BASSLINK INTEGRATED IMPACT ASSESSMENT STATEMENT

POTENTIAL EFFECTS OF CHANGES TO HYDRO POWER GENERATION

APPENDIX 2:

GORDON RIVER HYDROLOGY ASSESSMENT

L. Palmer[1]*, F. McConachy*[1]*, J. Peterson*[1]

June 2001

Prepared for

Hydro Tasmania
the renewable energy business

1. Hydrologist – Resource Analysis, Hydro Tasmania, GPO Box 355D, Hobart, 7001.

CONTENTS

TABLES

FIGURES

MAPS

1 INTRODUCTION

1.1 Aim

This report provides hydrological information for the Gordon River downstream of Gordon Power Station in South Western Tasmania. It is part of a series of environmental investigations in the Gordon Region into potential Basslink changes on the downstream environment. This document summarises current operation of the Gordon Power Station, predicted Basslink changes to the power station operation, and how these changes will affect flow patterns in the Gordon River downstream of the Power Station.

Additional hydrological analysis was undertaken at the request of specific Gordon River researchers and this has been presented in their reports (eg. Appendix 4 of this report series– Gordon River Fluvial Geomorphology Assessment, Appendix 7 of this report series – Gordon River Macroinvertebrate and Aquatic Mammal Assessment). This additional analysis included comparisons between natural and current situations, to provide a background understanding of the current power station impacts so that the researchers could understand current trends in environmental parameters.

1.2 Report Structure

This report is broadly divided into seven sections:

A methodology section (Section 2) presents an overview of the historical hydrological data available for analysis and identifies the sites chosen for presentation of information. An explanation of the TEMSIM model used to simulate power station operations under Basslink has also been provided in this section.

Hydrological comparisons between pre Gordon (natural) and current conditions have been made in Section 3. These include time series flow plots and a duration curve. A description of Gordon Power Station operation has been provided.

The effect of Basslink on water levels in the Gordon region has been assessed in Section 4. Current conditions and simulated Basslink conditions have been investigated and compared in Lake Gordon and also downstream of Gordon Dam.

Section 5 describes the response of the Gordon Power Station to changes in electricity demand patterns under Basslink. The comparisons include annual time series, event duration analyses and monthly median flows.

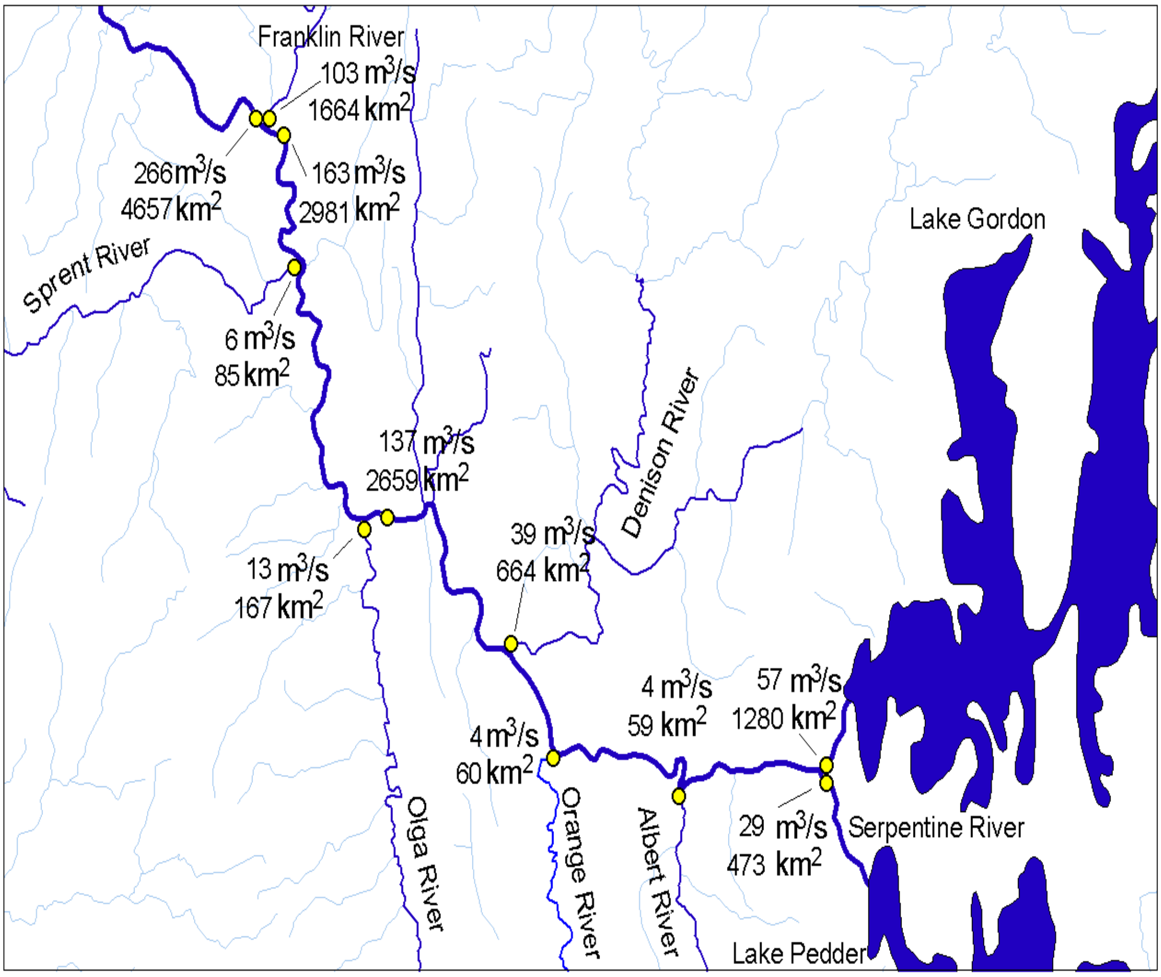
Section 6 provides comparisons of current versus Basslink-projected data at sites downstream of the Gordon Power Station. These comparisons include annual time series for selected wet and dry years, flow duration curves, monthly median flows, and flood frequency analyses. The impact of the tributaries on flows in the Gordon River has also been investigated in this section.

Section 7 provides a report summary.

2 AVAILABLE DATA AND METHODOLOGY

2.1 Catchment hydrology and data availability

The Gordon River has several tributaries of various sizes entering downstream of the power station. Some of these tributaries contribute a significant amount of inflow to the downstream Gordon Catchment. Map 1 shows the locations of these tributaries relative to the hydrographic recording stations within the river, the average annual discharge for these tributaries, and their catchment areas.



Map 1. Gordon River tributaries and hydrographic station localities for historical and simulated flow records (Period of records: between 1958-1998)

A list of all the hydrological sites used for analysis in this report has been presented below in Table I. The sites are also shown in Map 2. Hydrological data availability for the Gordon River is restricted due to the lack of previously installed instrumentation or lack of overlap in monitoring periods between various downstream stations. Also diminishing the direct applicability of data is the fact that only 2 turbines were present in the power station in the first 10 years of record rather than 3, thus reducing the record that is representative of the current set of operating parameters. Because of this, the majority of comparisons made in the report have used data beginning from 1989.

The sites presented in Table I have been numbered equivalent to their river distance upstream of the Gordon River mouth (in km). This numbering pattern has been used to remain consistent with corresponding Basslink environmental investigations in the Gordon region. The relative TimeStudio site number of each site has been listed in the table.

For the Basslink environmental investigations, six gauging stations were installed in 1999 (Sites 39, 62, 65, 69, 71 and 75) and Gordon above Franklin, site 47 has been reinstated. The Gordon upstream of Olga site is no longer gauged, but has a rating curve and reasonable historical record.

Table I. Hydrological Sites Used in Analyses

Site No	Site	TimeStudio No.	Start of Record	End of Record
	Gordon Power Station	254	1977	Present
39	Gordon River at No. 4 Damsite	729	1999	2000
47	Gordon River a/b Franklin River	187	1958	Present
50	Gordon River a/b Olga River	586	1968	1988
61	Gordon River 1km b/l Denison	2405	2000	2000
62	Gordon River b/l Denison River	1198	1999	2000
65	Gordon River a/b Orange River	2402	1999	2000
69	Gordon River a/b Second Split	2401	1999	2000
72	Gordon River b/l Albert River	2400	1999	2000
75	Gordon River at Albert Rapids	1192	1999	2000

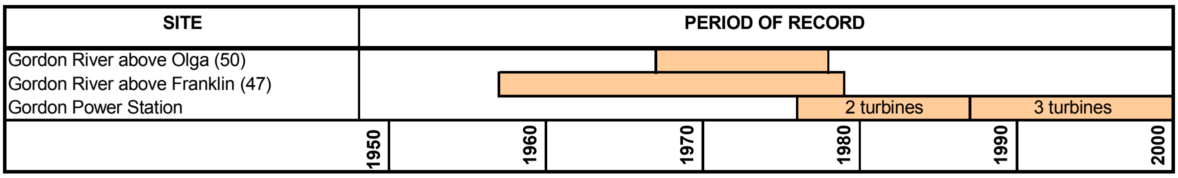
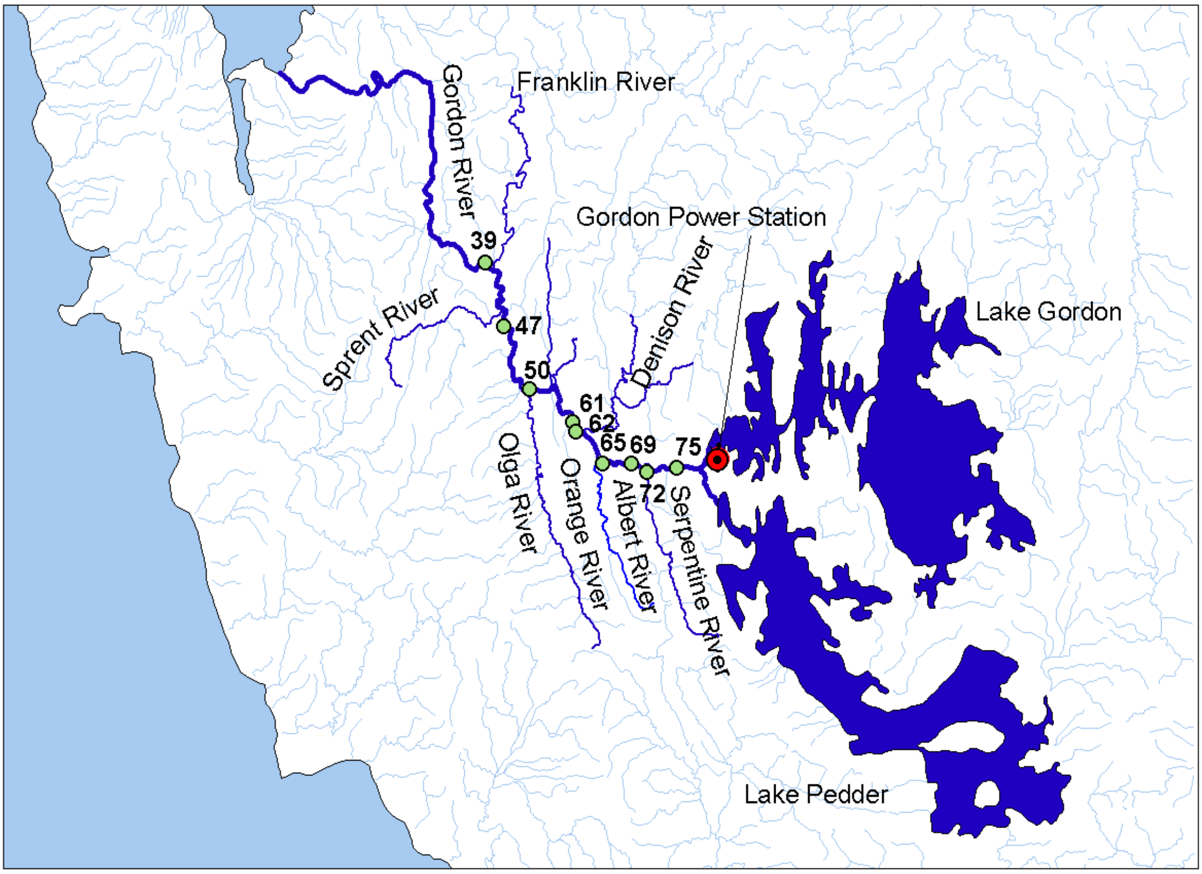


Figure 1. Period of Record of Sites used in Analyses



Map 2. Hydrological Sites used in this Report

The majority of the power station record exists in the form of daily average data, with only 2 years of hourly power station discharge data available (some of which is not of good quality). Consequently, many of the plots developed for comparison and analysis of the various scenarios use daily average data. This is only likely to affect the presentation of the time series plots, which may have more short-term variability than indicated. Analysis of the hourly data has been undertaken where short term variability is important. Flows from the power station are calculated using a rating from Energy or Power to flow. This is an average rating only, therefore there will be some error associated with the flow estimates when the level in Lake Gordon is very high or very low. As this is the only estimate of power station flow, this record was used in analysis.

2.2 Determination of Wet and Dry Years

Comparisons of current time series against modelled Basslink time series in this report have been carried out for both a wet year and a dry year. The historical operation of the Gordon Power Station varies considerably between a wet year and a dry year, because during a wet year much of the electricity demand can be met by the run-of-river stations rather than from Gordon. Wet and dry years were selected from total system yield data. System yield data is calculated from inflows to the entire Hydro-electric system over the period 1924 to 1998. It should be noted that a relatively wet year (high inflows) for the system as a whole does not necessarily indicate a particularly wet year for the catchment. However, the whole Hydro system operating under wet (or dry) conditions influences the operational regime of the Gordon Power Station.

The total system yield shown in Figure 2 reflects the inflows to Hydro storages in a given year. A relatively high total system yield in a given year indicates high rainfall across the State. The wet and dry years chosen for analysis have been labelled in the figure below. Note that units have not been provided for the system yield as this information is deemed to be confidential.

The period available for analysis (1989-1998) can be seen to contain many years where the system yield was near the mean with 1989 and 1996 being the only exceptions. In 1996 the parameter used when recording power station output was changed from energy (in MWh) to power (in MW). During this parameter conversion there was a period of over a month where no output was recorded from the power station. The year has still been chosen for analysis despite the missing data because it is the only obvious wet year throughout the available period of analysis. Load and transmission constraints affect the two years of hourly data available for the power station between 1997 and 1998. This limited the total output from the power station.

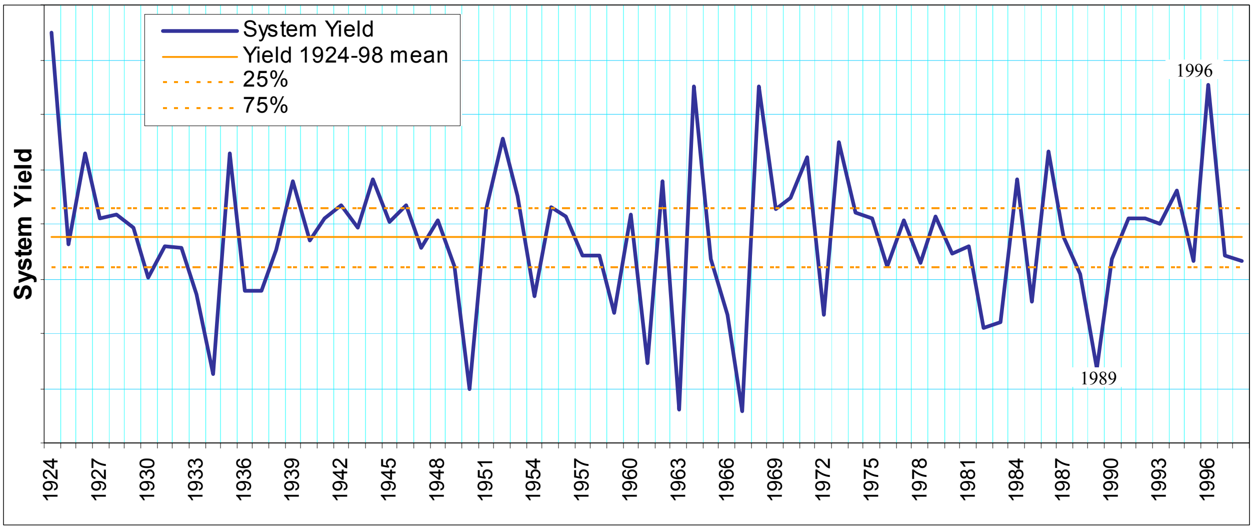


Figure 2. Total System Yield

2.3 Development of the Gordon River Hydrological Model

Flows down the Gordon River were modelled using a TimeStudio model. This hydrological model uses inflows from the Gordon tributaries and pick up for the Gordon River, and routes this through the catchment to simulate flows. The model was calibrated and found to provide excellent results. The model can be used to model historical or Basslink flows, depending upon the inputs.

The model allows for any simulated Gordon Power Station discharge to be routed down the Gordon River, with this flow augmented by the natural flow contribution from the tributaries to the Gordon River. The natural tributary flows downstream of the power station are based on the record of Franklin River at Mt Fincham, which extends from 1958 to 2000. These flows are then scaled according to catchment area, and appropriate lag times are included for some tributaries.

The simulated Gordon Power Station discharge will change depending upon whether the model is being run for an historical or Basslink scenario. The historical Gordon Power Station discharge is derived from the power and energy outputs of the power station. Predictions of Basslink changes have been derived via a computer model called TEMSIM that has been developed by Hydro Tasmania to simulate the effects that Basslink may have on Tasmanian generation.

TEMSIM has several inputs, including a financial model for the National Electricity Market, efficiency curves for turbines at power stations, and an inflow database based on 75 years of inflow data for the system. The model sets a generating schedule that is founded on generation offers from participating generators. System demand is determined hourly and is derived from average annual load forecasts. These forecasts are disaggregated into hourly fragments that reflect seasonal, weekday/weekend and within day variations. This results in an output of power station discharges, which is used to determine river discharge levels and lake level fluctuations.

TEMSIM was designed to model the overall system operation, based on the existing infrastructure. Whilst individual power station operation is modelled in TEMSIM, output of individual power station generation should be viewed as a preliminary indication of expected generation patterns. In TEMSIM, whole power stations are bid into the market at a time, not individual machines, as would be likely to happen in reality. Thus, either all machines are on or off at any given time.

Comparisons between TEMSIM and historical cases must be interpreted with care, as historical data reflects the system configuration and load demand at the time. For the TEMSIM modelling, the forecast annual Tasmanian system load for 2003 (when Basslink would come on line) was utilised, being 1135 MW. Start storages were estimated using the storage levels at June 1999 (76%) and running SYSOP (a model of Hydro Tasmania's system) to predict the storage levels at 1 January 2003. The TEMSIM model uses 75 years of inflow data for the system with its present day infrastructure, and actual changes in infrastructure in the Hydro operating system over the 75 year period are not considered in the model.

Another consideration in interpretation of the comparative plots produced from this model, is the form of the original data. All data from the TEMSIM model is hourly data, whereas historical data for the power station is converted from energy output. A daily average energy value for the power station has been calculated and is then converted to discharge. This has two implications, the first being that there are undoubtedly errors associated with the conversion of energy to discharge, the second being that the historical data sets would not indicate full gate operation of the power station if this occurred for less than 24 hours.

As an alternative to using historical data for comparison against TEMSIM, two other scenarios were considered. A TEMSIM case with a 0 MW cable size simulates operation without a Basslink cable in place. This scenario is inappropriate, as the TEMSIM model is market driven while historical power station operation has never been financially dependent on the National Electricity Market. The SYSOP model could be used to determine historic operations but by using SYSOP as a comparison to TEMSIM, two different models are being compared inducing modelling errors. It was found that due to the flaws associated with each scenario, historical data would provide the best means for comparison.

In summary it should be noted that the TEMSIM model is a financially driven model. The output from the model represents an extreme case and the simulated power station operation is likely to be higher in magnitude and variation in comparison to the actual power station output once Basslink is in place.

3 COMPARISON OF CURRENT CONDITIONS TO NATURAL (PRE DAM) HYDROLOGY

3.1 Time Series Plots

Figure 3 and Figure 4 display time series plots downstream of Gordon Power Station both before and after the development of Gordon dam. Each plot contains flows before and after the activation of the power station and shows the effects of power station operation on river flow. Note that the flows have been daily averaged. Unfortunately the Gordon River below Franklin site closed down in 1979 and only one full year of data is available for analysis after the commencement of the power station.

The plots show an increase in consistent flows after power station operation began with flows of around 200 m^3/s occurring more regularly. Zero flows are less frequent since the commencement of the power station. Peak flow events tend to be dampened and do not reach the magnitudes of the pre power station events.

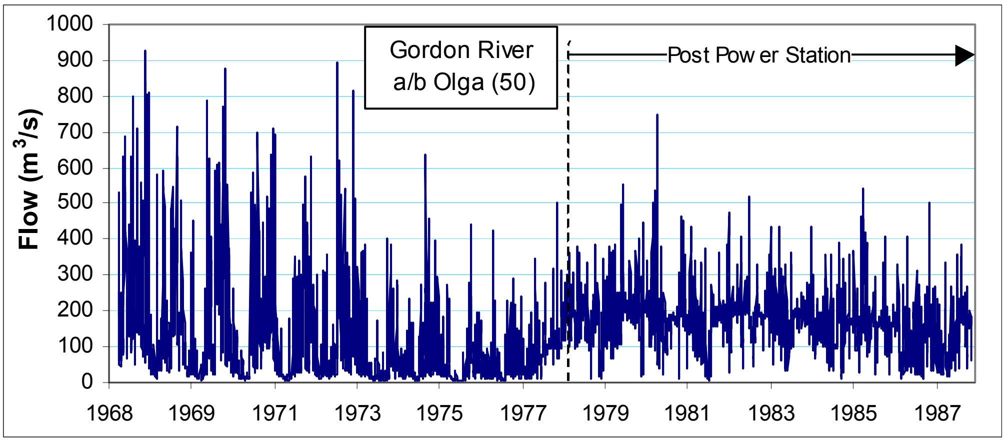


Figure 3. Time Series Plot at Gordon a/b Olga

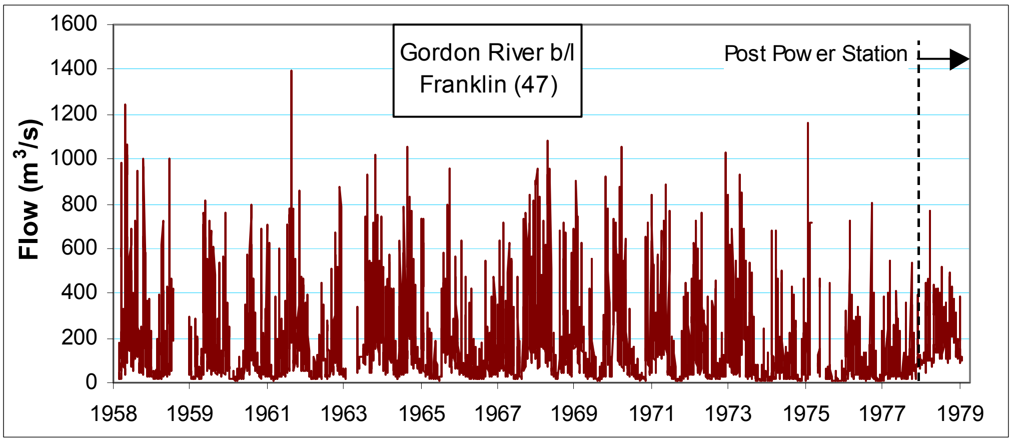


Figure 4. Time Series Plot at Gordon b/l Franklin

Figure 5 shows discharge duration curves for pre- and post- Hydro development periods, downstream of Gordon Power Station. The plot indicates changes to the natural flow regime and was generated from the flow data at Gordon River above Olga. There was approximately 10 years of data both before and after the commencement of the power station which was available for the plot.

The effect of Gordon Power Station can clearly be seen at flows up to 200 m^3/s with a separation of up to 120 m^3/s between the two lines. Median flows (flows exceeded 50% of the time) have increased from a natural flow of 50 m^3/s to approximately 170 m^3/s post-development. For flows exceeded less than 15% of the time the natural flows become greater than the post power station flows. This suggests that peak flows down Gordon River have been dampened since the construction of Gordon Dam.

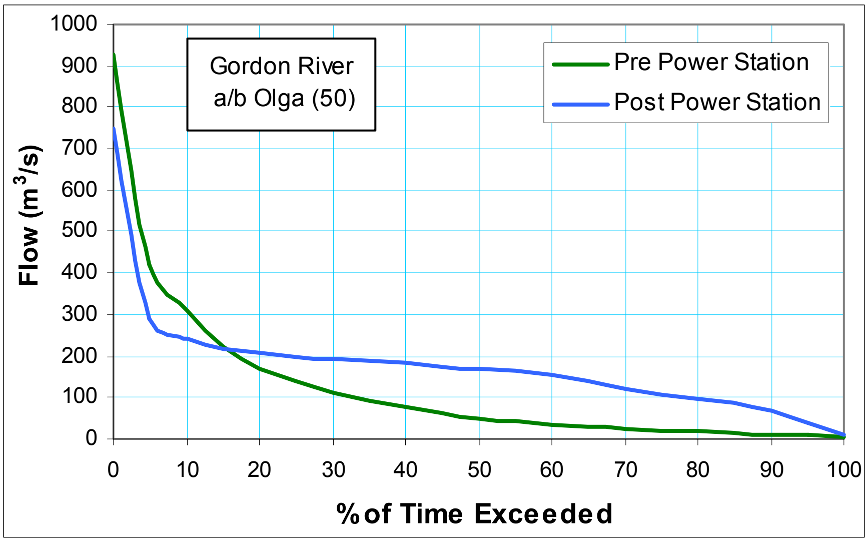


Figure 5. Natural and Post Development Flow Duration Curves Downstream of Gordon Power Station

3.2 Current Gordon Power Station operation

The Gordon Power Station has three turbines (144 MW each), and presently is most commonly operated to provide 'base load' or 'step load'. Base load is the load that is constantly required during the day to meet electricity demand. Thus power stations that operate to meet this load generate a constant load all day. 'Step load' describes the load that is generated when power stations are turned on for set periods within a day. Power stations meeting this load are turned on at a particular time in the day, generate power at a constant load for a certain number of hours, and are then turned off.

During the relatively dry summer period Gordon Power Station runs as a base load station. The number of turbines in use depends on the daily electricity demand. At other times of the year, Gordon operates on step load, and turbines are brought on or off depending on the changing electricity demand throughout the day. Depending on the water level in Lake Gordon, the Gordon Power Station discharges around 210 m^3/s of water when all three machines are operating at 'efficient load'. At 'full capacity', Gordon discharges up to 260 m^3/s, depending on lake Level.

4 EFFECT OF BASSLINK ON WATER LEVELS

4.1 Lake Gordon Levels

Historical record of levels at Lake Gordon began in 1974 and power station operation commenced in 1977 after the lake had filled to near full supply level. The historical levels vary greatly over the analysed period covering a range of over 40 metres. The levels under Basslink operations show less variation and are generally lower than the corresponding historical levels.

Lake level duration curves have been plotted in Figure 7 below. The historical curve is much higher than the Basslink curve except for at levels below 275 mASL. The median level (level exceeded 50% of the time) has dropped 6 metres under Basslink to 282 mASL. As the lake level increases, the separation between the two duration curves also increases with a difference of 15 metres at the 20th percentile. The monthly average plot (Figure 8) shows that the seasonal trend of the Basslink curve remains similar to the historical. Levels under Basslink are lower than historical for every month, the difference ranging between 2.5 and 4 metres. Figure 9 shows that there is a large reduction in the range of Lake Gordon levels under Basslink, with the 10 percentile level higher and the 90 percentile level far lower than in the Historical case.

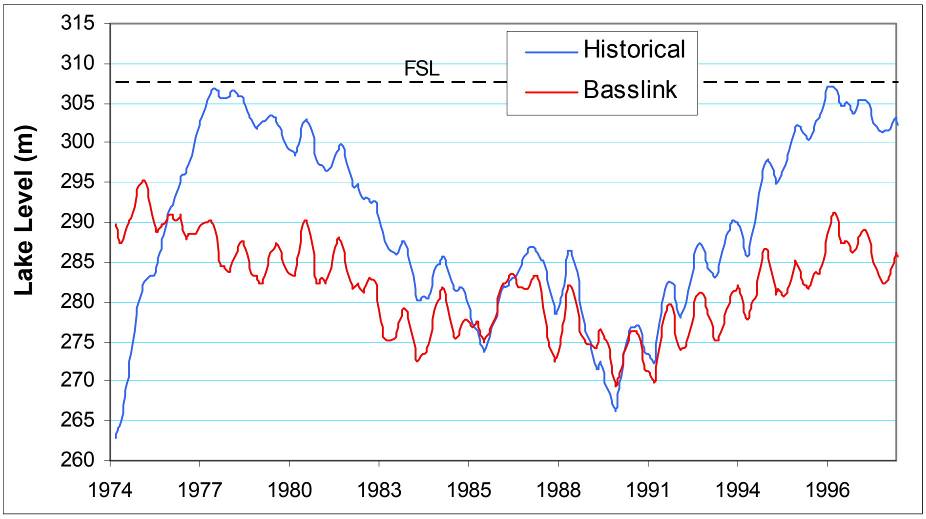


Figure 6. Lake Level Time Series Plot for Lake Gordon

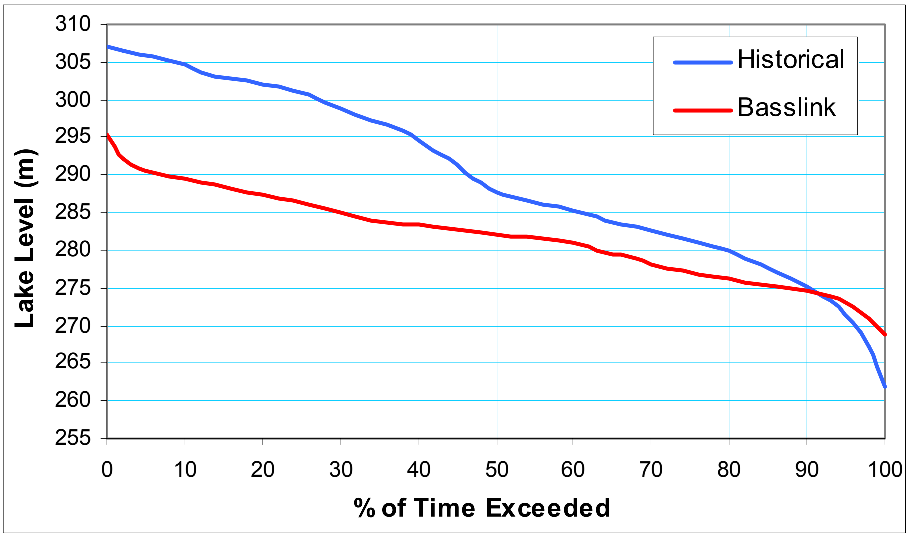


Figure 7. Lake Level Duration Plot for Lake Gordon

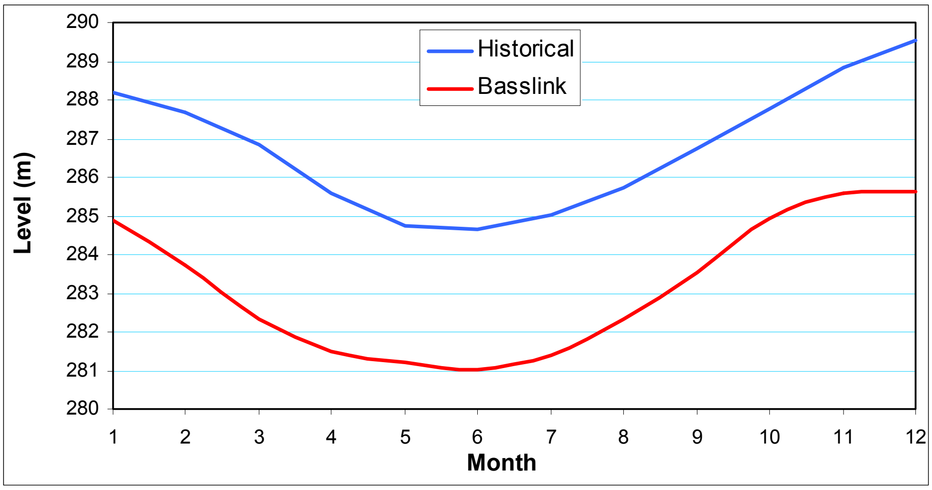


Figure 8. Average Monthly Lake Levels for Lake Gordon

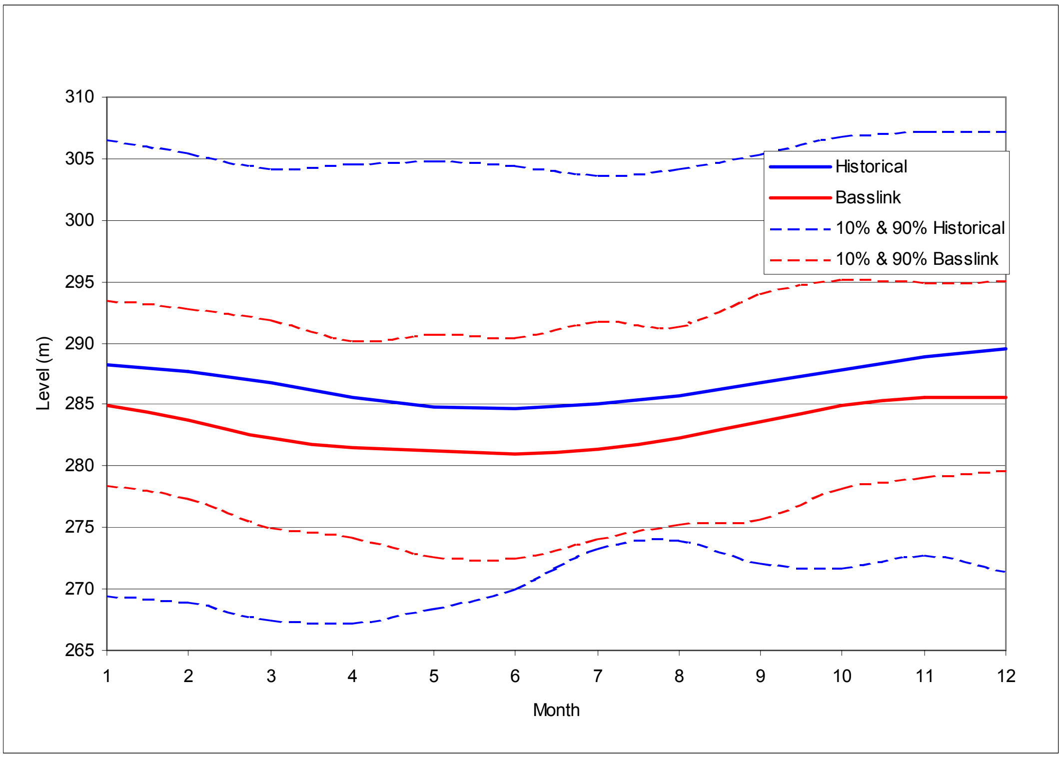


Figure 9. Mean, 10 and 90 percentile lake levels for Basslink and Historical scenarios

4.2 Downstream Propagation of Water Level Changes under Current Power Station Operations

A 3-day outage period at Gordon Power Station was carried out from 3rd – 7th March 2000 to simulate a common historical shutdown, and the effects on the downstream levels in the Gordon River have been analysed. Figures 9, 10, 11 and 12 display level plots at seven sites on the Gordon River during the outage. Figure 10 also shows the power station output which is in units of MW (x 0.01).

Note that for the plots below, the datum of the level recorders for each site are likely to be different. Also there is considerable variation in the cross-sections of downstream sites. This provides an explanation for the shifting starting levels at each site, and also the differences between level changes at downstream sites.

Downstream variation remains insignificant in the plots below except for at site 39 where the fluctuations in water level are likely to be due to the influence of the Franklin River.

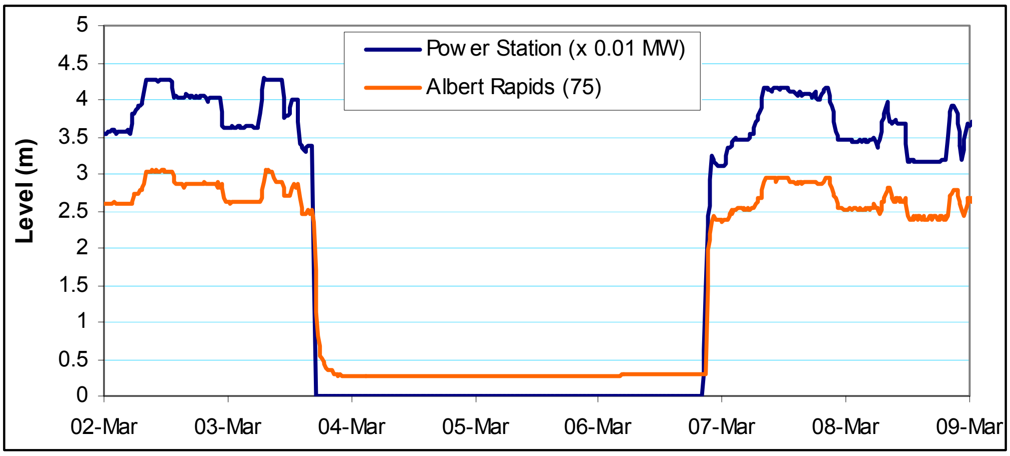


Figure 10. Gordon River Levels Under Current Conditions (Power Station and Site 75)

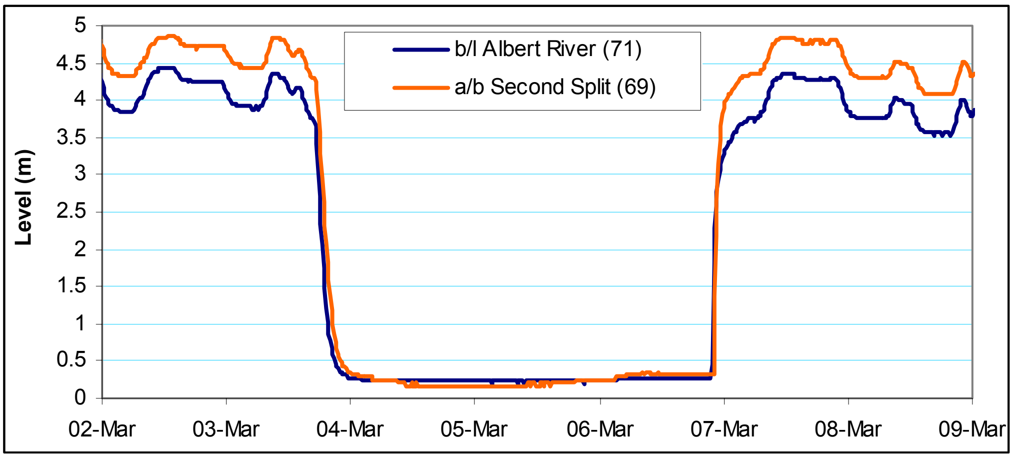


Figure 11. Gordon River Levels under Current Conditions (Sites 71 and 69)

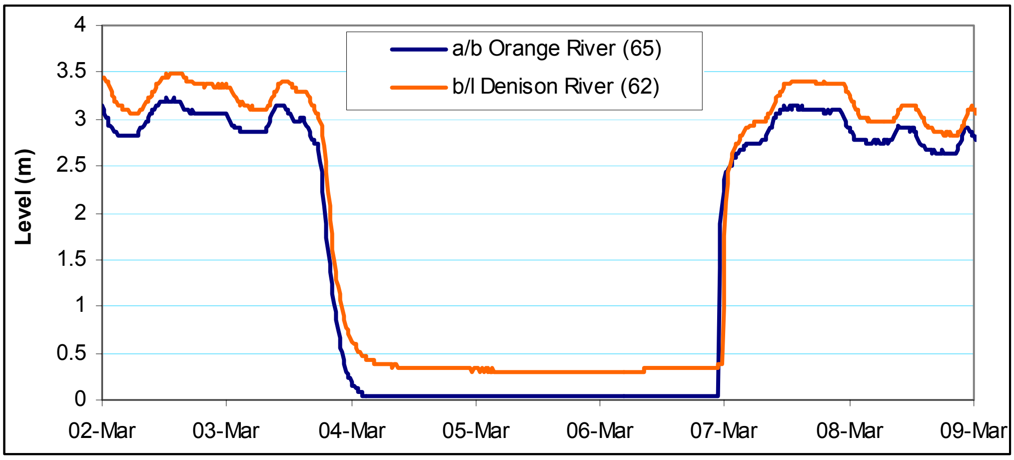


Figure 12. Gordon River Levels under Current Conditions (Sites 65 and 62)

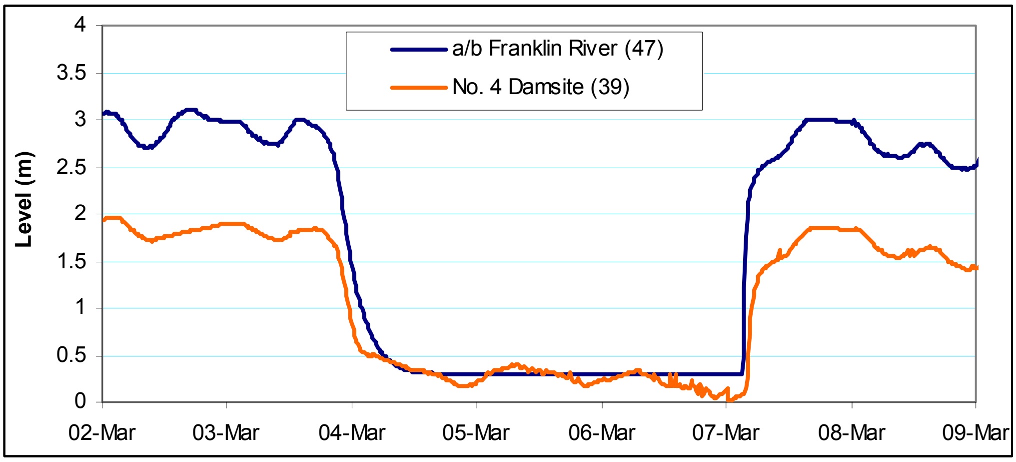


Figure 13. Gordon River Levels under Current Conditions (Sites 47 and 39)

Table II summarises the rise and fall times along with the lag times and water level changes at each monitored site downstream of Gordon Power Station. The river distance downstream of Gordon Power Station has also been included in the table.

Results from Table II show that for No. 4 Damsite (site 39), the rise lag time is twice as long as the drop lag time. Further upstream closer to the power station, the difference in time between rise and fall becomes much smaller. At all downstream sites the time to rise is less than the time taken for the water level to drop with a 17.25 hour difference between rise and fall times at site 39. The water level changes are larger in magnitude at sites closer to the power station.

Table II. Downstream Water Level Fluctuations in Response to On - Off - On Operation at Gordon Power Station

(note all times are in hours)		***Gordon Power Station Shutdown***		***Gordon Power Station Turn On***		
Site	*Chainage* (km)*	*Lag time in start of drop**	*Time taken to drop*	*Lag time in start of rise*	*Time to rise*	*Water level change (m)*
75	3.7	0.25	3.00	0.25	0.75	2.23
72	7.1	1.00	5.00	1.25	1.50	3.54
69	10.1	1.25	7.00	1.50	2.00	4.12
65	13.5	1.75	9.00	2.25	2.75	2.74
62	16.3	2.00	10.50	3.00	3.50	2.83
47	31.8	3.50	15.00	7.00	7.00	2.63
39	39.0	4.00	24.75	8.00	7.50	1.67

* Compared to Gordon Power Station (254)

4.3 Downstream Propagation of Water Level Changes under Basslink Power Station Operations

A shorter on-off sequence from the power station was performed in August 2000. This 5 hour shutdown event was designed to replicate a common Basslink event. Figures 13, 14 15 and 16 display level plots at seven sites downstream of the power station. Figure 14 also shows a plot of the power station output in MW (x 0.01).

In comparison to the current conditions, the Basslink plots below indicate a greater degree of level dampening at downstream sites. It should be noted that the period of record plotted in the current scenario (Figures 8-11) is 8 times longer than for the Basslink level plots.

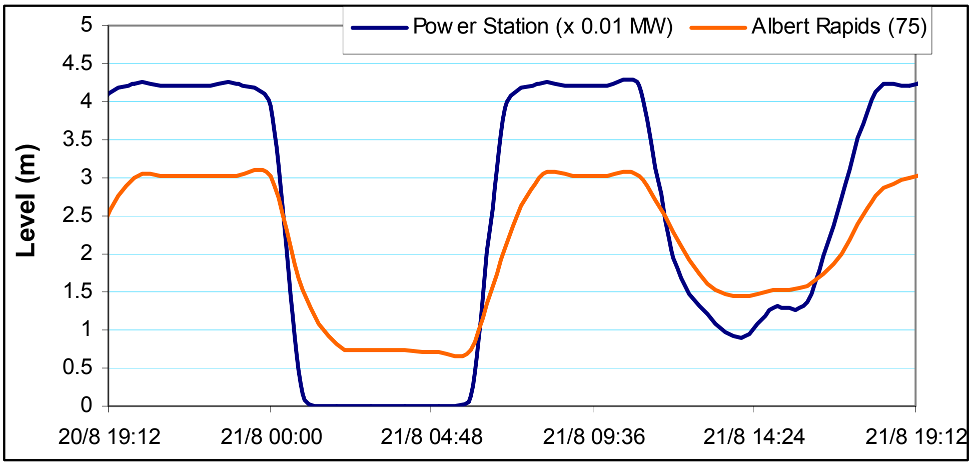


Figure 14. Gordon River Levels under Basslink Conditions (Power Station and Site 75)

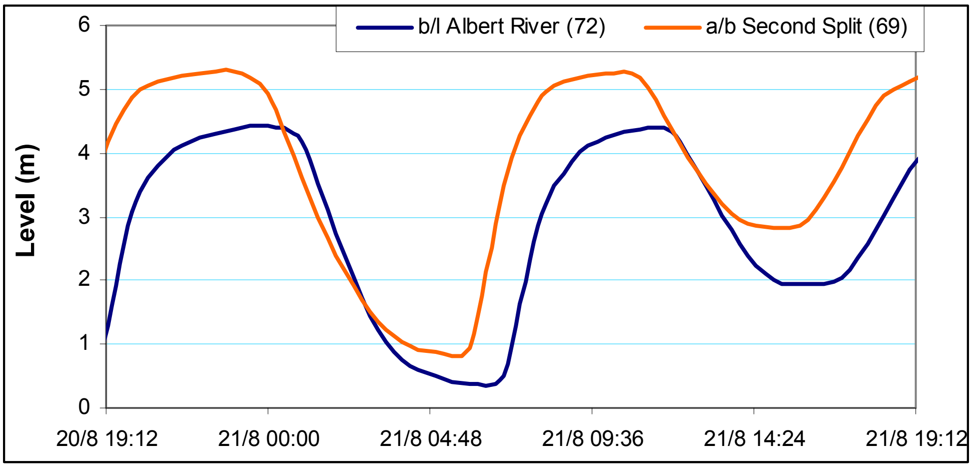


Figure 15. Gordon River Levels under Basslink Conditions (Sites 72 and 69)

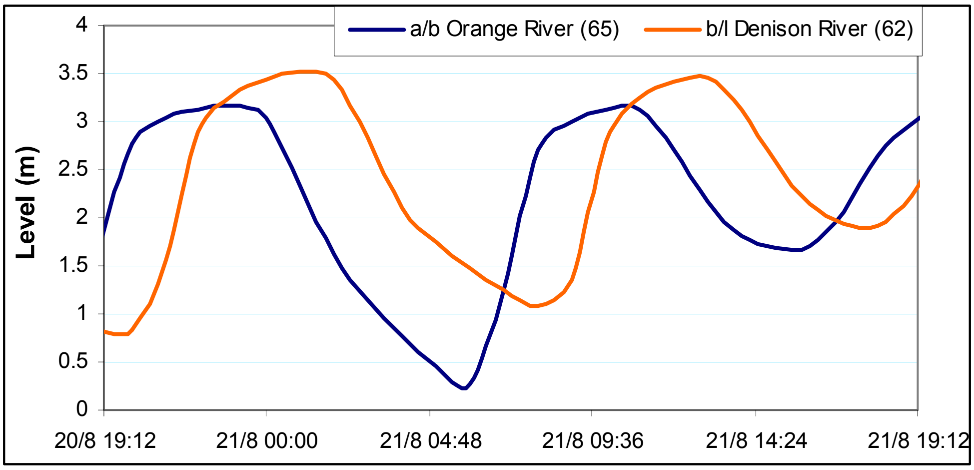


Figure 16. Gordon River Levels under Basslink Conditions (Sites 65 and 62)

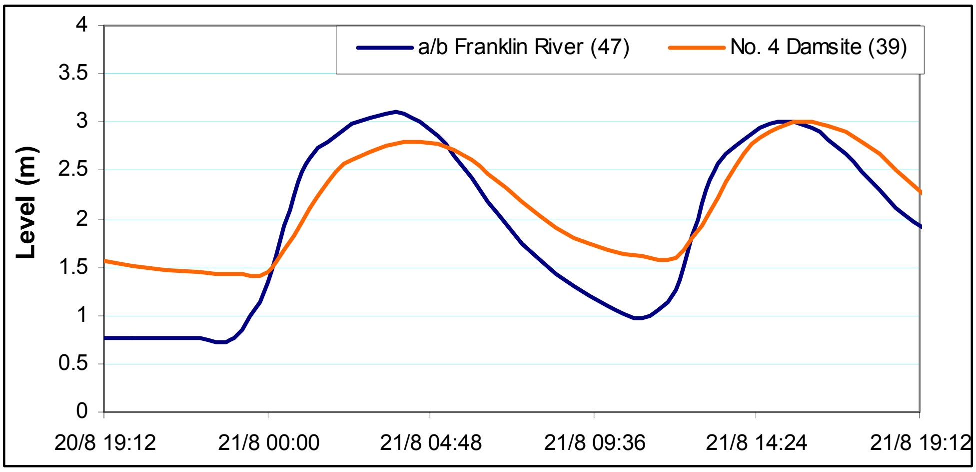


Figure 17. Gordon River Levels under Basslink Conditions (Sites 47 and 39)

Table III summarises the downstream effects of the 6 hour outage in August. Once again, rise lag times are greater than fall lag times, which remain similar in comparison to the current situation. The times taken for the levels to drop are considerably less than in the current case especially at sites further downstream. The times to rise in the table below remain virtually the same for each site. Water level changes under Basslink are slightly higher at sites close to the power station, and marginally lower at sites further downstream.

Table III. Downstream Water Level Fluctuations in Response to On - Off - On Operation at Gordon Power Station

(note all times are in hours)		***Gordon Power Station Shutdown***		***Gordon Power Station Turn On***		
Site	*Chainage* (km)*	*Lag time in start of drop**	*Time taken to drop*	*Lag time in start of rise*	*Time to rise*	*Water level change (m)*
75	3.7	0.25	2.00	0.50	1.25	2.30
72	7.1	0.50	3.25	1.00	3.25	4.05
69	10.1	1.00	3.75	1.25	3.50	4.48
65	13.5	1.25	4.50	1.75	3.50	2.98
62	16.3	1.75	6.25	3.00	3.75	2.52
47	31.8	3.75	8.00	5.75	3.50	2.19
39	39.0	4.75	8.25	7.00	3.50	1.23

- Compared to Gordon Power Station (254)

5 BASSLINK COMPARISONS AT GORDON POWER STATION

5.1 Annual Time Series Data

Figure 18 shows the annual time series for the Gordon power station during a dry year (1989) and a wet year (1996) comparing the modelled Basslink time series, and the actual measured (historical) power station flow. Caution must be taken when examining these plots, as the system configuration and load changed between 1989 and 1996. Also note the period of missing data in July 1996 as explained in Section 2.2.

The main differences between the scenarios can be summarised as follows.

Historically, there is more generation from Gordon during the dry year than the wet year. Both the wet and dry year record shows consistent high generation over the summer months in the historical case. Under Basslink, the output from the power station tends to remain similar in the wet and dry year with much less seasonal variation.

The Basslink scenario shows increased short term variability (ie. more “on-off”) of the power station operation in both a wet year and a dry year.

Basslink will not increase the current maximum release capacity of the power station as this is limited by the capacity of the three turbines. This analysis shows that rates of river level rise and fall will not change due to Basslink, because the power station turns on and off at the same rate as with current operations. However, changes in the number of machines turning on and off at any particular time may alter this, and the TEMSIM model does not simulate individual machine operation. Only the frequency, timing and duration of flow events are likely to be influenced by Basslink.

Figure 19 shows the monthly median flows for the historical and the Basslink scenario as measured or simulated at the Power Station location. The historical operation of the power station shifts the seasonality of the median flows so that the higher flows occur in summer and lower flows in winter. The Basslink case indicates higher median flows from the Power Station than that of the historical record during the drier months, and is bimodal, with a second peak in median flows over winter, indicating more operation simulated under Basslink to meet the winter heating electricity demand.

Median flows are the flows that are exceeded 50% of the time, or the most "common" flows rather than the average flows. A monthly median flow of zero does not mean the power station was not operating at all during a given month, but rather that it was shutdown more than 50% of the time during that month. Also shown in Figure 19 are the 10^{th} and 90^{th} percentiles for the Basslink and current cases. These show that flows are generally higher under Basslink, except in September and October. It is interesting to note that the 10^{th} percentile June flow rises from zero under current conditions to approximately 20 cumecs under Basslink. A comparison of average monthly flows (calculated using daily flows) (Table IV) showed that there was a significant difference between mean flows at a 5% significance level for the current and Basslink cases for all months except December.

Duration curves from Gordon Power Station plotted in Figure 21 show that the TEMSIM predictions of Gordon Power Station discharges greater than 210 cumecs are much greater than were historical discharges greater than 210 cumecs during 1997 and 1998. This is due to turbine and transmission line constraints during 1997 and 1998 which limited the total output from the power station. The transmission lines and turbine operations are subject to continual upgrades and refinements which may periodically impose constraints on power station output. As of the time of writing of this report, the transmission constraints which limited output during 1997-98 have been removed, and the work on the turbines to minimise vibration has been completed. The Gordon Power Station at present is capable of generating at full capacity.

The data presented in Figure 21 are also influenced by the bias of the TEMSIM model towards full power station discharge rather than one or two turbines operating, as was discussed in Section 2.3.2.

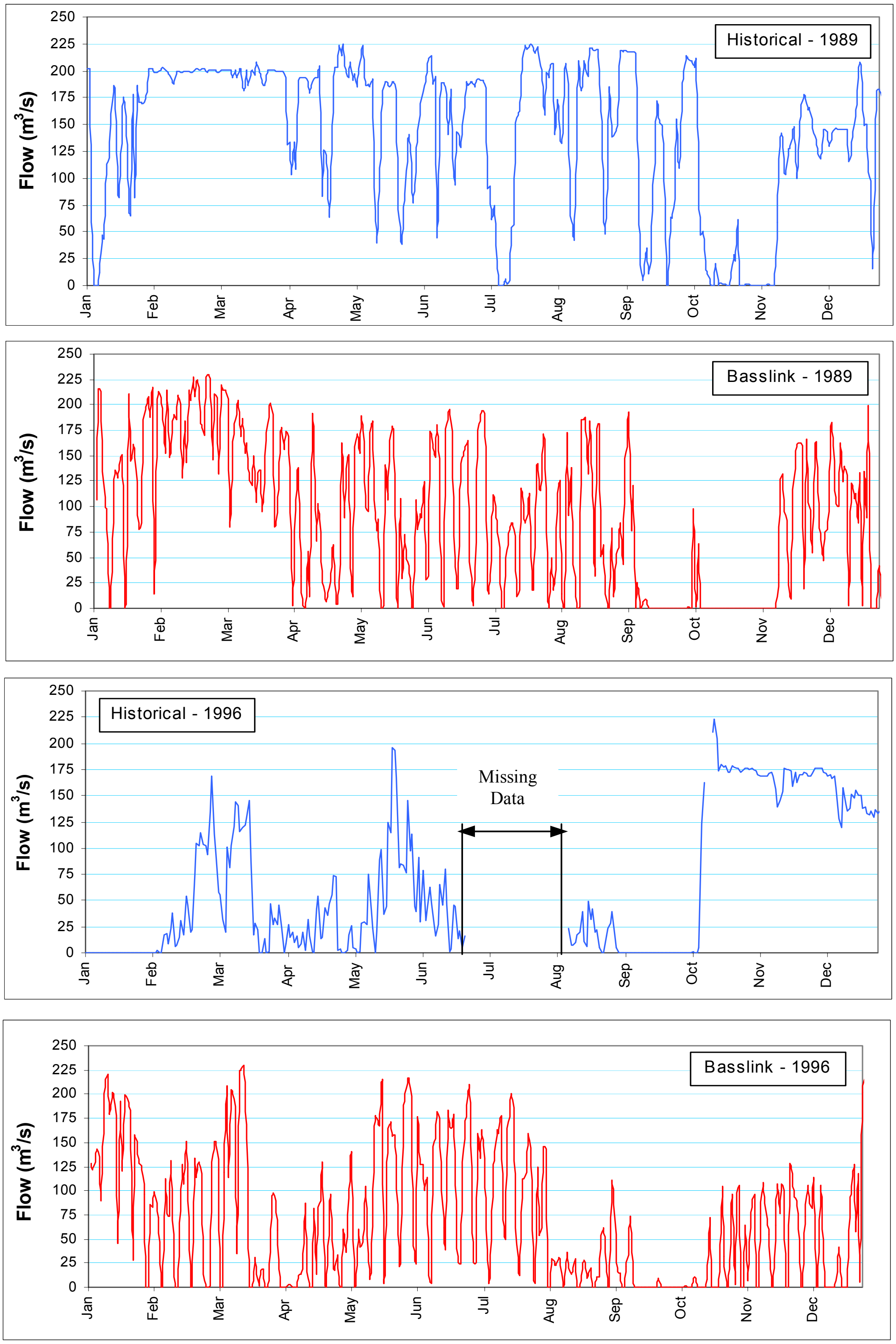


Figure 18. Flows During a Dry Year (1989) and a Wet Year (1996) at Gordon Power Station under Historical and Basslink Scenarios

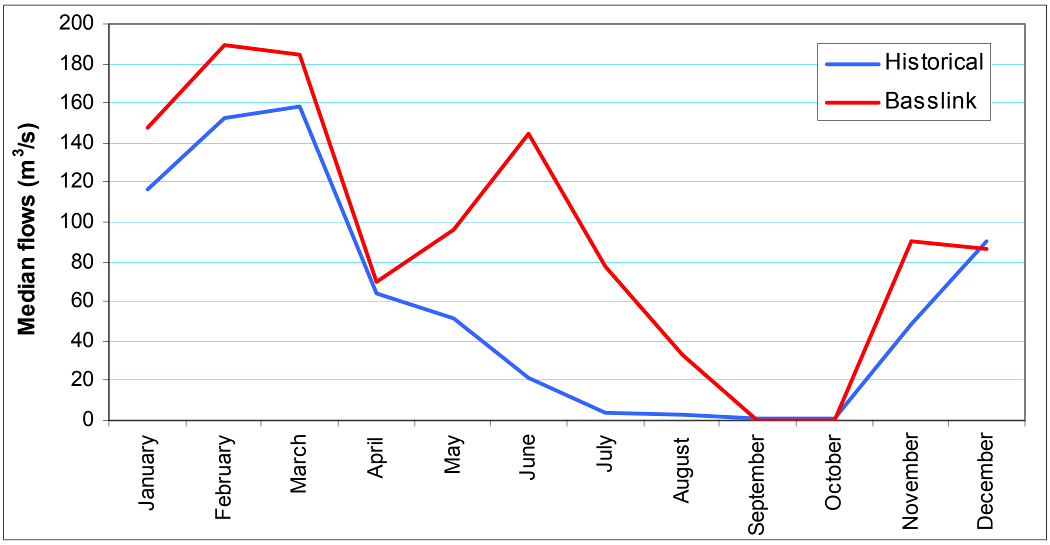


Figure 19. Comparison of Historical and Basslink Scenario Median Monthly Flows from the Gordon Power Station (1989-1998)

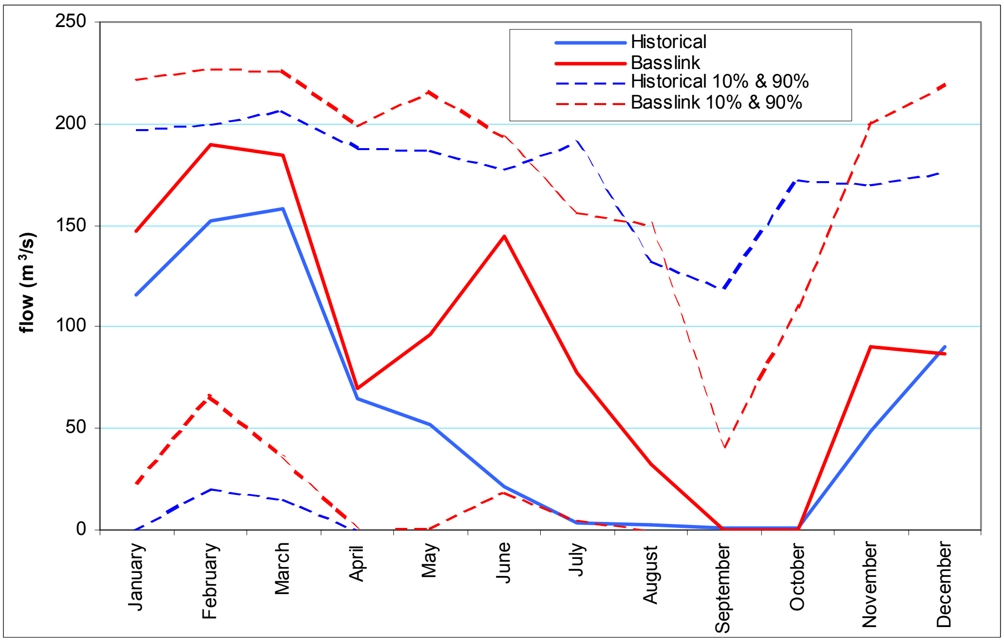
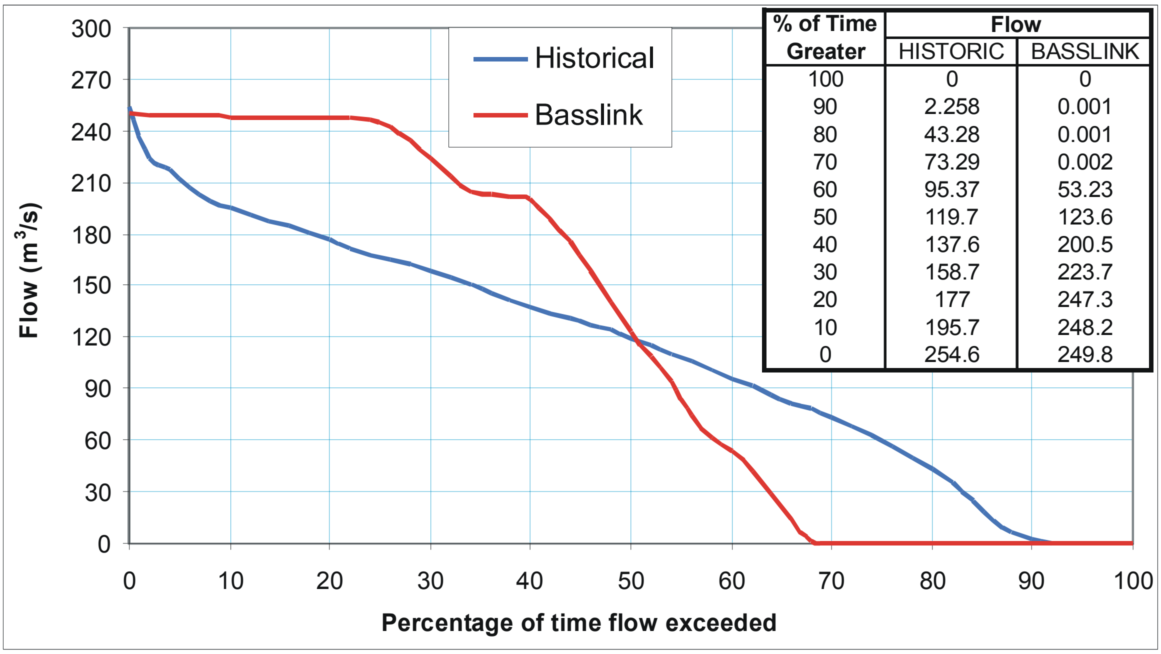


Figure 20. Comparison of Historical and Basslink Scenario flow percentiles from the Gordon Power Station (1989-1998)

Table IV. Results of t-test for difference in monthly means of Basslink and Historical data at Power Station at 5% significance level

MONTH	Current Average flow (cumecs)	Basslink Average flow (cumecs)	Difference in mean
January	136.0	148.4	Y
February	143.6	160.9	Y
March	143.0	160.6	Y
April	83.3	91.5	Y
May	93.0	109.4	Y
June	73.6	124.1	Y
July	51.3	78.7	Y
August	39.1	53.7	Y
September	22.8	13.4	Y
October	26.1	29.4	Y
November	73.4	89.7	Y
December	92.9	91.8	N



% of Time Greater	Flow HISTORIC	Flow BASSLINK
100	0	0
90	2.258	0.001
80	43.28	0.001
70	73.29	0.002
60	95.37	53.23
50	119.7	123.6
40	137.6	200.5
30	158.7	223.7
20	177	247.3
10	195.7	248.2
0	254.6	249.8

Figure 21. Flow Duration Curves from Gordon Power Station under Historic and Basslink Operation (Hourly data 1997-1998).

5.2 Event Analyses

The event analyses (Figure 22 and Figure 23) confirm that there is an increase in the on-off operation of the power station under a Basslink scenario. Generally under Basslink, the number of release events in a given year is 3.5 times larger than historical operation.

In Figure 22 the columns represent the average number of release events per year for each duration category. The number of release events of durations of 2-6 hours and 16-24 hours has greatly increased with Basslink operation compared to historical operation. In Figure 23 the columns represent the number of shutdown events per year for each duration category. The number of shorter shutdown events of durations up to 24 hours has greatly increased with Basslink, compared with historical operation.

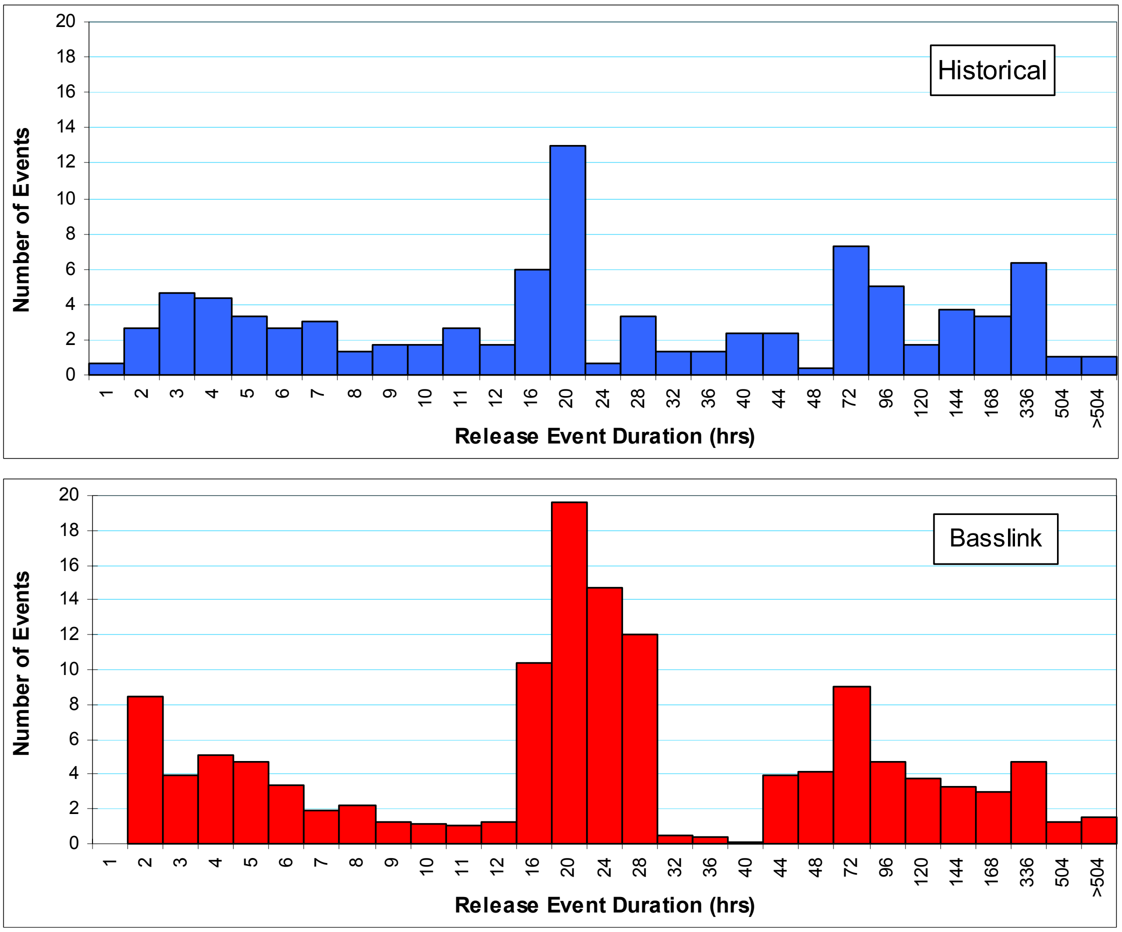


Figure 22. Duration of Events Greater than Zero m^3/s at Gordon Power Station

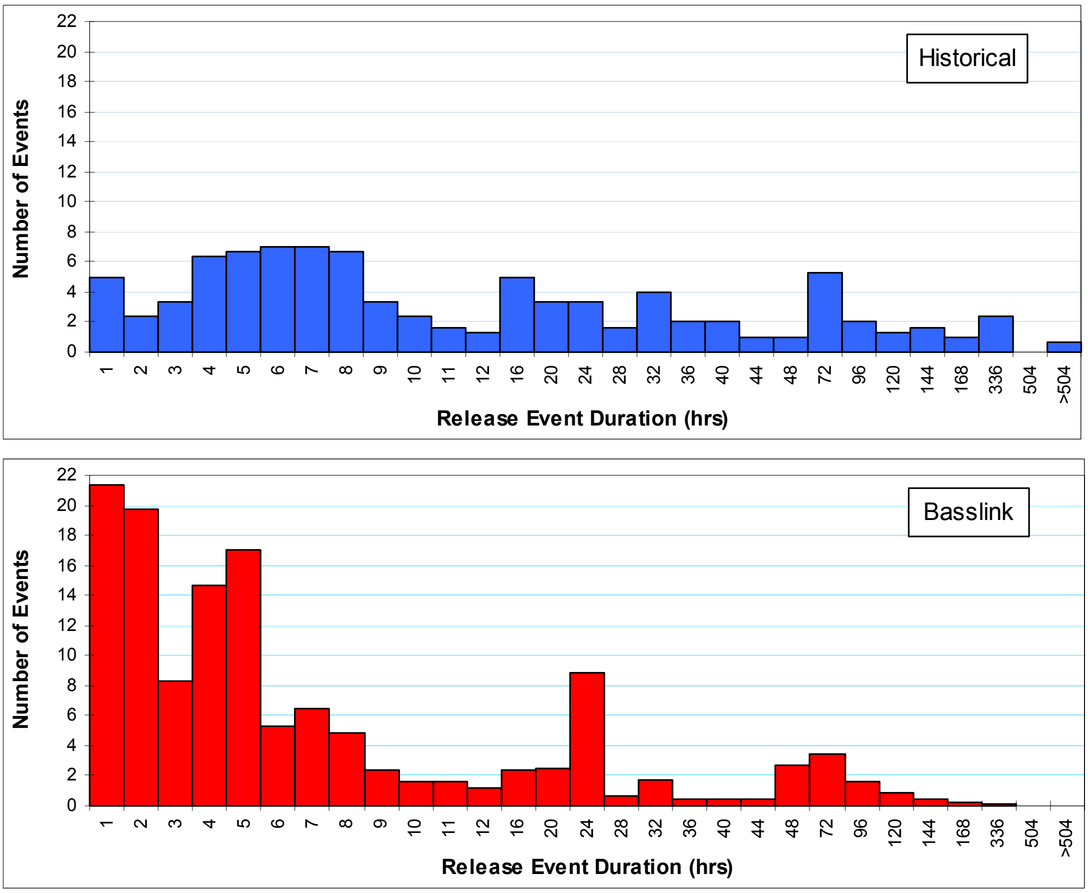


Figure 23. Duration of Zero Discharge (Shutdown) Events at Gordon Power Station

5.3 Summary Statistics

Table V shows summary statistics for the historical and Basslink flows at the power station for the period 1989-98 where all three turbines were in operation. Unfortunately these statistics have limitations in that the data for the power station is daily average data over the period of analysis. This means that variations of power station operation within the same day are averaged. For example, if the power station was on at full capacity (≈260 m^3/s) for 12 hours and off for 12 hours, the daily average value is 130 m^3/s. For this reason, separate analyses (Table VI) are provided for hourly data, however, as discussed previously only a short time period (2 years) is available.

Table V shows that the historical mean discharge from the Gordon Power Station is 18 m^3/s less than for Basslink. This lower mean is also reflected in lower median flows through the Power Station (Figure 19). A comparison with Table VI shows that these results are likely to be due to the daily averaging of the data. Table VI shows the same statistics for the time period 1997 to 1998 for which hourly data is available for the power station. From the available hourly data the historical mean discharge from the Gordon Power Station is 1 m^3/s less than for Basslink.

Table V also shows that with Basslink there is a slight increase in the 1-day and 7-day maximum flow (this is the highest flow sustained over 1 day and a week long period respectively), reflecting the increased percentage of full capacity flows. The number of flow "events" greater than mean flow of one day duration or more, increases with Basslink, from an annual average of 14 under current operations to 38 with Basslink. The number of shutdown events also increases under Basslink.

Table V also shows that with Basslink there is an increase in the 1-day and 7-day maximum flow (this is the highest flow sustained over 1 day and a week long period respectively), reflecting the increased percentage of full capacity flows. This increase is greater than that shown in Table VI. The number of flow "events" greater than mean flow of one day duration or more, increases significantly with Basslink, from 219 under current operations to 297 with Basslink. The number of shutdown events also increases significantly under Basslink.

The most significant difference between the use of hourly and daily data is the notable increase in the number of events between the historical and Basslink cases which was also made clear in the event analyses (Figures 20 and 21). Thus under current operations, there are on average each year 219 release events of greater than mean flow, compared to 297 events of greater than mean flow under Basslink. Zero flow events average 73 per year for the historical case, and 254 events for the Basslink case. Under historical operations the power station frequently switches between the number of turbines operating (explaining the high number of release events greater than the mean flow), but does not totally shutdown as often as is predicted to occur for Basslink.

Table V. Comparison of Historical and Basslink Daily Flow Records at the Gordon Power Station over a 10 year period (1989-1998)

STATISTICS	CURRENT OPERATION OF POWER STATION[1]		BASSLINK OPERATION OF POWER STATION	
Mean flow (m^3/s)	78		96	
Annual Mean Minimum Flow				
1 Day Minimum (m^3/s)	0		0	
7 Day Minimum (m^3/s)	1.2		0.1	
Annual Mean Maximum Flow				
1 Day Maximum (m^3/s)	222		240	
7 Day Maximum (m^3/s)	205		221	
The Number of Annual Events	Flow	No. Events	Flow	No. Events
-Greater than mean flow	78 m^3/s	14	96 m^3/s	38
- from and to 0 m^3/s	0 m^3/s	18	0 m^3/s	25

[1] Record contains missing values.

Table VI. Comparison of Historical and Basslink Hourly Flow Records at the Gordon Power Station over a one year period (1997-1998)

STATISTICS	CURRENT OPERATION OF POWER STATION [1]		BASSLINK OPERATION OF POWER STATION	
Mean flow (m^3/s)	116		115	
Annual Mean Minimum Flow				
1 Hour Minimum (m^3/s)	0		0	
7 Day Minimum (m^3/s)	6		0.3	
Annual Mean Maximum Flow				
1 Hour Maximum (m^3/s)	245		249	
7 Day Maximum (m^3/s)	206		229	
The Number of Annual Events	Flow	No. Events	Flow	No. Events
-Greater than mean flow	116 m^3/s	219	115 m^3/s	297
-from and to 0 m^3/s	0 m^3/s	73	0 m^3/s	254

[1] Record contains missing values.

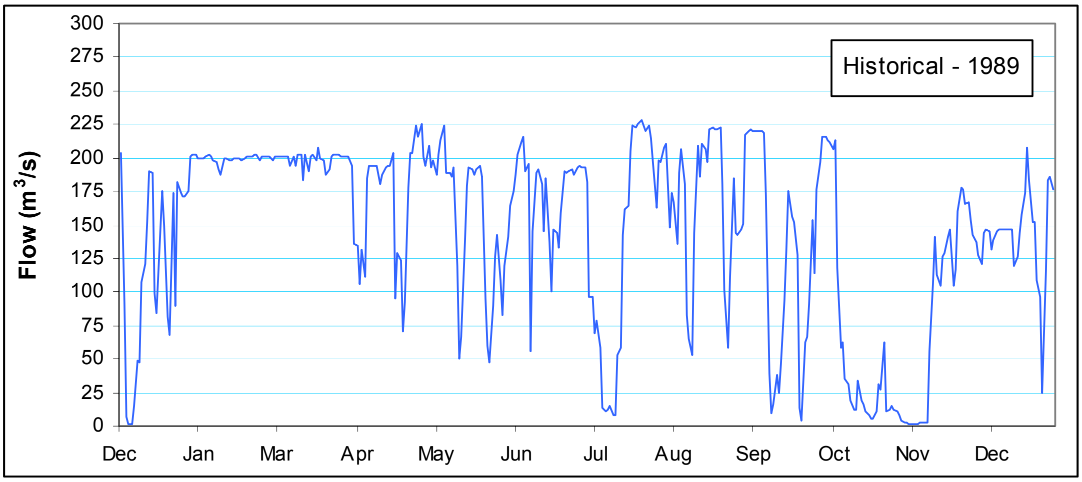
To summarise, the key Basslink change to that of current operation is an increase in the occurrence of the average annual number of "on-off" events for power station operation. Historically, flows tended to fluctuate at flows above zero, however, the Basslink simulations indicate that there will be a greater tendency to use the full operating range of the Gordon power station, along with more frequent "off" events with zero flow.

6 BASSLINK COMPARISONS DOWNSTREAM OF GORDON POWER STATION

6.1 Basslink Comparisons at the Gordon River below Albert River (Site 72)

Site 72 is located approximately 7 km downstream of the Gordon Power Station and contributes an additional 94 km^2 of catchment area.

Figures 22 and 23 show power station historical flow and the simulated Basslink flows at the Gordon River at Site 72 for the years 1989 and 1996. However due to the small additional catchment contribution there are no noticeable differences to that presented for the power station location. The power station is the major influence on river flows at this location despite the inflow of the Albert River upstream.



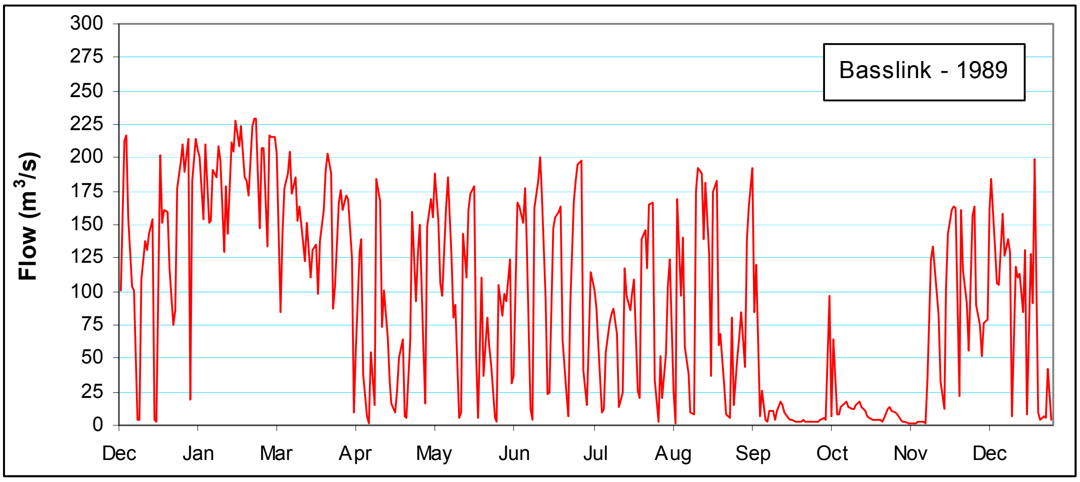


Figure 24. Comparison of Gordon River Daily Flow at Site 72 - Dry Year (1989)

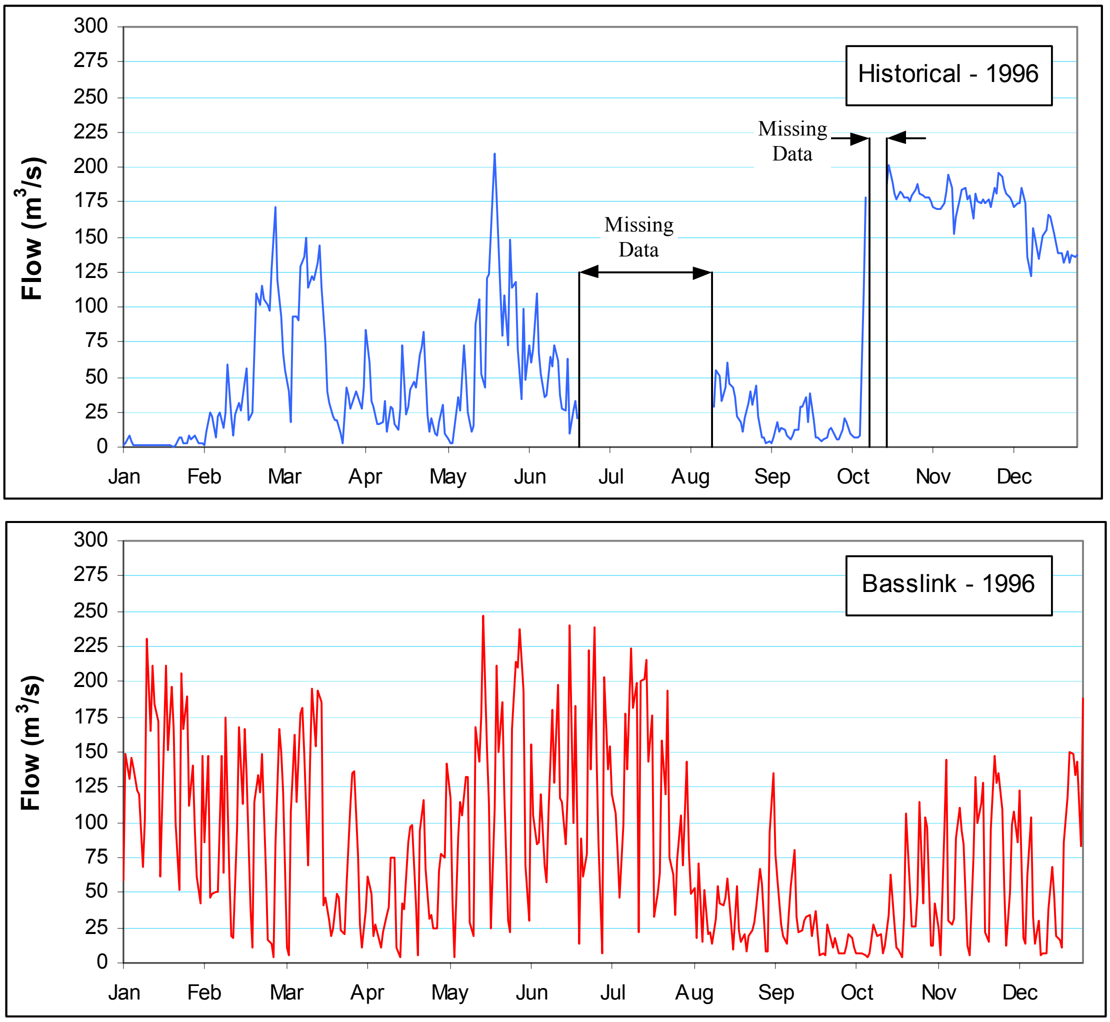


Figure 25. Comparison of Gordon River Daily Flow at Site 72 - Wet Year (1996)

Due to the influence of natural flow pickup to Site 72, monthly median flows increase especially over the winter months for the historical and Basslink record (Figure 26). There is a similar range of flows under both the Basslink and current scenarios. Table VII shows that there is a significant difference between the means of all months at a 5% significance level, with the mean Basslink flow greater for all months except September.

The flow duration curve (Figure 28) for the historical and Basslink scenarios have a similar shape but deviate due to the increased power station flow simulated under Basslink compared to actual historical records.

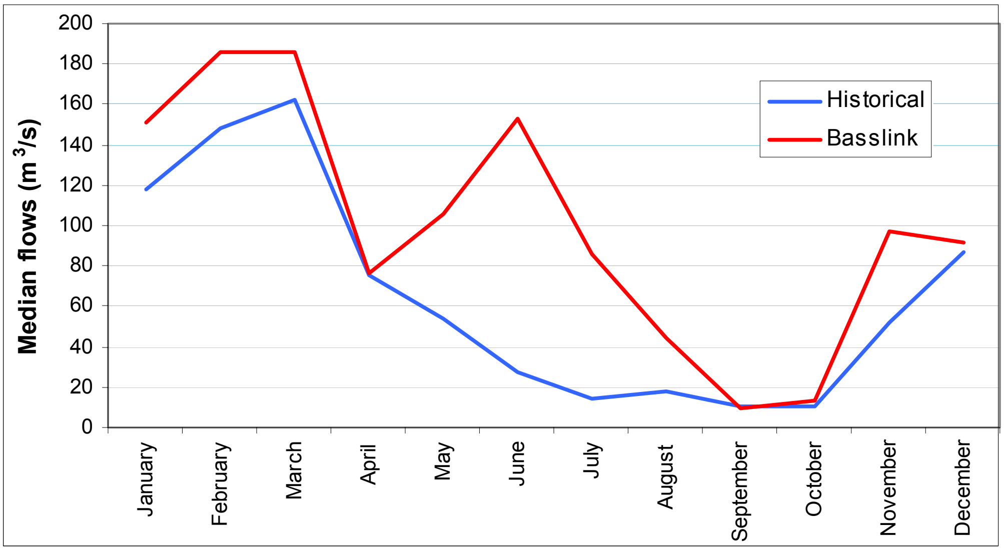


Figure 26. Comparison of Monthly Median Flows for the Gordon River at Site 72 (1989 – 1998)

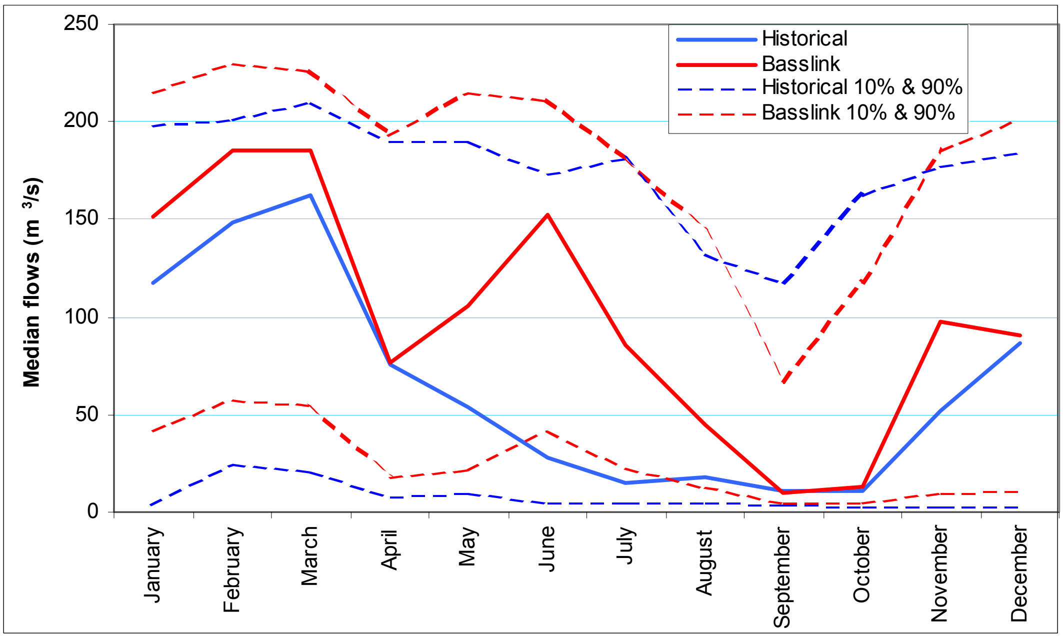


Figure 27. Comparison of Historical and Basslink Scenario flow percentiles for the Gordon River at Site 72 (1989-1998)

Table VII. Results of t-test for difference in monthly means of Basslink and Historical data at Gordon below Albert at 5% significance level

MONTH	Current Average flow (cumecs)	Basslink Average flow (cumecs)	Difference in mean
January	138.6	151.7	Y
February	144.9	164.3	Y
March	144.7	165.0	Y
April	87.4	100.6	Y
May	99.3	118.6	Y
June	79.9	132.5	Y
July	58.2	87.8	Y
August	46.7	66.8	Y
September	28.5	23.3	Y
October	31.4	38.9	Y
November	77.1	99.8	Y
December	95.9	102.2	Y

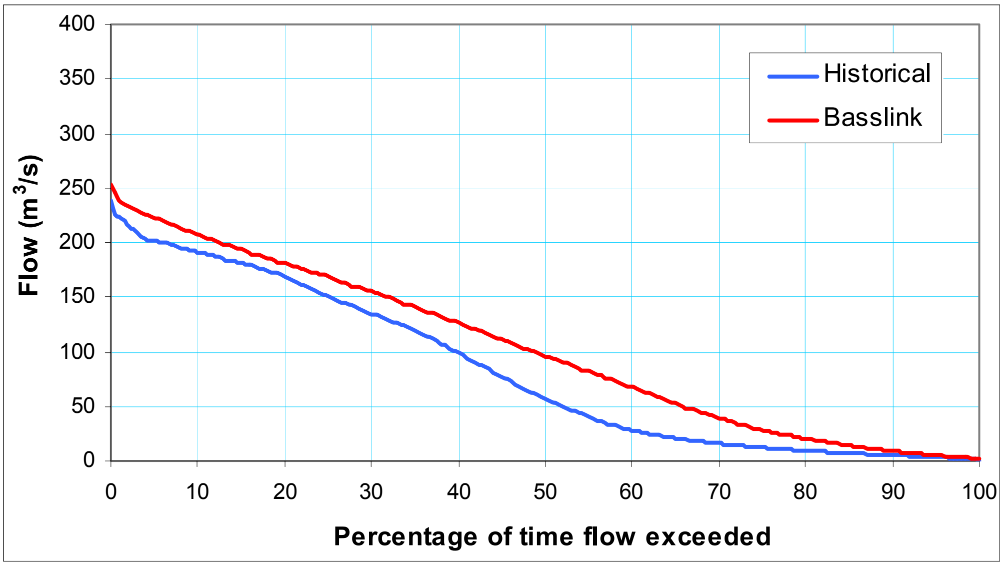


Figure 28. Comparison of Duration Curves for Gordon River Daily Flow at Site 72 (1989 – 1998)

6.2 Basslink Comparisons at the Gordon River above Olga River (Site 50)

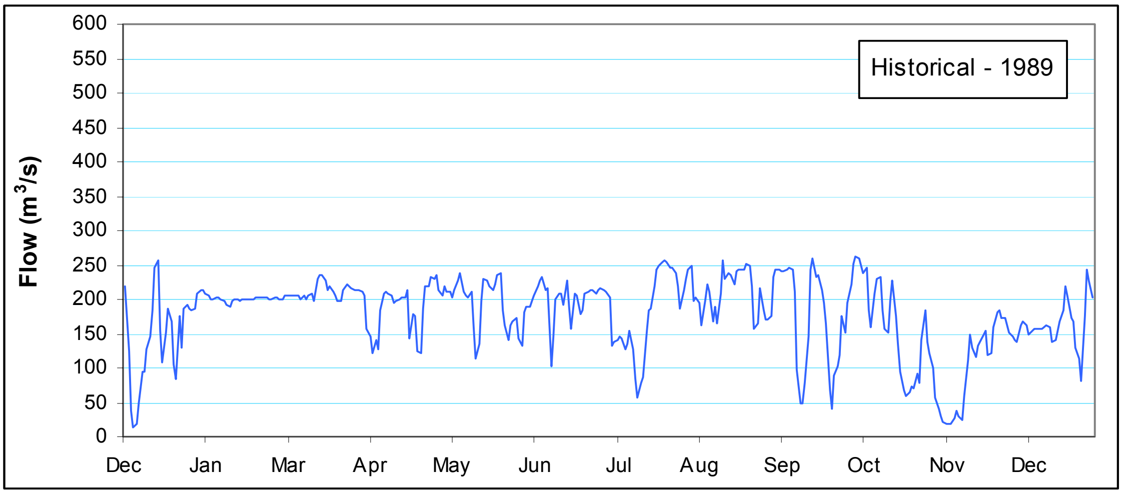
Actual measured flow record exists for the location Gordon River above Olga (Site 50) for the period 1968-88. Unfortunately power station operation with all three machines available does not commence until mid 1989. Thus the early record is used for frequency analysis, and a later record is simulated using the TimeStudio model to compare against Basslink simulated record. The catchment area to the Gordon above Olga location is about 2920 km^2 (including the Huon diversion), however 70% of the catchment is still controlled by the dams and power station.

Figure 29 and Figure 30 show power station historical flow and the Basslink scenario as simulated at Site 56 for the years 1989 and 1996. During the system dry year the power station operation has a greater influence on the flows observed at Olga as the natural flow pickup is less than during the wet year. During the dry year, summer flows at Olga are kept higher than natural by power station operation, with more base load generation throughout the year, especially for the historical case. For both years the influence of "on/off" operation of the power station under Basslink is still observed in the record at this location.

Figure 31 shows that the median flows for Gordon above Olga are higher under Basslink for every month except September. The range of flows is similar under current conditions and Basslink, but the 10th and 90th percentile flows are generally higher under Basslink, particularly in June and July (Figure 32). Table VIII shows that there is a significant increase in the mean monthly flow for all months except September and December under Basslink, at a 5% significance level. In December there is a significant decrease in mean flow at Gordon above Olga under Basslink.

The flow duration curve (Figure 33) for the historical and Basslink scenarios have a similar shape but deviate due to the increased power station flow simulated under Basslink compared to actual historical records.

Flood frequency for Gordon River above Olga (Figure 34) shows frequency curves for both the historical and Basslink flow. The only influence that Basslink operation will have on flood frequency at Olga compared to the historical operation, would be the coincident timing of the maximum release through the Gordon power station the same time as a flood event in the downstream catchment, but this appears to have little effect.



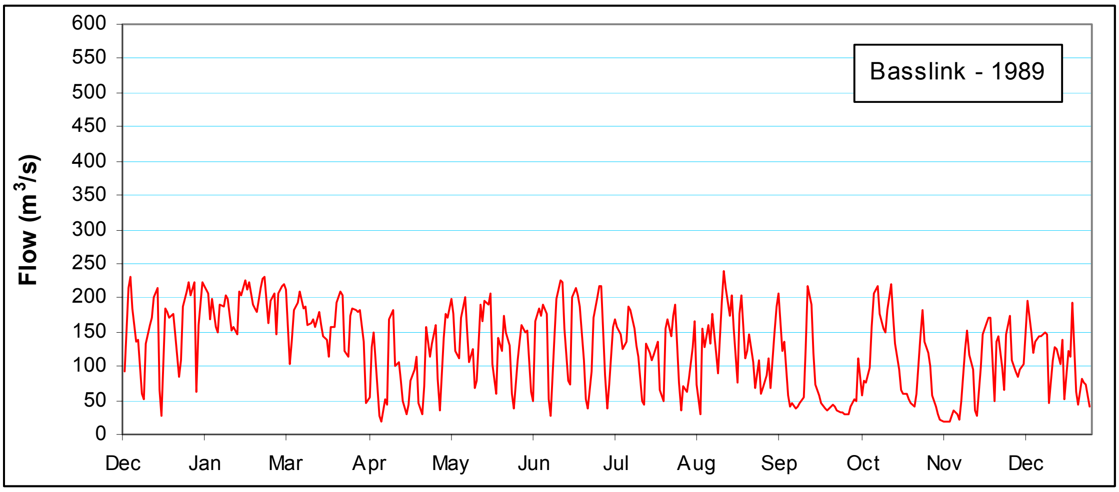
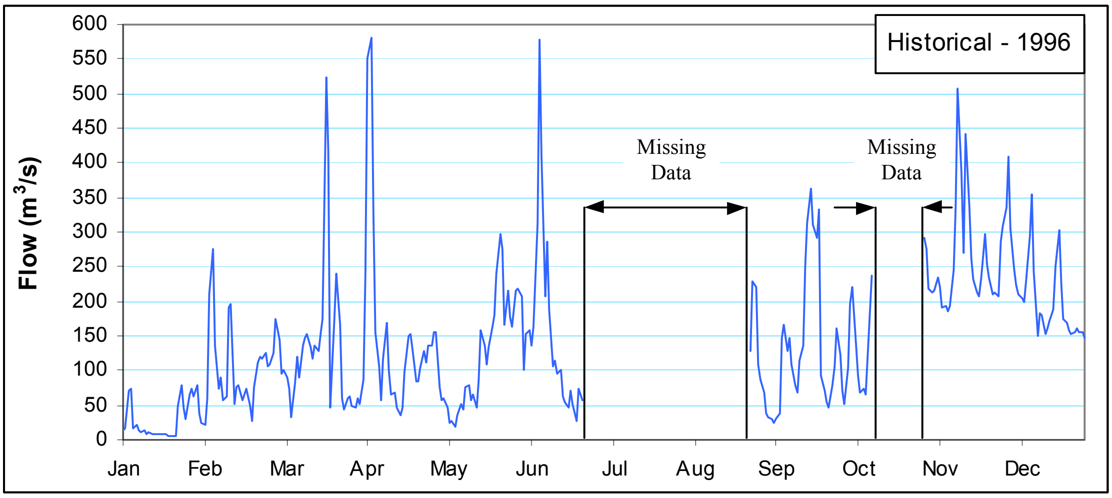


Figure 29. Comparison of Gordon River Daily Flow at Site 50 - Dry Year (1989)



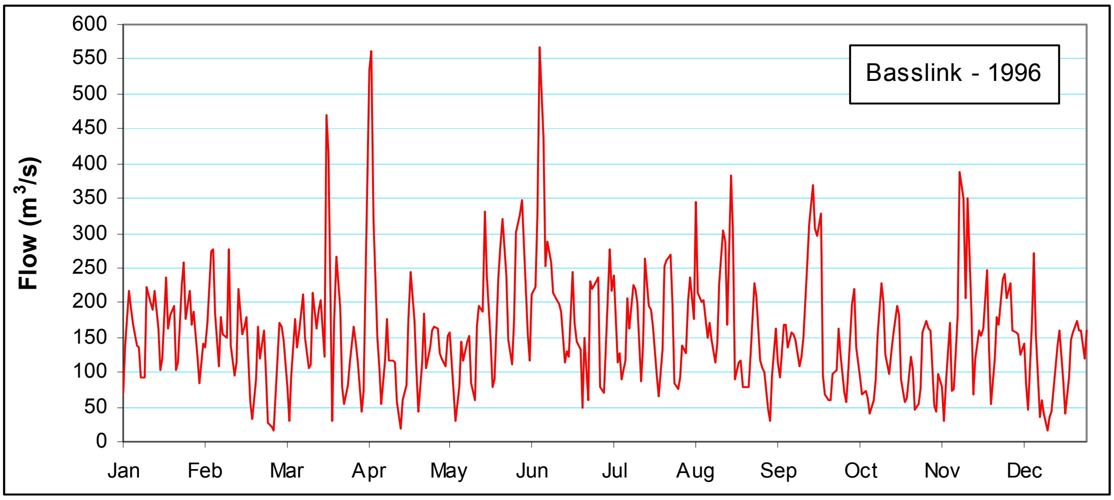


Figure 30. Comparison of Gordon River Daily Flow at Site 50 - Wet Year (1996)

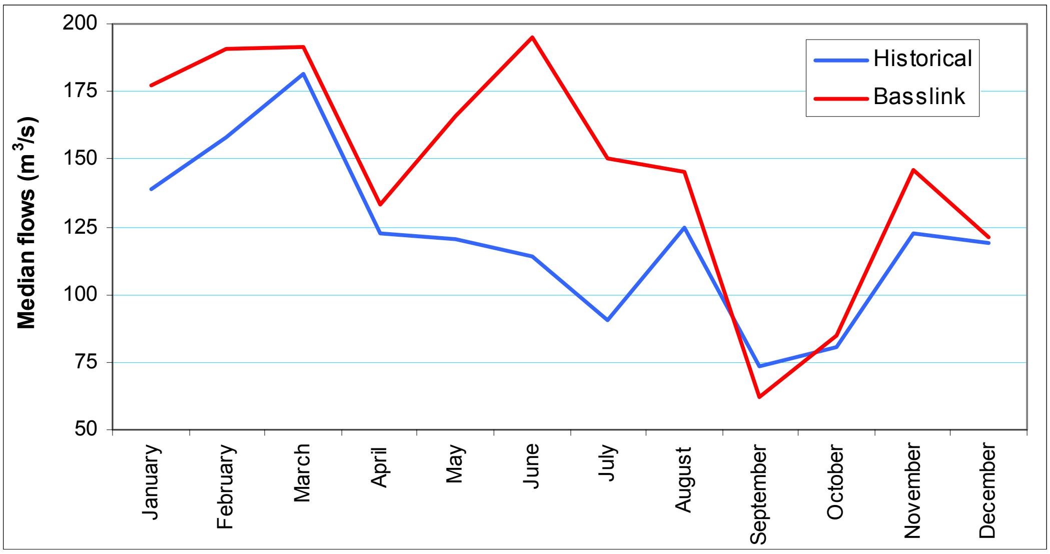


Figure 31. Comparison of Monthly Median Flows for Gordon River at Site 50 (1989 – 1998)

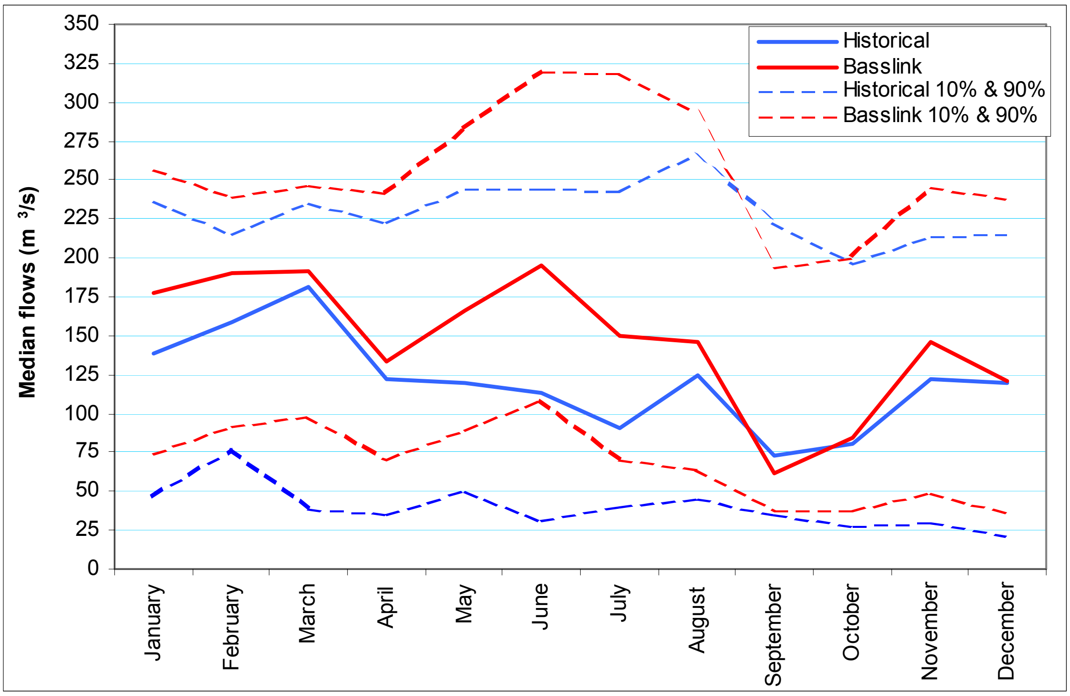


Figure 32. Comparison of Historical and Basslink Scenario flow percentiles for the Gordon River at Site 72 (1989-1998)

Table VIII. Results of t-test for difference in monthly means of Basslink and Historical data at Gordon above Olga at 5% significance level

Month	Current Average flow (cumecs)	Basslink Average flow (cumecs)	Difference in mean
January	162.7	170.4	Y
February	157.1	171.0	Y
March	159.9	171.5	Y
April	118.7	135.1	Y
May	151.0	179.0	Y
June	132.9	188.6	Y
July	121.3	162.7	Y
August	119.5	138.1	Y
September	81.7	83.2	N
October	78.9	89.1	Y
November	114.1	132.2	Y
December	116.8	113.6	Y

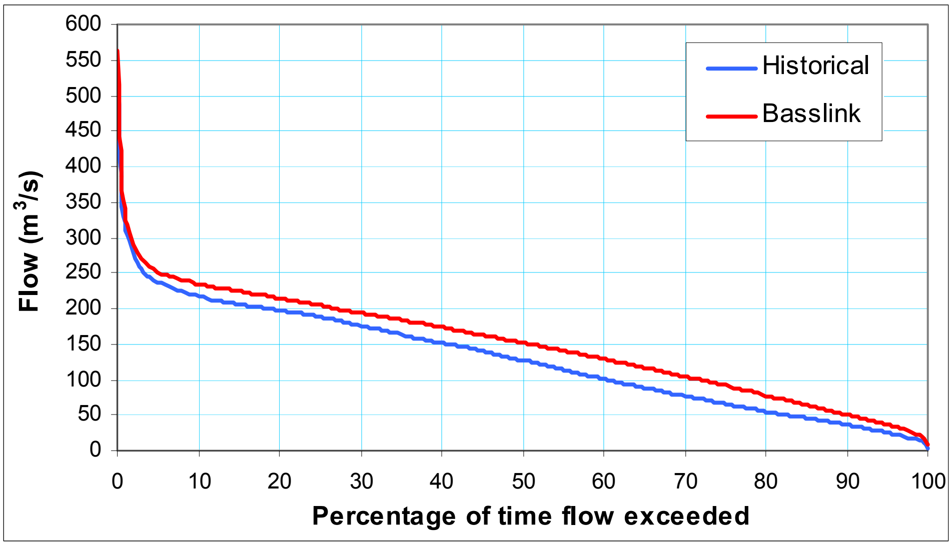


Figure 33. Comparison of Duration Curves for Gordon River Daily Flow at Site 50 (1989 – 1998)

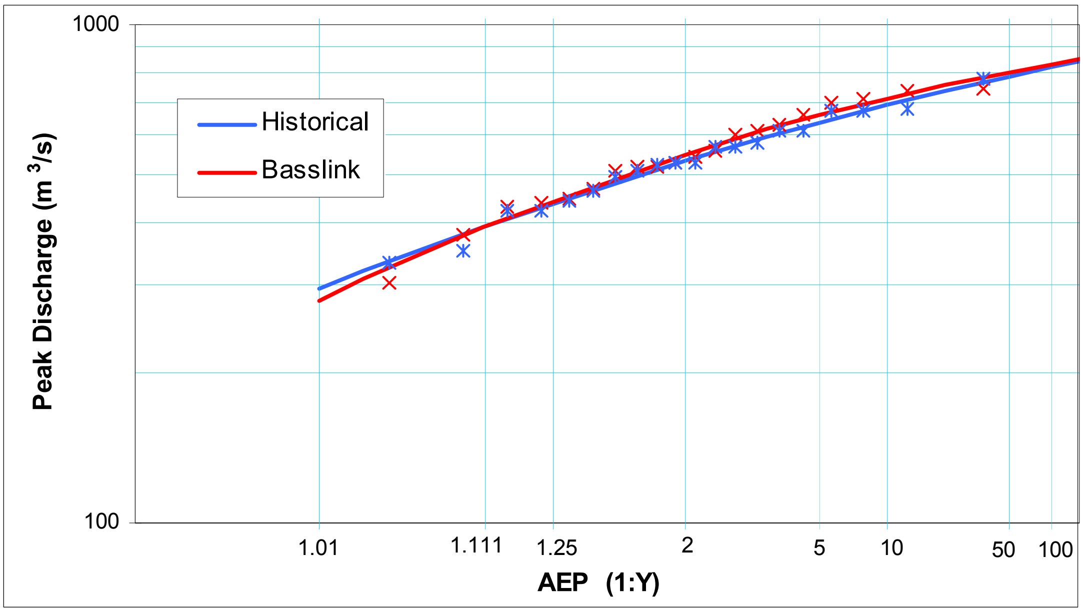


Figure 34. Comparison of Flood Frequency Analyses at Gordon River Site 50 (1979-1998)

6.3 Basslink Comparisons at the Gordon River above Franklin River (Site 47)

Actual measured flow record exists for the location Gordon River above Franklin for the period 1958-79. Unfortunately, power station operation with all three machines available does not commence until mid-1989. Thus a later record was simulated using the TimeStudio model to compare against Basslink simulated record. The catchment area to the Gordon above Olga location is around 3240 km^2 (including the Huon diversion). 62% of the catchment is still controlled by the lakes and power station operation.

Figure 35 and Figure 36 show historical flow and the Basslink scenario as simulated at the Gordon River above Franklin for the years 1989 and 1996. The influence of the power station on the flows above Franklin is still discernible for both the wet and dry years under Basslink.

The low winter median historical and Basslink power station flows are further augmented by natural pickup (Figure 37). Figure 39 shows that there is a large range of flows at this site, due to the range of natural pickup between the power station and the Gordon below Franklin site. The flow duration curve (Figure 39) for the historical and Basslink scenarios have a similar shape as for above Olga but are slightly higher for all curves due to the increased flow from natural pickup at this site. Flows greater than 100 m^3/s are exceeded about 70% of the time under historic station operation and 80% for Basslink scenarios. Mean monthly flows increase significantly under Basslink (Table IX).

Flood frequency for Gordon River above Franklin (Figure 40) shows that as with the other sites the only influence that Basslink operation will have on flood frequency at Franklin compared to the historical operation, would be the timing of the maximum release through the Gordon power station.

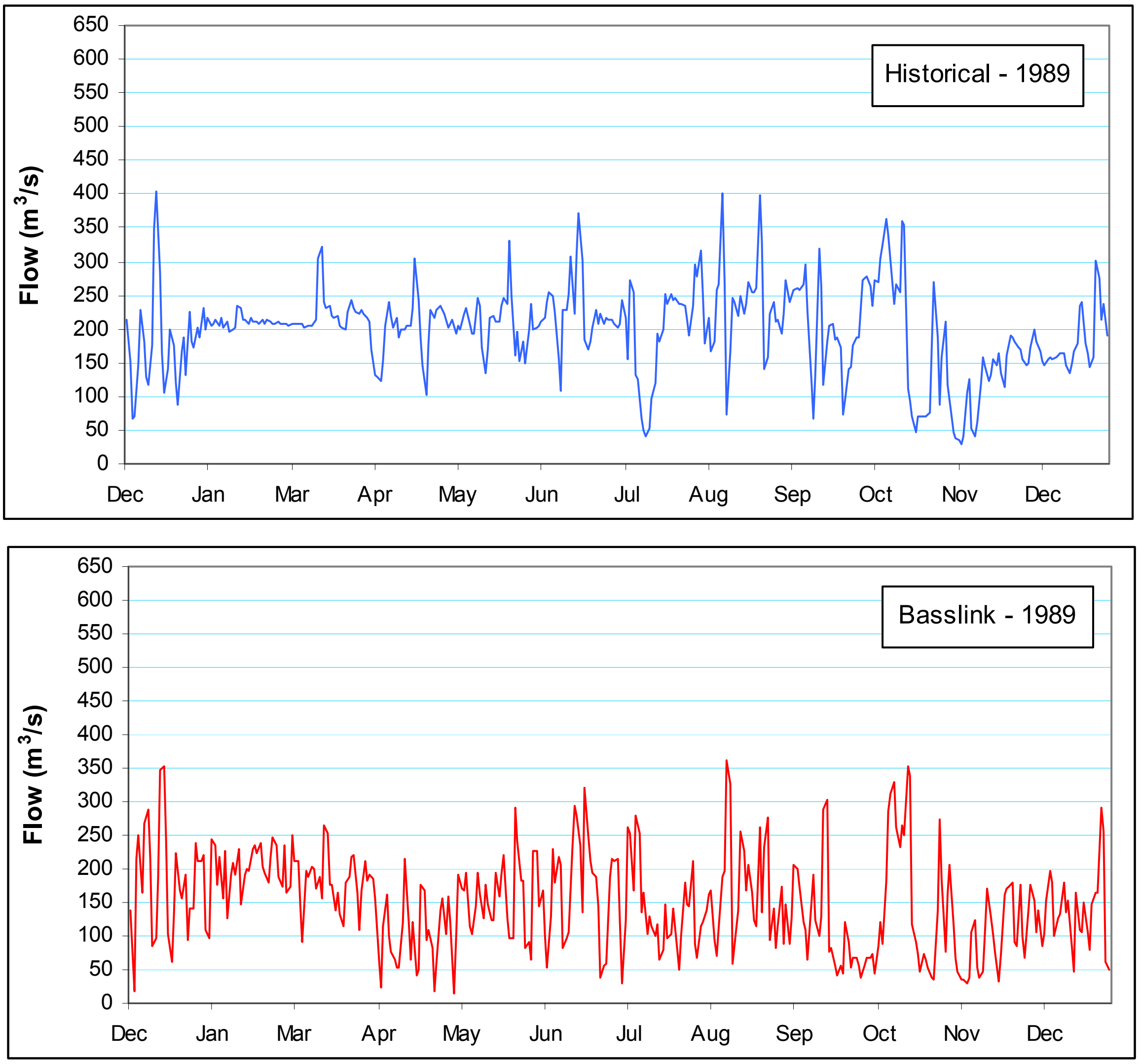


Figure 35. Comparison of Gordon River Daily Flows above Franklin (Site 47) - Dry Year (1989)

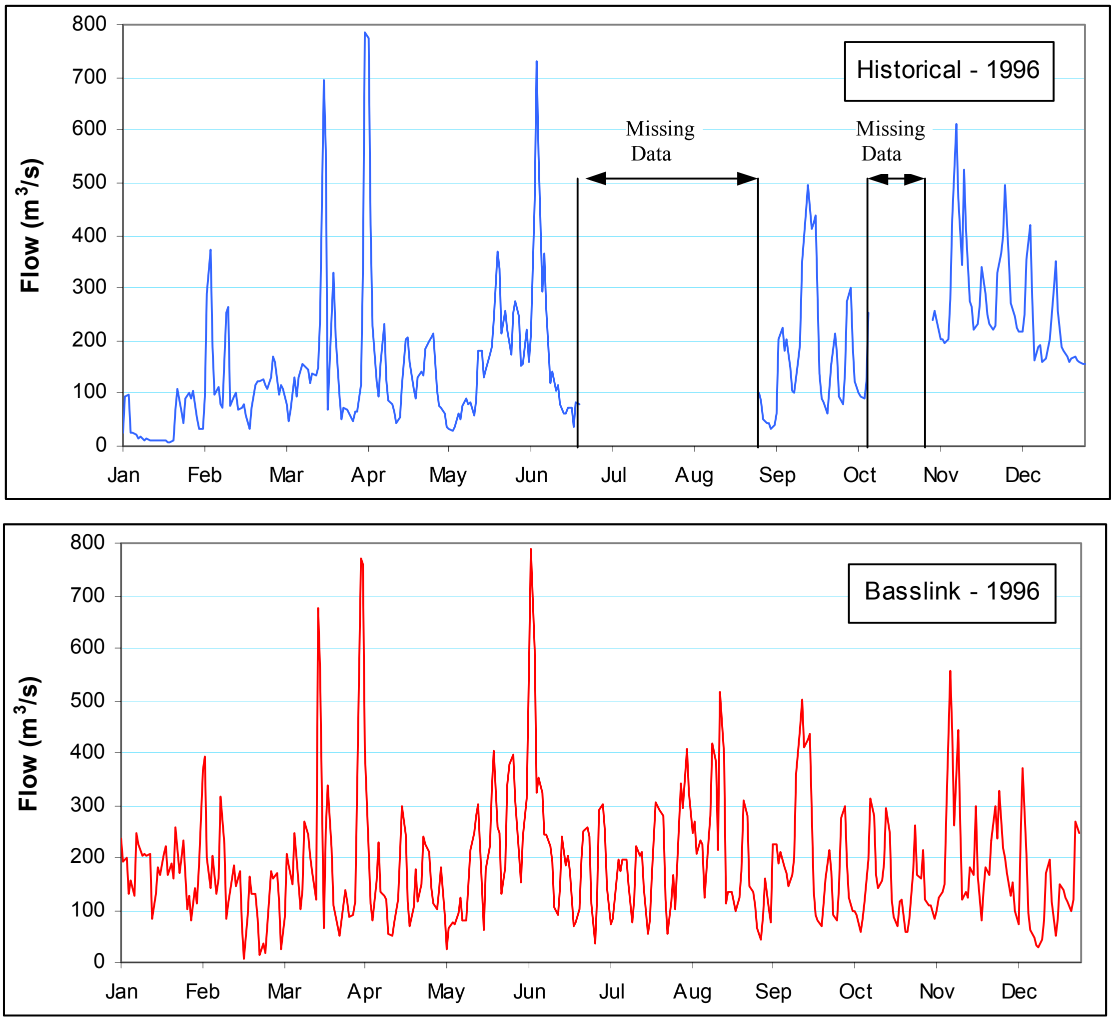


Figure 36. Comparison of Gordon River Daily Flow above Franklin (Site 47) - Wet Year (1986)

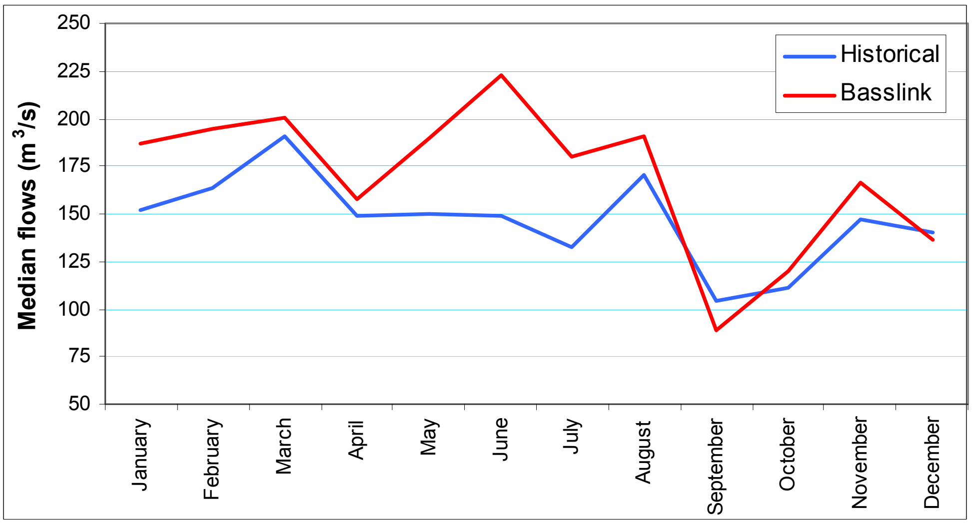


Figure 37. Comparison of Monthly Median Flows for Gordon River above Franklin (Site 47) (1989 – 1998)

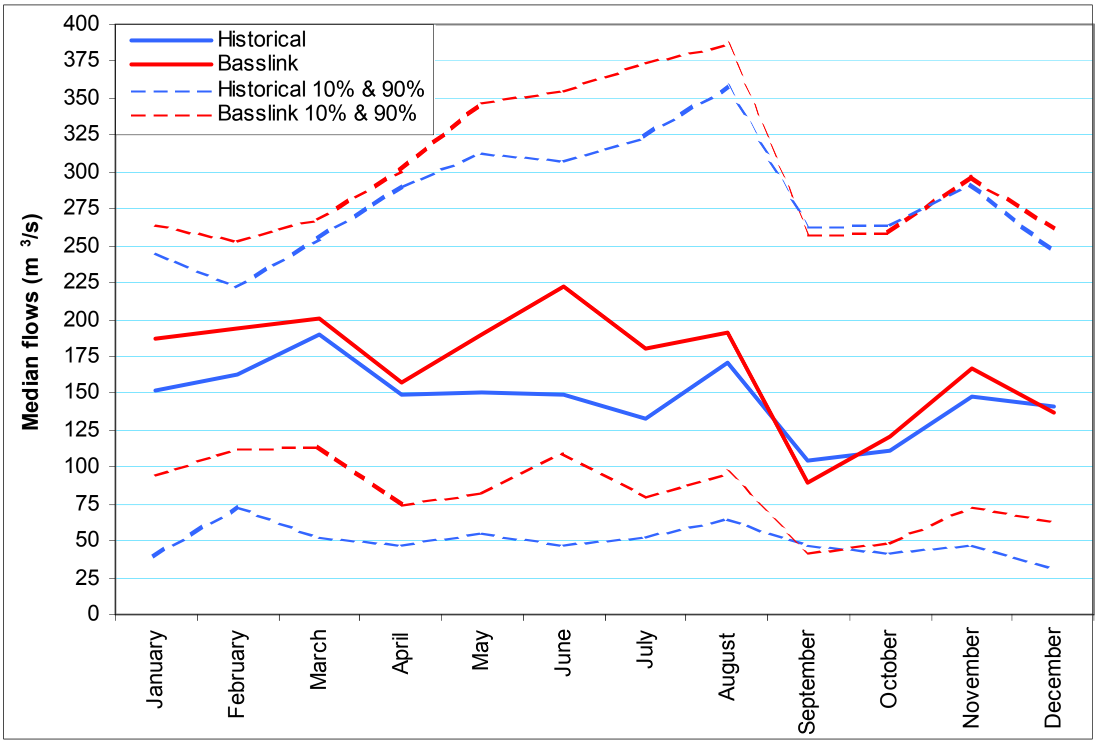


Figure 38. Comparison of Historical and Basslink Scenario flow percentiles for the Gordon River at Site 47 (1989-1998)

Table IX. Results of t-test for difference in monthly means of Basslink and Historical data at Gordon above Franklin at 5% significance level

Month	Current Average flow (cumecs)	Basslink Average flow (cumecs)	Difference in mean
January	172.9	193.5	Y
February	162.1	194.4	Y
March	166.5	200.9	Y
April	131.8	180.6	Y
May	173.0	210.9	Y
June	155.2	233.7	Y
July	148.0	202.0	Y
August	150.2	211.4	Y
September	104.2	130.1	Y
October	98.8	135.3	Y
November	129.7	176.4	Y
December	125.6	152.9	Y

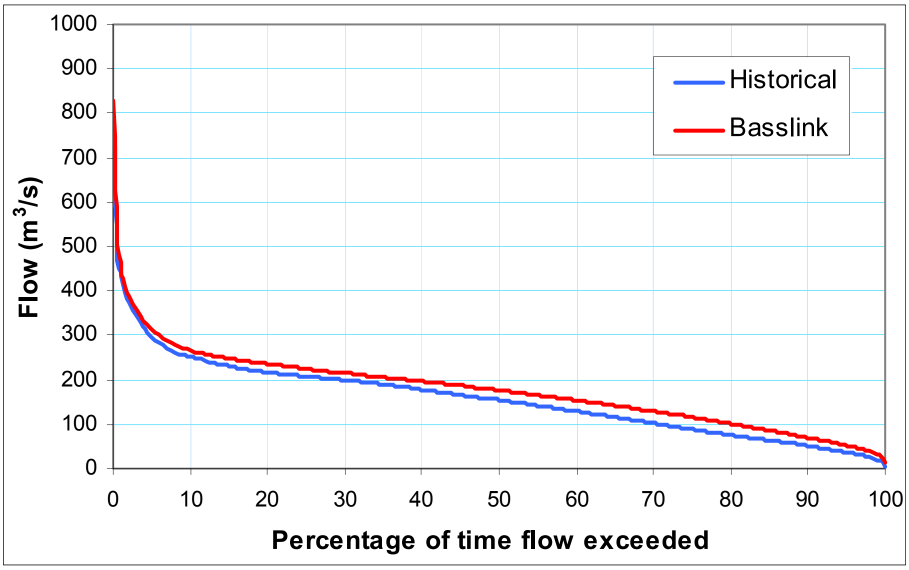


Figure 39. Comparison of Duration Curves for Gordon River Daily Flow above Franklin (Site 47) (1989 – 1998)

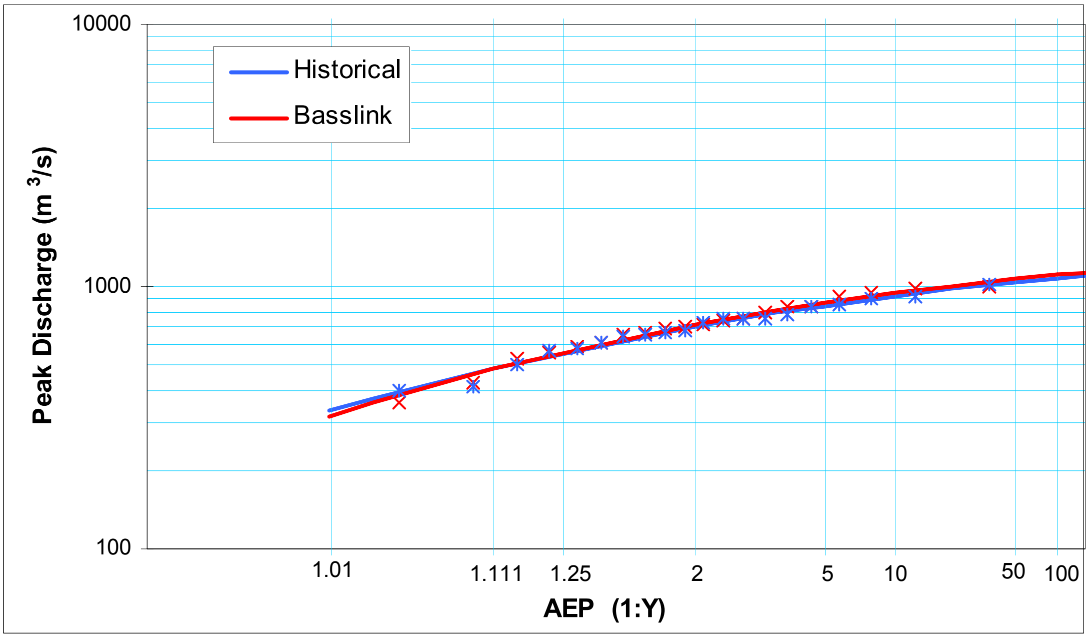


Figure 40. Comparison of Flood Frequency Analyses at Gordon River Site 47 (1979-1998)

6.4 Comparison of Flows Along Gordon River

Table X and Figure 41 show the natural pickup as a percentage of the total flow for various sites along the Gordon River under historical and Basslink scenarios. Under both Basslink and historical scenarios, the seasonality of natural flows is evident when compared to total. The contribution of natural flows to the total flow is greatest in winter and spring. On a monthly basis, the contribution of natural flows to the total flow at a site is generally greater under Basslink.

Figure 42 shows that, as expected due to tributary inflows, the 1:100 flood peak shows a steady increase with distance downstream. The flood peaks for the historical and Basslink cases do not differ significantly, indicating that any changes in the seasonality of releases from the power station between the two cases does not affect the flood peaks downstream of the power station.

Table X. Percentage of Natural Pickup to Total Flows Along the Gordon River

	HISTORICAL					
SITE	75	71	69	65	61	47
Jan	0%	2%	2%	4%	17%	22%
Feb	0%	1%	1%	2%	10%	14%
Mar	0%	2%	2%	3%	13%	17%
Apr	1%	4%	4%	7%	28%	36%
May	2%	6%	7%	11%	38%	47%
Jun	2%	7%	8%	12%	41%	49%
Jul	2%	9%	10%	15%	48%	56%
Aug	3%	11%	12%	19%	54%	62%
Sep	3%	13%	14%	21%	57%	65%
Oct	3%	11%	12%	18%	52%	61%
Nov	1%	5%	6%	9%	34%	42%
Dec	1%	3%	4%	6%	24%	31%
mean	2%	6%	7%	11%	35%	42%
	BASSLINK					
SITE	75	71	69	65	61	47
Jan	0%	2%	2%	3%	13%	18%
Feb	0%	1%	1%	2%	8%	12%
Mar	0%	1%	1%	2%	11%	15%
Apr	1%	5%	5%	8%	31%	39%
May	1%	5%	6%	9%	34%	42%
Jun	1%	5%	5%	8%	30%	38%
Jul	2%	9%	10%	15%	48%	56%
Aug	4%	14%	15%	23%	60%	68%
Sep	10%	33%	35%	47%	82%	86%
Oct	5%	19%	20%	29%	67%	75%
Nov	1%	5%	6%	9%	33%	41%
Dec	1%	4%	5%	7%	29%	36%
mean	2%	9%	9%	14%	37%	44%

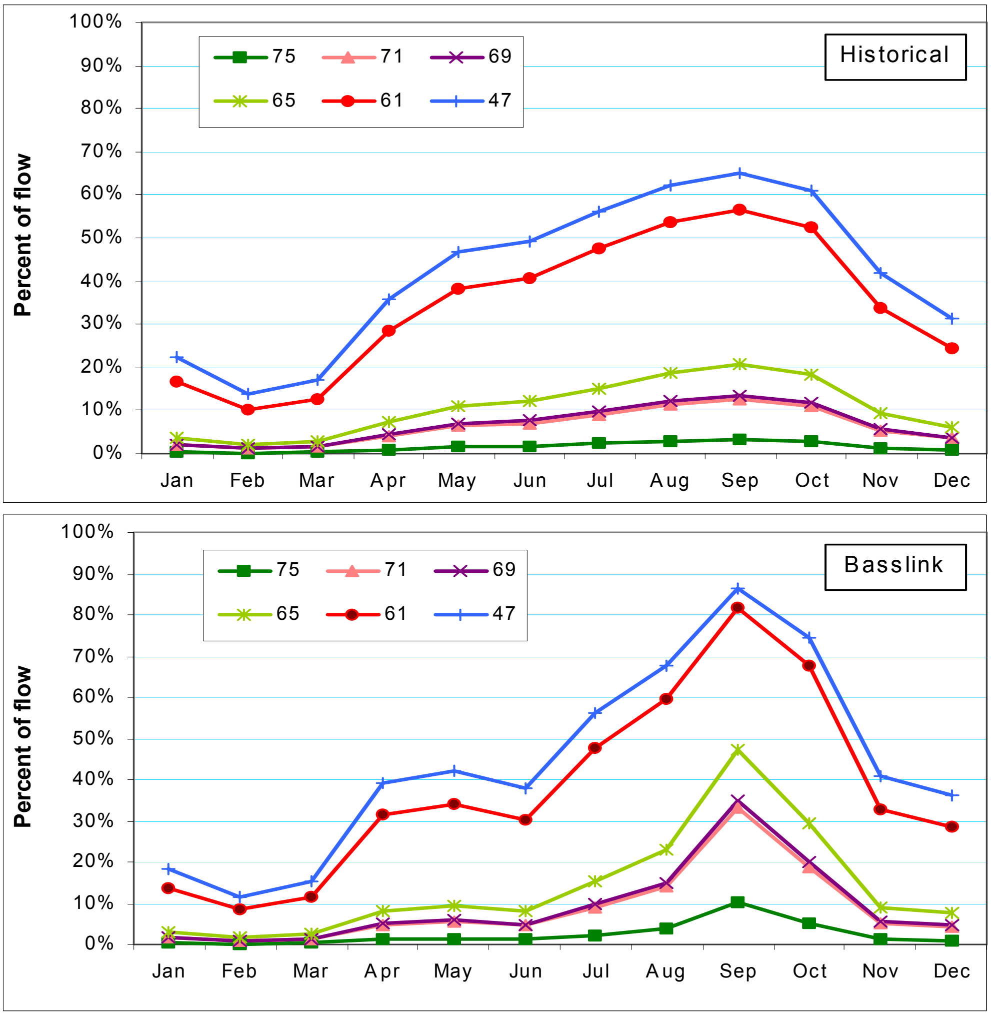


Figure 41. Percentage of Natural Pickup to Total Flows along the Gordon River under Current and Basslink scenarios (1977-1998)

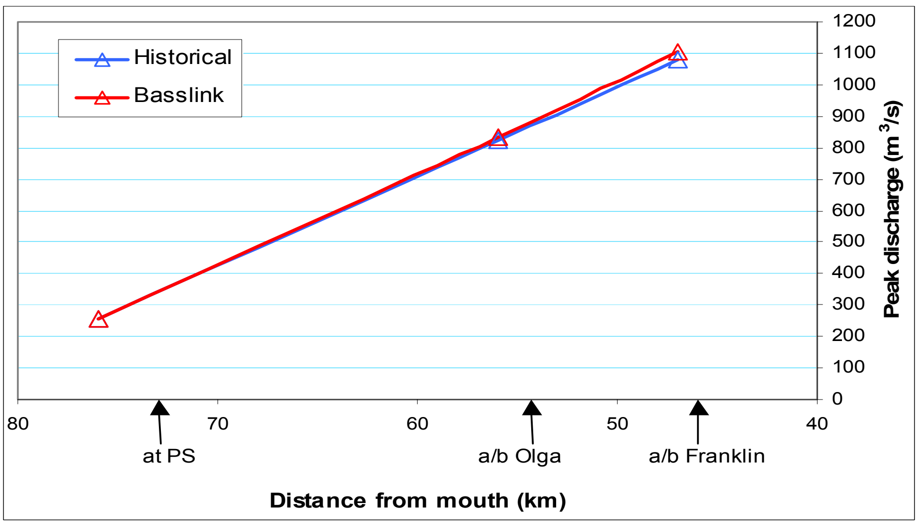


Figure 42. Comparison of 1:100 Flood Peaks along Gordon River under Current and Basslink Scenarios

7 SUMMARY

This document summarises the hydrological changes to the Gordon Power Station and downstream Gordon River that are predicted to occur with Basslink.

The most significant change is an increase in the on-off operation of the power station. The number of 'on events', indicated by hourly discharge events greater than the mean flow increase from 219 on average each year with current operations to 297 under Basslink. The number of off events increase from 73 on average each year with current operations to 254 under Basslink.

Downstream of the power station, the fluctuations in flow due to Basslink are still evident at Site 72, Site 56 and Site 47. However, the further downstream in the river, the greater the flow augmentation from the natural catchment, which results in proportionally less influence from power station operation. This is also evident in the monthly median flows at the sites. At the power station there is a changed seasonality between the natural flows and the power station modified flow.

Neither the flow duration curves nor flood frequency analyses show major changes between current operations and Basslink. Maximum station output would not change under Basslink.