Estimation of Secure Yield for Guyra Augmentation Options

Final Report

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1.0 INTRODUCTION

1.1 GENERAL

WREMA Pty Ltd were engaged by Armidale Regional Council to undertake a study to estimate of the "secure yield" for the existing Guyra water supply system and a range of proposed augmentation scenarios. The study utilised hydrologic information and models established as part of an investigation undertaken in 2015/16 to assess the secure yield for Armidale's water supply system. This report provides:

- Details of data used in the project;
- an estimate of inflows to the Guyra dams;
- a description of the water supply system model, and
- an estimate of the secure yield for the existing water supply system and selected augmentation scenarios.

1.2 STUDY PURPOSE AND OBJECTIVES

The primary objective of the study is to investigate a range of options to augments Guyra's water supply to meet existing and future demands. The study is required to determine the secure yield for each option and to provide other information, such as pumping flows, required to assess the preferred option.

Options assessed in the study include:

- Scenario 0: Existing water supply system
- Scenario 1: Raise existing Dam No. 2 by 3 m to increase the system storage by approximately 500 ML
- Scenario 2: Construct an off-river storage dam with a capacity of 500 ML
- Scenario 3: Construct a 14 km pipeline from Malpas Dam[1] to the Guyra water filtration plant
- Scenario 4: Construct an 8 km pipeline from Malpas Dam to supply industrial users
- Scenario 5: Raise existing Dam No. 2 by 3 m and augment industrial supply with treated sewerage effluent

1.3 SETTING

The township of Guyra has a population of approximately 2,000 people and an average annual water demand of 430 ML/a. The urban population has an average demand of 280 ML/a, whilst the average industrial demand is 150 ML/a. The maximum historical demand was 507 ML in 2014, consisting of 294 ML urban demand and 212 ML industrial demand. The main industrial users are hydroponic tomato farms that employ approximately 150 staff.

A previous study (Hunter Water Australia 2014) estimated that the existing water supply system had a secure yield of 390 ML/a, which is approximately 10% lower than the average annual consumption.

The existing water supply is provided by two dams on the Gara River, located approximately 7 km to the north east of Guyra. Dam 2 immediately upstream of Dam 1. Dam 1 has a

[1] Malpas Dam is part of Armidale's water supply system.

storage capacity of 110 ML, whilst Dam 2 has a storage capacity of 350 ML, giving a combined capacity of 460 ML.

The water supply for Armidale, which has a population of approximately 22,000 people, is provided by three dams, Malpas, Puddledock and Gara. Malpas Dam is the much larger dam and provides the majority of Armidale's water supply. Malpas Dam is located on the Gara River, approximately 15 km downstream of Dam 1.

Unlike most small townships Guyra has enjoyed a small population growth, largely as a result of growth by the tomato farms. Subject to water availability, the tomato farms and population are expected to continue to grow. The demand by the year 2066 has been projected to be in the range of 600 ML/a to 700 ML/a.

A number of options have been previously identified for augmenting Guyra's water supply including raising Dam 2, constructing an off-river storage, constructing a pipeline from Malpas Dam and utilisation of treated sewerage effluent.

Under existing conditions the Guyra dams spill frequently and there is no requirement to pass environmental flows. However, environmental flows may be required in the future, particularly if the system is augmented. A map showing the location of Guyra, Armidale, the various water supply dams and the Gara River catchment is provided in Figure 1.

1.4 PREVIOUS STUDIES

1.4.1 Guyra Water Supply – Secure Yield Study, Hunter Water Australia 2014

The above study estimated the secure yield of the existing Guyra water supply system and assessed four potential augmentation options to meet future demands. The study estimated the secure yield of the existing system to be 390 ML/a.

The augmentation options investigated were: raising of Dam 2 by 2m; raising of Dam 2 by 3m; construction of an off-river storage of 500 ML; and construction of a pipeline from Malpas Dam to the Guyra water filtration plant.

The hydrology for this investigation was undertaken by NSW Urban Water Services. Inflows to the Guyra dams were estimated for the period from 1895 to 2008 using an AWBM rainfall runoff model and historical climate data. The AWBM model was calibrated to recorded flows from a stream flow gauging station at Ryanda, which is located on the Gara River approximately 6 km upstream of the Guyra dams.

1.4.2 Estimation of Secure Yield of Armidale Dumaresq Water Supply Dams, WREMA 2016

The above study investigated the secure yield for Armidale's water supply system. The study assessed the contribution that Puddledock and Gara dams made to the yield and assessed the impact on the secure yield of decommissioning Gara Dam. The study also investigated the impact on Armidale's secure yield should Guyra augment its supply with a pipeline from Malpas Dam.

The secure yield was assessed using the WATHNET water supply system model. The WATHNET model included the Guyra water supply system, as well as the Armidale water supply system because extractions for Guyra's water supply and the operation of the Guyra dams would impact on the secure yield of Armidale. Inflows to each of the dams were estimated for the period from 1889 to 2014 using a Sacramento water balance model. The Sacramento model was calibrated against recorded flows at five streamflow gauging stations within the water supply catchment, including four on the Gara River. The estimated inflows were validated by comparing modelled water levels at the two Guyra dams and Malpas Dam against recorded water levels.

This study utilised revised storage curves for the two Guyra dams based on a survey undertaken by CEH Survey in 2015. Based on the revised survey, the combined storage capacity of the dams was 460 ML, whereas the previous study by Hunter Water Australia assumed a combined storage capacity of 480 ML.

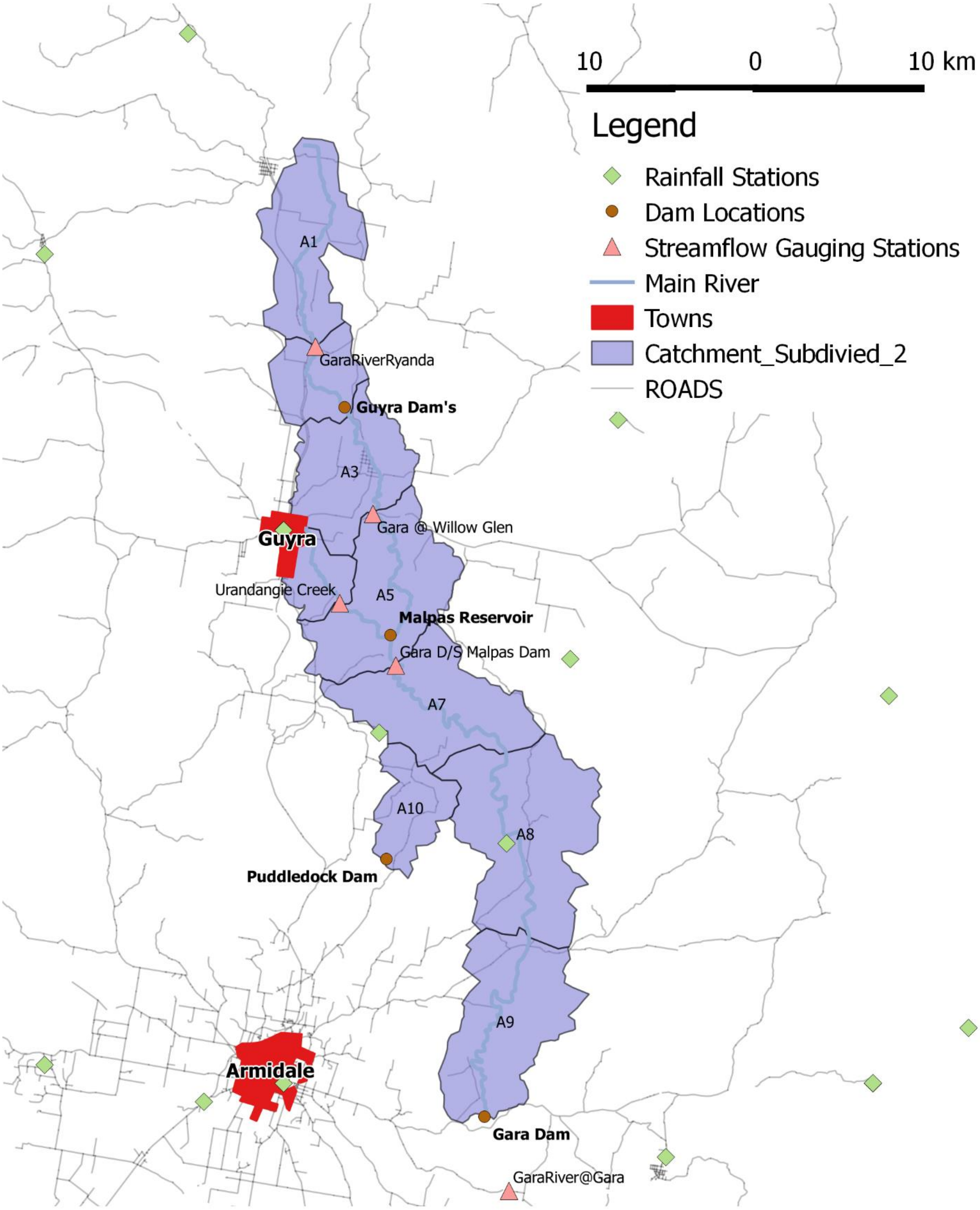


Figure 1: Gara River Catchment - Location Map

2.0 INFLOW HYDROGRAPHS

2.1 GENERAL

Inflows to the Guyra dams were computed as part of the Armidale secure yield investigations. Details of the hydrologic investigations are provided in WREMA 2016. Inflows were estimated for the period from 1889 to 2014 using a Sacramento rainfall runoff model and historical climate data (sourced from SILO grid point data). The Sacramento model was calibrated to flow data recorded at the Ryanda stream flow gauging station, which is located approximately 6 km upstream of the Guyra dams. An excellent calibration was achieved, as shown in Figure 2.

The Ryanda stream flow gauging station only operated for four years, which is not normally sufficient to establish a reliable rating curve. However, in this instance the station had a Cippolletti Weir and the gauged flows are accurate.

A time series and flow duration curve for the modelled historical inflows are provided in Figures 3 and 4, respectively. The modelled 126 year time series had a mean flow of 15.4 ML/day and a median flow of 3.35 ML/day, compared to a mean of 15.1 ML/day and median of 4.76 for the four year recorded flow sequence. The modelled historical flow sequence had zero flows for approximately 19% of the time, whereas the recorded flow sequence had zero flows approximately 4% of the time. This indicates that the recorded four year flow time series that was used to calibrate the model approximately represented average conditions, although the long term flow record included more dry spells.

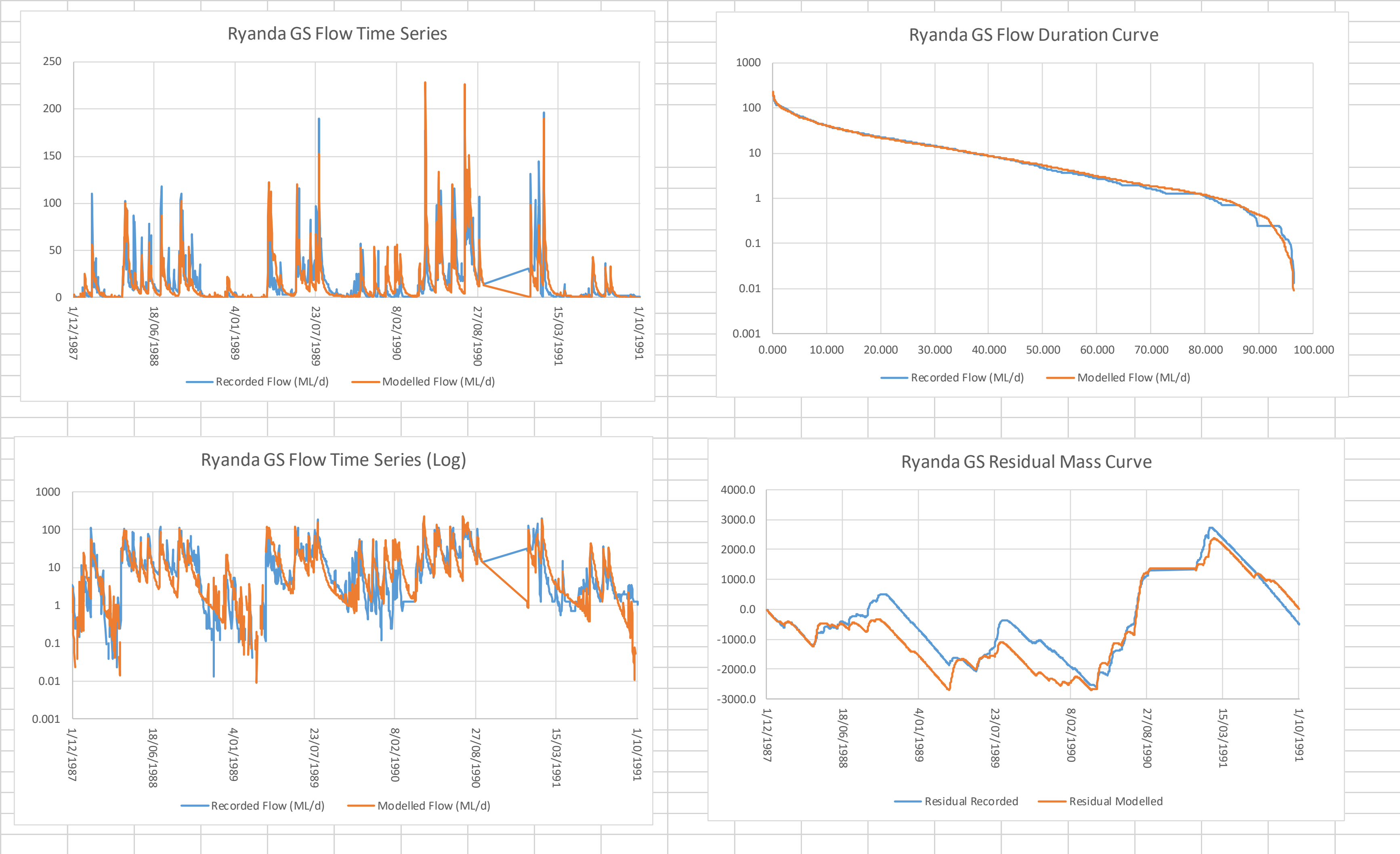


Figure 2: Ryanda Gauging Station - Sacramento Model Calibration Charts

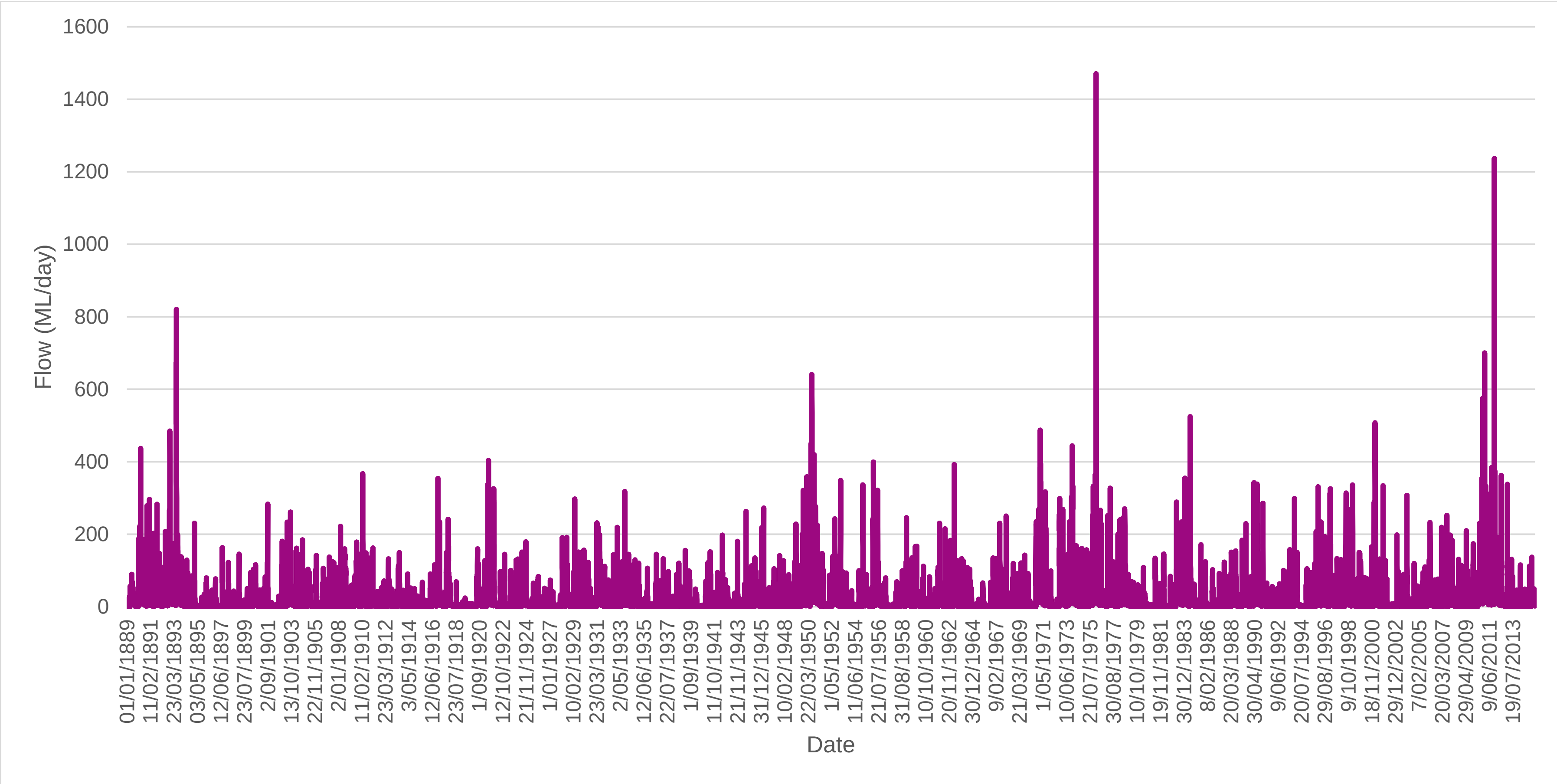


Figure 3: Inflows to Guyra Dams - Time Series

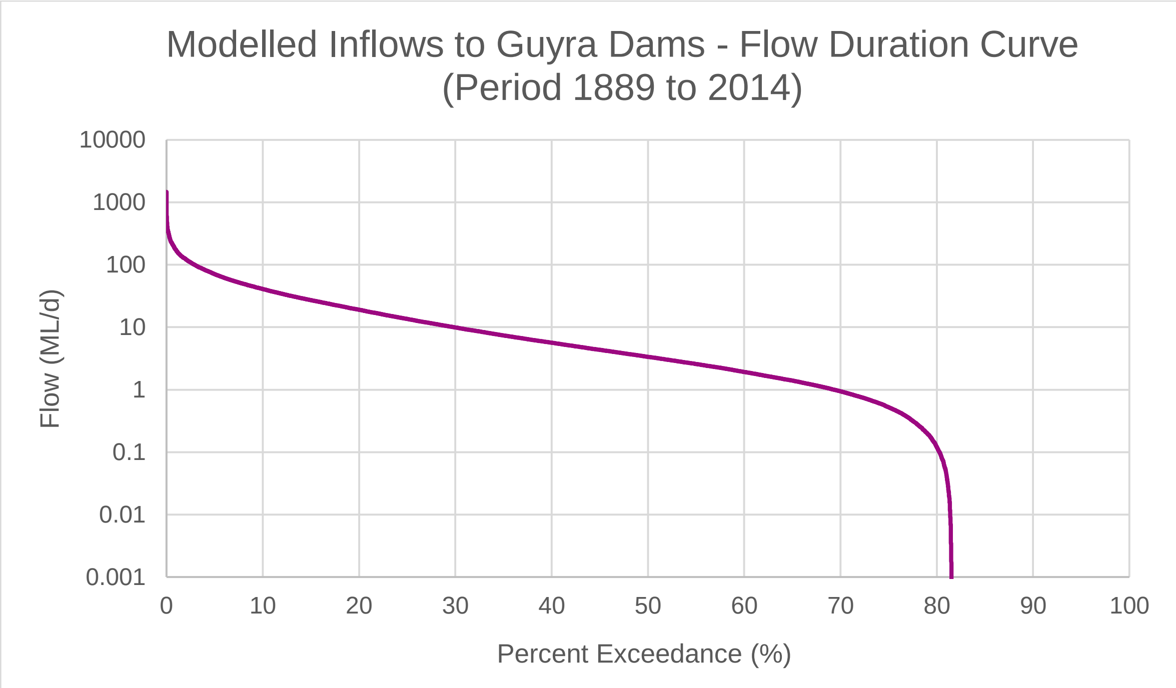


Figure 4: Inflows to Guyra Dams - Flow Duration Curve (Period 1889 to 2014)

3.0 YIELD ASSESSMENT

The secure yield for Guyra's water supply system was estimated utilising a WATHNET water supply system model that included both the Armidale and Guyra water supply systems.

3.1 Water Supply System Model

The water supply system model included the two Guyra water supply dams, the three Armidale water supply dams and climate driven demands for both Armidale and Guyra. A diagrammatic representation of the model is provided in Figure 5. The model also included a pipeline to transfer water from Malpas Dam to Guyra if required, depending on the scenario modelled.

3.2 Climate Driven Demand Model

A climate driven demand model provided by Armidale Regional Council was utilised to prepare estimates of the demand patterns for the period from 1/1/1889 to 31/12/2014 (126 years). This allowed the effect of climate on demands to be included in the model at daily, seasonal and annual time scales. The maximum annual demand was found to be 32% higher than the mean. The minimum annual demand was 11% less than the mean.

3.3 Approach

Secure yield is a design concept providing information on the suitability of a given system to satisfy pre-defined water supply security criteria such as duration, frequency and severity of restrictions. Ideally a secure yield would provide a maximum possible average annual demand which can be extracted from a given system with duration of restrictions D (%), frequency of restrictions F (%) and severity of restrictions S (%) which are referred to as a D/F/S rule. The current standard is to define a secure yield as a maximum demand which can be supplied from a water supply system under a 5/10/10 rule meaning that the yield (demand) which can be extracted from a given system would not have to be restricted longer than 5% of the time, in less than 10% of the years, while supplying 90% of the demand during the period when restrictions are announced (using the worst historical drought sequence).

A trial and error exercise is usually applied to define a secure yield by varying the demand and trigger storage levels when restrictions are announced aiming at the maximum yield. WATHNET has the capability of applying network linear programming (NLP) and genetic algorithm optimisation (GAO) to establish the optimal solution for given criteria. Our methodology maximises the use of NLP and GAO to automate the definition of secure yield, thus minimising the time and the cost of the analyses, while ensuring that future users of the model can repeat the same exercise without any subjectivity.

A restriction storage trigger level curve was established (Refer to Figure 6 for an example) initially as a function of a demand. A 90% demand is applied to the system, assuming the available storage is equal to the trigger level of restrictions. The 90% demand which would just empty the "trigger level" storage is the demand which can be supplied from the system during the worst historical drought. The maximum yield of the system was then defined by analysing the frequency and the duration of restrictions selecting the demand/trigger which would result in 5% duration and/or 10% frequency of restrictions, refer to Figure 7.

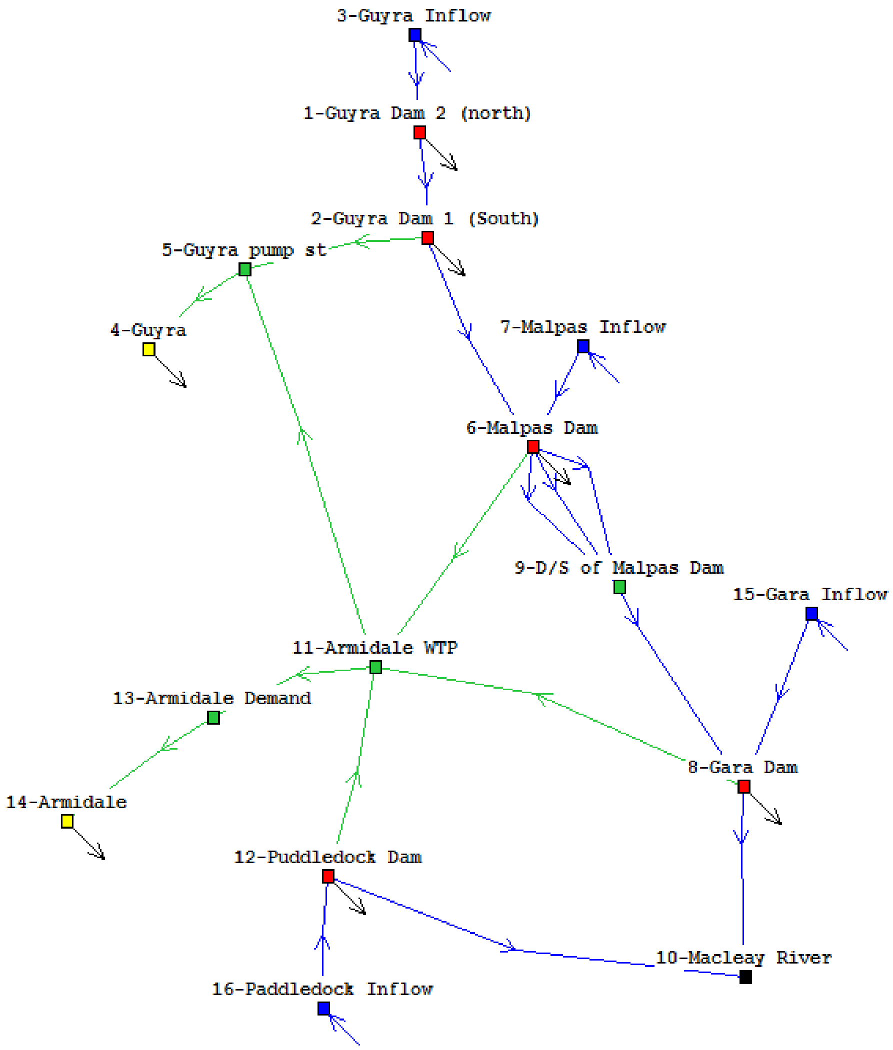


Figure 5: Schematic of Water Supply System Model

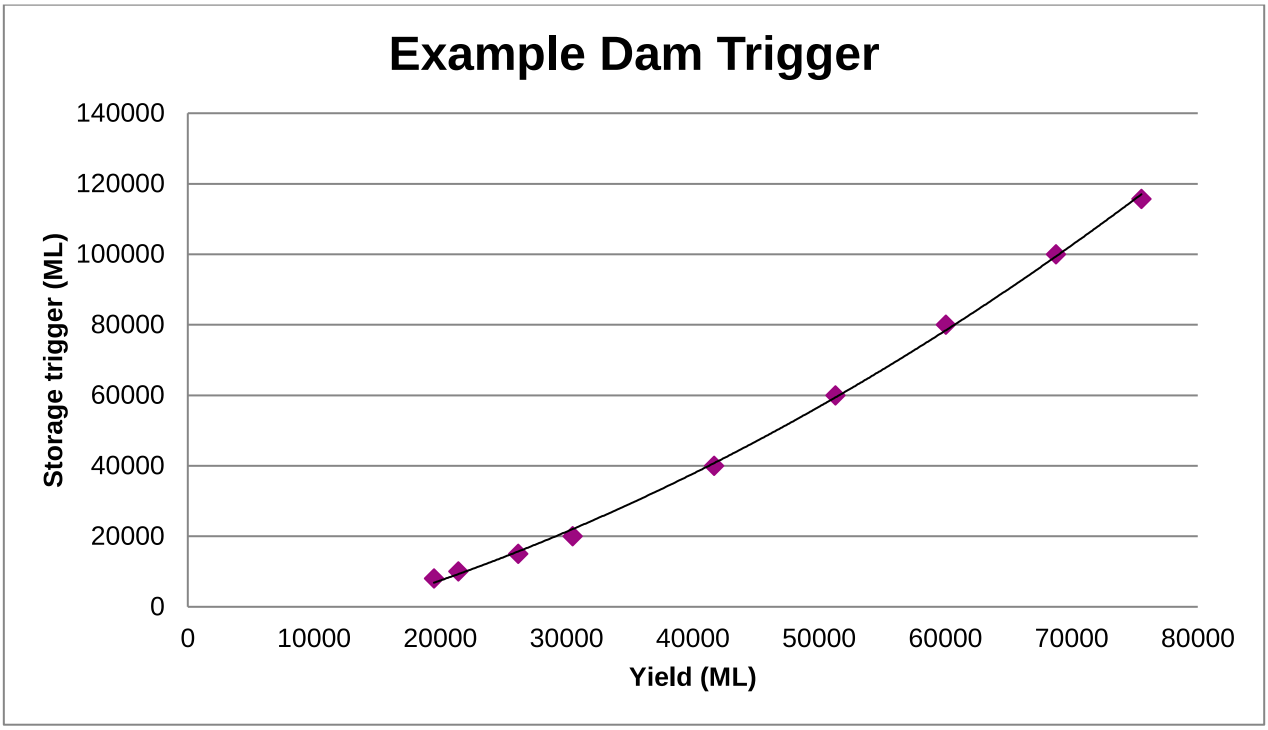


Figure 6: Example Restriction Storage Trigger Level Curve

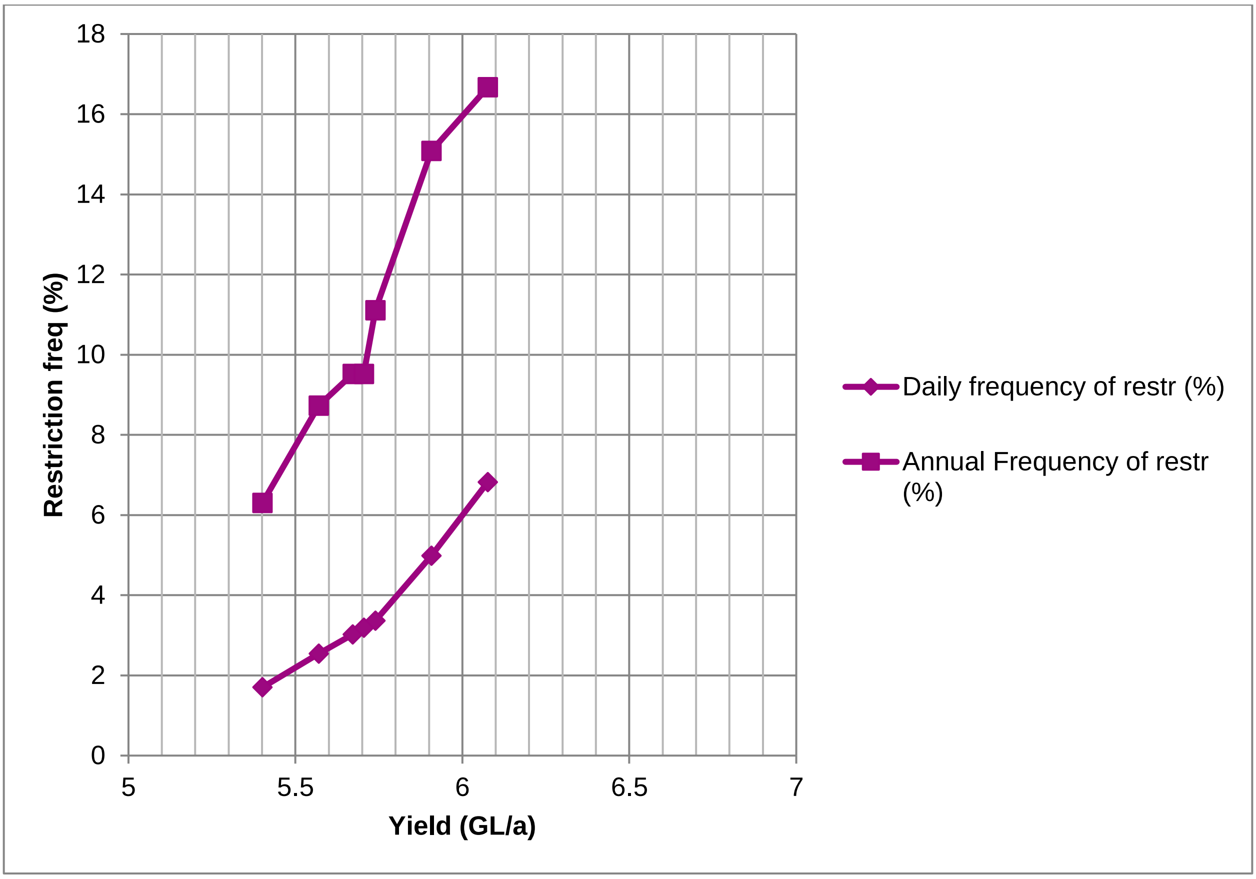


Figure 7: Example Frequency of Restriction for given Yield

3.4 Description of Scenarios

A description of each scenario investigated is provided below.

Scenario 0: Existing water supply system

This scenario represents the existing Guyra water supply system. Dam 1 was modelled with a storage capacity of 110 ML and Dam 2 with a storage capacity of 350[2] ML, giving a combined capacity of 460 ML. There are no environmental flow releases under existing conditions.

Scenario 1: Raise existing Dam No. 2 by 3 m

This scenario increases the capacity of Dam 2 from 350 ML to 850 ML, an increase of 500 ML. The total storage capacity increases from 460 ML to 960 ML.

Scenario 2: Construct an off-river storage dam with a capacity of 500 ML

This scenario is similar to Scenario 1 in that it increases the total storage capacity by 500 ML. The assumed stage-storage and stage-discharge curves are provided in Table 1[3].

Table 1: Stage Storage/Area Curve for Off-river Storage

Depth (m)	Surface Area (ha)	Storage Vol (ML)
0	7.334	0.0
1	7.682	75.1
2	8.038	153.7
3	8.400	235.9
4	8.770	321.8
5	9.146	411.4
6	9.530	504.9

Scenario 3: Construct a 14 km pipeline from Malpas Dam

This scenario provides a pipeline from Malpas Dam to the Guyra water filtration plant to augment supply. The pipeline was configured with a capacity of 4 ML/day. Malpas Dam has sufficient capacity to meet any demand from Guyra (within the range of projected demands). For this scenario the mean annual demand for Guyra was set at 740 ML. The model was used to establish the portion of demand met by Guyra's dams and the portion met by the pipeline from Malpas Dam. The model was configured so that demand was first be met by water from the Guyra dams and water would only be drawn from Malpas when the Guyra storages were empty. When drawing from the Guyra dams the full demand was met i.e. no restrictions were applied when there was water available from the Guyra Dams. When drawing from Malpas the full demand was met, unless it exceeded the pipeline capacity, or Armidale was in restrictions i.e. when restrictions were applied to Armidale they were also applied to Guyra. In accordance with the Guidelines restrictions were set at 10%.

Scenario 4: Construct an 8 km pipeline from Malpas Dam to supply industrial users

This option reduces the construction costs of the pipeline (compared to Scenario 3), but only augments water supply for industrial users. The mean annual demand for industrial users was set at 252 ML. The pipeline was configured with a capacity of 4 ML/day. In this

[2] It is assumed that the 50 ML of dead storage can be accessed.
[3] This is the same stage storage curve used in the previous Hunter Water Australia (2014) study.

scenario the entire industrial demand is met by the Malpas pipeline with the Guyra dams being required to supply the urban demand only.

Scenario 5: Raise existing Dam No. 2 by 3 m and augment industrial supply with treated sewerage effluent

This option combines Scenario 1 with the use of treated effluent for industrial use. The effluent supply was assumed to be 130 ML/yr.

3.5 Environmental Flows

Currently there are no environmental flow requirements for the Guyra dams, but it is likely that environmental releases will be required if the system is augmented.

It is common to set environmental flows in two parts, the transparent and translucent components. The transparent component of environmental flows protects all low flows below a specified trigger, as this protects the river environment during severe dry spells. For a dam, all inflows equal to, or less than this value must be released and the dam acts as though it is transparent to flow. For perennial rivers (that flow continuously) the transparent trigger is typically set at a value somewhere between the 95th percentile flow (i.e. the flow that is exceeded 95% of days) and the 80th percentile flow. In this instance, the Gara River is ephemeral and ceases to flow at the 81st percentile and the transparent trigger was investigated for the 75th percentile and the 65th percentile flows. The 75th percentile flow is 0.52 ML/d, whilst the 65th percentile flow is 1.40 ML/d.

The translucent portion of environmental flows protects a percentage of all flow above the transparent trigger and is typically set at 20% i.e. 20% of all flows above the transparent flow trigger are to be released. For this portion of the flow, the dam acts as though it is translucent to flow.

3.6 Results

Initially all scenarios were run without environmental flows. Scenarios 1 and 3 were then run with environmental flows. The results are summarised in Table 2, whilst detailed statistics on storage levels, demands and pipe transfers are provided in Table 3. Appendix A includes charts that show the storage levels, demands and pipeline transfers.

The secure yield of the existing system was estimated to be 277 ML/a, which is significantly less than the previous estimate of 390 ML/a by Hunter Water Australia. Some of the difference can be attributed to the revised storage curves and the use of a climate driven demand model. However, it is likely that the main factor responsible for the lower secure yield estimate is that the inflow sequence used in this study exhibited more severe dry spells.

Scenario 3 is the only option that meets the long-term target of a secure yield in the range of 600-700 ML/yr. Under Scenario 3 average annual transfers from Malpas Dam supply a small portion of the actual demand, with most of the demand being supplied by the Guyra dams. Having the pipeline allows the Guyra dams to be worked much harder. For example, under existing conditions (Scenario 0) the lowest storage achieved is 104 ML, or 23% of full supply. Under Scenario 3 the Guyra dams empty 10 times over a 126 year period. The Guyra dams were empty for a total of 946 days or 2.1% of days. The mean flow transferred from Malpas Dam was 14 ML/a, which represents only 2% of the total supply. When environmental flow rules are imposed the volume of flows associated with environmental releases are approximately matched by a reduction in the volume of spills, and the volume transferred from Malpas Dam increases from 14 to 21 ML/a.

Scenario 1 provides a secure yield of 539 ML/a, without environmental flows. When a 75/20 environmental flow rule is imposed the secure yield for Scenario 1 drops to 509 ML/a.

Scenario 2 provides a secure yield of 554 (without environmental flows), which slightly higher than the secure yield for Scenario 1. Scenario 4 provides a secure yield of 541 ML/a (without environmental flows), which is similar to the secure yield from Scenarios 1 and 2. Under Scenario 4 the entire industrial demand is supplied from Malpas Dam, with the Guyra Dams supplying all other demands. Scenario 5 provides a secure yield of 588 ML/a (without environmental flows). It can be concluded that effluent re-use increases the secure yield of Scenario 1 by 49 ML/yr.

Table 2: Summary of Results

Scenario	Description	Trigger for restrictions - Storage volume (ML)	Secure Yield (ML/yr)	Daily Restrictions (% days)	Annual Restrictions (% years)	Supplied from Guyra (ML/yr)	Supplied from Malpas (ML/a)	Effluent Reuse (ML/a)	Percentage of Spill days (%)
0	Existing	273	**277**	1.28	10.3	277			68
1	Dam 2 raised +500ML no EnFlow	588	**539**	1.81	10.3	539			60
1a	Dam 2 raised +500ML EF 75-20	604	**509**	1.91	10.3				67
2	Offriver storage no EnFlow	607	**554**	1.8	10.3				61
3	Supply from Armidale Qmax=4 ML/d no EnFlow	72,972#	**741**	3.3	10.3	27	14		53
3.1	Supply from Armidale Qmax=4 ML/d EF 75-20	72,972#	**741**	3.3	10.3	722	19		80
3.2	Supply from Armidale Qmax=4 ML/d EF 65-20	72,972#	**741**	3.3	10.3	722	19		80
4	Supply from Armidale to Tomato farm only	209	**541**	1.2	10.3	289	252		70
5	Effluent re-use plus dam raised 500 ML no EnFlow	580	**588**	1.89	10.3	442		146	64

 # Storage of Malpas Dam

Table 3: Detailed Statistics

Statistic	Storage Level (ML)			Spill (ML/d)	EFlow (ML/d)	Supply/Transfers			
	Dam 2	Dam 1	Offriver			from all Guyra Dams (ML/d)	from offriver storage (ML/d)	From effluent reuse (ML/d)	from Malpas pipeline (ML/d)
Scenario 0: Existing – no EFlow									
Min	82.00	22.00		0.00		0.50			
Max	350.00	110.00		1488.7		1.80			
Median	349.20	110.00		2.20		0.70			
Mean	333.67	104.79		14.62		0.76			
Scenario 1: Raise dam 2 by 3 m – no EFlow									
Min	178.80	23.00		0.00		1.00			
Max	850.00	110.00		1496.0		3.60			
Median	850.00	110.00		0.90		1.40			
Mean	812.01	104.51		13.88		1.48			
Scenario 1a: Raise dam 2 by 3 m – 75/20 EFlow									
Min	209.30	24.50		0.00	0.00	0.90			
Max	850.00	110.00		1202.5	293.50	3.50			
Median	850.00	110.00		0.90	0.20	1.30			
Mean	812.75	104.59		11.29	2.67	1.39			
Scenario 2: Offriver Storage – no EFlow									
Min	84.80	27.50	123.70	0.00		0.00	0.00		
Max	350.00	110.00	500.00	1488.1		3.50	3.50		
Median	350.00	110.00	500.00	1.20		1.30	0.00		
Mean	334.61	105.38	478.14	13.86		1.22	0.30		
Scenario 3: Malpas pipeline to Guyra Water Filtration Plant – no EFLOW									
Min	0.00	0.00		0.00		0.00			0.00
Max	350.00	110.00		1487.8		5.00			4.00
Median	331.10	104.20		0.40		1.90			0.00
Mean	294.00	92.31		13.40		1.99			0.04
Scenario 3a: Malpas pipeline to Guyra Water Filtration Plant – 75/20 EFLOW									
Min	0.00	0.00		0.00	0.00	0.00			0.00
Max	350.00	110.00		1193.4	294.40	5.00			4.00
Median	322.90	101.70		0.00	1.10	1.90			0.00
Mean	284.65	89.44		10.02	3.39	1.98			0.05
Scenario 3b: Malpas pipeline to Guyra Water Filtration Plant – 65/20 EFLOW									
Min	0.00	0.00		0.00	0.00	0.00			0.00
Max	350.00	110.00		1193.6	294.20	5.00			4.00
Median	323.90	101.10		0.00	1.00	1.90			0.00
Mean	284.17	89.25		10.10	3.31	1.98			0.05

Statistic	Storage Level (ML)			Spill (ML/d)	EFlow (ML/d)	Supply/Transfers			
	Dam 2	Dam 1	Offriver			from all Guyra Dams (ML/d)	from offriver storage (ML/d)	From effluent reuse (ML/d)	from Malpas pipeline (ML/d)
Scenario 4: Malpas Pipeline to Industrial users – no EFLOW									
Min	13.90	5.50		0.00		0.50			0.40
Max	320.00	110.00		1488.7		2.00			1.70
Median	305.00	104.50		2.20		0.70			0.70
Mean	292.58	99.50		14.59		0.79			0.69
Scenario 5: Raise dam 2 by 3 m plus Effluent Reuse – no EFLow									
Min	283.50	36.90		0.00		0.70		0.30	
Max	850.00	110.00		1496.3		3.60		0.40	
Median	850.00	110.00		1.30		1.10		0.40	
Mean	818.57	105.35		14.14		1.21		0.40	

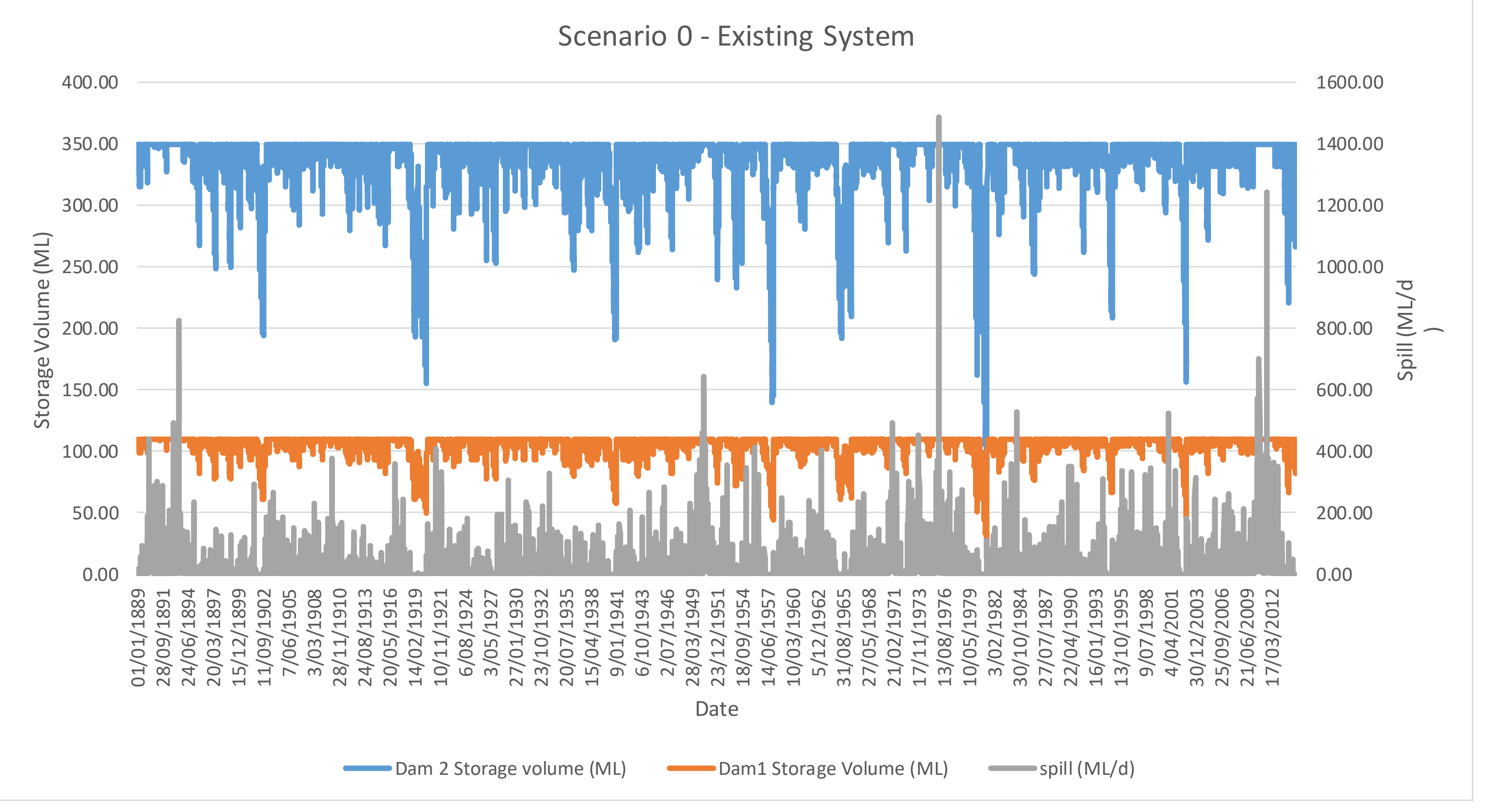
4.0 REFERENCES

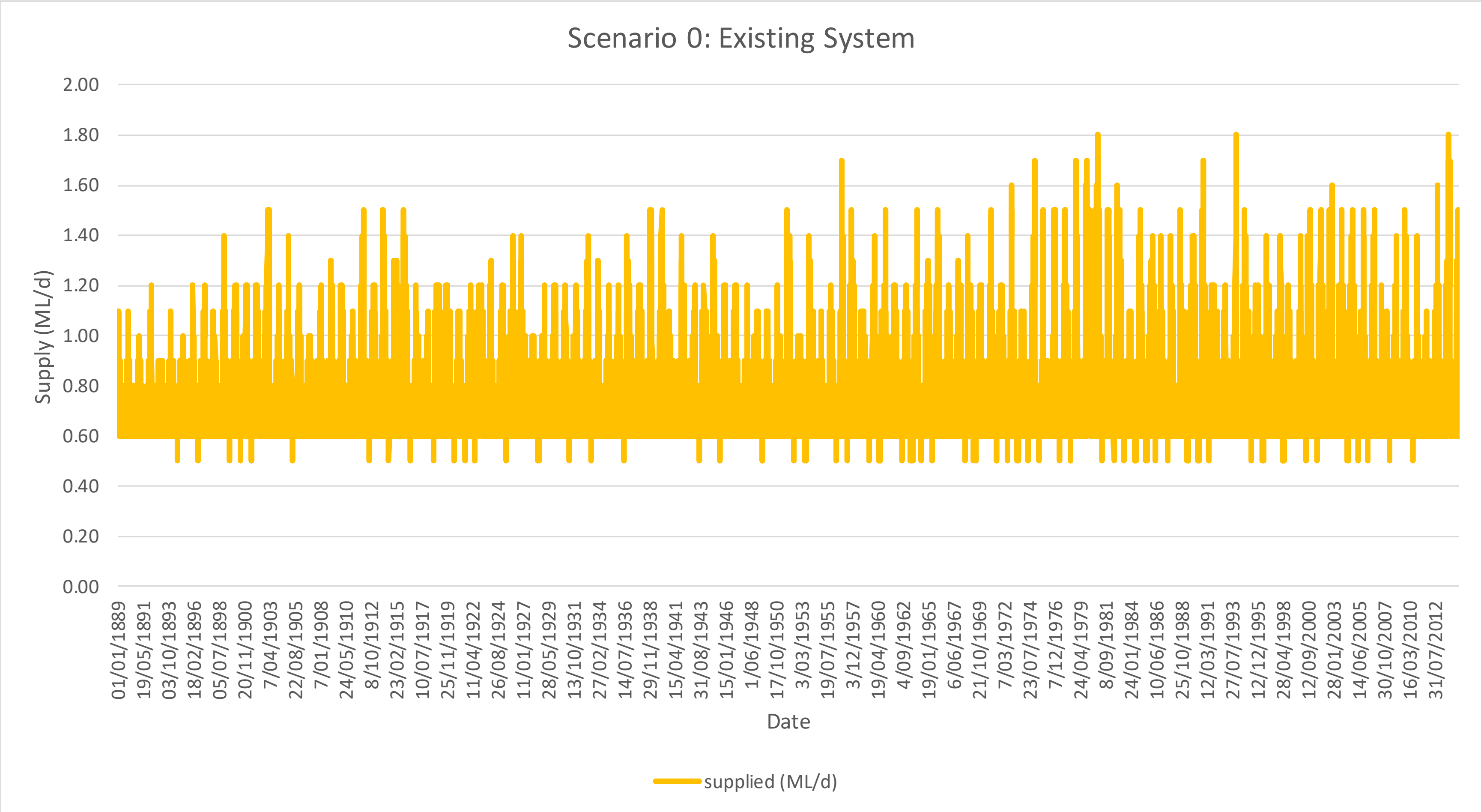
1. Hunter Water Australia (HWA), 2014 “Guyra Water Supply, Secure Yield Study”, for Guyra Shire Council.

2. WREMA, 2016, “Estimation of Secure Yield of Armidale Dumaresq Water Supply Dams”, for Armidale Regional Council.

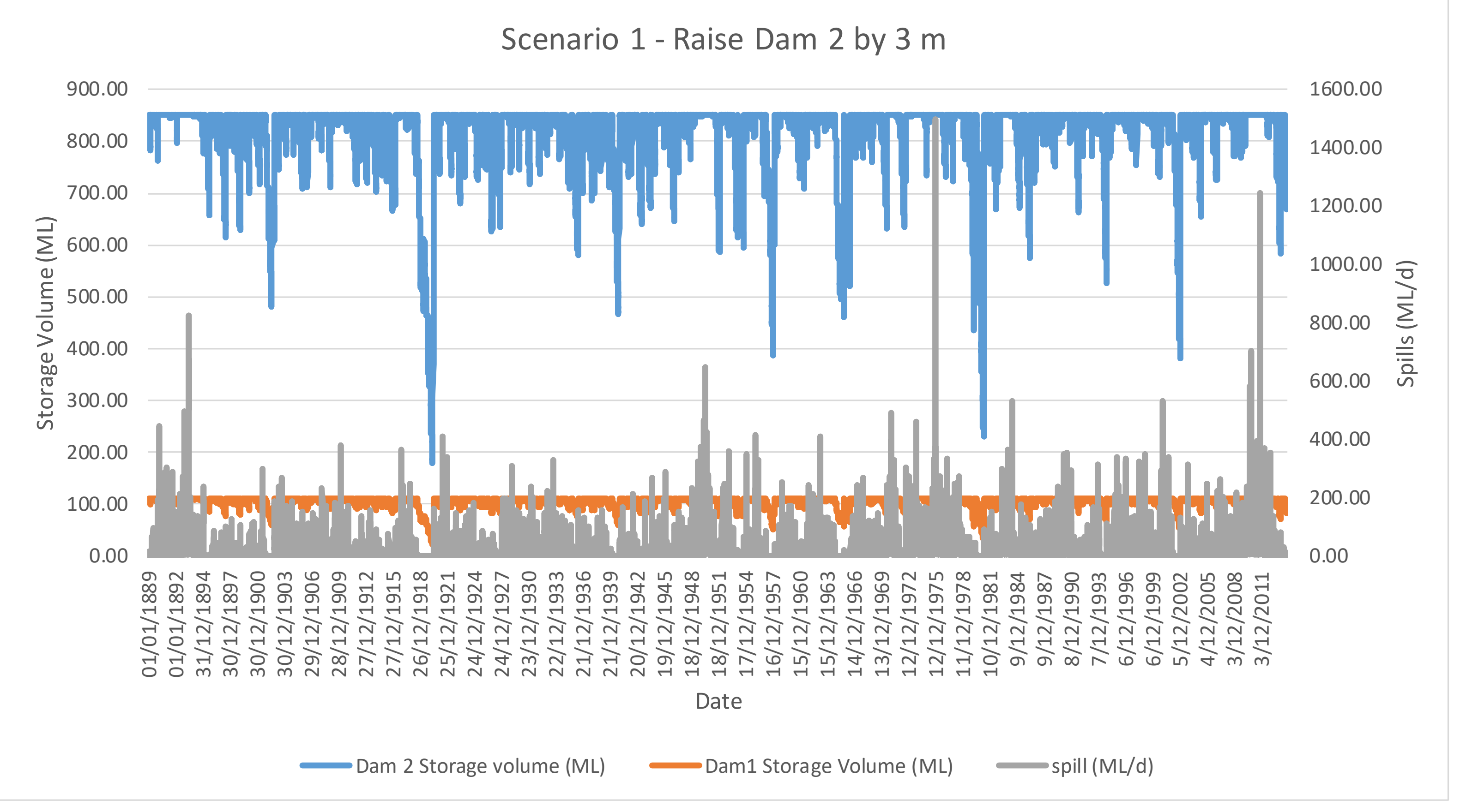
APPENDIX A – CHARTS

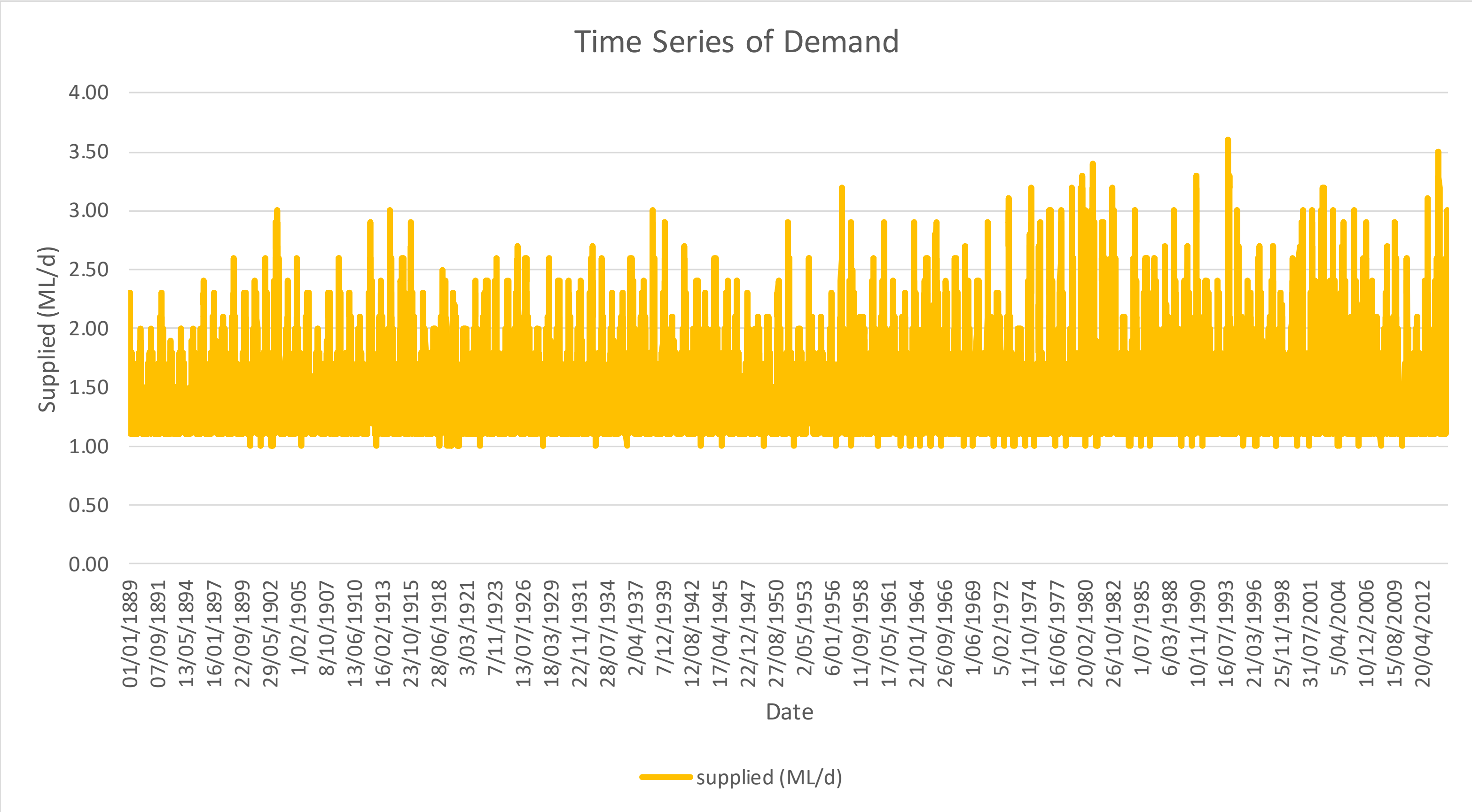
Scenario 0: Existing System



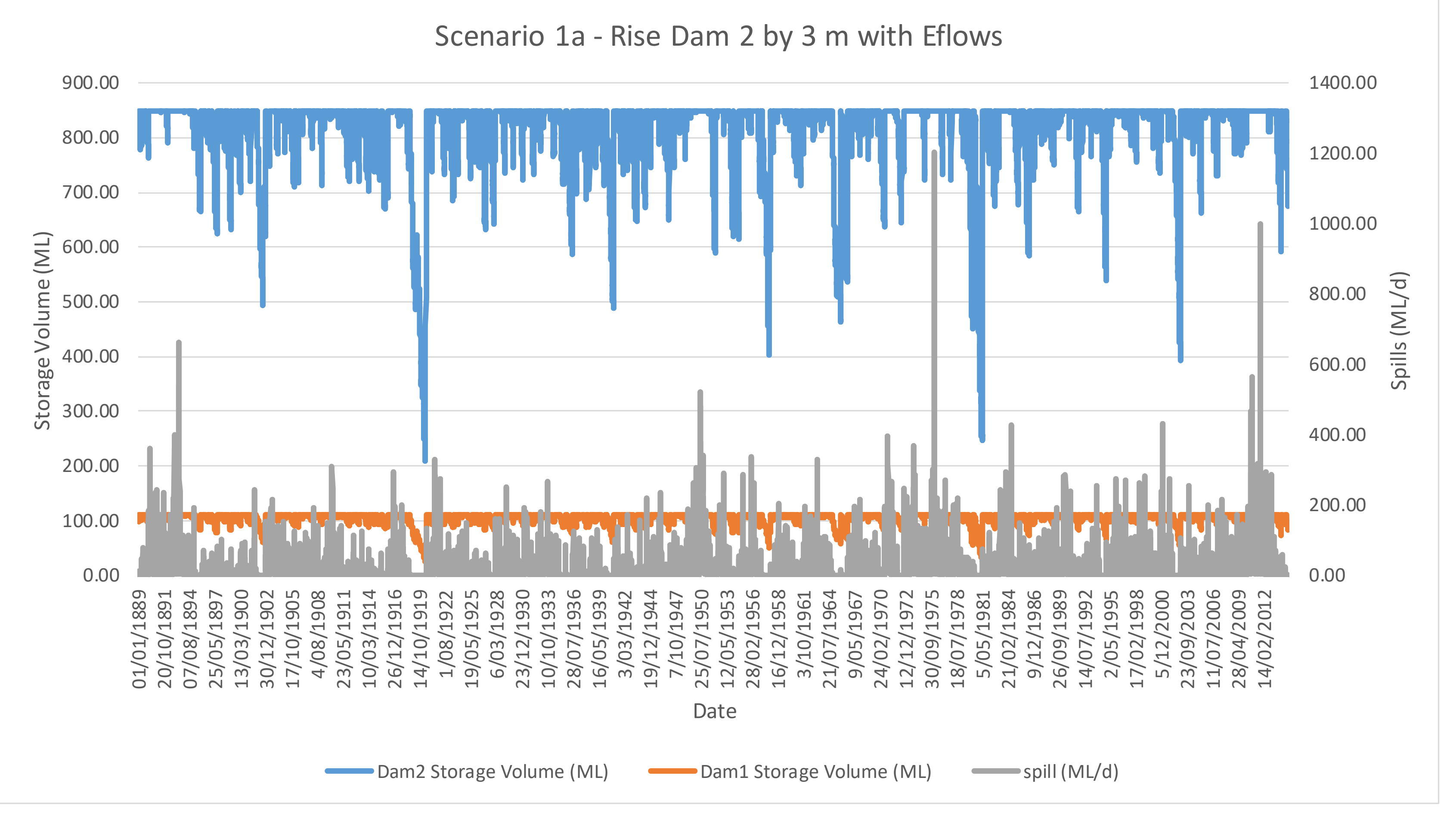

Scenario 0: Existing System
Supply (ML/d)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Date
supplied (ML/d)

Scenario 1: Raise dam 2 by 3 m

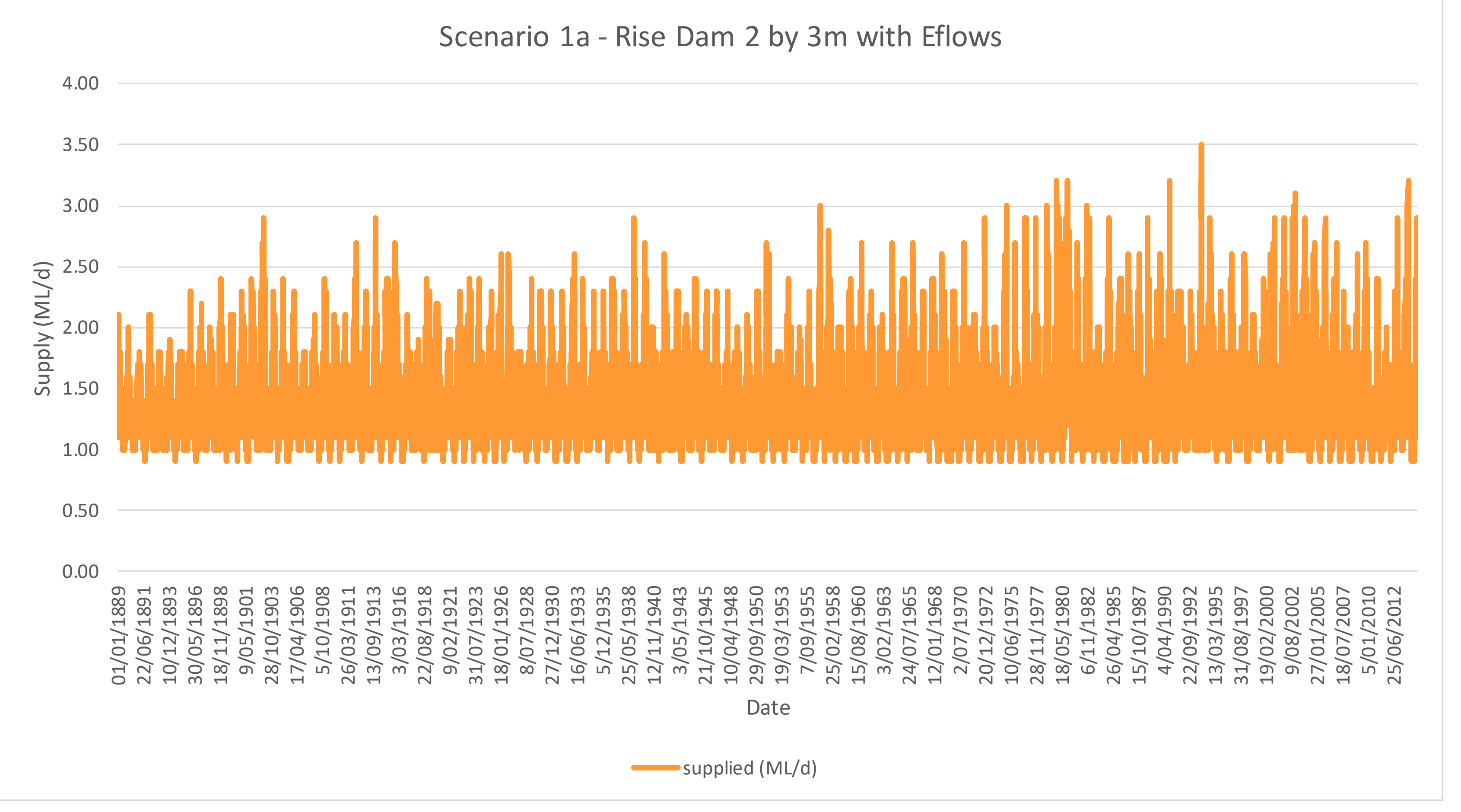



Time Series of Demand
Supplied (ML/d)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
01/01/1889
07/09/1891
13/05/1894
16/01/1897
22/09/1899
29/05/1902
1/02/1905
8/10/1907
13/06/1910
16/02/1913
23/10/1915
28/06/1918
3/03/1921
7/11/1923
13/07/1926
18/03/1929
22/11/1931
28/07/1934
2/04/1937
7/12/1939
12/08/1942
17/04/1945
22/12/1947
27/08/1950
2/05/1953
6/01/1956
11/09/1958
17/05/1961
21/01/1964
26/09/1966
1/06/1969
5/02/1972
11/10/1974
16/06/1977
20/02/1980
26/10/1982
1/07/1985
6/03/1988
10/11/1990
16/07/1993
21/03/1996
25/11/1998
31/07/2001
5/04/2004
10/12/2006
15/08/2009
20/04/2012
Date
supplied (ML/d)

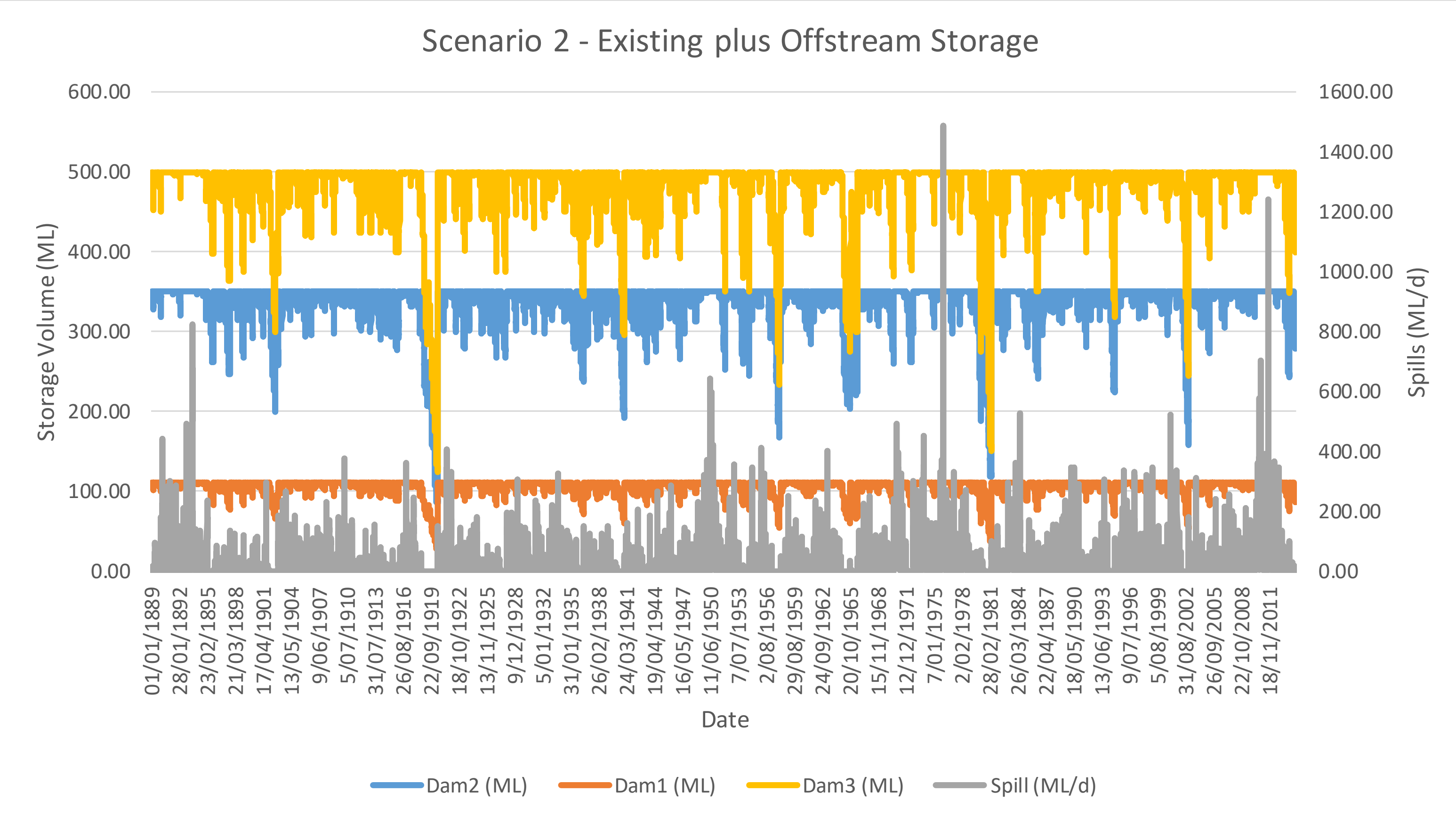
Scenario 1a: Raise dam 2 by 3 m with Eflows

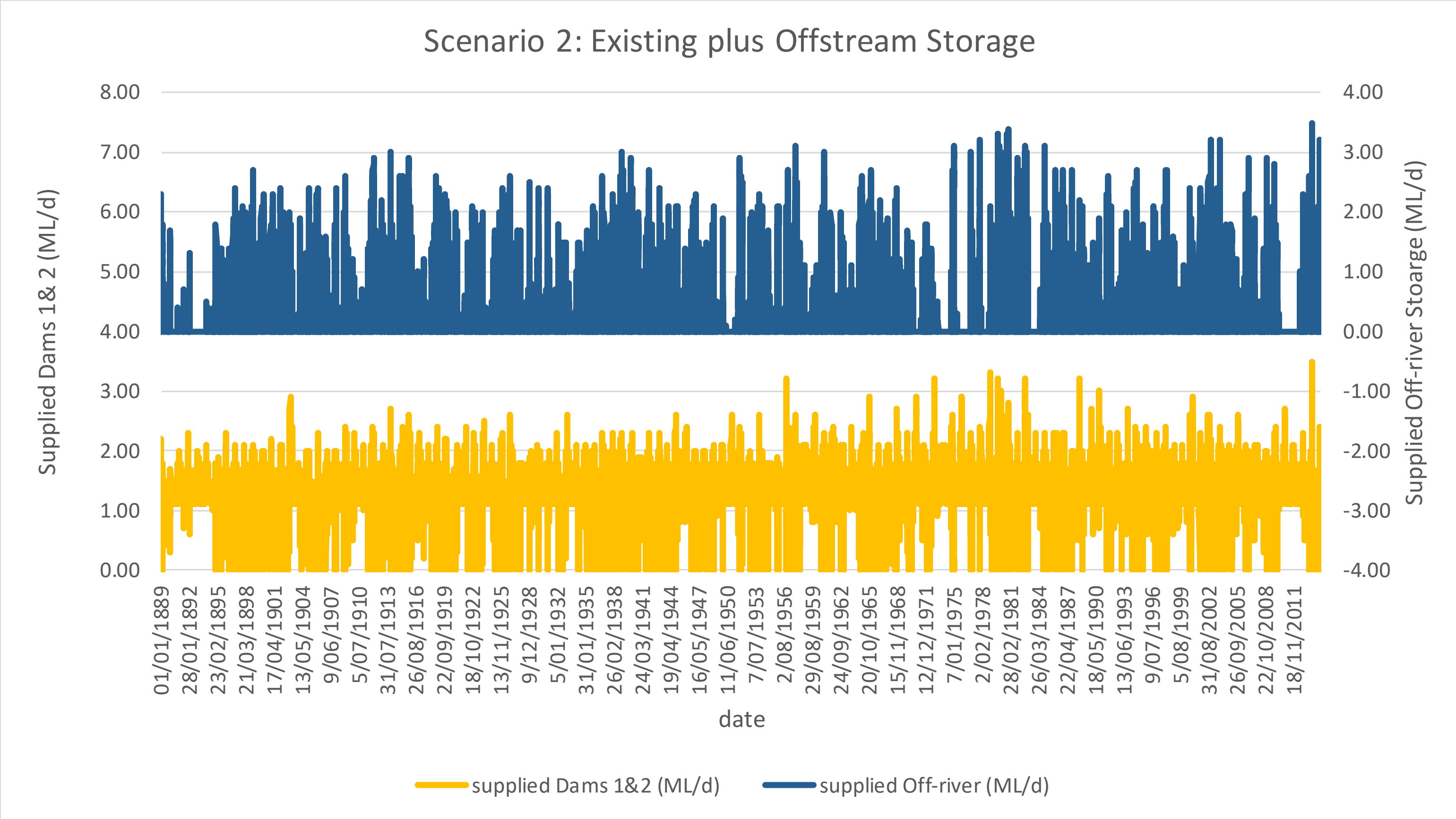


WREMA Water + Environment

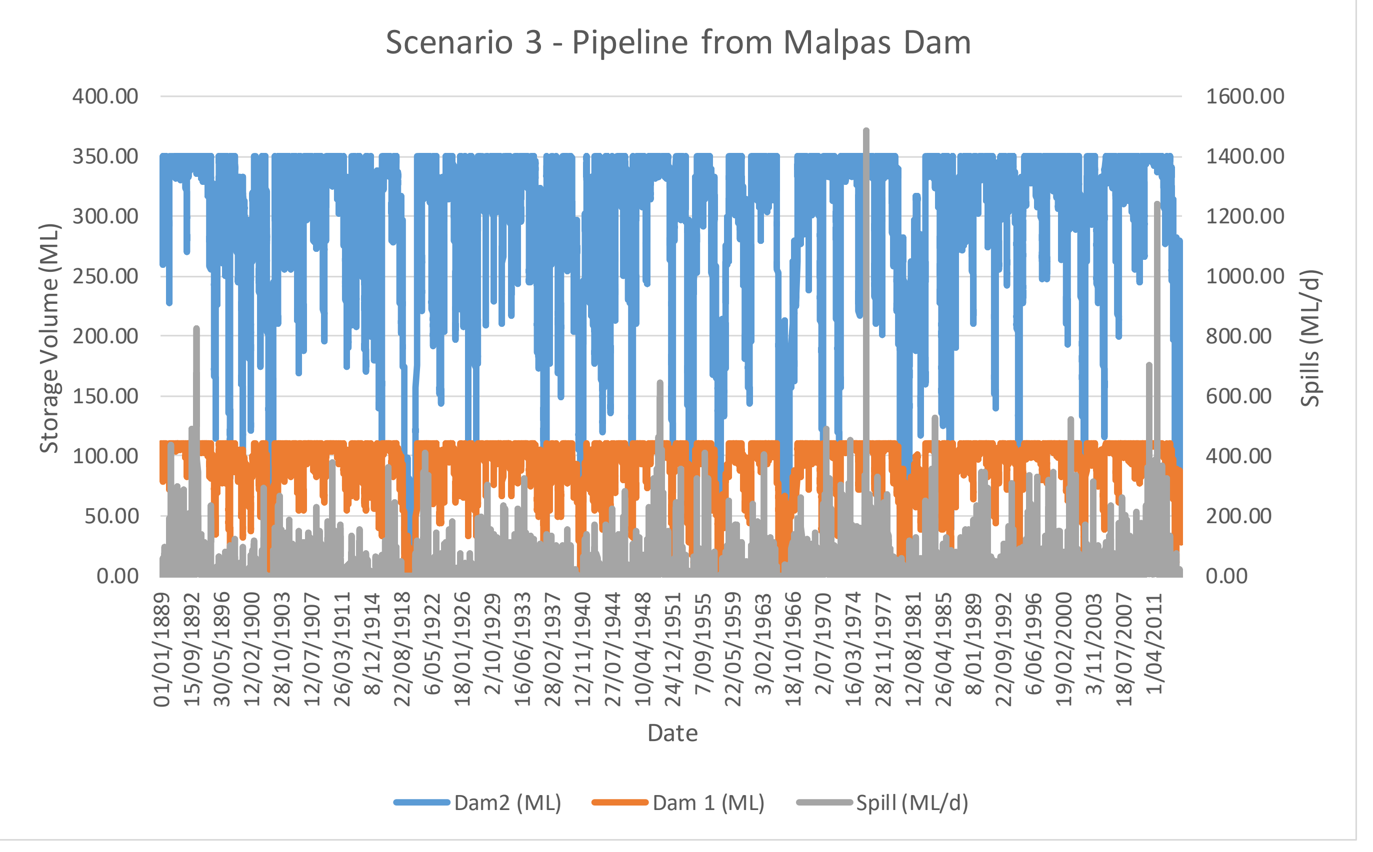

Scenario 1a - Rise Dam 2 by 3m with Eflows
Supply (ML/d)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
01/01/1889
22/06/1891
10/12/1893
30/05/1896
18/11/1898
9/05/1901
28/10/1903
17/04/1906
5/10/1908
26/03/1911
13/09/1913
3/03/1916
22/08/1918
9/02/1921
31/07/1923
18/01/1926
8/07/1928
27/12/1930
16/06/1933
5/12/1935
25/05/1938
12/11/1940
3/05/1943
21/10/1945
10/04/1948
29/09/1950
19/03/1953
7/09/1955
25/02/1958
15/08/1960
3/02/1963
24/07/1965
12/01/1968
2/07/1970
20/12/1972
10/06/1975
28/11/1977
18/05/1980
6/11/1982
26/04/1985
15/10/1987
4/04/1990
22/09/1992
13/03/1995
31/08/1997
19/02/2000
9/08/2002
27/01/2005
18/07/2007
5/01/2010
25/06/2012
Date
supplied (ML/d)

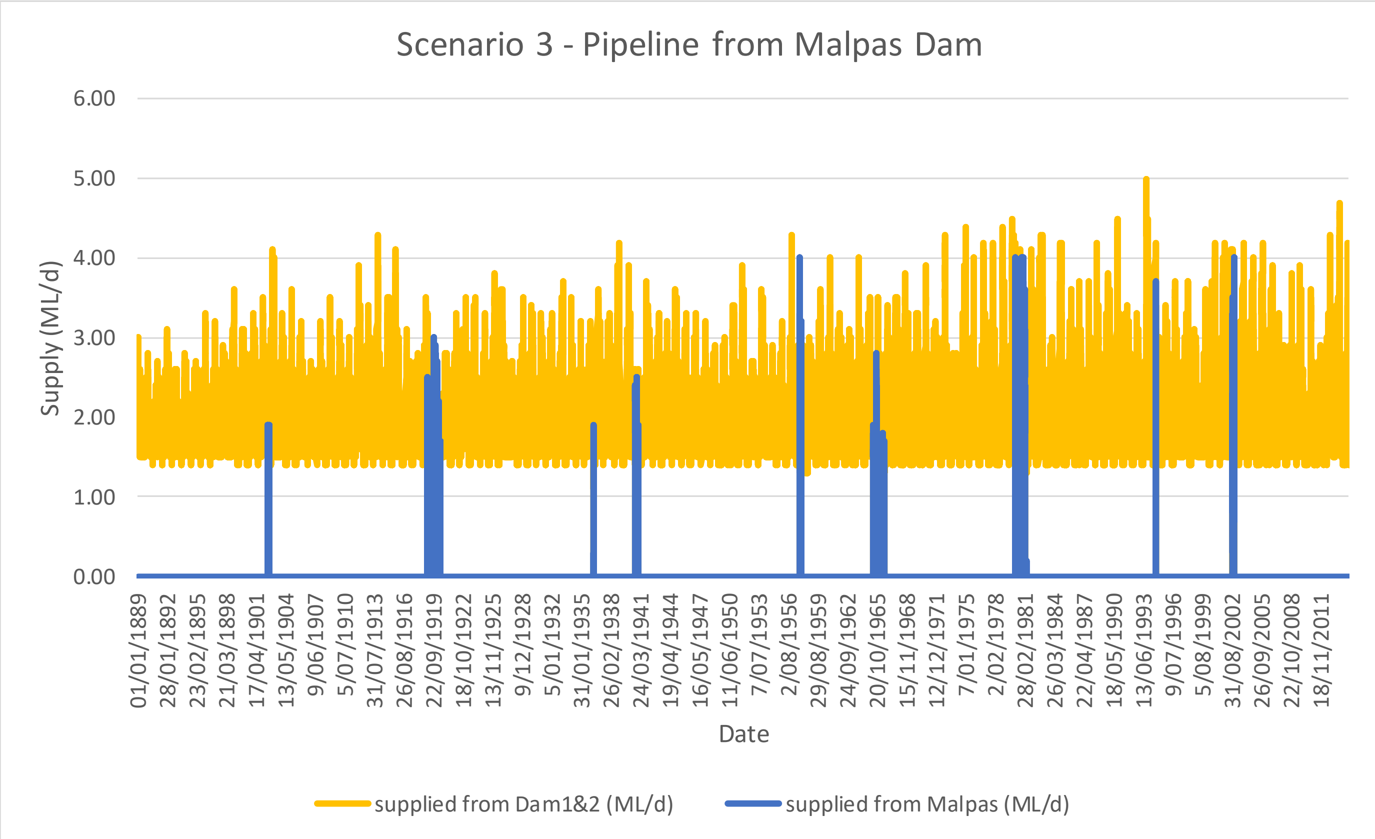
Scenario 2: Off-river Storage



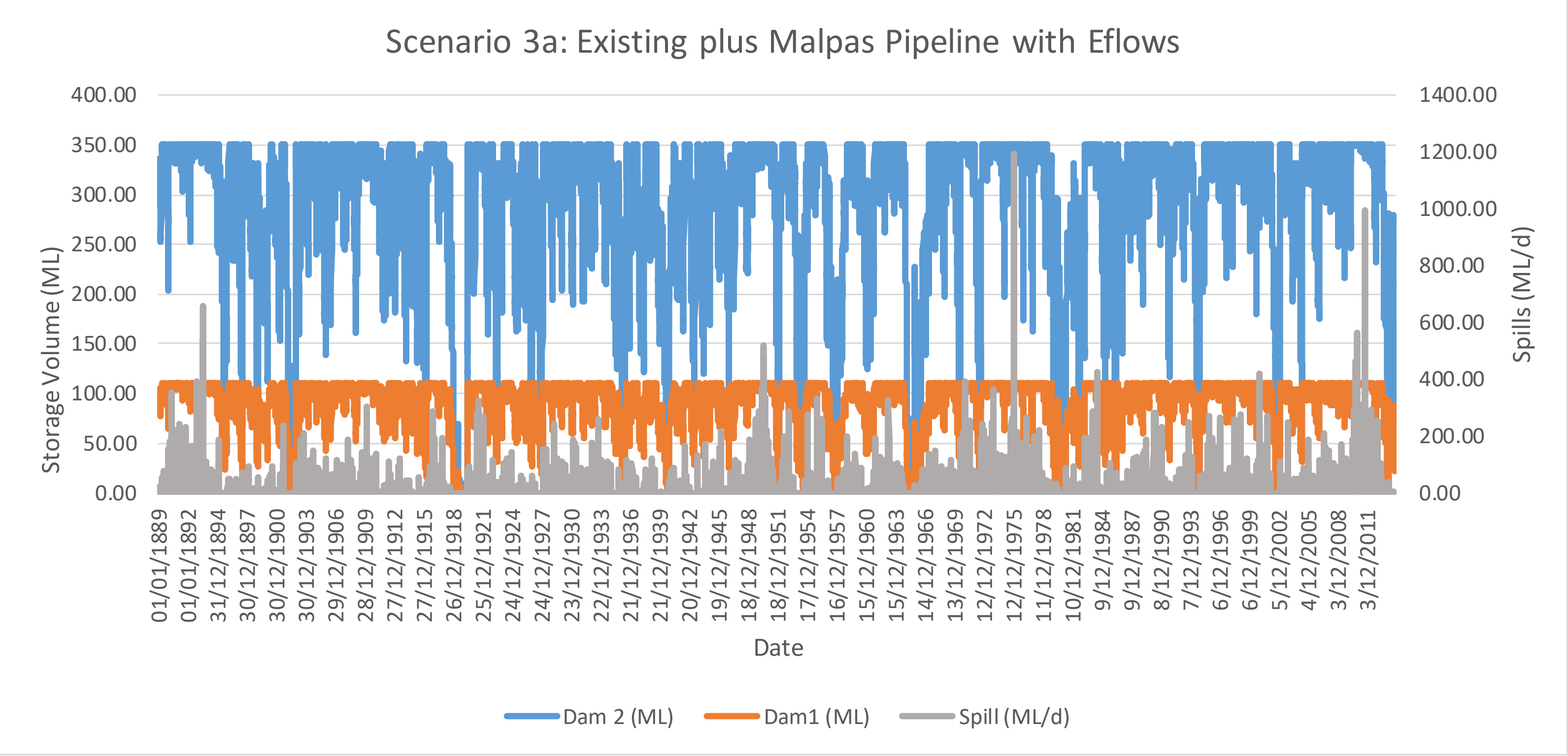

Scenario 2: Existing plus Offstream Storage
Supplied Dams 1& 2 (ML/d)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
Supplied Off-river Stoarge (ML/d)
01/01/1889
28/01/1892
23/02/1895
21/03/1898
17/04/1901
13/05/1904
9/06/1907
5/07/1910
31/07/1913
26/08/1916
22/09/1919
18/10/1922
13/11/1925
9/12/1928
5/01/1932
31/01/1935
26/02/1938
24/03/1941
19/04/1944
16/05/1947
11/06/1950
7/07/1953
2/08/1956
29/08/1959
24/09/1962
20/10/1965
15/11/1968
12/12/1971
7/01/1975
2/02/1978
28/02/1981
26/03/1984
22/04/1987
18/05/1990
13/06/1993
9/07/1996
5/08/1999
31/08/2002
26/09/2005
22/10/2008
18/11/2011
date
supplied Dams 1&2 (ML/d)
supplied Off-river (ML/d)

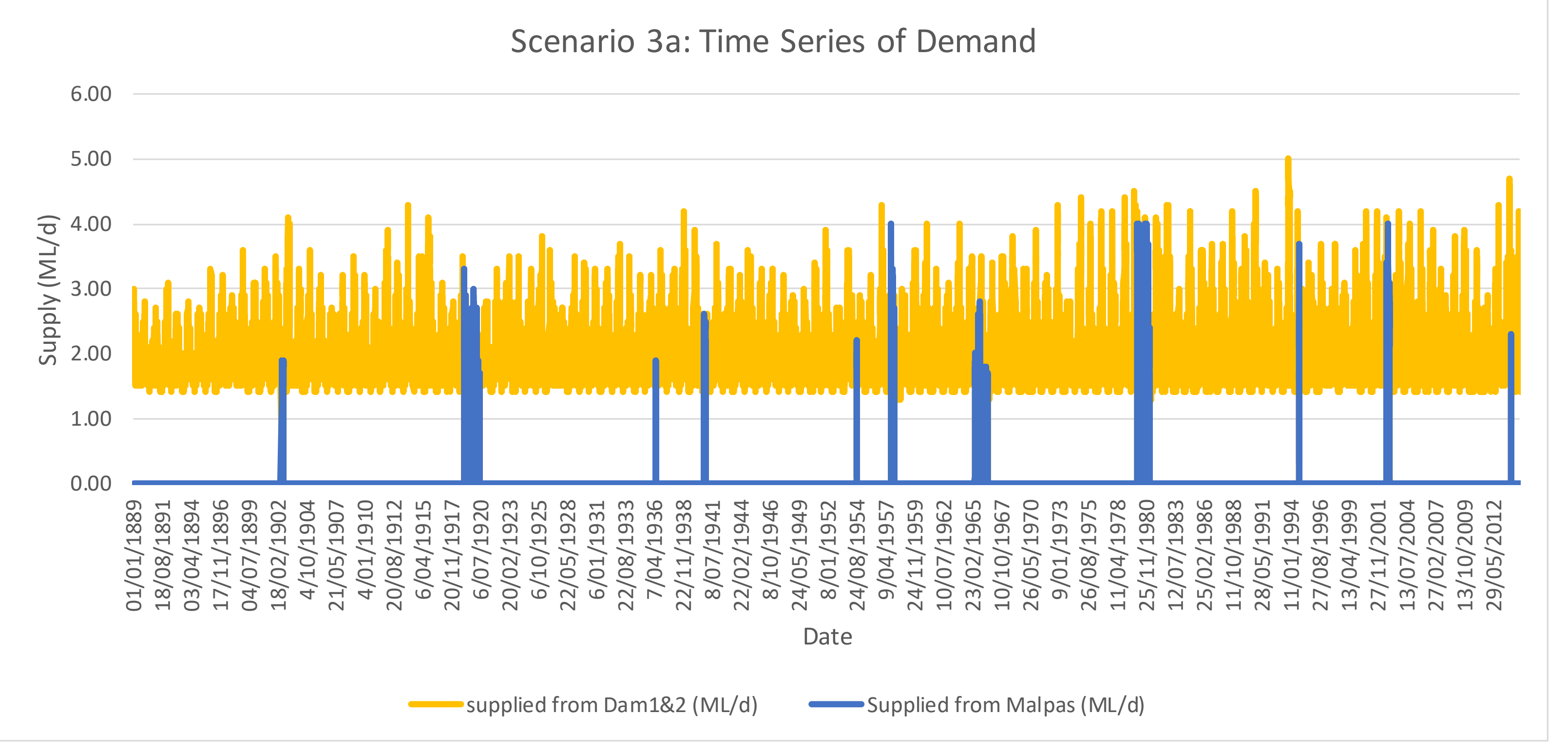
Scenario 3: Pipeline from Malpas Dam to Guyra Water Filtration Plant – no EFlow




Scenario 3 - Pipeline from Malpas Dam
Supply (ML/d)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
01/01/1889
28/01/1892
23/02/1895
21/03/1898
17/04/1901
13/05/1904
9/06/1907
5/07/1910
31/07/1913
26/08/1916
22/09/1919
18/10/1922
13/11/1925
9/12/1928
5/01/1932
31/01/1935
26/02/1938
24/03/1941
19/04/1944
16/05/1947
11/06/1950
7/07/1953
2/08/1956
29/08/1959
24/09/1962
20/10/1965
15/11/1968
12/12/1971
7/01/1975
2/02/1978
28/02/1981
26/03/1984
22/04/1987
18/05/1990
13/06/1993
9/07/1996
5/08/1999
31/08/2002
26/09/2005
22/10/2008
18/11/2011
Date
supplied from Dam1&2 (ML/d)
supplied from Malpas (ML/d)

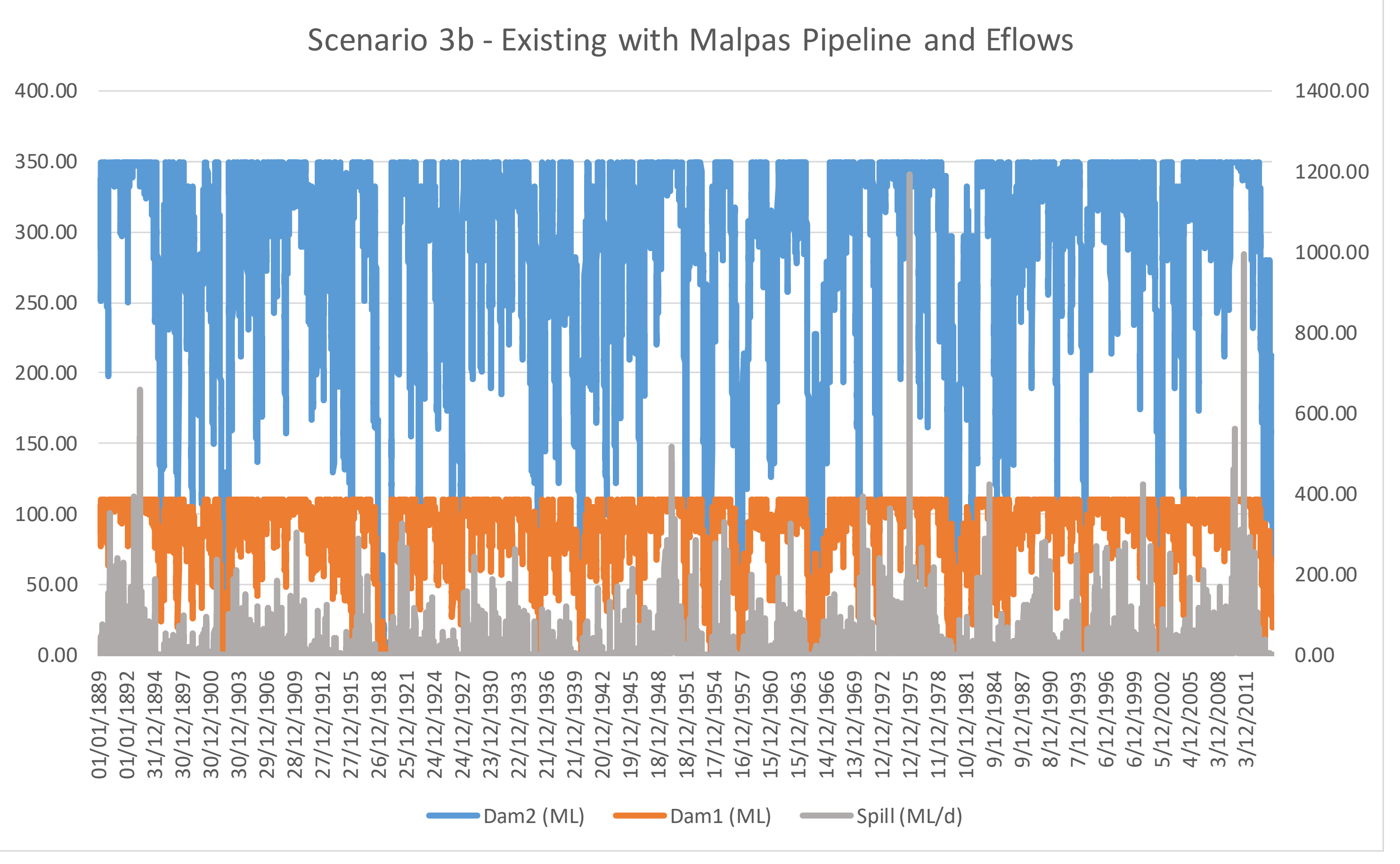
Scenario 3a: Pipeline from Malpas Dam to Guyra Water Filtration Plant – 75/20 EFlow

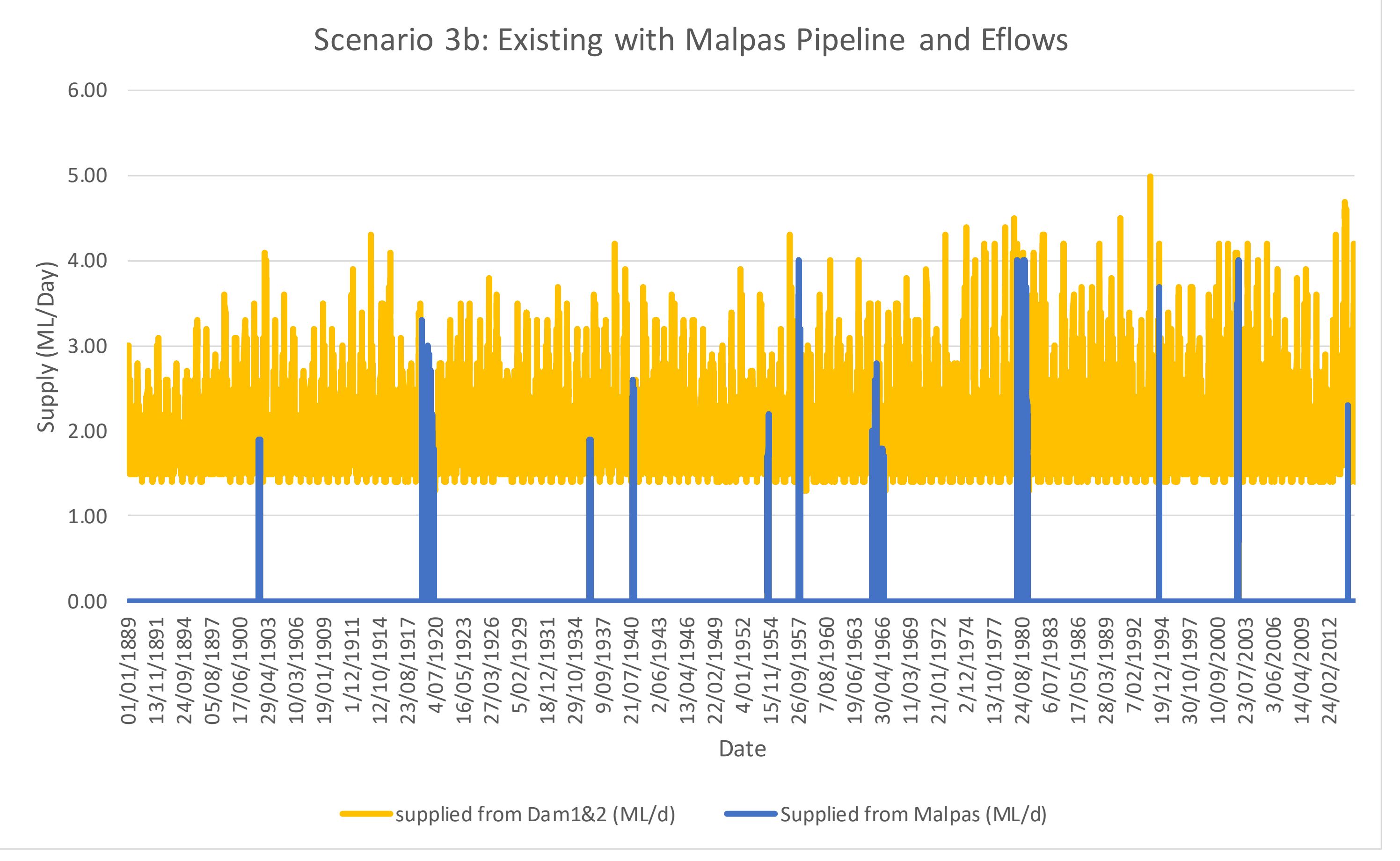




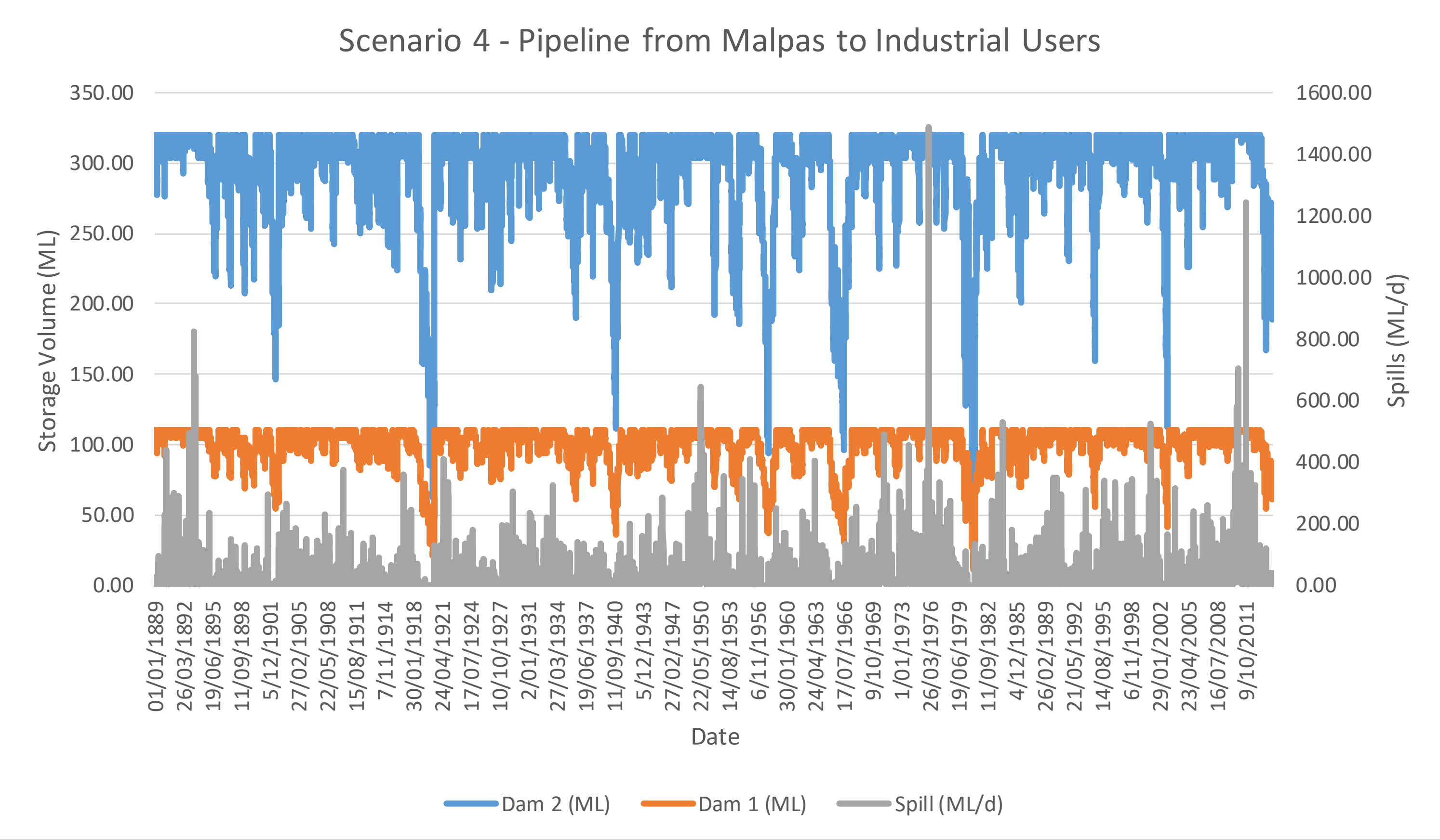
Scenario 3a: Time Series of Demand
Supply (ML/d)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
01/01/1889
18/08/1891
03/04/1894
17/11/1896
04/07/1899
18/02/1902
4/10/1904
21/05/1907
4/01/1910
20/08/1912
6/04/1915
20/11/1917
6/07/1920
20/02/1923
6/10/1925
22/05/1928
6/01/1931
22/08/1933
7/04/1936
22/11/1938
8/07/1941
22/02/1944
8/10/1946
24/05/1949
8/01/1952
24/08/1954
9/04/1957
24/11/1959
10/07/1962
23/02/1965
10/10/1967
26/05/1970
9/01/1973
26/08/1975
11/04/1978
25/11/1980
12/07/1983
25/02/1986
11/10/1988
28/05/1991
11/01/1994
27/08/1996
13/04/1999
27/11/2001
13/07/2004
27/02/2007
13/10/2009
29/05/2012
Date
supplied from Dam1&2 (ML/d)
Supplied from Malpas (ML/d)

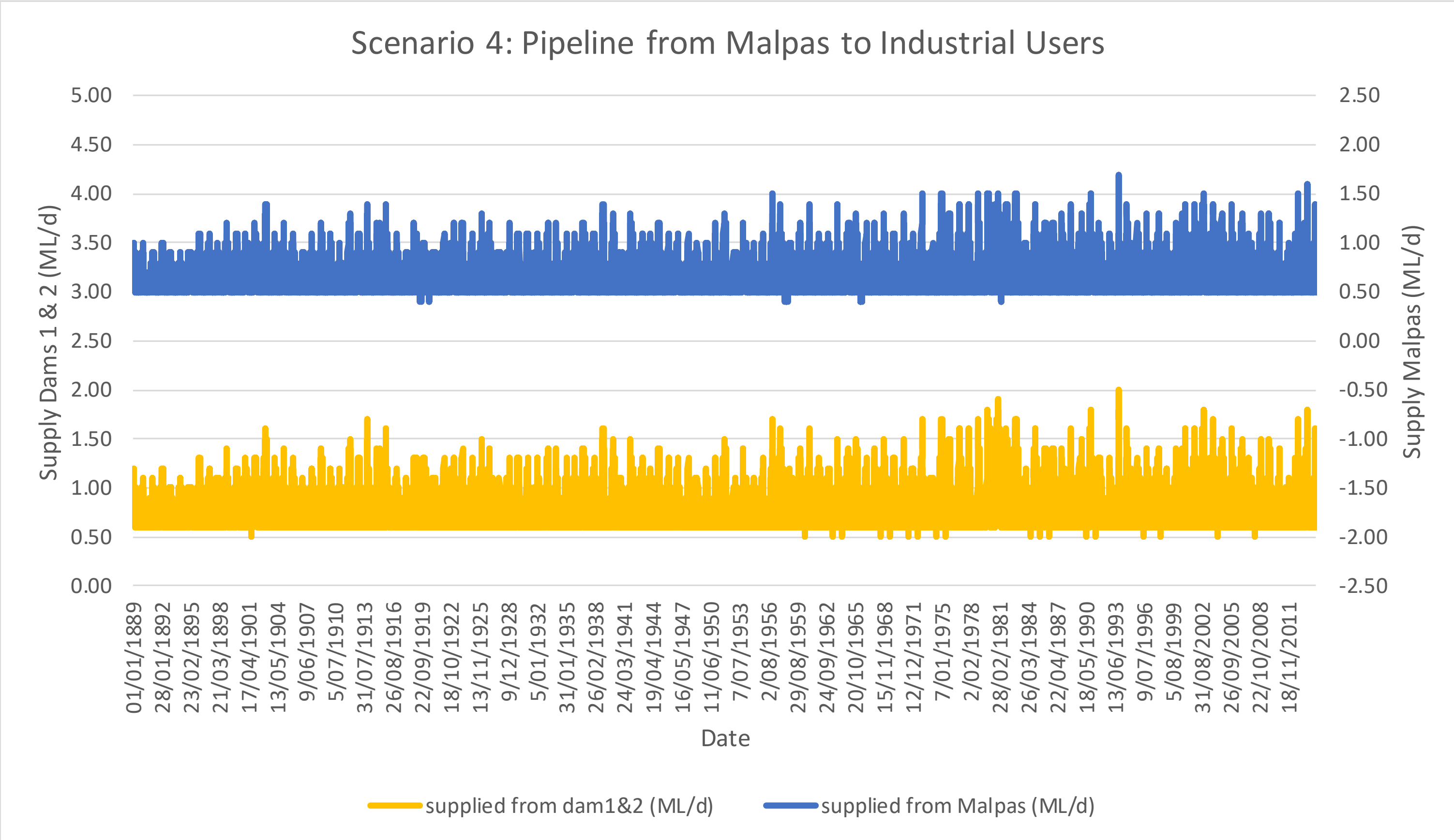
Scenario 3b: Pipeline from Malpas Dam to Guyra Water Filtration Plant – 65/20 EFlow



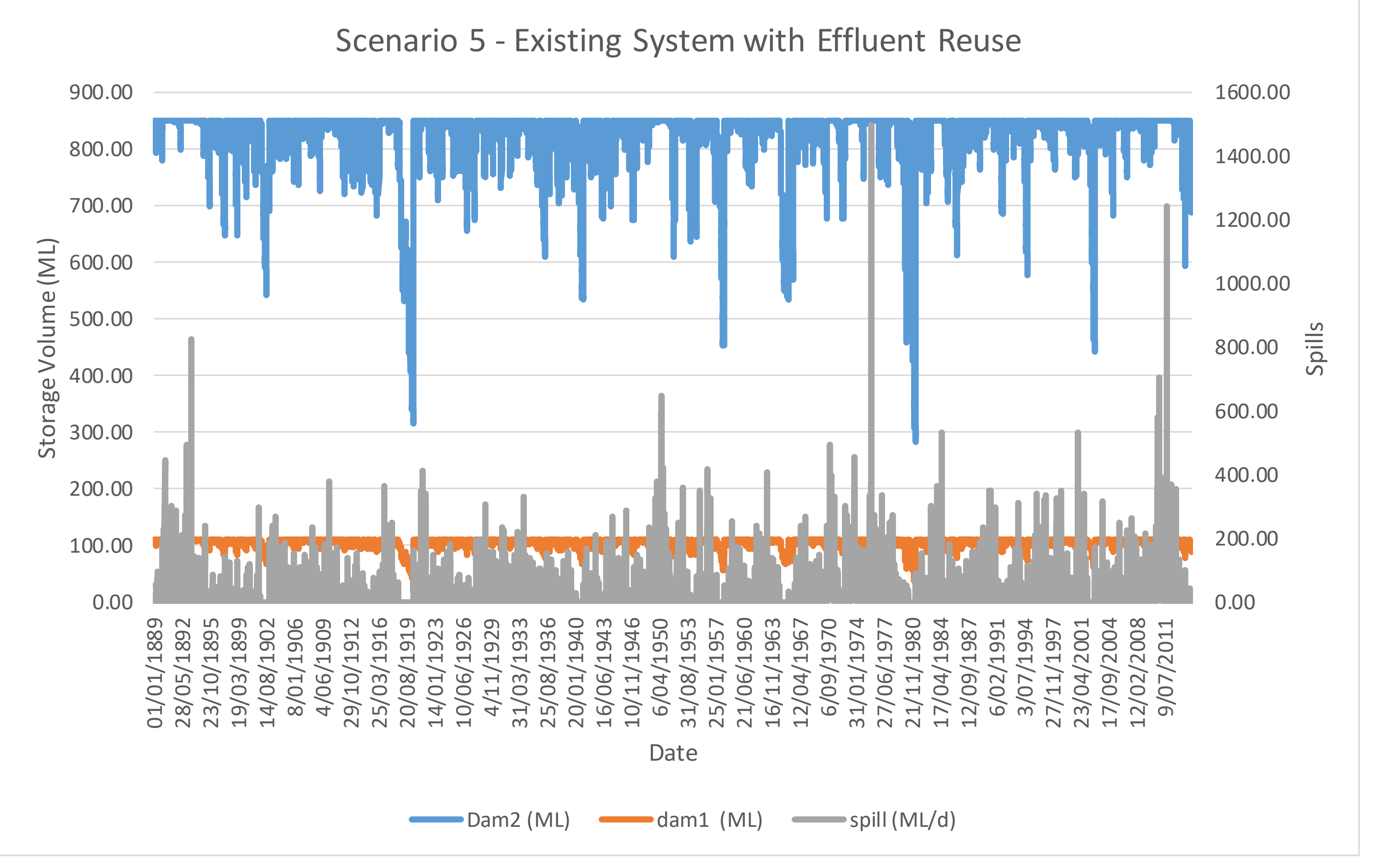

Scenario 3b: Existing with Malpas Pipeline and Eflows
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Supply (ML/Day)
01/01/1889
13/11/1891
24/09/1894
05/08/1897
17/06/1900
29/04/1903
10/03/1906
19/01/1909
1/12/1911
12/10/1914
23/08/1917
4/07/1920
16/05/1923
27/03/1926
5/02/1929
18/12/1931
29/10/1934
9/09/1937
21/07/1940
2/06/1943
13/04/1946
22/02/1949
4/01/1952
15/11/1954
26/09/1957
7/08/1960
19/06/1963
30/04/1966
11/03/1969
21/01/1972
2/12/1974
13/10/1977
24/08/1980
6/07/1983
17/05/1986
28/03/1989
7/02/1992
19/12/1994
30/10/1997
10/09/2000
23/07/2003
3/06/2006
14/04/2009
24/02/2012
Date
supplied from Dam1&2 (ML/d)
Supplied from Malpas (ML/d)

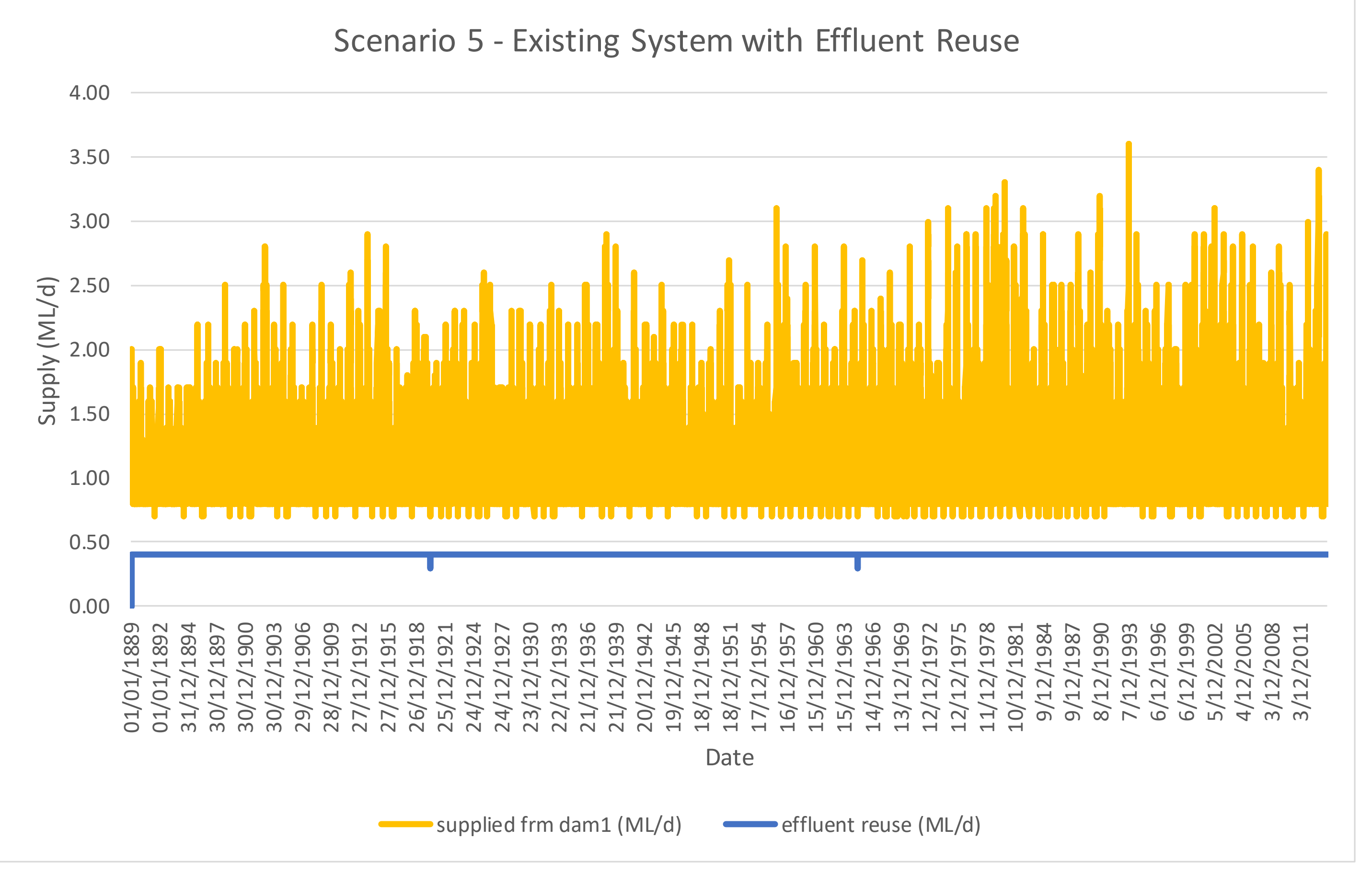
Scenario 4: Pipeline from Malpas Dam to Industrial Users – no EFlows




Scenario 4: Pipeline from Malpas to Industrial Users
Supply Dams 1 & 2 (ML/d)
Supply Malpas (ML/d)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
01/01/1889
28/01/1892
23/02/1895
21/03/1898
17/04/1901
13/05/1904
9/06/1907
5/07/1910
31/07/1913
26/08/1916
22/09/1919
18/10/1922
13/11/1925
9/12/1928
5/01/1932
31/01/1935
26/02/1938
24/03/1941
19/04/1944
16/05/1947
11/06/1950
7/07/1953
2/08/1956
29/08/1959
24/09/1962
20/10/1965
15/11/1968
12/12/1971
7/01/1975
2/02/1978
28/02/1981
26/03/1984
22/04/1987
18/05/1990
13/06/1993
9/07/1996
5/08/1999
31/08/2002
26/09/2005
22/10/2008
18/11/2011
Date
supplied from dam1&2 (ML/d)
supplied from Malpas (ML/d)

Scenario 5: Raise Dam 2 by 3m plus Effluent Re-use for Industrial Users




Scenario 5 - Existing System with Effluent Reuse
Supply (ML/d)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
01/01/1889
01/01/1892
31/12/1894
30/12/1897
30/12/1900
30/12/1903
29/12/1906
28/12/1909
27/12/1912
27/12/1915
26/12/1918
25/12/1921
24/12/1924
24/12/1927
23/12/1930
22/12/1933
21/12/1936
21/12/1939
20/12/1942
19/12/1945
18/12/1948
18/12/1951
17/12/1954
16/12/1957
15/12/1960
15/12/1963
14/12/1966
13/12/1969
12/12/1972
12/12/1975
11/12/1978
10/12/1981
9/12/1984
9/12/1987
8/12/1990
7/12/1993
6/12/1996
6/12/1999
5/12/2002
4/12/2005
3/12/2008
3/12/2011
Date
supplied frm dam1 (ML/d)
effluent reuse (ML/d)