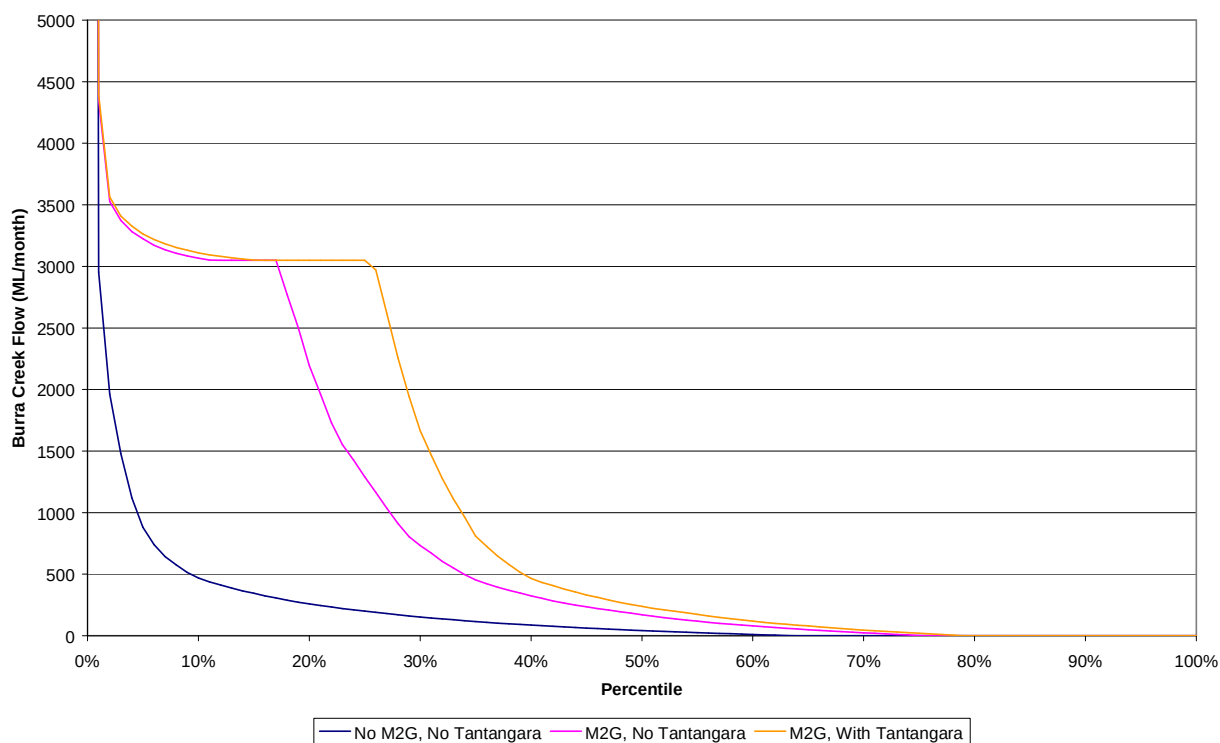


*Figure 16 – Burra Creek Flow Duration Curve, Generated with Stochastic Data*

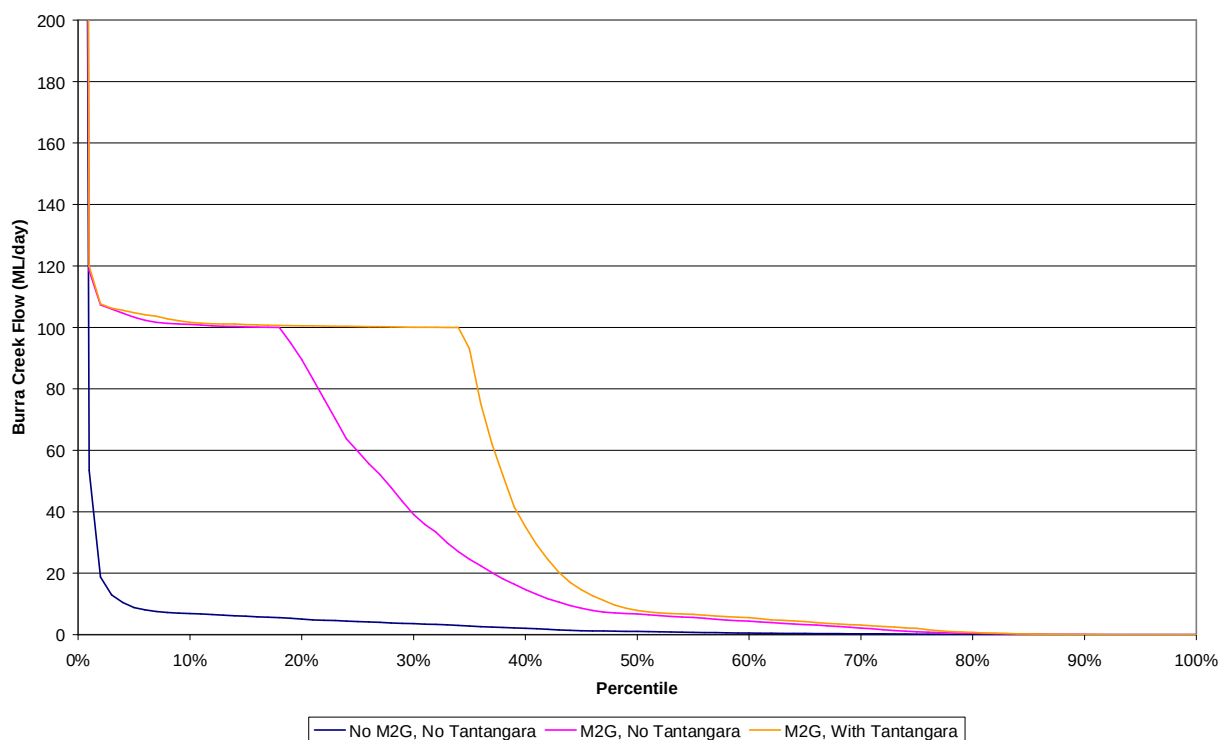


*Figure 17 – Burra Creek Flow Duration Curve, Generated with Data from the last ten Years*



### System Outflow

The overall impact of the M2G on flow leaving the ACT has been estimated by examining the model output for the flow downstream of Googong Dam and in the Murrumbidgee River downstream of the Cotter Pump Station. These points have been selected because they are at the downstream limits of ACT water supply abstraction effects.

The flow at these two points is historically equivalent to 70% of flow leaving the ACT on average<sup>5</sup>.

Three climate sequences have been modelled to examine this impact:

1. 2030 climate change stochastic data
2. Inflow and demand from the last ten years
3. Period of record historical inflow from 1871 to present

The impact is shown in Table 7, Table 8 and Table 9 as well as Figure 18, Figure 19 and Figure 20. The impact on total flow is clearly relatively small. The M2G will lead to a small decrease in average flow leaving the system, resulting from increased consumption, higher dam storages and increased evaporation. The decrease in median flows is somewhat larger. However, average total outflow will increase if Tantangara releases are added to the system, albeit with a decrease in median outflow. The changes in flow are typically smallest when considering the period of record data. This occurs because the new infrastructure is used less frequently in this scenario because dam inflows are relatively high.

*Table 7 – Overall Impact of M2G on ACT Flows (ML/month), Generated with Stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 24,314                | 24,216             | -0.4%    | 24,481               | 0.7%     |
| Median Flow     | 10,135                | 9,814              | -3.2%    | 10,071               | -0.6%    |
| 5th Percentile  | 82,843                | 83,174             | 0.4%     | 83,647               | 1.0%     |
| 95th Percentile | 967                   | 992                | 2.6%     | 943                  | -2.5%    |

<sup>5</sup> ActewAGL, WA0809\_017, *Impact of M2G on ACT Flows (Angle Crossing Option)*, February 2009



*Table 8 – Overall Impact of M2G on ACT Flows (ML/month), Generated with Data from the last ten Years*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 13,709                | 13,555             | -1.1%    | 13,994               | 2.1%     |
| Median Flow     | 7,696                 | 7,429              | -3.5%    | 7,570                | -1.6%    |
| 5th Percentile  | 43,697                | 44,536             | 1.9%     | 47,134               | 7.9%     |
| 95th Percentile | 914                   | 1,025              | 12.2%    | 1,031                | 12.8%    |

*Table 9 – Overall Impact of M2G on ACT Flows (ML/month), Generated with Period of Record Historical Data (1871 – present)*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 58,263                | 58,249             | -0.02%   | 58,351               | 0.15%    |
| Median Flow     | 24,196                | 24,048             | -0.61%   | 24,154               | -0.17%   |
| 5th Percentile  | 224,910               | 224,920            | 0.00%    | 224,946              | 0.02%    |
| 95th Percentile | 2,232                 | 2,075              | -7.05%   | 2,133                | -4.44%   |

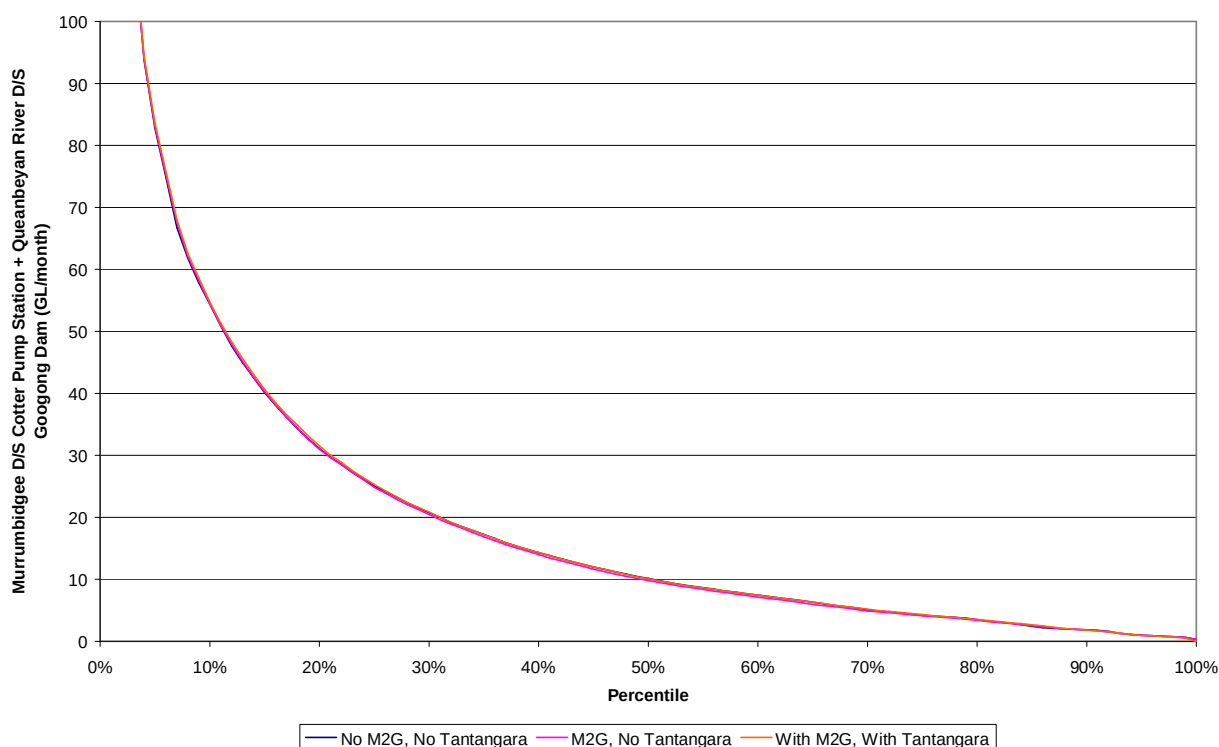


*Figure 18 – Murrumbidgee at Cotter Pump Station plus Queanbeyan River Downstream Googong Dam Combined Flow Duration Curve, Generated with Stochastic Data*



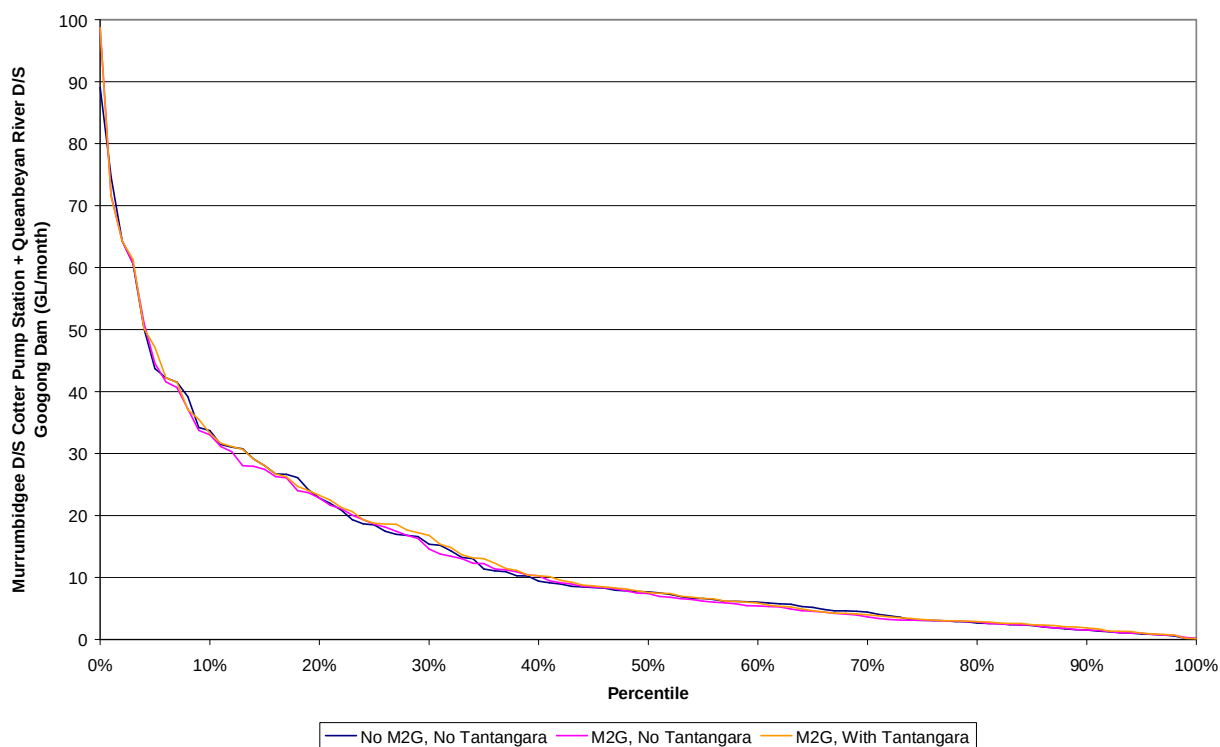


*Figure 19 – Murrumbidgee at Cotter Pump Station plus Queanbeyan River Downstream Googong Dam Combined Flow Duration Curve, Generated with Data from the last ten Years*

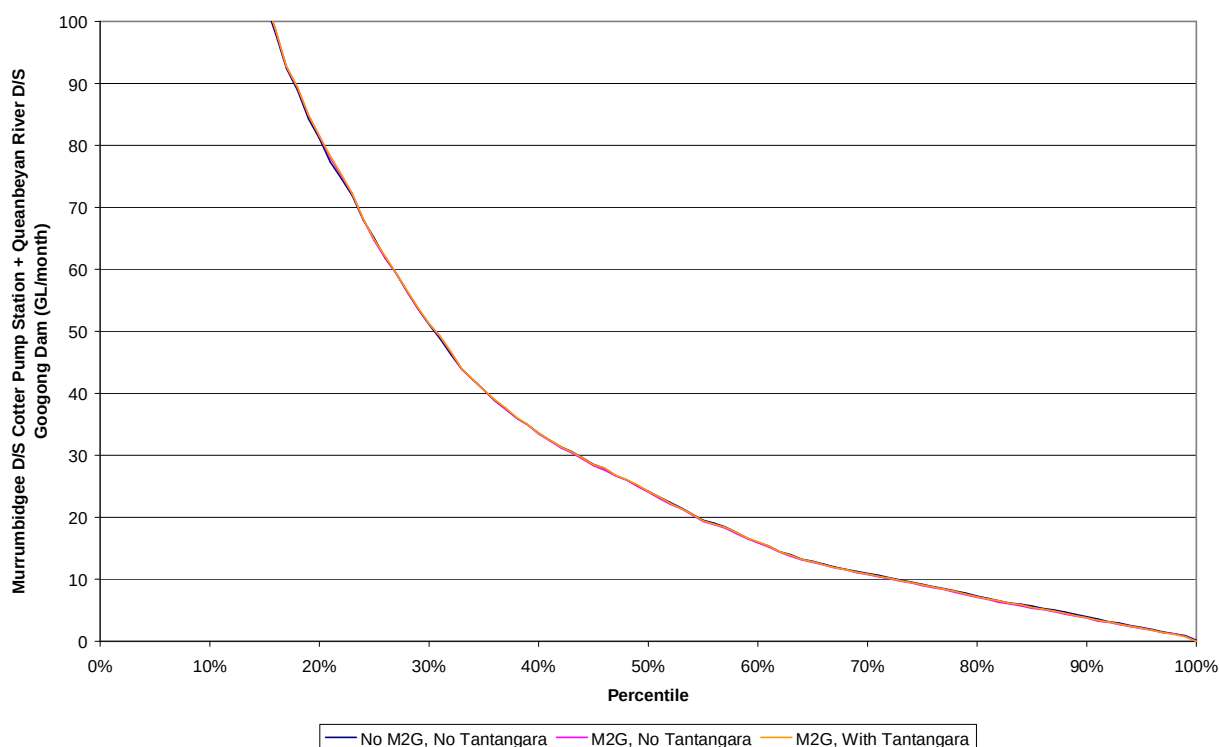


*Figure 20 – Murrumbidgee at Cotter Pump Station plus Queanbeyan River Downstream Googong Dam Combined Flow Duration Curve, Generated with Period*



#### **4.4 How will the M2G change depth and velocity?**

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##### Burra Creek

A particular Burra Creek reach was selected for depth and velocity analysis because it contains a riffle and a pool and will therefore give an indication of the range of conditions typically occurring in the creek. Figure 21 shows the location of the selected reach, 'Reach 2'.

Figure 22 shows a profile of Burra Creek elevation versus stream length. This profile shows a distinct change of slope at approximately 3 km downstream of the Burra Rd Bridge. The site at 'Reach 2' may not be representative of the higher gradient section of the creek, because the section with higher slope is likely to typically contain higher velocities and lower depths than the flatter section.



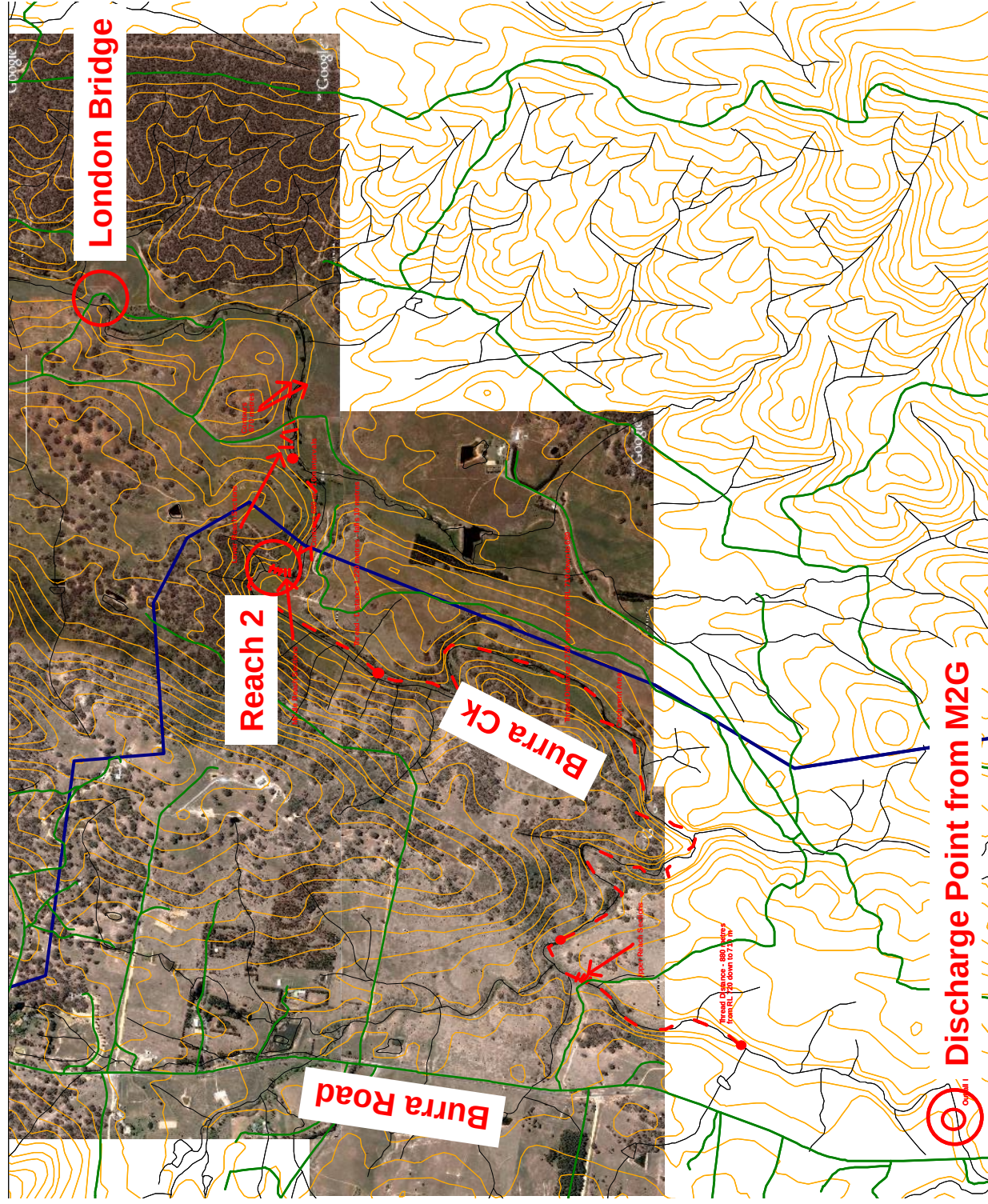


*Figure 21 – Location of Reach Selected for Analysis*



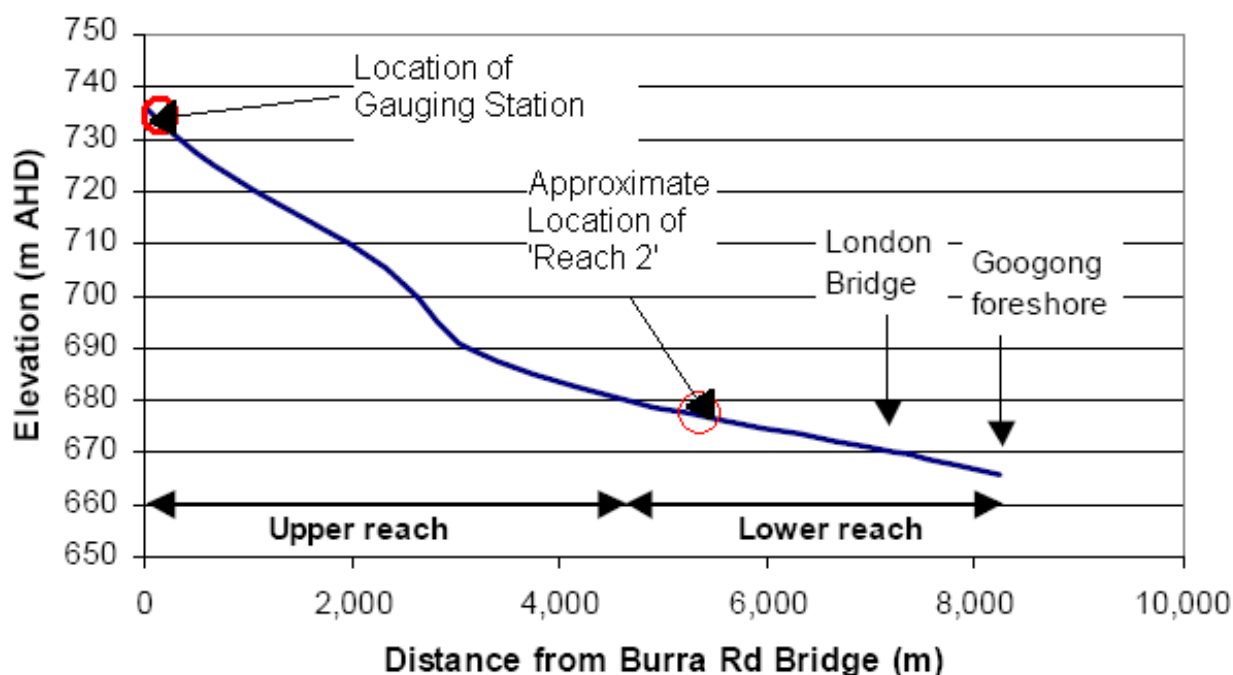


Figure 22 – Burra Creek Long Profile<sup>6</sup>

Table 10 to Table 17 show the depth and velocity for median, 5<sup>th</sup> Percentile and 95<sup>th</sup> percentile flows in a Burra Creek pool and riffle. In general the median depth and velocity is increased approximately 2.5 to 4 fold with the introduction of M2G. There tends to be a larger percentage increase when looking at flows from the last 10 years, as the natural flows in Burra Creek are lower in this scenario than the stochastic data generated flows.

Depth cumulative probability curves for Burra Creek are included as Figure 23 and Figure 24. Velocity cumulative probability curves are included below as Figure 25 and Figure 26. These show that for both depth and velocity, high levels will occur for much more of the time with M2G in place, although there are still times of low or no flow. M2G with Tantangara would result in high flows of the same magnitude for slightly more of the time than M2G without Tantangara.

<sup>6</sup> Original graph (without references to 'Reach 2' and the gauging station) reproduced from Gippel, Christopher and Nayar, Mike, *Prediction of Transmission Losses in Burra Creek*, Fluvial Systems Pty Ltd and Marsden Jacob Associates, March 2005

*Table 10 – Depth in a Burra Creek riffle (m), generated from stochastic data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.024                 | 0.089              | 275.3%   | 0.099                | 319.8%   |
| 5th Percentile  | 0.198                 | 0.466              | 135.8%   | 0.465                | 135.3%   |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |

*Table 11 – Depth in a Burra Creek riffle (m), generated from the last 10 years data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.018                 | 0.094              | 425.9%   | 0.099                | 455.4%   |
| 5th Percentile  | 0.104                 | 0.463              | 346.3%   | 0.465                | 347.9%   |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |

*Table 12 – Depth in a Burra Creek pool (m), generated from Stochastic data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.060                 | 0.220              | 269.5%   | 0.234                | 291.3%   |
| 5th Percentile  | 0.357                 | 0.650              | 82.2%    | 0.652                | 82.6%    |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |

*Table 13 – Depth in a Burra Creek pool (m), generated from the last 10 years data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.045                 | 0.227              | 403.4%   | 0.234                | 418.1%   |
| 5th Percentile  | 0.239                 | 0.648              | 170.6%   | 0.649                | 171.3%   |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |



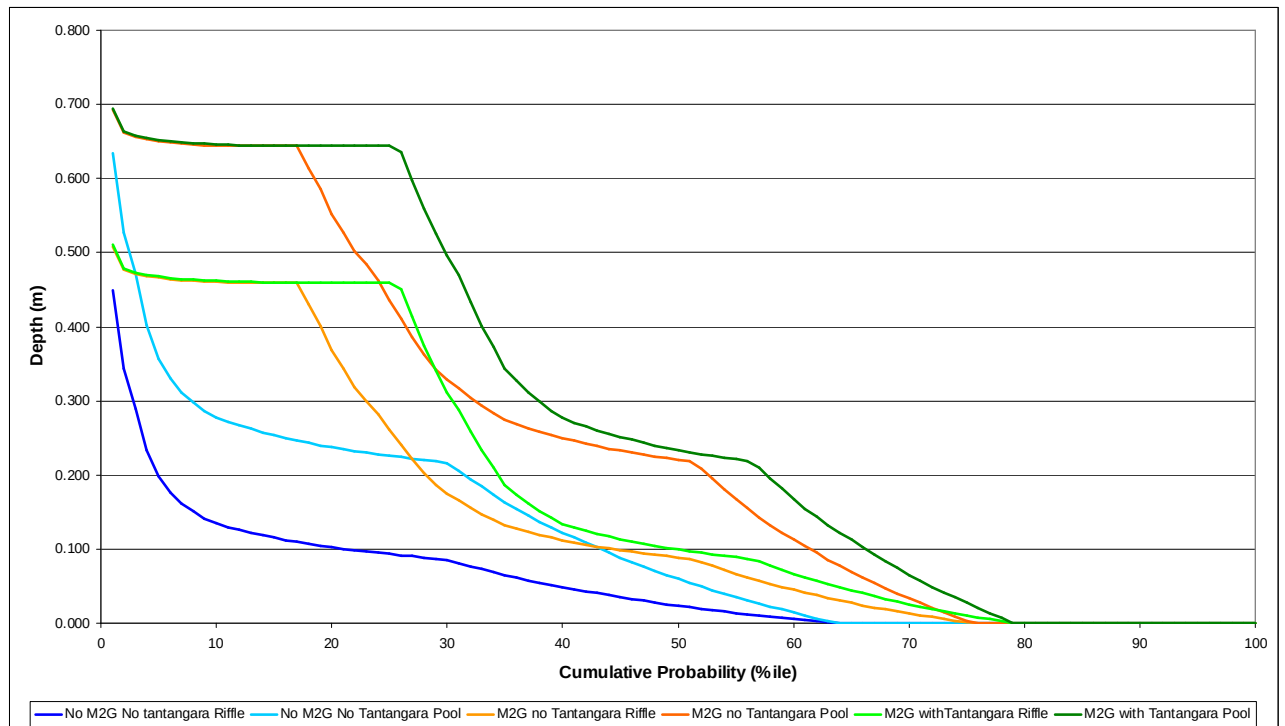


Figure 23 – Depth Cumulative Probability Curves in Burra Creek, based on Stochastic Flows

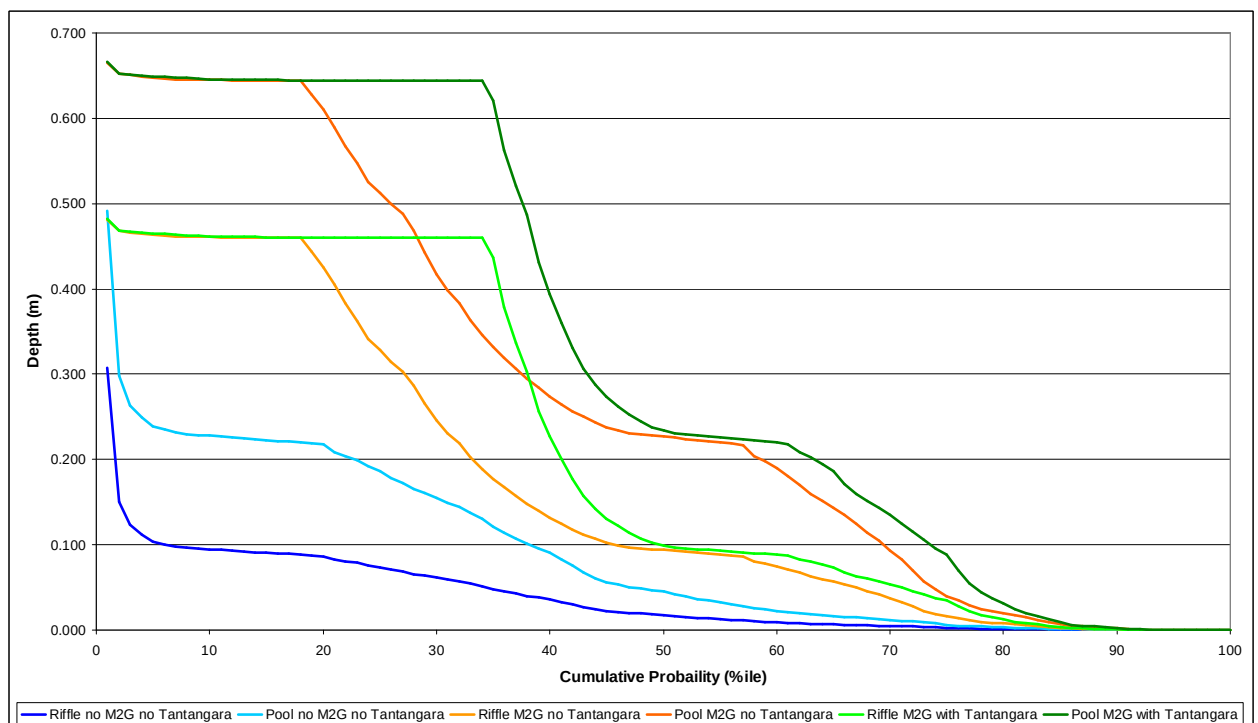


Figure 24 – Depth Cumulative Probability Curves for Burra Creek, based on last 10 years flows



*Table 14 – Velocity in a Burra Creek riffle ( $\text{ms}^{-1}$ ), Generated from Stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.124                 | 0.455              | 267.5%   | 0.472                | 281.8%   |
| 5th Percentile  | 0.640                 | 0.820              | 28.1%    | 0.821                | 28.2%    |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |

*Table 15 – Velocity in a Burra Creek riffle ( $\text{ms}^{-1}$ ), Generated from the last 10 years Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.094                 | 0.464              | 395.7%   | 0.473                | 405.4%   |
| 5th Percentile  | 0.480                 | 0.819              | 70.4%    | 0.819                | 70.6%    |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |

*Table 16 – Velocity in a Burra Creek pool ( $\text{ms}^{-1}$ ), Generated from Stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.030                 | 0.111              | 273.7%   | 0.123                | 311.7%   |
| 5th Percentile  | 0.230                 | 0.453              | 97.2%    | 0.454                | 97.5%    |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |

*Table 17 – Velocity in a Burra Creek Pool ( $\text{ms}^{-1}$ ), Generated from the last 10 years Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.023                 | 0.117              | 419.8%   | 0.123                | 445.3%   |
| 5th Percentile  | 0.128                 | 0.451              | 253.5%   | 0.452                | 254.3%   |
| 95th Percentile | 0.000                 | 0.000              | 0.0%     | 0.000                | 0.0%     |



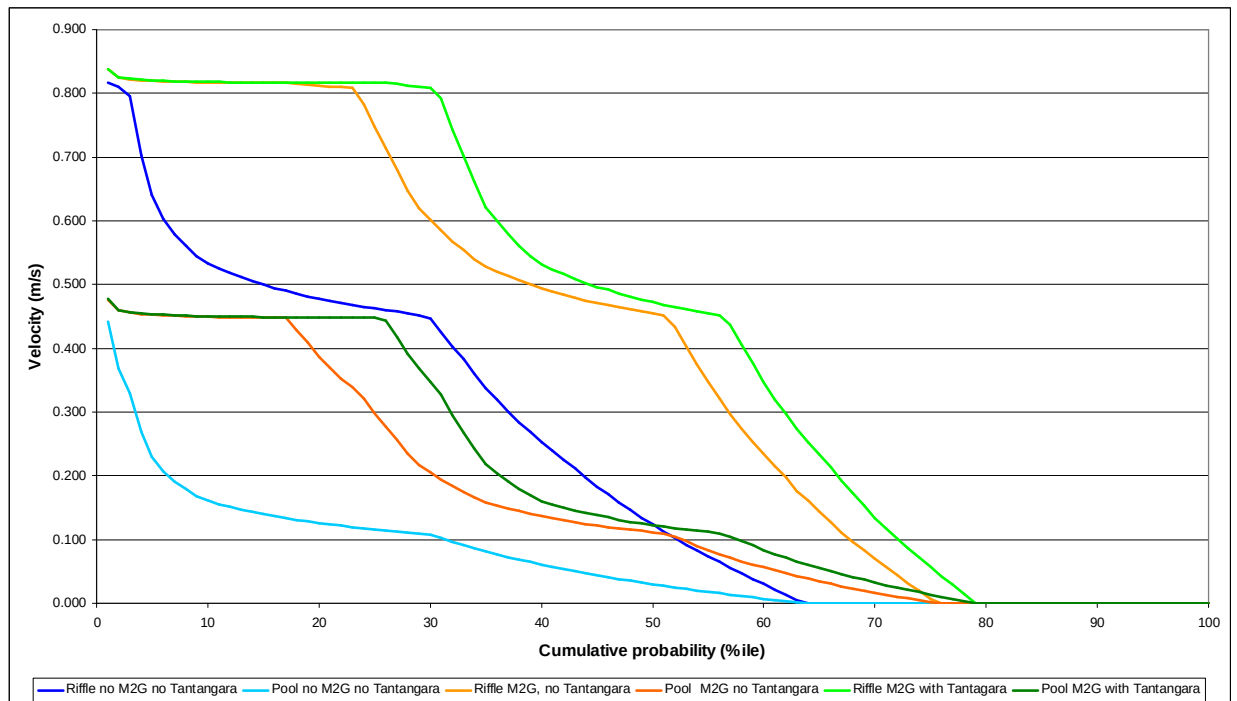


*Figure 25 – Velocity Cumulative Probability Curves for Burra Creek using Stochastic Flows*

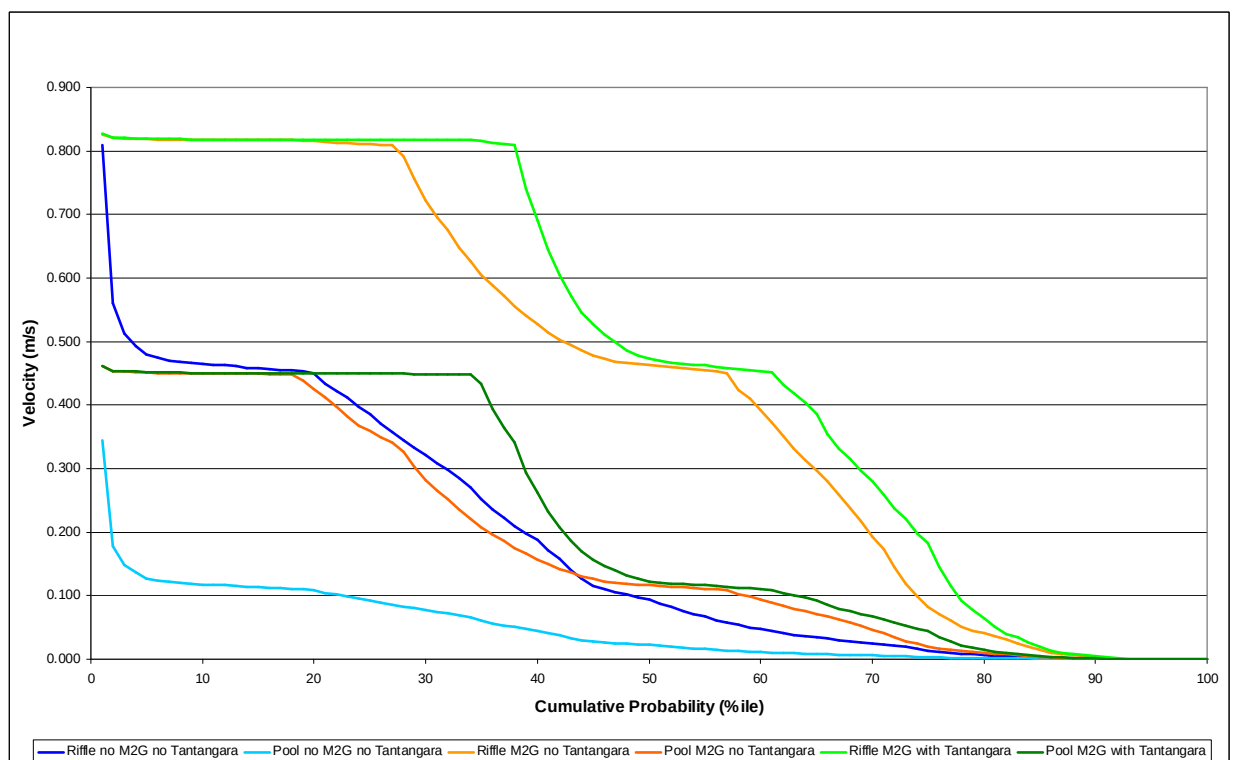


*Figure 26 – Velocity Cumulative Probability Curves for Burra Creek using 10 year Flows*



### Murrumbidgee at Angle Crossing

The flow profile over the road crossing at Angle Crossing is reproduced in Figure 27 (flow from right to left). Depth and velocity for median, 5<sup>th</sup> percentile and 95<sup>th</sup> percentile flows in the Murrumbidgee River immediately upstream and downstream of Angle Crossing are shown in Table 18 to Table 25.

In general the changes are quite small in percentage terms. An exception is in Table 20, which shows a 55% increase in velocity upstream of Angle Crossing when Tantangara is used with the last 10 years climate scenario. This is because the last 10 years median flow is quite low. While the increase is only small in absolute terms (0.04 m/s increase), this results in large percentage increase when compared with a low initial flow.

Depth cumulative probability curves are included as Figure 28 and Figure 29. Velocity cumulative probability curves are included as Figure 30 and Figure 31.

The impact of the M2G with and without Tantangara releases on the Murrumbidgee is less obvious than on Burra Creek. Upstream of Angle Crossing the depth never drops below 1m, as the road crossing acts as a weir 1 m deep. Both upstream and downstream of Angle Crossing the depths are only changed slightly by the introduction of the M2G, with or without Tantangara.

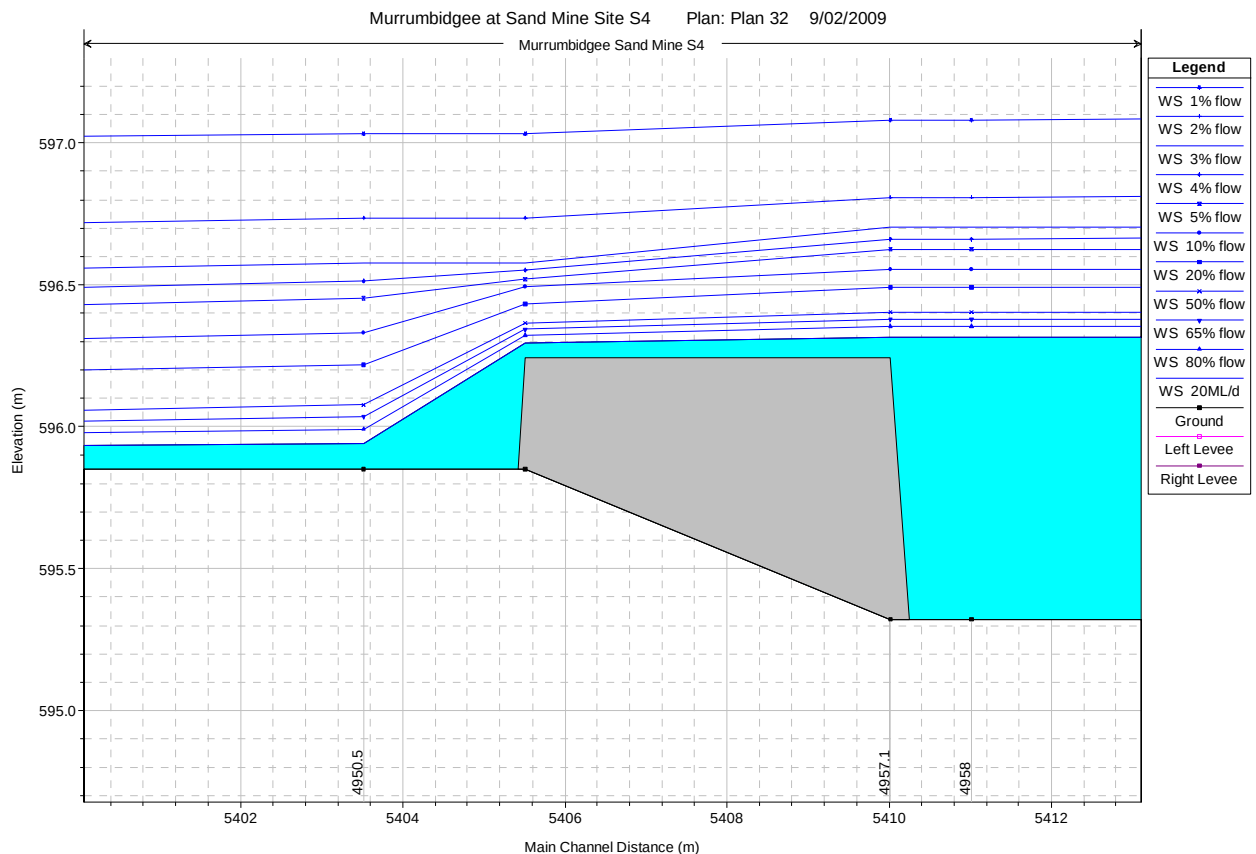


Figure 27 – Flow Profiles over Road Crossing (Percentile Values Correspond to Stochastic Data)<sup>7</sup>

<sup>7</sup> GHD (Ian Hampton), Draft Report – Computed hydraulic conditions in vicinity of Angle Crossing, February 2009



*Table 18 – Depth in the Murrumbidgee Upstream of Angle Crossing (m) from last 10 years Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 1.08                  | 1.08               | 0.0%     | 1.10                 | 2.2%     |
| 5th Percentile  | 1.21                  | 1.21               | 0.0%     | 1.21                 | 0.0%     |
| 95th Percentile | 1.00                  | 1.00               | 0.0%     | 1.01                 | 0.1%     |

*Table 19 – Depth in the Murrumbidgee Upstream of Angle Crossing (m) from stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 1.10                  | 1.10               | 0.0%     | 1.10                 | 0.3%     |
| 5th Percentile  | 1.32                  | 1.32               | 0.0%     | 1.32                 | 0.0%     |
| 95th Percentile | 1.01                  | 1.01               | 0.0%     | 1.02                 | 0.3%     |

*Table 20 – Velocity in the Murrumbidgee Upstream of Angle Crossing ( $\text{ms}^{-1}$ ) from last 10 years Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.06                  | 0.06               | 0.0%     | 0.10                 | 55.5%    |
| 5th Percentile  | 0.29                  | 0.29               | 0.0%     | 0.29                 | 0.0%     |
| 95th Percentile | 0.00                  | 0.00               | 0.0%     | 0.01                 | 32.1%    |

*Table 21 – Velocity in the Murrumbidgee Upstream of Angle Crossing ( $\text{ms}^{-1}$ ) from Stochastic Data*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.101                 | 0.101              | 0.0%     | 0.106                | 4.8%     |
| 5th Percentile  | 0.443                 | 0.443              | 0.0%     | 0.443                | 0.0%     |
| 95th Percentile | 0.013                 | 0.013              | 0.0%     | 0.016                | 26.6%    |



*Table 22 – Depth in the Murrumbidgee Downstream of Angle Crossing (m), Stochastic*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.23                  | 0.21               | -8.0%    | 0.22                 | -3.3%    |
| 5th Percentile  | 0.63                  | 0.62               | -1.5%    | 0.62                 | -0.8%    |
| 95th Percentile | 0.12                  | 0.12               | -1.8%    | 0.12                 | -1.2%    |

*Table 23 – Depth in Murrumbidgee Downstream of Angle Crossing (m), 10 year*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.19                  | 0.16               | -16.1%   | 0.18                 | -7.2%    |
| 5th Percentile  | 0.45                  | 0.43               | -4.2%    | 0.44                 | -3.7%    |
| 95th Percentile | 0.05                  | 0.05               | 0.0%     | 0.05                 | 0.0%     |

*Table 24 – Velocity in Murrumbidgee Downstream of Angle Crossing ( $\text{ms}^{-1}$ ), Stochastic*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.41                  | 0.38               | -7.2%    | 0.40                 | -3.0%    |
| 5th Percentile  | 0.89                  | 0.89               | -0.4%    | 0.89                 | -0.2%    |
| 95th Percentile | 0.19                  | 0.18               | -3.6%    | 0.18                 | -2.3%    |

*Table 25 – Velocity in Murrumbidgee Downstream of Angle Crossing ( $\text{ms}^{-1}$ ), 10 year*

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Median Flow     | 0.35                  | 0.29               | -17.4%   | 0.33                 | -6.5%    |
| 5th Percentile  | 0.75                  | 0.72               | -3.2%    | 0.72                 | -2.8%    |
| 95th Percentile | 0.08                  | 0.08               | 0.0%     | 0.08                 | 0.0%     |



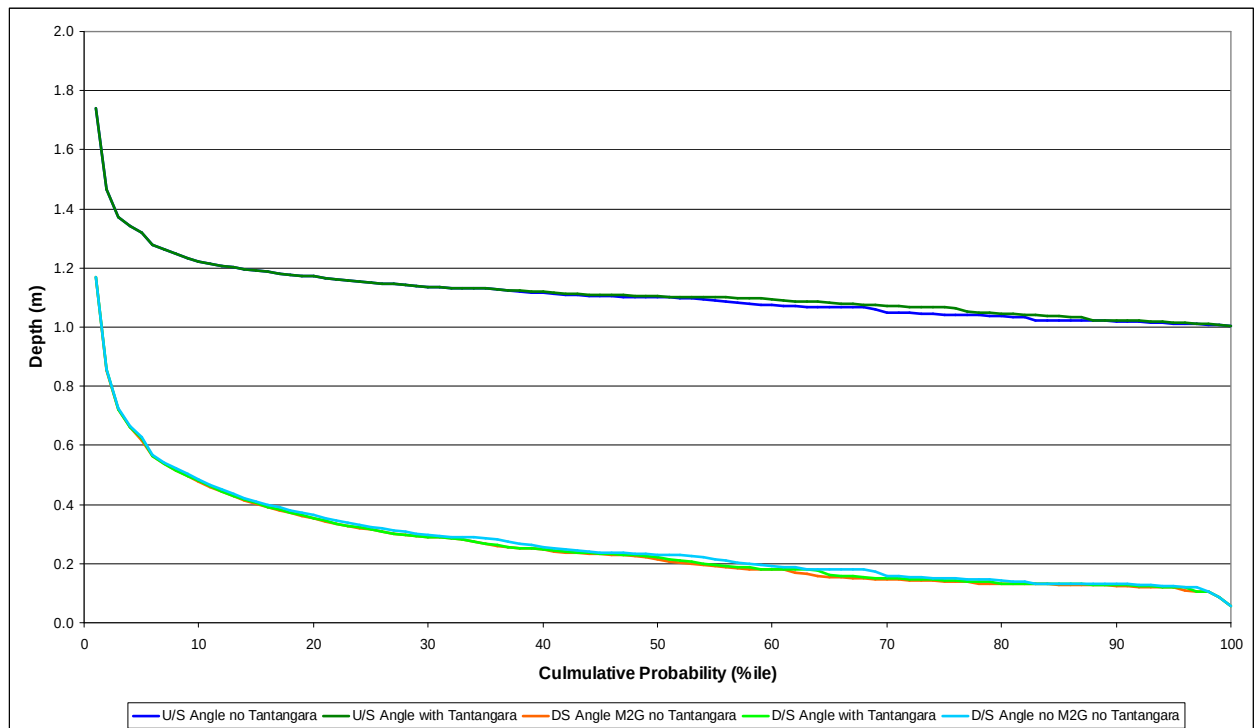


*Figure 28 – Depth Cumulative Probability Curves for the Murrumbidgee Upstream and Downstream of Angle Crossing from Stochastic Data*

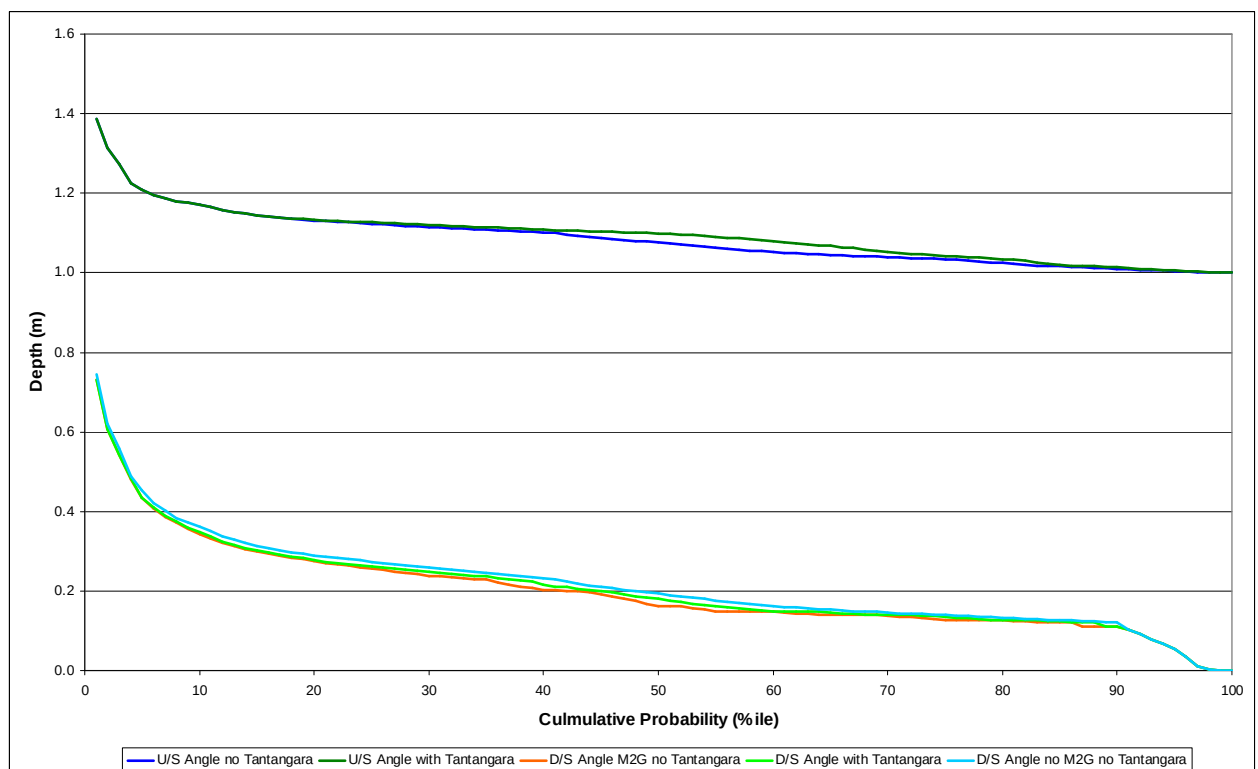


*Figure 29 – Depth Cumulative Probability Curves for the Murrumbidgee Upstream and Downstream of Angle Crossing from last 10 years Data*



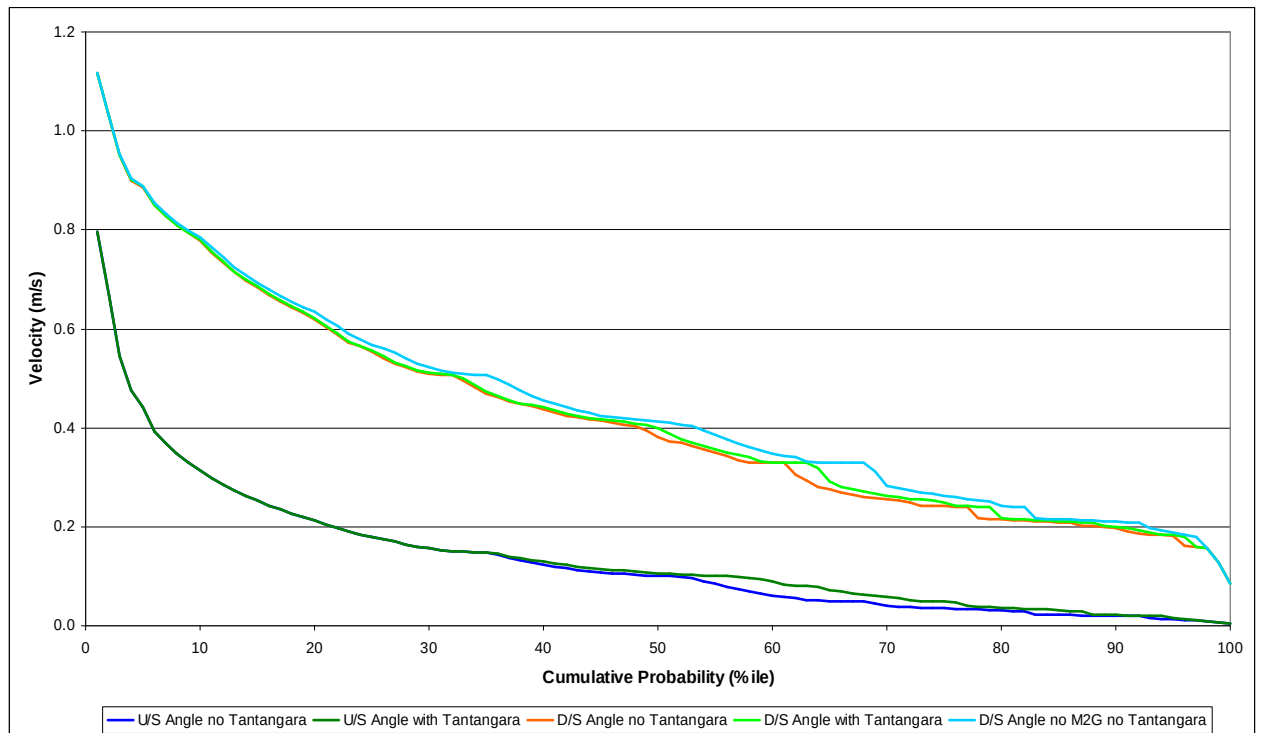


*Figure 30 – Velocity Cumulative Probability Curves for the Murrumbidgee Upstream and Downstream of Angle Crossing from Stochastic Data*

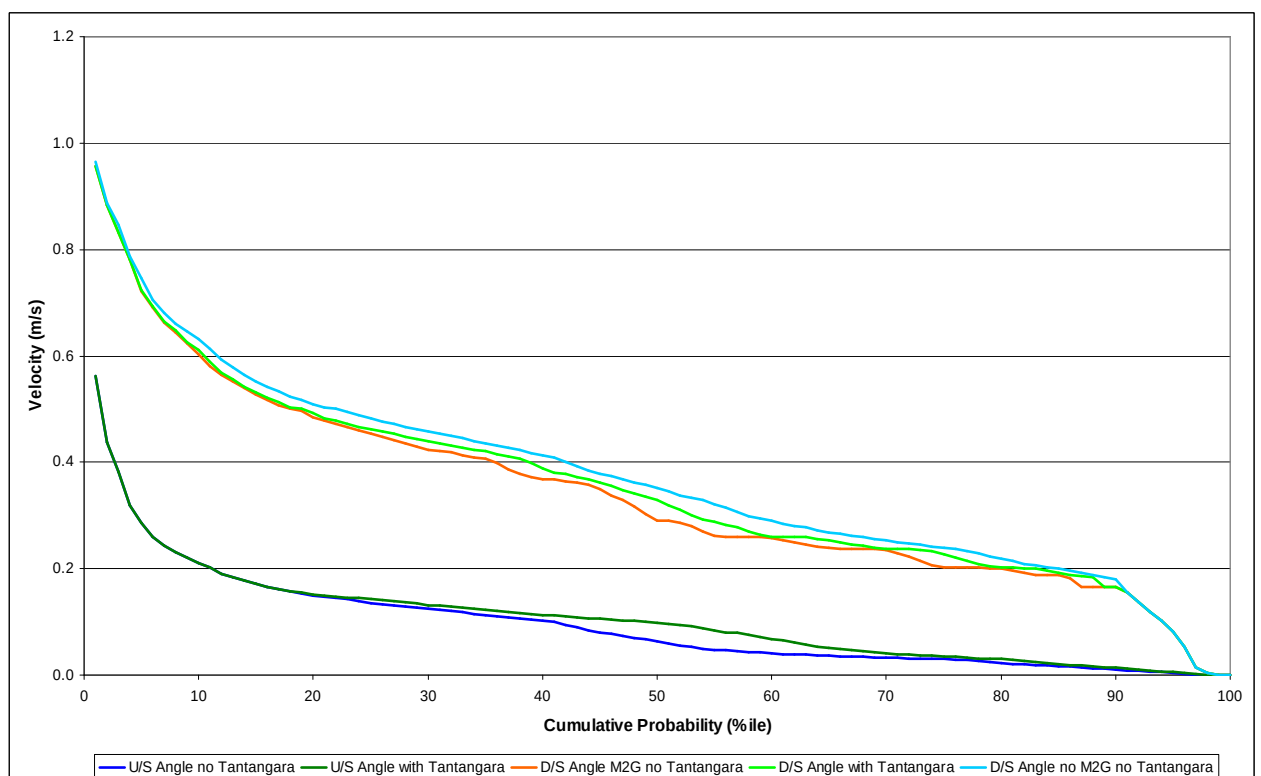


*Figure 31 – Velocity Cumulative Probability Curves for the Murrumbidgee Upstream and Downstream of Angle Crossing from the last 10 years Data*



# APPENDIX – RESPONSE TO DWE QUESTIONS

## ADVICE PAPER



(Reference Number)

WA0809\_047

|                                              |                              |  |
|----------------------------------------------|------------------------------|--|
| <b>BWA Contact:</b> Ian Ross                 | <b>Telephone:</b> 0404804783 |  |
| <b>Topic:</b> Response to Questions from DWE |                              |  |

**This advice is:**

|                                                  |                                     |
|--------------------------------------------------|-------------------------------------|
| <b>(a) Unsolicited</b>                           | <input type="checkbox"/>            |
| <b>(b) In response to a BWA question/request</b> | <input checked="" type="checkbox"/> |

### ACTEW Question

|                                                                                             |            |                            |
|---------------------------------------------------------------------------------------------|------------|----------------------------|
| <b>Question/Request from</b>                                                                | Ian Ross   | <b>Date:</b> 14th May 2009 |
| <b>Question/Request of</b>                                                                  | Tim Purves |                            |
| <b><u>Question/Request</u></b>                                                              |            |                            |
| Can you please respond to the questions from Paul Simpson (Department of Water and Energy). |            |                            |



# RESPONSE

## 1. Response to Question 1

*Detail of the model used-how it was calibrated and validated. Is there a background report describes this?*

The REALM water resources model of the ACT water supply system has been maintained and used by ActewAGL since 2004. For example, this model has been used in ACTEW's *Future Water Options* and *Water Security Program* projects. It was also used to provide input for CSIRO's Murray-Darling Basin Sustainable Yields Report.

A recent report detailing our modelling approach is included in this submission, as is a 2004 peer review of the modelling approach conducted by SKM (Paul Pretto and Brad Neal).

## 2. Response to Question 2

*To better understand why the average Murrumbidgee extractions are significantly larger than the average reduction in flows leaving the ACT the report needs to incorporate a water balance for each of the three climate scenarios (total of nine scenarios with pump and Tantangara options) including:*

1. Spills from Cotter Dam
2. Releases from Cotter Dam
3. Spills from Googong Dam
4. Releases from Googong Dam
5. Net evaporation from the Cotter Dams
6. Net evaporation from Googong Dam
7. Supply to Canberra
8. Catchment inflows to the Cotter Dams
9. Catchment inflows to Googong Dam
10. Cotter pump supply
11. Angle Crossing pump supply
12. Angle Crossing flows

**Table 26 to Table 28** provide this information. An Excel file with this information and showing some calculations will also be provided. Note that the Cotter Dam environmental base flow release is not applied in the model because this may be supplied with Murrumbidgee River water, which then returns to the Murrumbidgee.



**Table 26 – 2011-2020 Water Balance Produced Using 2030 Stochastic Climate Data**

|                            |                                                                            | Without M2G,<br>No Tantangara<br>(GL/year) | With M2G, No<br>Tantangara<br>(GL/year) | With M2G &<br>Tantangara<br>(GL/year) |
|----------------------------|----------------------------------------------------------------------------|--------------------------------------------|-----------------------------------------|---------------------------------------|
| <b>Average Inflows</b>     | <i>Corin Dam</i>                                                           | 39.8                                       | 39.8                                    | 39.8                                  |
|                            | <i>Bendora Dam (downstream Corin catchment)</i>                            | 22.9                                       | 22.9                                    | 22.9                                  |
|                            | <i>Cotter Dam (downstream Bendora catchment)</i>                           | 18.8                                       | 18.8                                    | 18.8                                  |
|                            | Total Cotter River Upstream of Cotter Dam                                  | 81.5                                       | 81.5                                    | 81.5                                  |
|                            | Queanbeyan River Upstream of Googong Dam                                   | 43.1                                       | 43.1                                    | 43.1                                  |
|                            | Murrumbidgee Upstream of Angle Crossing                                    | 173.7                                      | 173.7                                   | 173.7                                 |
|                            | Murrumbidgee Between Angle Crossing and Cotter River                       | 73.5                                       | 73.5                                    | 73.5                                  |
|                            | <b>Total Inflow</b>                                                        | <b>371.8</b>                               | <b>371.8</b>                            | <b>371.8</b>                          |
|                            |                                                                            |                                            |                                         |                                       |
| <b>Water Purchase</b>      | Release From Tantangara                                                    | 0.0                                        | 0.0                                     | 5.1                                   |
|                            | Losses Tantangara to Angle Crossing                                        | 0.0                                        | 0.0                                     | 0.7                                   |
|                            | Losses Angle Crossing to Cotter                                            | 0.0                                        | 0.0                                     | 0.7                                   |
|                            | <b>Net Tantangara Inflow</b>                                               | <b>0.0</b>                                 | <b>0.0</b>                              | <b>3.6</b>                            |
|                            |                                                                            |                                            |                                         |                                       |
| <b>Water Supply</b>        | Bendora Dam to Stromlo Treatment Plant                                     | 35.3                                       | 34.5                                    | 34.2                                  |
|                            | Cotter Dam to Stromlo Treatment Plant                                      | 8.4                                        | 5.8                                     | 4.5                                   |
|                            | Murrumbidgee at Cotter to Stromlo Treatment Plant                          | 4.7                                        | 2.6                                     | 2.4                                   |
|                            | Googong Dam to Googong Treatment Plant                                     | 22.0                                       | 26.4                                    | 28.2                                  |
|                            |                                                                            |                                            |                                         |                                       |
| <b>Catchment Transfers</b> | Murrumbidgee at Angle Crossing to Googong                                  | 0.0                                        | 7.8                                     | 10.5                                  |
|                            | Cotter to Googong Bulk Transfer                                            | 2.3                                        | 1.1                                     | 0.9                                   |
|                            |                                                                            |                                            |                                         |                                       |
|                            | <b>Total Consumption</b>                                                   | <b>68.1</b>                                | <b>68.3</b>                             | <b>68.4</b>                           |
|                            |                                                                            |                                            |                                         |                                       |
| <b>Storage Change</b>      | Corin Dam                                                                  | 0.7                                        | 0.8                                     | 0.9                                   |
|                            | Bendora Dam                                                                | 0.0                                        | 0.0                                     | 0.0                                   |
|                            | Cotter Dam                                                                 | 6.4                                        | 6.5                                     | 6.6                                   |
|                            | Googong Dam                                                                | -0.9                                       | -0.3                                    | -0.3                                  |
|                            | <b>Total Storage Increase</b>                                              | <b>6.2</b>                                 | <b>7.0</b>                              | <b>7.2</b>                            |
|                            |                                                                            |                                            |                                         |                                       |
| <b>Net Evaporation</b>     | Corin Dam                                                                  | 0.4                                        | 0.4                                     | 0.4                                   |
|                            | Bendora Dam                                                                | 0.0                                        | 0.0                                     | 0.0                                   |
|                            | Cotter Dam                                                                 | 0.9                                        | 0.9                                     | 0.9                                   |
|                            | Googong Dam                                                                | 4.5                                        | 4.7                                     | 4.8                                   |
|                            | <b>Total Net Evaporation</b>                                               | <b>5.7</b>                                 | <b>5.9</b>                              | <b>6.1</b>                            |
|                            |                                                                            |                                            |                                         |                                       |
| <b>Outflow</b>             | <i>Spill from Cotter Dam</i>                                               | 29.1                                       | 32.2                                    | 33.7                                  |
|                            | <i>Flushing Releases from Cotter Dam</i>                                   | 0.3                                        | 0.3                                     | 0.3                                   |
|                            | <i>Total Downstream of Cotter Dam</i>                                      | 29.5                                       | 32.5                                    | 34.1                                  |
|                            | Murrumbidgee Downstream of Cotter Pump Station                             | 272.0                                      | 269.4                                   | 272.1                                 |
|                            | <i>Spill from Googong Dam</i>                                              | 16.2                                       | 17.7                                    | 18.2                                  |
|                            | <i>Releases from Googong Dam</i>                                           | 3.5                                        | 3.5                                     | 3.5                                   |
|                            | Total Downstream of Googong Dam                                            | 19.7                                       | 21.2                                    | 21.7                                  |
|                            | <b>Total Outflow</b>                                                       | <b>291.8</b>                               | <b>290.6</b>                            | <b>293.8</b>                          |
|                            |                                                                            |                                            |                                         |                                       |
|                            | <b>Inflow - Consumption - Storage Increase - Net Evaporation - Outflow</b> | <b>0.0</b>                                 | <b>0.0</b>                              | <b>0.0</b>                            |



**Table 27 – 2011-2020 Water Balance Produced Using Last 10 Years Climate Data**

|                            |                                                                            | Without M2G,<br>No Tantangara<br>(GL/year) | With M2G,<br>No<br>Tantangara<br>(GL/year) | With M2G &<br>Tantangara<br>(GL/year) |
|----------------------------|----------------------------------------------------------------------------|--------------------------------------------|--------------------------------------------|---------------------------------------|
| <b>Average Inflows</b>     | <i>Corin Dam</i>                                                           | 37.9                                       | 37.9                                       | 37.9                                  |
|                            | <i>Bendora Dam (downstream Corin catchment)</i>                            | 18.8                                       | 18.8                                       | 18.8                                  |
|                            | <i>Cotter Dam (downstream Bendora catchment)</i>                           | 17.6                                       | 17.6                                       | 17.6                                  |
|                            | Total Cotter River Upstream of Cotter Dam                                  | 74.3                                       | 74.3                                       | 74.3                                  |
|                            | Queanbeyan River Upstream of Googong Dam                                   | 18.5                                       | 18.5                                       | 18.5                                  |
|                            | Murrumbidgee Upstream of Angle Crossing                                    | 101.7                                      | 101.7                                      | 101.7                                 |
|                            | Murrumbidgee Between Angle Crossing and Cotter River                       | 46.6                                       | 46.6                                       | 46.6                                  |
|                            | <b>Total Inflow</b>                                                        | <b>241.2</b>                               | <b>241.2</b>                               | <b>241.2</b>                          |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Water Purchase</b>      | Release From Tantangara                                                    | 0.0                                        | 0.0                                        | 6.9                                   |
|                            | Losses Tantangara to Angle Crossing                                        | 0.0                                        | 0.0                                        | 0.8                                   |
|                            | Losses Angle Crossing to Cotter                                            | 0.0                                        | 0.0                                        | 0.7                                   |
|                            | <b>Net Tantangara Inflow</b>                                               | <b>0.0</b>                                 | <b>0.0</b>                                 | <b>5.4</b>                            |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Water Supply</b>        | Bendora Dam to Stromlo Treatment Plant                                     | 34.6                                       | 33.2                                       | 32.9                                  |
|                            | Cotter Dam to Stromlo Treatment Plant                                      | 14.3                                       | 8.5                                        | 5.4                                   |
|                            | Murrumbidgee at Cotter to Stromlo Treatment Plant                          | 4.6                                        | 2.8                                        | 2.3                                   |
|                            | Googong Dam to Googong Treatment Plant                                     | 15.3                                       | 23.0                                       | 26.5                                  |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Catchment Transfers</b> | Murrumbidgee at Angle Crossing to Googong                                  | 0.0                                        | 10.2                                       | 14.0                                  |
|                            | Cotter to Googong Bulk Transfer                                            | 3.0                                        | 1.7                                        | 1.2                                   |
|                            |                                                                            |                                            |                                            |                                       |
|                            | <b>Total Consumption</b>                                                   | <b>65.8</b>                                | <b>65.8</b>                                | <b>65.9</b>                           |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Storage Change</b>      | Corin Dam                                                                  | 0.5                                        | 0.9                                        | 1.0                                   |
|                            | Bendora Dam                                                                | 0.0                                        | 0.0                                        | 0.0                                   |
|                            | Cotter Dam                                                                 | 6.4                                        | 6.6                                        | 6.7                                   |
|                            | Googong Dam                                                                | -0.8                                       | 0.1                                        | -0.2                                  |
|                            | <b>Total Storage Increase</b>                                              | <b>6.1</b>                                 | <b>7.6</b>                                 | <b>7.6</b>                            |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Net Evaporation</b>     | Corin Dam                                                                  | 0.2                                        | 0.2                                        | 0.2                                   |
|                            | Bendora Dam                                                                | 0.0                                        | 0.0                                        | 0.0                                   |
|                            | Cotter Dam                                                                 | 1.1                                        | 1.1                                        | 1.2                                   |
|                            | Googong Dam                                                                | 3.4                                        | 3.6                                        | 3.7                                   |
|                            | <b>Total Net Evaporation</b>                                               | <b>4.8</b>                                 | <b>5.1</b>                                 | <b>5.1</b>                            |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Outflow</b>             | <i>Spill from Cotter Dam</i>                                               | 16.8                                       | 23.4                                       | 26.5                                  |
|                            | <i>Flushing Releases from Cotter Dam</i>                                   | 0.3                                        | 0.3                                        | 0.3                                   |
|                            | <i>Total Downstream of Cotter Dam</i>                                      | 17.1                                       | 23.7                                       | 26.8                                  |
|                            | Murrumbidgee Downstream of Cotter Pump Station                             | 160.8                                      | 159.0                                      | 164.2                                 |
|                            | <i>Spill from Googong Dam</i>                                              | 0.0                                        | 0.0                                        | 0.0                                   |
|                            | <i>Releases from Googong Dam</i>                                           | 3.7                                        | 3.7                                        | 3.7                                   |
|                            | Total Downstream of Googong Dam                                            | 3.7                                        | 3.7                                        | 3.7                                   |
|                            | <b>Total Outflow</b>                                                       | <b>164.5</b>                               | <b>162.7</b>                               | <b>167.9</b>                          |
|                            |                                                                            |                                            |                                            |                                       |
|                            | <b>Inflow - Consumption - Storage Increase - Net Evaporation - Outflow</b> | <b>0.0</b>                                 | <b>0.0</b>                                 | <b>0.0</b>                            |



**Table 28 – 2011-2020 Water Balance Produced Using 1871 to Present Historical Data**

|                            |                                                                            | Without M2G,<br>No Tantangara<br>(GL/year) | With M2G,<br>No<br>Tantangara<br>(GL/year) | With M2G &<br>Tantangara<br>(GL/year) |
|----------------------------|----------------------------------------------------------------------------|--------------------------------------------|--------------------------------------------|---------------------------------------|
| <b>Average Inflows</b>     | <i>Corin Dam</i>                                                           | 58.8                                       | 58.8                                       | 58.8                                  |
|                            | <i>Bendora Dam (downstream Corin catchment)</i>                            | 38.0                                       | 38.0                                       | 38.0                                  |
|                            | <i>Cotter Dam (downstream Bendora catchment)</i>                           | 39.2                                       | 39.2                                       | 39.2                                  |
|                            | Total Cotter River Upstream of Cotter Dam                                  | 136.0                                      | 136.0                                      | 136.0                                 |
|                            | Queanbeyan River Upstream of Googong Dam                                   | 91.3                                       | 91.3                                       | 91.3                                  |
|                            | Murrumbidgee Upstream of Angle Crossing                                    | 375.5                                      | 375.5                                      | 375.5                                 |
|                            | Murrumbidgee Between Angle Crossing and Cotter River                       | 172.3                                      | 172.3                                      | 172.3                                 |
|                            | <b>Total Inflow</b>                                                        | <b>775.2</b>                               | <b>775.2</b>                               | <b>775.2</b>                          |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Water Purchase</b>      | Release From Tantangara                                                    | 0.0                                        | 0.0                                        | 1.6                                   |
|                            | Losses Tantangara to Angle Crossing                                        | 0.0                                        | 0.0                                        | 0.2                                   |
|                            | Losses Angle Crossing to Cotter                                            | 0.0                                        | 0.0                                        | 0.2                                   |
|                            | <b>Net Tantangara Inflow</b>                                               | <b>0.0</b>                                 | <b>0.0</b>                                 | <b>1.2</b>                            |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Water Supply</b>        | Bendora Dam to Stromlo Treatment Plant                                     | 41.6                                       | 41.2                                       | 41.1                                  |
|                            | Cotter Dam to Stromlo Treatment Plant                                      | 1.8                                        | 1.2                                        | 0.7                                   |
|                            | Murrumbidgee at Cotter to Stromlo Treatment Plant                          | 0.5                                        | 0.3                                        | 0.3                                   |
|                            | Googong Dam to Googong Treatment Plant                                     | 22.3                                       | 23.1                                       | 23.6                                  |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Catchment Transfers</b> | Murrumbidgee at Angle Crossing to Googong                                  | 0.0                                        | 2.4                                        | 3.2                                   |
|                            | Cotter to Googong Bulk Transfer                                            | 0.7                                        | 0.3                                        | 0.2                                   |
|                            |                                                                            |                                            |                                            |                                       |
|                            | <b>Total Consumption</b>                                                   | <b>65.5</b>                                | <b>65.5</b>                                | <b>65.5</b>                           |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Storage Change</b>      | Corin Dam                                                                  | 0.8                                        | 0.9                                        | 0.9                                   |
|                            | Bendora Dam                                                                | 0.0                                        | 0.0                                        | 0.0                                   |
|                            | Cotter Dam                                                                 | 6.7                                        | 6.8                                        | 6.8                                   |
|                            | Googong Dam                                                                | -0.3                                       | -0.1                                       | -0.2                                  |
|                            | <b>Total Storage Increase</b>                                              | <b>7.4</b>                                 | <b>7.5</b>                                 | <b>7.5</b>                            |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Net Evaporation</b>     | Corin Dam                                                                  | -0.2                                       | -0.2                                       | -0.2                                  |
|                            | Bendora Dam                                                                | -0.2                                       | -0.2                                       | -0.2                                  |
|                            | Cotter Dam                                                                 | 0.4                                        | 0.4                                        | 0.4                                   |
|                            | Googong Dam                                                                | 3.1                                        | 3.1                                        | 3.2                                   |
|                            | <b>Total Net Evaporation</b>                                               | <b>3.1</b>                                 | <b>3.1</b>                                 | <b>3.1</b>                            |
|                            |                                                                            |                                            |                                            |                                       |
| <b>Outflow</b>             | <i>Spill from Cotter Dam</i>                                               | 84.6                                       | 85.6                                       | 86.1                                  |
|                            | <i>Flushing Releases from Cotter Dam</i>                                   | 0.4                                        | 0.4                                        | 0.4                                   |
|                            | <i>Total Downstream of Cotter Dam</i>                                      | 85.0                                       | 86.0                                       | 86.5                                  |
|                            | Murrumbidgee Downstream of Cotter Pump Station                             | 632.3                                      | 631.1                                      | 632.1                                 |
|                            | <i>Spill from Googong Dam</i>                                              | 62.7                                       | 63.8                                       | 64.0                                  |
|                            | <i>Releases from Googong Dam</i>                                           | 4.1                                        | 4.1                                        | 4.1                                   |
|                            | Total Downstream of Googong Dam                                            | 66.8                                       | 67.9                                       | 68.1                                  |
|                            | <b>Total Outflow</b>                                                       | <b>699.2</b>                               | <b>699.0</b>                               | <b>700.2</b>                          |
|                            |                                                                            |                                            |                                            |                                       |
|                            | <b>Inflow - Consumption - Storage Increase - Net Evaporation - Outflow</b> | <b>0.0</b>                                 | <b>0.0</b>                                 | <b>0.0</b>                            |



### 3. Response to Question 3

*Explain how the stochastic inflow sequences were derived.*

ActewAGL engaged SKM to provide 10 000 years of cross-correlated stochastically generated rainfall and evaporation data for six sites in the ACT. This dataset maintains the properties of the observed ACT rainfall. Please see the attached report *Update of Water Resources Strategy for Canberra and Queanbeyan* (SKM, 2004) for details of this process.

The rainfall and evaporation data were then adjusted using climate change forecasts for the ACT produced by CSIRO<sup>8</sup>. **Table 29** shows the adjustments used in modelling in the ‘Modelled’ columns. These adjustments were deliberately applied in all data to produce a step change to ‘2030 climate’.

**Table 29 – Predicted, Modelled and Observed Climate Change**

| Season | Change in Rainfall   |                     |          |                     | Change in Evaporation |                     |          |                     |
|--------|----------------------|---------------------|----------|---------------------|-----------------------|---------------------|----------|---------------------|
|        | Predicted Worst Case | Predicted Best Case | Modelled | Observed Since 2000 | Predicted Worst Case  | Predicted Best Case | Modelled | Observed Since 2000 |
| Summer | -9%                  | 12%                 | -8.9%    | -4.2%               | 11.0%                 | 0.5%                | 8.7%     | 1.2%                |
| Autumn | -5%                  | 5%                  | -4.9%    | -39.6%              | 10.8%                 | 0.8%                | 8.5%     | 5.2%                |
| Winter | -11%                 | 2%                  | -10.9%   | -4.7%               | 12.8%                 | 2.2%                | 10.5%    | 3.7%                |
| Spring | -11%                 | 0%                  | -10.9%   | -9.4%               | 12.0%                 | 2.1%                | 9.7%     | 6.5%                |
| Annual | -9%                  | 2%                  | -9.0%    | -13.6%              | 9.1%                  | 1.4%                | 9.1%     | 4.6%                |

The rainfall and evaporation data are then converted into inflow using rainfall-runoff models for each catchment that have been calibrated and validated using observed data.

Stochastic climate data for the Murrumbidgee have not been produced to date. Consequently, Murrumbidgee flow data have been generated using correlations in the observed data with the neighbouring Gudgenby catchment.

### 4. Response to Question 4

*The climate change scenario needs to be explained: which emission scenario, which GCM, single or ensemble, downscaling, etc.*

The climate change adjustments used in the modelling are shown in **Table 29**. These forecasts were produced by CSIRO in 2003, and ActewAGL is in the process of updating this forecast. The 2003 report used 13 climate models to determine climate change for the ACT in 2030 and 2070. ActewAGL applied the worst annual outcome from the models when generating rainfall and evaporation. Downscaling was not applied in this forecast, but will be incorporated in ActewAGL’s revised climate change predictions.

<sup>8</sup> Bates et al., *Climate Change Projections for the Australian Capital Territory*, Consultancy for ACT Electricity and Water, CSIRO Land and Water, October 2003



## 5. Response to Question 5

*The providence of the Angle Crossing flows is not mentioned; where did they come from, how were they adjusted for future climate?*

The Murrumbidgee River Below Lobbs Hole Creek (410761) gauging station has been used to estimate Angle Crossing flow. There are no major tributary inflows between Angle Crossing and this site, so it is assumed that there is no change in flow. As described in the responses to questions 3 and 4, climate change is applied to the stochastic data to produce climate change inflows for water supply catchments. A correlation with the Gudgenby River, generated using observed data, is then used to produce Murrumbidgee climate change data.

## 6. Response to Question 6

*State assumptions about water restrictions and population levels for generating water demands.*

The model applies water restrictions on the basis of system storage and time of year. Restrictions are also lifted at a higher storage than they are introduced. **Table 30** shows these triggers.

The model reduces demand by a different factor in each stage of restrictions. These factors have been determined using observed data, or estimated in line with target reductions for Stages 4 and 5. A certain proportion of the demand is assumed to be constant and unaffected by restrictions.

**Table 30 – Storage Triggers for Water Restrictions, Expressed as a Percentage of Existing Storage (Total 207 GL)**

|                  | Trigger for Introducing |         |         |         |         | Trigger for Lifting |         |         |         |         |
|------------------|-------------------------|---------|---------|---------|---------|---------------------|---------|---------|---------|---------|
|                  | Stage 1                 | Stage 2 | Stage 3 | Stage 4 | Stage 5 | Stage 1             | Stage 2 | Stage 3 | Stage 4 | Stage 5 |
| <b>January</b>   | 52%                     | 41%     | 35%     | 30%     | 20%     | 78%                 | 66%     | 48%     | 40%     | 30%     |
| <b>February</b>  | 49%                     | 39%     | 34%     | 30%     | 20%     | 75%                 | 63%     | 47%     | 39%     | 30%     |
| <b>March</b>     | 47%                     | 38%     | 33%     | 30%     | 20%     | 73%                 | 61%     | 46%     | 39%     | 30%     |
| <b>April</b>     | 46%                     | 36%     | 33%     | 30%     | 20%     | 69%                 | 58%     | 45%     | 38%     | 30%     |
| <b>May</b>       | 45%                     | 35%     | 33%     | 30%     | 20%     | 68%                 | 57%     | 45%     | 38%     | 30%     |
| <b>June</b>      | 44%                     | 35%     | 34%     | 31%     | 20%     | 67%                 | 56%     | 44%     | 38%     | 30%     |
| <b>July</b>      | 47%                     | 38%     | 34%     | 31%     | 20%     | 69%                 | 58%     | 44%     | 38%     | 30%     |
| <b>August</b>    | 50%                     | 40%     | 35%     | 32%     | 20%     | 72%                 | 60%     | 46%     | 38%     | 30%     |
| <b>September</b> | 52%                     | 42%     | 36%     | 32%     | 20%     | 74%                 | 62%     | 47%     | 39%     | 30%     |
| <b>October</b>   | 55%                     | 44%     | 37%     | 32%     | 20%     | 77%                 | 63%     | 48%     | 40%     | 30%     |
| <b>November</b>  | 58%                     | 47%     | 38%     | 33%     | 20%     | 80%                 | 66%     | 48%     | 40%     | 30%     |
| <b>December</b>  | 55%                     | 44%     | 36%     | 31%     | 20%     | 79%                 | 66%     | 47%     | 39%     | 30%     |

The ABS high population forecast for the ACT has been used to generate demand. An allowance has also been made for future supply to additional surrounding areas of regional NSW, such as Yass. **Table 31** shows the water supply population used in the modelling.

Demand is also reduced according to the demand reduction targets specified by the ACT Government. This applies a 25% demand reduction by 2023, relative to 1990s/early 2000s consumption levels. The reduction is applied linearly from 8% in 2005 to 25% in 2023.



**Table 31 – Modelled Water Supply Population**

| Year | Modelled Water Supply Population |
|------|----------------------------------|
| 2009 | 389243                           |
| 2010 | 396034                           |
| 2011 | 402826                           |
| 2012 | 409840                           |
| 2013 | 416855                           |
| 2014 | 423869                           |
| 2015 | 437573                           |
| 2016 | 444918                           |
| 2017 | 452490                           |
| 2018 | 459949                           |
| 2019 | 467633                           |
| 2020 | 475318                           |

## 7. Response to Question 7

*The explanation of the environmental flows needs to be expanded as the Licence to Take Water appears to be a not readily available document, so the explanation needs to be independent of it.*

The following environmental flow rules (**Table 32**, **Table 33** and **Table 34**) have been applied in the model. These are taken from the *2006 Environmental Flow Guidelines* unless these have been superseded by the *Licence to Take Water*. The flow volume for the Bendora Dam pool release differs from the Licence because physical constraints prevent release of more than 300 ML/day.

**Table 32 – Modelled Environmental Base Flow Release**

|                                      | No Water Restrictions                                                                             | Stage 1 Water Restrictions                                                                                                                             | Stage 2 and Above Water Restrictions                                                              |
|--------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Below Corin Dam                      | Maintain 75% of the 80th percentile of the monthly natural inflow, or inflow, whichever is less   | Maintain a flow of 40 ML/day or 75% of the 80 <sup>th</sup> percentile of the monthly natural inflow, or natural inflow whichever is lesser volume     | Maintain an average of 20 ML/day                                                                  |
| Below Bendora Dam                    | Maintain 75% of the 80th percentile of the monthly natural inflow, or inflow, whichever is less   | Maintain a flow of 40 ML/day or 75% of the 80 <sup>th</sup> percentile of the monthly natural inflow, or natural inflow whichever is the lesser volume | Maintain an average of 20 ML/day                                                                  |
| Below Cotter Dam                     | Not applied in the model because this may be supplied using recirculation of Murrumbidgee water   | Not applied in the model because this may be supplied using recirculation of Murrumbidgee water                                                        | Not applied in the model because this may be supplied using recirculation of Murrumbidgee water   |
| Below Googong Dam                    | Maintain an average flow of 10 ML/day or natural inflow which ever is the lesser volume           | Maintain an average flow of 10 ML/day or natural inflow which ever is the lesser volume                                                                | Maintain an average of 10 ML/day or inflow which ever is the lesser volume                        |
| Murrumbidgee River at Angle Crossing | Protect all flow up to the 80th Percentile (November to May) or 90th Percentile (June to October) | Protect all flow up to the 80th Percentile (November to May) or 90th Percentile (June to October)                                                      | Protect all flow up to the 80th Percentile (November to May) or 90th Percentile (June to October) |
| Murrumbidgee River at Cotter         | Protect all flow up to the 80th Percentile (November to May) or 90th Percentile (June to October) | Protect all flow up to 20 ML/day from abstraction                                                                                                      | Protect all flow up to 20 ML/day from abstraction                                                 |



**Table 33 – Modelled Environmental Riffle Flow Release**

|                                      | No Water Restrictions                                               | Stage 1 Water Restrictions                                          | Stage 2 and Above Water Restrictions                                |
|--------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------|
| Below Corin Dam                      | Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months | Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months | Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months |
| Below Bendora Dam                    | Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months | Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months | Maintain a flow of 150 ML/Day for 3 consecutive days every 2 months |
| Below Cotter Dam                     | Maintain a flow of 100 ML/Day for 1 day every 2 months              | Nil                                                                 | Nil                                                                 |
| Below Googong Dam                    | Maintain a flow of 100 ML/Day for 1 day every 2 months              | Maintain a flow of 100 ML/Day for 1 day every 12 months             | Maintain a flow of 100 ML/Day for 1 day every 12 months             |
| Murrumbidgee River at Angle Crossing | Nil                                                                 | Nil                                                                 | Nil                                                                 |
| Murrumbidgee River at Cotter         | Nil                                                                 | Nil                                                                 | Nil                                                                 |

**Table 34 – Modelled Environmental Pool Flow Release**

|                                      | No Water Restrictions                                                                                          | Stage 1 Water Restrictions                                                                                     | Stage 2 and Above Water Restrictions                                                                           |
|--------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| Below Corin Dam                      | Maintain a flow of 550 ML/day for 2 consecutive days between mid-July and mid- October (modelled as September) | Maintain a flow of 550 ML/day for 2 consecutive days between mid-July and mid- October (modelled as September) | Maintain a flow of 550 ML/day for 2 consecutive days between mid-July and mid- October (modelled as September) |
| Below Bendora Dam                    | Maintain a flow of 300 ML/day for 2 consecutive days between mid-July and mid- October (modelled as September) | Maintain a flow of 300 ML/day for 2 consecutive days between mid-July and mid- October (modelled as September) | Maintain a flow of 300 ML/day for 2 consecutive days between mid-July and mid- October (modelled as September) |
| Below Cotter Dam                     | Nil                                                                                                            | Nil                                                                                                            | Nil                                                                                                            |
| Below Googong Dam                    | Nil                                                                                                            | Nil                                                                                                            | Nil                                                                                                            |
| Murrumbidgee River at Angle Crossing | Nil                                                                                                            | Nil                                                                                                            | Nil                                                                                                            |
| Murrumbidgee River at Cotter         | Nil                                                                                                            | Nil                                                                                                            | Nil                                                                                                            |

## 8. Response to Question 8

*Explain how the transmission costs between Tantangara and the ACT were estimated.*

Transmission losses between Tantangara and the ACT have been modelled as 10% of the release volume from Tantangara. This modelling assumption was determined by the BWA.

## 9. Response to Question 9

*The plateau in the flow duration curve at around 10 000 ML/month in Figure 14 needs an explanation.*

The curve is reproduced below in **Figure 32**. The plateau around 10 000 ML/month is present in the initial flow data and is not generated by the infrastructure or releases from Tantangara Dam.



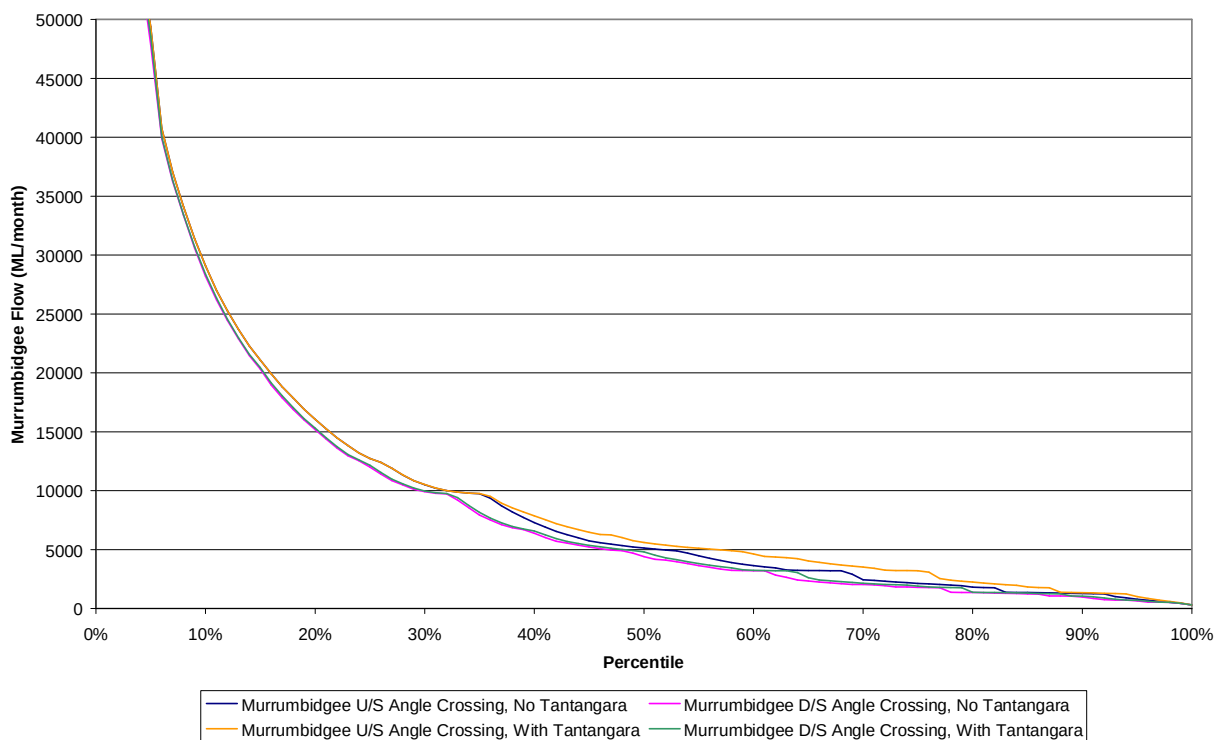


**Figure 32 – Murrumbidgee at Angle Crossing Flow Duration Curve, Generated with Stochastic Data**

As noted above, Murrumbidgee River flow is generated using a correlation with the Gudgenby catchment. The plateau around 10 000 ML/month is an artefact of the particular correlation used, which converts a range of flows to approximately 10 000 ML/month. In this flow quantile the correlation is quite poor, although it is generally good. While the plateau itself is not realistic, this is not significant from a long term modelling perspective. A flow of approximately 10 000 ML/month is an appropriate value to adopt for each of those months given the available data.

## 10. Response to Question 10

Table 3 and 4 to include the historic climate case.

See Table 35, below.

**Table 35 – Murrumbidgee Flow Downstream Angle Crossing (ML/month), Generated with Period of Record Historical Data (1871 – present)**

|                 | No M2G, No Tantangara | M2G, No Tantangara | % Change | M2G, With Tantangara | % Change |
|-----------------|-----------------------|--------------------|----------|----------------------|----------|
| Average Flow    | 31292                 | 31095              | -0.6%    | 31143                | -0.5%    |
| Median Flow     | 12634                 | 12427              | -1.6%    | 12437                | -1.6%    |
| 5th Percentile  | 118402                | 118402             | 0.0%     | 118402               | 0.0%     |
| 95th Percentile | 985                   | 889                | -9.7%    | 930                  | -5.6%    |



## 11. Response to Question 11

*How does the presence of the M2G pipeline increase 95<sup>th</sup> flows from the base case for the climate change/stochastic data and last 10 years scenarios but reduces it in the historic climate case?*

In the climate change stochastic analysis the 95<sup>th</sup> percentile flow is 967 ML/month without the M2G and 992 ML/month with the M2G. In the analysis using climate from the last 10 years the 95<sup>th</sup> percentile flow is 914 ML/month without the M2G and 1025 ML/month with the M2G. These flows are all in the range of 30-34 ML/day. In this flow range abstraction of water from Angle Crossing is not possible due to the environmental flow requirements. The slight increase in flow leaving the system occurs because environmental flow reductions from Cotter Dam, Goongong Dam and in the Murrumbidgee at Cotter are triggered by water restrictions. If the M2G pipeline is built water restrictions will occur less frequently and the environmental releases will therefore be a little higher on average.

In the historic climate scenario the 95<sup>th</sup> percentile flow is much higher, 2232 ML/month (73 ML/day) without the M2G and 2075 ML/month (68 ML/day) with the M2G. From January to April this flow rate may be high enough for abstraction at Angle Crossing because the 80<sup>th</sup> percentile flow is low enough during these months. This abstraction reduces the 95<sup>th</sup> percentile flow in this scenario.

## 12. Response to Question 12

*It is not clear how the last 10 years of observed data was used - not clear how the 10 sequences operate.*

In all the modelling (stochastic, period of record historical and last 10 years) the runs begin at current date and storage levels and project forwards using different inflow and demand sequences. We can produce results using this method with the hypothesis that future climate is like the last ten years. However, the order of the data is important. For example, if the first two years are wet it may not be necessary to use the M2G extensively, but if they are dry it may be used a great deal.

We do not wish to assume that the next year will be like 1999 or another particular year from the recent climate. Instead, the method used considers any year from the last ten years to be equally likely to occur in the next twelve months. To preserve inter-annual dependence we have maintained the order of the sequence wherever possible, so that 2000 follows 1999 and so on. When the end of the data is reached (2009) the sequence returns to the first year. This creates the ten sequences shown in



**Table 36.**



**Table 36 – Sequences Used in Modelling With Climate from the Last Ten Years**

|            | Data From   |             |             |             |             |             |             |             |             |              |
|------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|
| Model Year | Replicate 1 | Replicate 2 | Replicate 3 | Replicate 4 | Replicate 5 | Replicate 6 | Replicate 7 | Replicate 8 | Replicate 9 | Replicate 10 |
| 2009       | 1999        | 2000        | 2001        | 2002        | 2003        | 2004        | 2005        | 2006        | 2007        | 2008         |
| 2010       | 2000        | 2001        | 2002        | 2003        | 2004        | 2005        | 2006        | 2007        | 2008        | 2009/1999    |
| 2011       | 2001        | 2002        | 2003        | 2004        | 2005        | 2006        | 2007        | 2008        | 2009/1999   | 2000         |
| 2012       | 2002        | 2003        | 2004        | 2005        | 2006        | 2007        | 2008        | 2009/1999   | 2000        | 2001         |
| 2013       | 2003        | 2004        | 2005        | 2006        | 2007        | 2008        | 2009/1999   | 2000        | 2001        | 2002         |
| 2014       | 2004        | 2005        | 2006        | 2007        | 2008        | 2009/1999   | 2000        | 2001        | 2002        | 2003         |
| 2015       | 2005        | 2006        | 2007        | 2008        | 2009/1999   | 2000        | 2001        | 2002        | 2003        | 2004         |
| 2016       | 2006        | 2007        | 2008        | 2009/1999   | 2000        | 2001        | 2002        | 2003        | 2004        | 2005         |
| 2017       | 2007        | 2008        | 2009/1999   | 2000        | 2001        | 2002        | 2003        | 2004        | 2005        | 2006         |
| 2018       | 2008        | 2009/1999   | 2000        | 2001        | 2002        | 2003        | 2004        | 2005        | 2006        | 2007         |
| 2019       | 2009/1999   | 2000        | 2001        | 2002        | 2003        | 2004        | 2005        | 2006        | 2007        | 2008         |
| 2020       | 2000        | 2001        | 2002        | 2003        | 2004        | 2005        | 2006        | 2007        | 2008        | 2009/1999    |

### 13. Response to Question 13

*Comment further on why the modelling of the Tantangara transfers is not considered accurate enough to provide monthly distributions of M2G transfers but is considered to be accurate enough to estimate transmission losses (which are dependant on the season they take place in).*

As noted in the response to question 8, transmission losses have not been modelled with that level of sophistication. It is difficult to provide monthly distributions for the M2G transfer rate because this relies upon:

- The agreement between Snowy Hydro and ActewAGL over the timing of the release of water.
- Determining a suitable time for releases that will not impact upon native fish. This issue is yet to be fully investigated, and may or may not be significant. It is not considered in the model.
- Availability of natural flows in the Murrumbidgee (Tantangara releases not required when flow is high). This is the limiting factor in dry conditions because Googong Dam is low.
- Seasonal distribution of storage volume in Googong Dam (relies on operating rules for using Googong/Cotter storages as well as the ratio of inflows to Googong and the Cotter Dams). This is the limiting factor in wet (e.g. historical average) conditions because Googong Dam is high and flow is typically available in the Murrumbidgee.

All of these factors are difficult to predict at this stage, leading to high uncertainty in the timing of releases.



## Project Report

# Response to Public Comments to M2G EIS

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## *1. Introduction*

This document provides:

- Responses to M2G comments from the Murray-Darling Basin Authority (section 2 of this document).
- Responses to M2G comments from Brian Egloff, Paul Room and Graham Blinksell (section 3 of this document).
- Responses to M2G comments on potential flooding issues in Burra Creek (section 4 of this document).
- Responses to M2G comments on intake structure flood impacts (section 5 of this document).

## ***2. Responses to M2G comments from the Murray-Darling Basin Authority***

This section addresses the 7 items indicated in a letter from MDBA on M2G.

### **Item 1 – Natural flow downstream of Angle Crossing**

*No text required, based on discussions with MDBA.*

### **Item 2 – Flow depths and velocity downstream of Angle Crossing**

*No text required, based on discussions with MDBA.*

### **Item 3 – Flow leaving the ACT**

In addressing this question, it needs to be firstly made clear that all existing Canberra and Queanbeyan demand is met through abstractions from the Murrumbidgee, either by interception before the flows arrive there or directly from the River. This fact also applies to effluent reuse and stormwater harvesting, as these flows would have otherwise entered the Murrumbidgee River.

Therefore, after the initial filling of the Enlarged Cotter Dam, flows leaving the ACT will only be affected by the following two factors relating to the proposed supply augmentation measures:

1. Increased consumption as a result of fewer restrictions on water use. (Although approximately half of supply is returned to the Murrumbidgee via the LMWQCC, because restrictions predominantly target outdoor consumption, here it is assumed that all extra consumption will be effectively removed from Murrumbidgee flows).
2. Increased evaporation from storages as a result of increased storage surface areas.

The table below summarises the annual reduction in flows leaving the ACT (over the next 47 years), with the Murrumbidgee to Googong Water Transfer (M2G), as well as with other combinations of options.

Overall, the Murrumbidgee to Googong Water Transfer would result in a 1 % change in average flows leaving the ACT (with the average being 509 GL/annum).

**Table 1: Average Annual Reduction in Flows Leaving the ACT over the next 47 years**

|                                            | Average Annual Evaporation (GL) | Average Annual Supply (GL) | Average Annual Total Change (GL) | Change as a percentage of Average Flows Leaving the ACT (Ave = 509 GL/annum) |
|--------------------------------------------|---------------------------------|----------------------------|----------------------------------|------------------------------------------------------------------------------|
| Existing System                            | 5.09                            | 73.6                       |                                  |                                                                              |
| Existing System with ECD                   | 5.14                            | 77.5                       |                                  |                                                                              |
| Extra due to ECD                           | 0.05                            | 3.9                        | 4.0                              | 0.8%                                                                         |
| Existing System with ECD & M2G             | 5.76                            | 82.1                       |                                  |                                                                              |
| Extra due to M2G                           | 0.62                            | 4.6                        | 5.2                              | 1.0%                                                                         |
| Existing System with ECD, M2G & Tantangara | 5.89                            | 82.8                       |                                  |                                                                              |
| Extra due to Tantangara                    | 0.13                            | 0.7                        | 0.8                              | 0.16%                                                                        |

The abovementioned change will not impact on environmental flow requirements as transfers to Googong will only occur once there are sufficient environmental flows in the Murrumbidgee River.

Furthermore, the ACT will still meet its requirements under the Murray-Darling Cap (which is an agreement between the Murray-Darling Basin Ministerial Council and state/territory governments to help with the sustainable management of water in the Murray-Darling Basin). The current Cap for the ACT is 40 GL/year (which is defined as the difference between the amount of water extracted and the amount returned as treated wastewater).

#### **Item 4 – Benefits provided by Tantangara releases**

The Murrumbidgee to Googong Water Transfer EIS and EA does not directly address the issues raised by the Tantangara Transfer (which involves the purchase of water in Tantangara Dam by the ACT Government, and its subsequent release and extraction from the Murrumbidgee River for use by the ACT). The two projects are discrete activities. A separate approvals processes will be required for Tantangara. However, if implemented, the Tantangara Transfer project would provide benefits to the Murrumbidgee to Googong Transfer project (in terms of increased flows in the Murrumbidgee River).

#### **Item 5 – Salinity and operating rules**

##### **5A Salinity impacts in the Murray River at Morgan**

Salinity differences in the Murray River at Morgan (with or without the Murrumbidgee to Googong Water Transfer project), will be insignificant due to the number and extent of other inputs between the ACT and Morgan (such as other tributaries of the Murray-Darling system and other point- as well as non-point inputs).

## 5B Salinity impacts in the Murrumbidgee River at Halls Crossing

Total flows – and thus TDS – are almost unchanged at Hall's Crossing (see Table 1 above).

However, during low flows, salinity is likely to be slightly higher at Hall's Crossing (northern ACT Border) as a result of the Murrumbidgee to Googong Water Transfer project. However, such salinity variations at Hall's Crossing will be negated by:

- Burrinjuck Reservoir's 1.025TL storage (which is twice the average annual flow past Hall's Crossing).
- Other downstream flows into the Murrumbidgee River, which are 6.5 times greater than flows at Hall's Crossing (<http://www.clw.csiro.au/help/murrumbidgee.html>)

## 5C Likely operating rules

The modelled flow based operating rules for the Murrumbidgee to Googong Water Transfer project are as follows. These rules may be refined before or after the M2G project is completed, but are ActewAGL's current best estimate of the final operating rules:

- If Googong is less than 75% full, then pump at 100 ML/day or the river flow rate minus the environmental flow rate, whichever is lower.
- If Googong is more than 75% full, then zero pumping.

Environmental flow requirements are set by Environment ACT, and have not been specified for Angle Crossing as yet. ActewAGL modelling assumes the same requirements as have been previously set for Murrumbidgee extractions at the Cotter Pump Station in terms of monthly percentiles. The resultant (assumed) ML/day requirements for Angle Crossing are tabulated in Table 2 below.

**Table 2: Assumed Environmental Flow Requirements at Angle Crossing**

| Month     | Percentile | ML/day |
|-----------|------------|--------|
| January   | 80         | 34     |
| February  | 80         | 25     |
| March     | 80         | 17     |
| April     | 80         | 35     |
| May       | 80         | 59     |
| June      | 90         | 68     |
| July      | 90         | 91     |
| August    | 90         | 128    |
| September | 90         | 185    |
| October   | 90         | 134    |
| November  | 80         | 164    |
| December  | 80         | 58     |

Apart from the abovementioned flow based pumping rules, the Murrumbidgee to Googong Water Transfer project will also need to meet a number of water quality operating rules (such as turbidity).

**6 Update to MDBA during construction and operational phases**

ACTEW will provide updates on the Murrumbidgee to Googong Water Transfer project (during the construction and the operational phases), to ACT, NSW and Commonwealth Government Departments and/or Agencies. These updates will during the construction and operational phases. These updates will include information on water quantity and quality, as well as water consumption.

**7 Update to MDBA on Tantangara releases**

*No text required, based on discussions with MDBA.*

### 3. Responses to M2G comments from Brian Egloff, Paul Room and Graham Blinksell

This section addresses items raised by Brian Egloff, Paul Room and Graham Blinksell. All three of these comments relate to changes to flows in the Murrumbidgee River as a result of the Murrumbidgee to Googong Water Transfer project, which are addressed below. Some of the text below is the same as the text addressing similar issues raised by the MDBA.

#### Flows in the Murrumbidgee River

In addressing this question, it needs to be firstly made clear that all existing Canberra and Queanbeyan demand is met through abstractions from the Murrumbidgee, either by interception before the flows arrive there or directly from the River. This fact also applies to effluent reuse and stormwater harvesting, as these flows would have otherwise entered the Murrumbidgee River.

Therefore, after the initial filling of the Enlarged Cotter Dam, flows leaving the ACT will only be affected by the following two factors relating to the proposed supply augmentation measures:

1. Increased consumption as a result of fewer restrictions on water use. (Although approximately half of supply is returned to the Murrumbidgee via the LMWQCC, because restrictions predominantly target outdoor consumption, here it is assumed that all extra consumption will be effectively removed from Murrumbidgee flows).
2. Increased evaporation from storages as a result of increased storage surface areas.

The table below summarises the annual reduction in flows leaving the ACT (over the next 47 years), with the Murrumbidgee to Googong Water Transfer (M2G), as well as with other combinations of options.

Overall, the Murrumbidgee to Googong Water Transfer would result in a 1 % change in average flows leaving the ACT (with the average being 509 GL/annum).

**Table 3: Average Annual Reduction in Flows Leaving the ACT over the next 47 years**

|                                            | Average Annual Evaporation (GL) | Average Annual Supply (GL) | Average Annual Total Change (GL) | Change as a percentage of Average Flows Leaving the ACT (Ave = 509 GL/annum) |
|--------------------------------------------|---------------------------------|----------------------------|----------------------------------|------------------------------------------------------------------------------|
| Existing System                            | 5.09                            | 73.6                       |                                  |                                                                              |
| Existing System with ECD                   | 5.14                            | 77.5                       |                                  |                                                                              |
| Extra due to ECD                           | 0.05                            | 3.9                        | 4.0                              | 0.8%                                                                         |
| Existing System with ECD & M2G             | 5.76                            | 82.1                       |                                  |                                                                              |
| Extra due to M2G                           | 0.62                            | 4.6                        | 5.2                              | 1.0%                                                                         |
| Existing System with ECD, M2G & Tantangara | 5.89                            | 82.8                       |                                  |                                                                              |
| Extra due to Tantangara                    | 0.13                            | 0.7                        | 0.8                              | 0.16%                                                                        |

The abovementioned change will not impact on environmental flow requirements as transfers to Googong will only occur once there are sufficient environmental flows in the Murrumbidgee River. Environmental flow requirements are set by Environment ACT, and have not been specified for Angle Crossing as yet. ActewAGL modelling assumes the same requirements as have been previously set for Murrumbidgee extractions at the Cotter Pump Station in terms of monthly percentiles. The resultant (assumed) ML/day requirements for Angle Crossing are tabulated in Table 2 below.

**Table 4: Assumed Environmental Flow Requirements at Angle Crossing**

| Month     | Percentile | ML/day |
|-----------|------------|--------|
| January   | 80         | 34     |
| February  | 80         | 25     |
| March     | 80         | 17     |
| April     | 80         | 35     |
| May       | 80         | 59     |
| June      | 90         | 68     |
| July      | 90         | 91     |
| August    | 90         | 128    |
| September | 90         | 185    |
| October   | 90         | 134    |
| November  | 80         | 164    |
| December  | 80         | 58     |

Furthermore, the ACT will still meet its requirements under the Murray-Darling Cap (which is an agreement between the Murray-Darling Basin Ministerial Council and state/territory governments to help with the sustainable management of water in the Murray-Darling Basin). The current Cap for the ACT is 40 GL/year (which is defined as the difference between the amount of water extracted and the amount returned as treated wastewater).

#### *4. Responses to M2G comments on potential flooding issues in Burra Creek and the Murrumbidgee River*

A comment from the public has stated that:

“There is a limited discussion regarding the history of flooding in Burra Creek, and no detail is provided on the Murrumbidgee River. Provide some discussion regarding the history of flooding in both surface waters.”

The Burra Creek part of the above comment is addressed in the email below (from Tim Purves to Teresa Morey on 11 September 2008).

The Murrumbidgee River component of the question is addressed in section 5.

**From:** Purves, Timothy  
**Sent:** Thursday, 11 September 2008 5:19 PM  
**To:** Morey, Teresa  
**Subject:** FW: What is the 1 in 2 year flow at Burra Creek?

Hi Teresa,

My work on Burra from about 1 year ago is shown in the forwarded email below. I also pulled out the same results from HYDSTRA today - it is shown immediately below. The only year without a peak flow above 100 ML/day is 2006 - when the maximum flow was a miserable 9 ML/day.

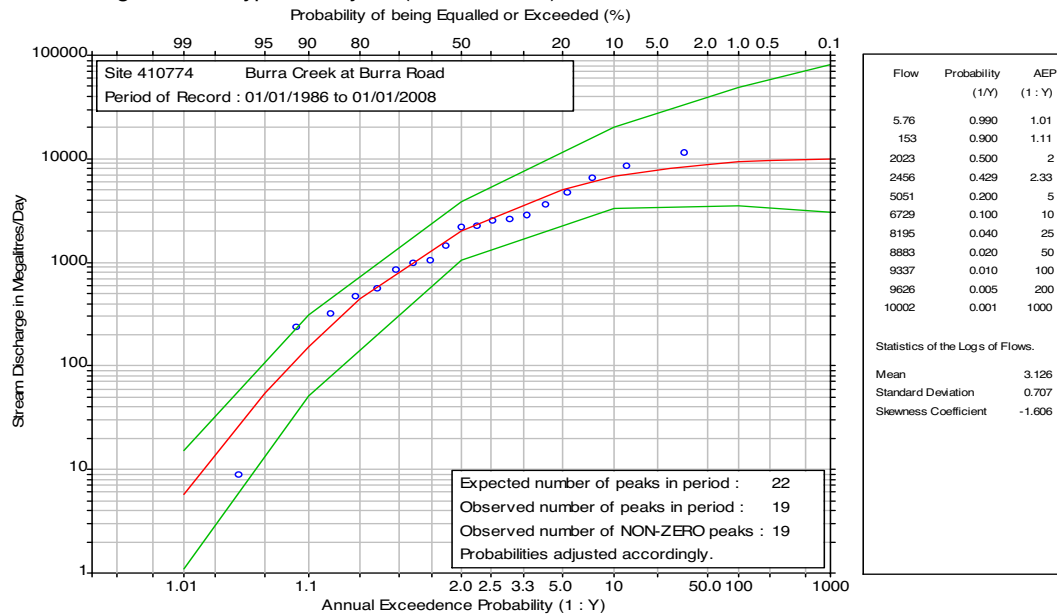
A quick look at the available data for the missing years indicates that 1985, 2000, 2001 & 2005 also contained flows above 100 ML/day. This leaves only 1 year in 23 where the flow has not exceeded 100 ML/day. However, the peak flow in 2008 up to July is 3.5 ML/day, so a second occurrence is on the cards depending upon how spring shapes up.

|      |                    |      |                                                                             |
|------|--------------------|------|-----------------------------------------------------------------------------|
| Time | 410774             |      |                                                                             |
| and  | 141                |      |                                                                             |
| Date | Discharge (MI/Day) |      |                                                                             |
|      | Max                | Qual | Comment                                                                     |
| 1985 |                    | 255  |                                                                             |
| 1986 | 2905               | 76   |                                                                             |
| 1987 | 319                | 104  |                                                                             |
| 1988 | 8588               | 150  |                                                                             |
| 1989 | 11480              | 150  |                                                                             |
| 1990 | 1056               | 104  |                                                                             |
| 1991 | 4808               | 82   |                                                                             |
| 1992 | 2217               | 82   |                                                                             |
| 1993 | 986                | 4    |                                                                             |
| 1994 | 2258               | 1    |                                                                             |
| 1995 | 6635               | 1    |                                                                             |
| 1996 | 472                | 1    |                                                                             |
| 1997 | 563                | 4    |                                                                             |
| 1998 | 2589               | 3    |                                                                             |
| 1999 | 2548               | 145  | Data considered innacurate due to siltation and reed growth at gauging site |
| 2000 |                    | 255  |                                                                             |
| 2001 |                    | 255  |                                                                             |
| 2002 | 3656               | 145  |                                                                             |
| 2003 | 1431               | 145  |                                                                             |
| 2004 | 843                | 145  |                                                                             |
| 2005 |                    | 156  |                                                                             |
| 2006 | 9                  | 5    |                                                                             |
| 2007 | 237                | 5    |                                                                             |
| 2008 |                    | 255  |                                                                             |
| 2009 |                    | 255  |                                                                             |

**Ecowise Environmental**

HYLP3 V95 Output 11/09/2008

**Log-Pearson Type III Analysis. (Annual Series)**



Regards,

Tim

**From:** Purves, Timothy  
**Sent:** Wednesday, 24 October 2007 6:33 PM  
**To:** Crocker, Leigh; Costin, Graham  
**Cc:** Barratt, Richard  
**Subject:** What is the 1 in 2 year flow at Burra Creek?

Gents,

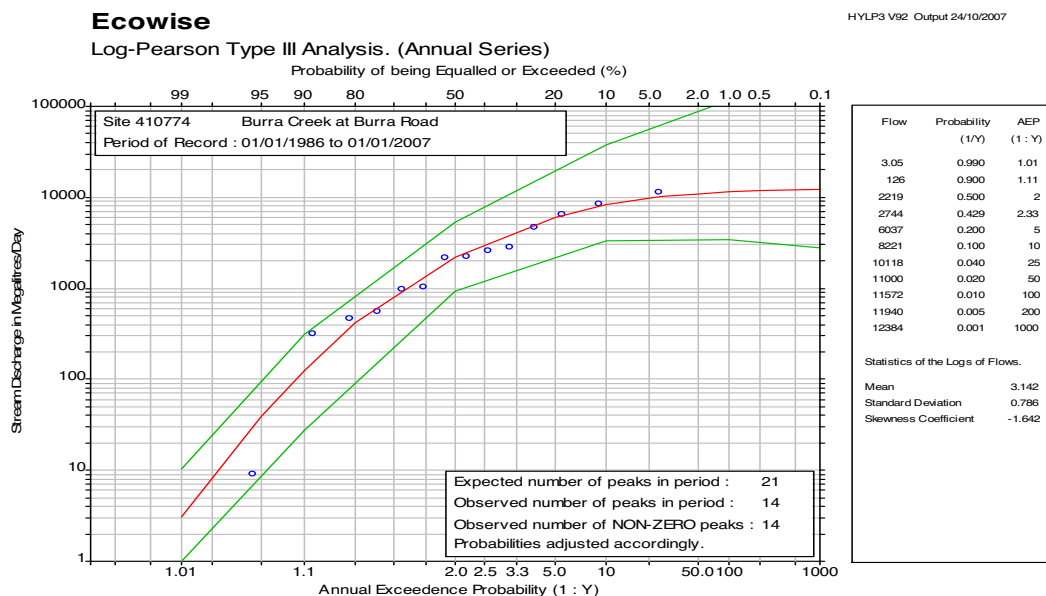
This addresses the request from Barry Starr for Burra Creek flow information:

ACTEW is considering a number of pipeline routes for transporting water from the Murrumbidgee River into Googong Dam. One option is to abstract Murrumbidgee water from Angle Crossing and release into Burra Creek, which is a tributary of the Queanbeyan River. Flow in Burra Creek is recorded at the 410774 gauging station, which is near the proposed discharge point.

A gauging station has been in place at this site since 1985. However, from 1999 to 2004 flows were not recorded because the site changed and the rating table became inaccurate. A new gauging point was selected and flows have been recorded from August 2004 onwards. However, some periods of 2005 are missing data. The record of annual maximum flows at the site is shown below:

| Year | Maximum Instantaneous Flow (ML/day) |
|------|-------------------------------------|
| 1986 | 2905                                |
| 1987 | 319                                 |
| 1988 | 8588                                |
| 1989 | 11480                               |
| 1990 | 1056                                |
| 1991 | 4808                                |
| 1992 | 2217                                |
| 1993 | 986                                 |
| 1994 | 2258                                |
| 1995 | 6635                                |
| 1996 | 472                                 |
| 1997 | 563                                 |
| 1998 | 2589                                |
| 1999 |                                     |
| 2000 |                                     |
| 2001 |                                     |
| 2002 |                                     |
| 2003 |                                     |
| 2004 |                                     |
| 2005 |                                     |
| 2006 | 9                                   |

A Log-Pearson type III flood frequency distribution has been fitted to this series of 14 annual maximum flows. It is important to note that 14 is a small sample for fitting this distribution, and that the distribution would be changed if the flows from 1999 to 2006 were included (these flows would probably be lower than in the earlier period). Nevertheless, it will provide a good indication of the return interval of various flows. The distribution is shown below:



Using this method, the 2 year ARI flood can be calculated at 2219 ML/day. This return interval is useful because, as an approximate rule of thumb, overbank flow begins at floods above the 2 year ARI.

Regards,

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## 5. Information on how intake structure will affect flooding and how flooding will impact on the intake structure

A comment from the public has requested:

“Detail provided regarding how the intake will affect flooding and how flooding will impact on the intake structure.”

The diagram below provides information on the above issue for the Murrumbidgee River at Lobbs Hole.

