Gordon River Monitoring Report 2016–18

September 2018

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Executive summary

This Gordon River Monitoring Annual Report presents the results of the monitoring undertaken on 2-3 March 2018 pursuant to the Gordon River Monitoring Program.

Hydrology and water management

The downstream flow in the Gordon River in 2016–17 and 2017-18 was closely correlated with discharges from the Gordon Power Station. Discharges were lower than average for most of 2016-17 and 2017-18 to allow levels in Lake Gordon to be rebuilt following the extended Basslink outage and dry conditions in 2015-16. Low median discharges were observed in all months of 2016-17 and in the period July 2017 to January 2018 during 2017-18. Discharges between February and June 2018 were closer to the long term median. The Basslink cable was not operational in the period from 24 March 2018 to 5 June 2018. During the months of July to September 2016 and July to September 2017 there was greater proportion of downstream flows originating from tributaries following seasonal increases in natural flow.

The revised ramp-down rule was implemented successfully, with all generation reductions being set at the 1 MW per minute ramping requirement. Full compliance was achieved as the generation control system automatically applied the rule whenever the conditions requiring its use were met. The ramp-rule was also implemented during the Basslink outage even though this is not required under the Special Water Licence Agreement. Some instances, representing a short period of time, that required implementation of the ramp-down rule exceeded the 1 MW per minute target (2016-18: 2.7%). The major causes for these exceedances were rapid responses in relation to frequency excursions in the NEM and machine trips. These occurrences are not considered to be non-conformances as they were outside of operational control.

The minimum environmental flow was met, although not required to be released, whilst the Basslink cable was not operational. For the periods when the minimum environmental flow release was required, it was achieved in summer for 99.84 % (2016-17) and 100 % (2017-18) of the time, and in winter for 99.66 % (2016-17) and 99.84 % (2017-18) of the time.

Fluvial geomorphology

Geomorphology monitoring was completed between the Gordon Power Station and upstream of Sunshine Gorge on 3 April 2018. The April 2018 monitoring results were consistent with the understanding of geomorphic processes in the middle Gordon River, and the role of power station discharge in these processes.

Monitoring results reflect the low discharge from the Gordon Power Station since the previous sampling in April 2016, with observations of limited scour of the bank faces and the establishment of vegetation on bank toes and bank faces. The low power station usage enabled vegetation growth on the banks and increased deposition of sediment due to increasing bank roughness. This process contributed to the low erosion rates that were recorded in zones 3 and 4.

The occurrence of short-duration increases in power station discharge between 2016 and 2018 affected bank toes more than bank faces. Erosion pin measurements and field observations indicated a trend of bank toe flattening, and was consistent with the long-term trend of channel widening in alluvial reaches with low-angle bank slopes.

Very high natural flow events in May and July 2016 did not appear to have a lasting impact on the river, with little evidence of their impact on bank erosion. The lack of evidence of erosion may be partially due to the subsequent deposition on bank faces promoted by the low power station discharge and high natural sediment inputs from tributaries over the long period since the previous monitoring.

Macroinvertebrates

Macroinvertebrates were sampled at eight sites in the Gordon River between the Gordon Power Station and the Franklin River junction. Six reference sites were also sampled in the Franklin, Denison, Maxwell and Jane rivers.

The current status for the twelfth year of the post-Basslink period is:

- five of the nine macroinvertebrate metrics had all values within usual bounds;
- two metrics were slightly above their upper trigger bounds (positive result);
- two substantial upper trigger bound exceedances were observed for abundance of EPT (proportional and absolute), due to increased hydropsychid caddis densities (positive result).

The latter two exceedances reflect a response to power station discharges during 2016-17 and 2017-18 and are not of ecological concern. They can be regarded as representing improvement in biological condition relative to pre-Basslink conditions, due to a spike in the abundance of the hydropsychid caddis *Asmicridea sp. AV1*. This is directly related to more stable flow conditions in the river, which favour this species, in the year prior to sampling. These more stable conditions are characterised by the high proportion of low power station discharges (< 50 m^3s^{-1}) and the reduced frequency of peaking events up to 200 m^3s^{-1}.

Inter-annual variations in power station release patterns, particularly the incidence of sustained peaking and high flows, continue to drive swings in metric values. Overall, the condition of macroinvertebrate communities has been relatively stable from 2015-16 to 2017-18, reversing the previous substantial decline observed between 2012 and 2014.

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Acronyms and abbreviations

AEMO	Australian Energy Market Operator – founded in 2009 with NEMMCO as a founding entity
AETV	Aurora Energy Tamar Valley
AUSRIVAS	Australian River Assessment System
BBR	Basslink Baseline Report
EPT	Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies)
FLOCAP	Flow calculator application to convert station output to flow
IIAS	Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro Power Generation
LOAC	Level of acceptable change
NEMMCO	National Electricity Market Management Company – incorporated into AEMO in 2009
O/E	Biological index of the 'observed' to 'expected' ratio which describes the proportion of macroinvertebrate taxa predicted to be at a site under undisturbed conditions that are actually found at that site. O/E scores range between 0, with no predicted taxa occurring at the site, to around 1, with all expected taxa being observed (i.e. a community composition equivalent to reference condition).
O/Epa	O/E value calculated using an AUSRIVAS model based on presence-absence data
O/Erk	O/E value calculated based on rank abundance category data
RBA	Rapid Biological Assessment - macroinvertebrate sampling protocol
WOR	Whole-of-river

Glossary

Bray-Curtis index	a measure of assemblage similarity between sites/samples
Cavitation	the formation and subsequent collapse of vapour bubbles (cavities) within water moving at high velocity. Cavitation is responsible for the pitting of turbine blades.
Confluence	the location when two rivers or tributaries flow together
Environmental flow	water which has been provided or released for the benefit of the downstream aquatic ecosystem and broader environment
Full gate	is the discharge which produces the maximum amount of energy by the turbine
Geomorphic	the study of the earth’s shape or configuration
GordonRatingApp	the stand alone application used for calculating discharge from the Gordon Power Station
GWh	gigawatt hours (10^9 watt hours) – a standard measure of energy equivalent to the production of one gigawatt of power for one hour
Hydrology	the study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks and in the atmosphere
Hydro-peaking	variable flow in power station discharge on a daily scale
Inundation	an area of vegetation or bank which becomes covered by water associated with flows from either an upstream dam or tributary input
m^3s^{-1}	cubic metres per second, units for the measure of flow rate
MW	megawatts (10^6 watts) - a standard measure of power
Piezometer	an instrument for measuring pressure
Post-Basslink	the period following commissioning of the Basslink interconnector
Pre-Basslink	the period prior to commissioning of the Basslink interconnector
Riffle habitat	habitat comprising rocky shoal or sandbar lying just below the surface of a waterway
Rill	a small stream of water
Tailrace	the outflow structure of the power station, from which water is discharged into the river
Taxon	a taxonomic category or group, such as a phylum, order, family, genus, or species
Temporal	change or pattern over time

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1.0 Introduction and background

The purpose of this Gordon River Monitoring Report is to present the results of the monitoring undertaken pursuant to the monitoring and reporting requirements in Hydro Tasmania's Special Licence Agreement. The requirement to undertake biennial monitoring was due in autumn 2018.

This is the twelfth year of post-Basslink operation. The monitoring area is shown in Figure 1-1.

1.1 Context

The aims of the original Gordon River Basslink Monitoring Program were to:

- undertake pre-Basslink monitoring (2001–05) in order to extend the understanding gained during the 1999–2000 investigative years on the present condition, trends, and spatial and temporal variability of potentially Basslink-affected aspects of the middle Gordon River ecosystem;
- undertake six years of post-Basslink monitoring to determine the effects of Basslink operations on the environment of the Gordon River below the power station and to assess the effectiveness of mitigation measures; and
- obtain long-term datasets for aspects of the middle Gordon River ecosystem potentially affected by Basslink that will allow refinement of theories and more precise quantification of spatial and temporal variability, processes and rates.

The focus of the pre-Basslink monitoring program was to measure conditions under the existing operating regime, rather than attempting to relate them to 'natural' or 'pristine' conditions. This approach was an essential element of the monitoring program given the highly modified conditions that exist due to the presence of, and the flow regulation resulting from, the existing Gordon Power Scheme.

A major component of the post-Basslink monitoring program was to compare post-Basslink data with trigger values derived from pre-Basslink data and to assess the effectiveness of two operational mitigation measures; a minimum environmental flow and a power station discharge ramp-down requirement (ramp-down rule).

The subsequent Gordon River Interim Basslink Monitoring Program comprised a monitoring regime for two years from May 2012 to April 2014 to assess the effectiveness of the mitigation measures (ramp-down rule and minimum environmental flow). Continued monitoring beyond the original period was due to the revision of the ramp-down rule in mid-2012 which better aligned operational and environmental objectives. It was considered prudent to ensure that the aims of the revised ramp-down rule were being achieved, and monitoring continued with a focus on hydrology, fluvial geomorphology and macroinvertebrate disciplines.

The current Gordon River Monitoring Program focusses on hydrology, fluvial geomorphology and macroinvertebrate monitoring. The main aim of the current Gordon River monitoring is to validate the conceptual models presented in the Basslink Review Report 2006-12 (Hydro Tasmania 2013) and improve our understanding of the responses if the power station is operating outside 'historical' ranges. Under the Special Licence Agreement, monitoring was to be undertaken on one occasion between February and April in each of the years 2016, 2018 and 2020.

Monitoring is also required in years between those mentioned above if one of the following hydrological triggers are exceeded in the previous 12 months:

- Flow at Gordon Compliance site over a 90 day period exceeds:
    i. 100 m^3s^{-1} for more than 99% of the time; or
    ii. 200 m^3s^{-1} for more than 93% of the time; and
- Gordon Power Station discharge over a 90 day period rises from:
    i. 35 to 100 m^3s^{-1} in 4 hours or less on more than 75 occasions; or
    ii. 35 to 200 m^3s^{-1} in 4 hours or less on more than 40 occasions.

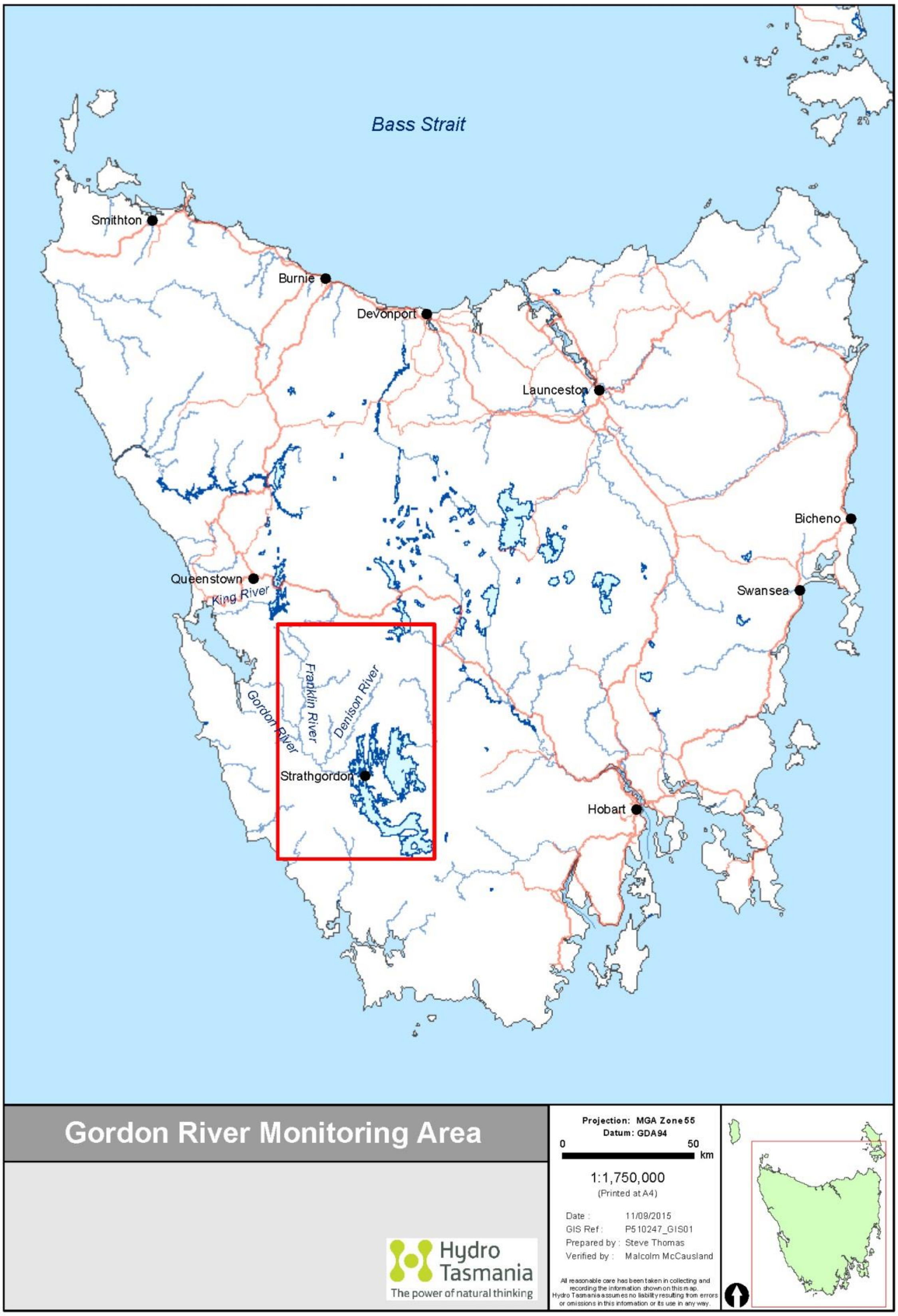

Figure 1-1: Gordon River monitoring area.

1.2 Logistical considerations and monitoring in March (autumn) 2018

Site access presents significant challenges in this part of the Tasmanian Wilderness World Heritage Area. On-site monitoring activities require helicopter support due to the density of the terrestrial vegetation, the absence of access to infrastructure and the extent of the study area.

Power station outages are needed to conduct monitoring because the majority of viable helicopter landing sites are on cobble bars in the river bed that are exposed only when there is little or no discharge from the power station. Outages are also necessary because most of the biotic and geomorphic monitoring activities require measurements or sampling to take place within the river channel, which would not be possible under normal or high flow conditions.

The 2018 monitoring field trip was conducted on 2-3 March 2018.

1.3 Geographic datum

Map coordinates in this document use the 1966 Australian Geodetic Datum (AGD) which corresponds to topographic maps available for the area when the pre-Basslink monitoring was completed. A later datum, the Geocentric Datum for Australia (GDA), was subsequently adopted for new maps. Site references using the AGD will be approximately 200 m different (-112 m east and -183 m north) from those using the GDA.

1.4 Document structure

The report is organised into four chapters and four appendices.

This first chapter discusses the requirements, context, logistical considerations and constraints of the program. Chapters 2–4 report on the monitoring work that was undertaken during 2018, and present the consolidated results of each of the individual monitoring elements. These are:

- Hydrology and water management (Chapter 2);
- Fluvial geomorphology (Chapter 3); and
- Macroinvertebrates (Chapter 4).

The report also contains the following four appendices:

- Power station discharges graphed per month (Appendix A);
- Ramp-down rule exceedence events (Appendix B);
- Fluvial geomorphology photo-monitoring (Appendix C); and
- Macroinvertebrate data (Appendix D).

1.5 Authorship of chapters

The information presented in chapters 2–4 is based on field reports produced by scientists engaged to conduct the monitoring, as shown in Table 1-1. The efforts and original contributions of these researchers are duly acknowledged.

This document was collated by Malcolm McCausland (Entura), with review from Sarah Metcalf, Marie Egerrup and Greg Carson (Hydro Tasmania).

Table 1-1: Chapter numbers, titles and original authors from whose reports the information in chapters 2–4 was extracted.

Chapter	Chapter title	Lead Author(s)
2	Hydrology	Malcolm McCausland (Entura) and Roger Parkyn (Hydro Tasmania)
3	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
4	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)

1.6 Site numbers

Throughout this report monitoring locations are identified by site number. These represent the approximate distance upstream from the Gordon River mouth at the south-eastern end of Macquarie Harbour. The monitoring work is conducted between sites 44 (immediately upstream of the Franklin confluence) and site 77 (the power station tailrace).

The fluvial geomorphology discipline uses zones rather than the standard site numbering system. This is because the work is associated with longer reaches of river bank than are suitable for the 'site' nomenclature.

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2.0 Hydrology and water management

This chapter of the Gordon River Monitoring Biennial Report provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the period July 2016 to June 2018. Conformance with the two mitigation measures, namely the minimum environmental flow and the ramp-down rule, is presented. In addition, operation is compared to the hydrological triggers.

2.1 Factors affecting Gordon Power Station discharge

An overview of hydro generation drivers in previous years is shown in Figure 2-1. The Gordon Power Station running regime has always been heavily influenced by a number of factors including:

- inflows to Hydro Tasmania catchments (volume, distribution and temporal variation);
- overall storage position, in particular, the storage positions of Tasmania's largest two storages, *yingina/*Great Lake and Lake Gordon;
- National Electricity Market price signals;
- energy supply/demand in Tasmania; and
- system constraints (e.g. Basslink outage, bushfires).

The number and potential influence of factors on Gordon Power Station operation is very large, and the identification and quantification of the influence of each of these remains difficult to define.

In all but five of the last 23 years, Tasmanian electricity demand was higher than the annual hydro energy yield (Figure 2-2). Other sources of energy (wind, import, gas/diesel) make up the remainder of the energy demand (Figure 2-3). The overall hydro system storage (Figure 2-4) is determined by variation in hydro yield between years, the amount of hydro generation and the availability and use of other energy sources (wind, import, gas/diesel).

System wide hydro generation (Figure 2-3) was 8,043 GWh in 2016-17, and 9,202 GWh in 2017-18. The generation at Gordon Power Station (Figure 2-3) was one of the lowest on record in 2016-17 (402 GWh) with annual generation being lower on only one occasion (2011-12). The low generation in 2016-17 at Gordon Power Station was the result of a strategy to rebuild the storage following the extended Basslink outage and extended period of dry conditions in 2015-16. Subsequently, the annual output from Gordon Power Station more than doubled in 2017-18 (1,013 GWh). System-wide inflows in 2016-17 and 2017-18 increased from the previous two years and were in excess of hydro generation (Figure 2-3) in both years. As a result, increases in overall system storage including Lake Gordon and *yingina*/Great Lake were observed in both years (Figure 2-4).

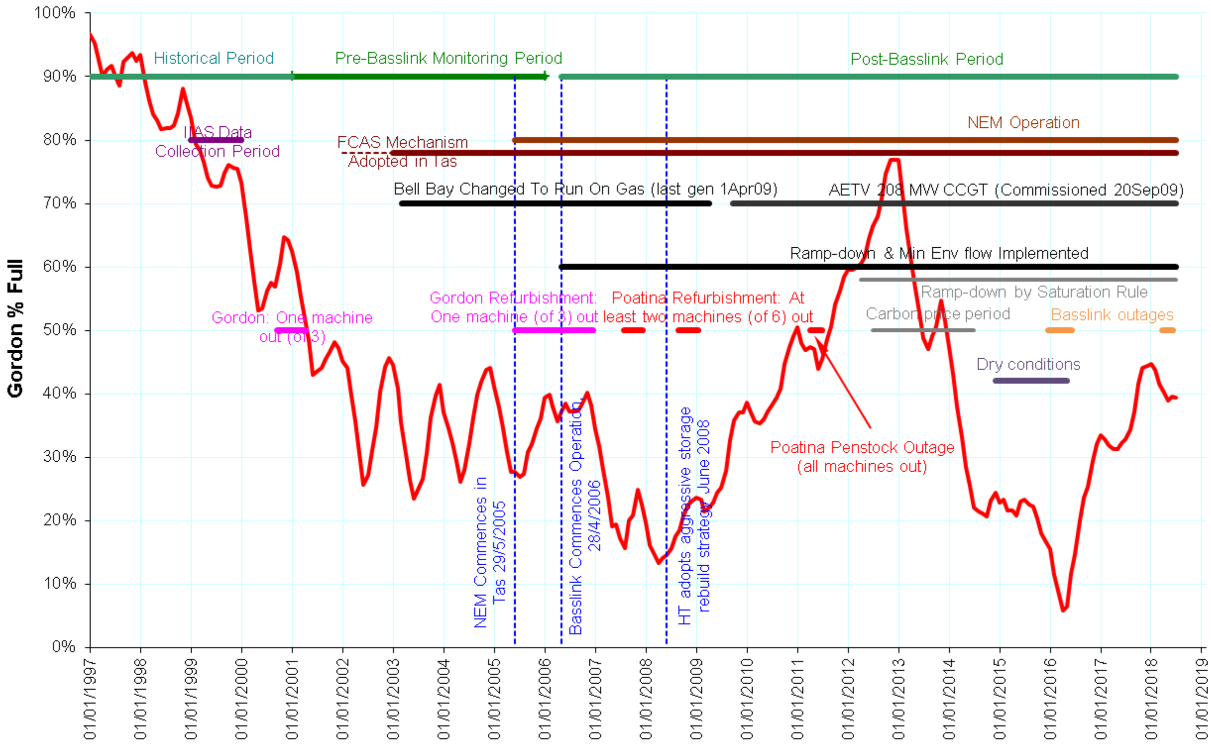


Figure 2-1: Lake Gordon water level (% full, red line) with a timeline of significant factors affecting Gordon Power Station operation (including storage levels) relative to Basslink monitoring periods.

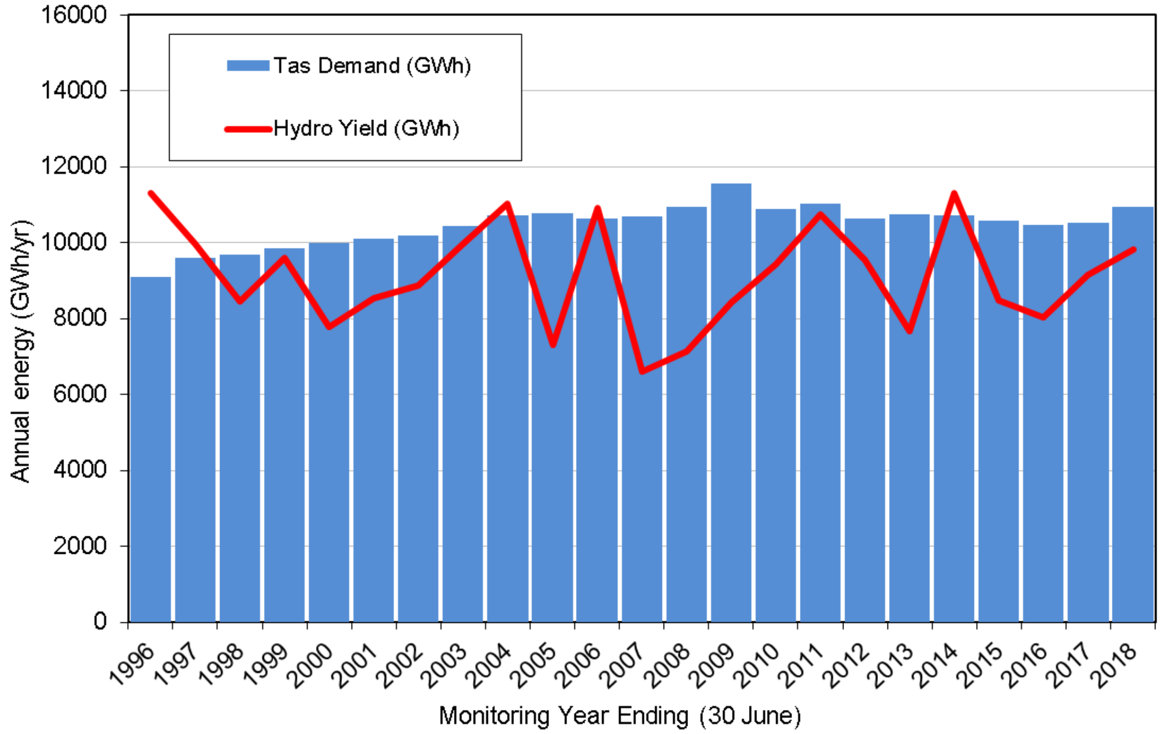


Figure 2-2: Annual Tasmanian electricity demand (total generation + net import or total generation – net export) and hydro energy yield representing system inflows converted to GWh.

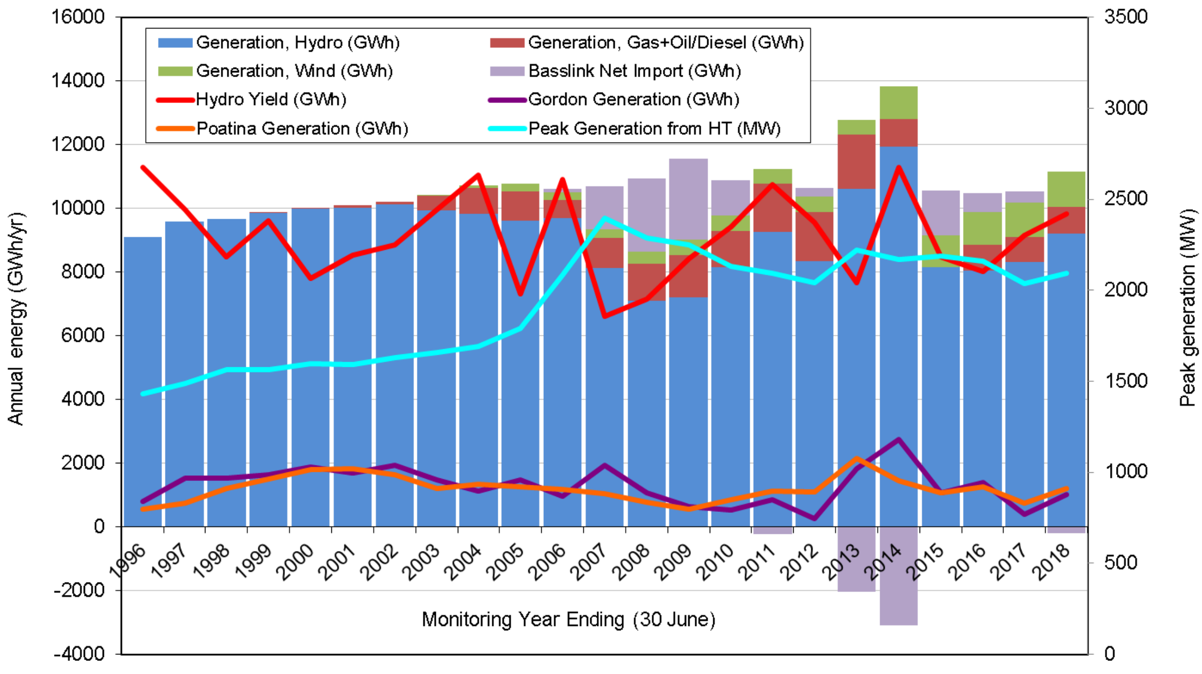


Figure 2-3: Hydro generation, wind and gas generation, Gordon and Poatina generation, net import (in GWh) and peak generation (in MW) for financial years from 1995–96 to 2017-18.

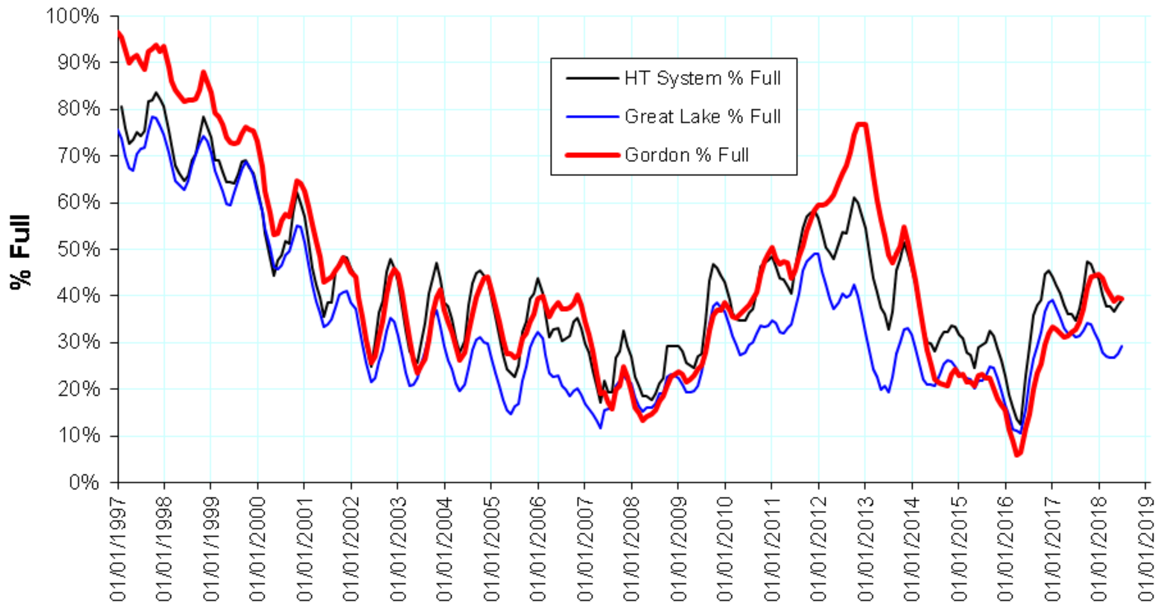


Figure 2-4: System, Lake Gordon and *yingina* /Great Lake water level presented as per cent full for 1997-2018.

2.2 Power output to flow ratings

Due to the difficulty in accurately measuring flow in the tailrace, flow records have been derived from power station output (MW) using a stand-alone rating application (GordonRatingApp). This application mimics the real-time tool used by the operators for the calculation of discharge from Gordon Power Station. It is the most accurate method of determining flow from the Gordon Power Station and is presented in all analyses in this report. This application utilises the following input data to determine discharge from Gordon Power Station:

- Individual machine output;
- storage water height; and
- machine power-discharge rating.

The application sends discharge data to the hydrological database for each five-minute interval.

2.3 Site locations

The flow monitoring sites reported in this chapter are from gauged sites at Gordon above Denison (site 65; also known as the flow compliance site) as well as the derived flow for Gordon Power Station tailrace (site 77).

The sites reported in this chapter are shown in Figure 2–5.

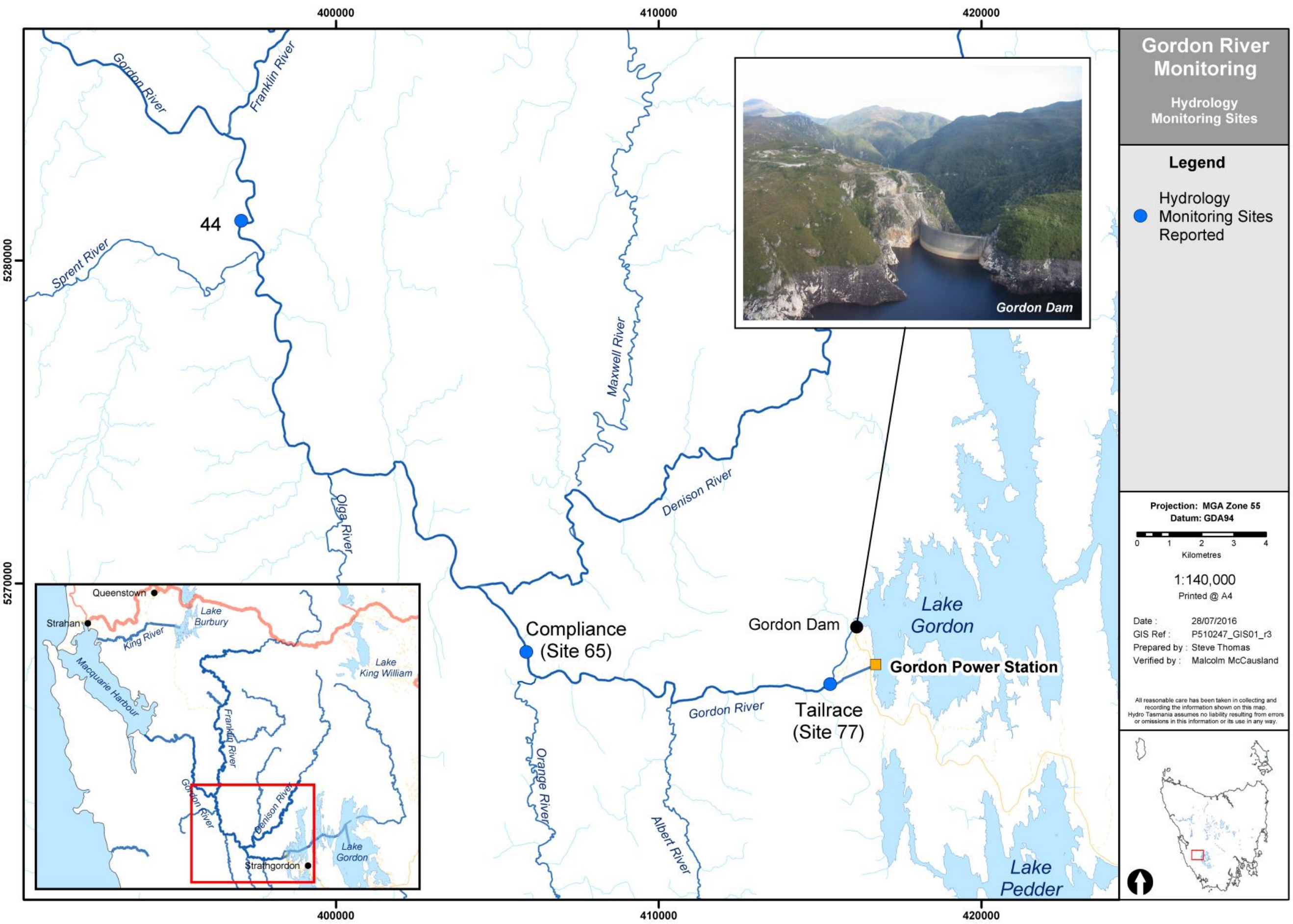


Figure 2-5: Gordon River hydrology monitoring sites

2.4 Data analysis

2.4.1 General flow analysis

For 2016–17 and 2017-18, flow analysis was undertaken for site 77 (the tailrace) and site 65 (compliance site). The derived flow at Site 77 is representative of flows immediately downstream from the power station, whilst site 65 is representative of flows in the middle reaches of the study area, downstream of the tributaries of the Albert River and Orange River, yet upstream of the larger tributary, the Denison River.

Both of these sites are required for compliance monitoring and the following general flow analysis was undertaken and is presented in Section 2.5.3 and Section 2.5.4.

- hourly power station discharge;
- median monthly flow and annual duration curves were plotted;

Analyses at sites 77 and 65 provide a comparison of the 2016-17 and 2017-18 years to the long-term average at these sites. The long-term average is calculated by using all available data at a site, which means that the date range for the long-term average periods will differ for each site depending on when data records commenced. Additional duration curves for the pre-Basslink, post-Basslink and historical periods, as well as each of the individual post-Basslink years, are presented for power station discharge data.

2.4.2 Hydrological triggers

An analysis of the discharges relative to the hydrological triggers was undertaken for 2016-17 and 2017-18 (Sections 2.5.3 and 2.5.4).

Peaking triggers

The peaking triggers utilise discharge from Gordon Power Station (site 77) in the previous 90 days and are exceeded when discharge increases from:

- 35 to 100 m^3s^{-1} in 4 hours or less on more than 75 occasions; or
- 35 to 200 m^3s^{-1} in 4 hours or less on more than 40 occasions.

The analysis of the data utilises aggregated hourly data and identifies the following conditions:

- discharge reduced below 35 m^3s^{-1}; and
- subsequently increased to greater than 100 m^3s^{-1} (trigger 1) or 200 m^3s^{-1} (trigger 2) within a four-hour period; and
- the number of occurrences these events that have occurred in the previous 90 days.

The data is presented in this report in Section 2.5.3as a time-series of the number of occasions the peaking events have occurred in the past 90 days, and are compared to the trigger value.

High flow duration triggers

The high flow triggers are based on the flow measured at the Compliance Site (Site 65) in the previous 90 days and are exceeded when:

- flow is in excess of 100 m^3s^{-1} for 93 % (or more) of the preceding period; or
- flow is in excess of 200 m^3s^{-1} for 99% (or more) of the preceding period.

The analysis of the data identifies the following conditions at each hourly time-step:

- flow record for previous 90 days;
- duration analysis on the data set;
- determination of the percentile that each of the trigger flow values (100 or 200 m^3s^{-1}) constitutes for that period.

The data is presented in this report (Section 2.5.4) as a time-series of the percentile values of each of the trigger flows in the previous 90 day period.

2.4.3 Ramp-down rule

Background

A ramp-down rule mitigation measure has been in place at Gordon Power Station since the commissioning of Basslink in April 2006. A revised and improved ramp-down rule was implemented from 1 April 2012. Its aim is to limit the rate of seepage erosion.

The revised rule utilises a Bank Saturation Regression Model to determine when the ramp-down rule is required to be applied. The Bank Saturation Regression Model utilises real-time discharge data from the Gordon Power Station to predict the level of saturation of the banks at Site 71 (Gordon River below Albert River)

The rule is as follows:

- whenever the bank saturation level at site 71, as calculated by the Bank Saturation Model, is greater than 2.75 m above the local datum and the discharge from the Gordon Power Station is greater than 150 m^3s^{-1}, the plant control system must be set to control any reductions in generation load at a rate of 1 MW per minute until the power station discharge is less than 150 m^3s^{-1}.

Test of compliance with ramp-down rule

The rule requires the ramp-down rule (i.e. to set the plant control system generation to avoid reductions exceeding 1 MW per minute) be applied when both:

- bank saturation level (from the Bank Saturation Model) exceeds 2.75 m; and
- power station discharge exceeds 150 m^3s^{-1}.

Hence the testing approach identified such periods (on a 5-minute basis) and determined if the plant control system was in place for these periods. In addition, while the plant control system was in place, comparison was made between the actual generation change-rate with the -1.0 MW/minute target. The results of the compliance test are presented in Section 2.5.3.6.

2.4.4 Minimum environmental flow

A minimum environmental flow requirement has been in place as a mitigation measure at Gordon Power Station since the commissioning of Basslink in April 2006. This measure requires that a minimum flow is released to the Gordon River from the power station to ensure that the flow at site 65 (compliance site) is not less than:

- 10 m^3s^{-1} between 1 December and 31 May; or
- 20 m^3s^{-1} between 1 June and 31 November.

Flow data at this site is presented to report on the compliance with this requirement (Section 2.5.4). The analysis for compliance with the minimum environmental flow excludes those periods when power station outages were in place, and when the Basslink cable was out of service. The exclusion of periods in the analysis when power station or Basslink outages occrred was undertaken as there is no requirement to maintain the minimum environmental flow whilst these outages are in place. The remaining flow record was subsequently analysed to identify periods when flows reduced below the minimum flow requirements.

2.5 Results

2.5.1 Data availability

There was no missing data from sites 77 or 65 in the 2016-17 and 2017-18 monitoring periods.

2.5.2 General analysis

System yield

The inflows to Hydro Tasmania's state-wide system during 2016–17 and 2017-18 were both above the long-term average levels (1996-2018). The total system inflows (system yield) in 2016-17 of 9,163 GWh was only marginally higher at 101% of the long-term average. In 2017-18 the total system inflows of 9,825 GWh were 108% of the long-term average.

Figure 2-6 shows the monthly total system yield during 2016-17 and 2017-18 compared with the long-term (1976–2016) median, 20th and 80th percentile inflows. The main features of each year were:

2016-17

- very high inflows in July, October and November 2016.
- inflows below the long term 20th percentile in March, April and June 2017; and
- below median inflows for most of the remaining months (August and September 2016, January and May 2017);

2017-18

- near median inflows or above for nine months of the year;
- of these September 2017 and March 2018 exceeded the 80th percentile inflow; and
- two months (November 2017 and January 2018) where inflows were below the 20th percentile.

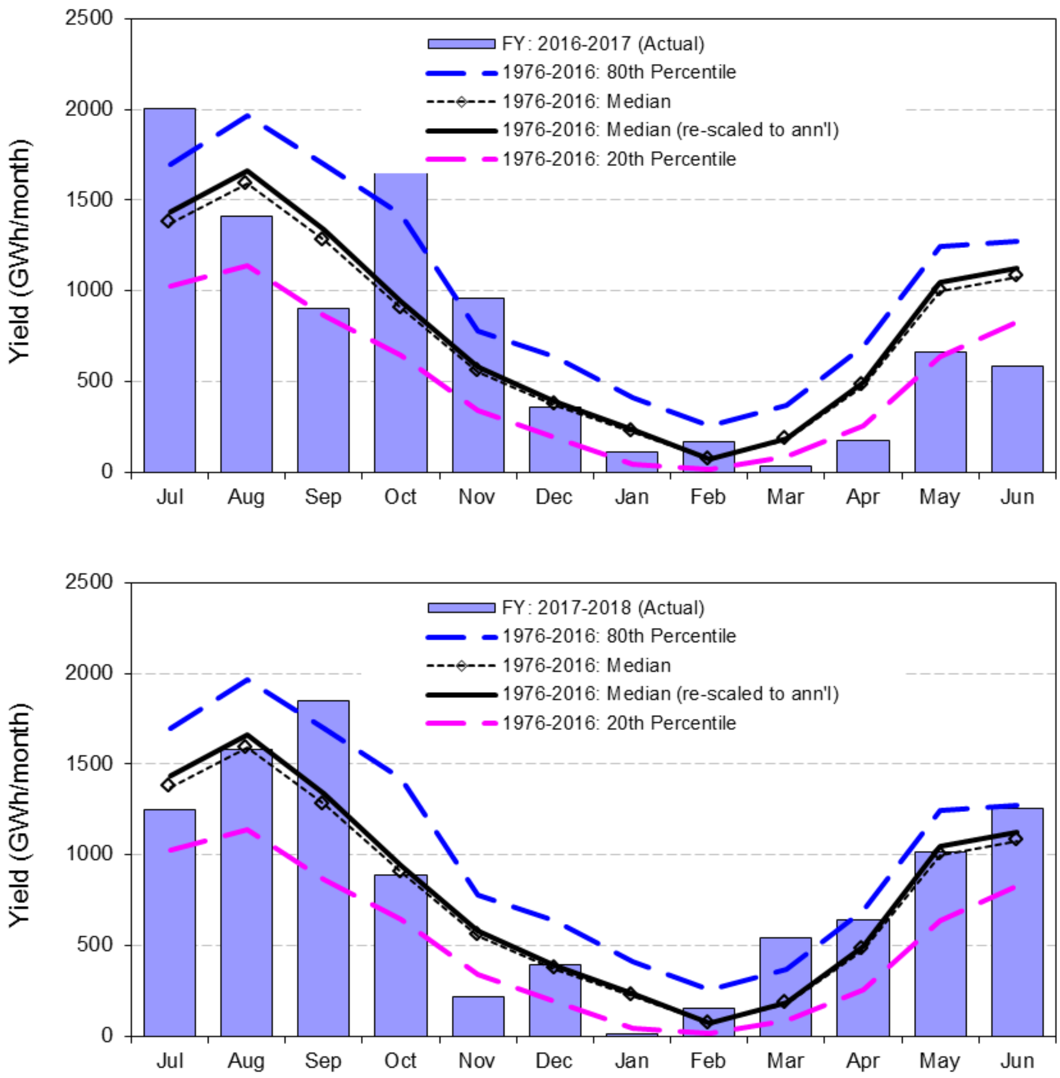


Figure 2-6: Monthly total system yield for 2016–17 (top) and 2017-18 (bottom) compared to the long-term median, 20th and 80th percentiles for 1976–2016.

Strathgordon rainfall

The Strathgordon meteorological station has rainfall records beginning in 1970. These allow the calculation of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2016–17 and 2017-18.

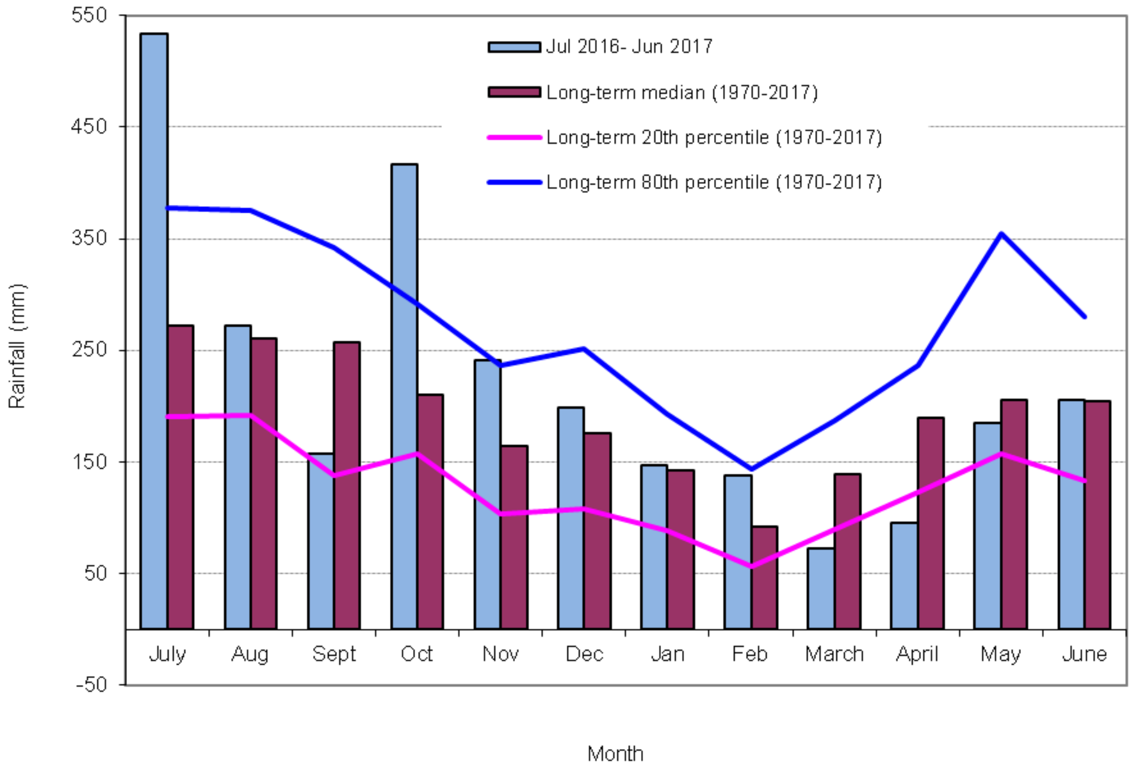
Figure 2-7 shows the total monthly and long-term average monthly rainfall values. In 2016–17 and 2017-18 the annual rainfall at Strathgordon (2,662 mm and 2,626 mm, respectively) were both higher than the long-term median (2,464 mm). The pattern of rainfall in Strathgordon throughout each year differed from the long term average in the following ways:

2016-17

- July and October 2016 were very wet months, receiving substantially higher rainfall than the long term 80th percentile rainfall value, which was nearly double the monthly median.
- Rapid inflows in the Pedder-Gordon catchment in July 2016 required the release (i.e. spill) of water from Lake Pedder via the Serpentine Dam on 27 July 2016. This was the first such release since 1988.; and
- March and April 2017 were dry months, receiving less than the long term 20th percentile rainfall.

2017-18

- September 2017, February and March 2018 were wetter months, receiving rainfall in excess of the long term 80th percentile rainfall value; and
- November 2017 and January 2018 were drier months, receiving rainfall just below the 20th percentile value.



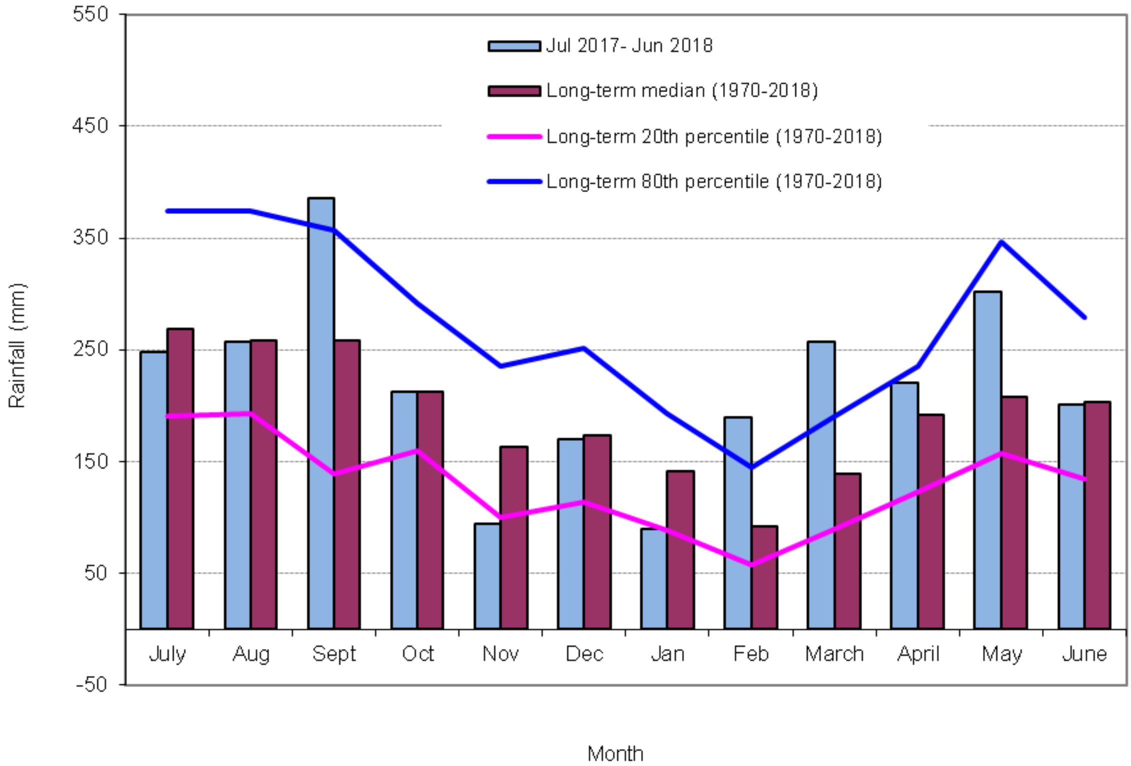


Figure 2-7: Total monthly rainfall values recorded at Strathgordon for 2016–16 (top) and 2017-18 (bottom) compared with the long-term median (1970–2016).

2.5.3 Gordon Power Station operation

Discharge and power station operation

As previously discussed (see Section 2.1), the discharge pattern for the Gordon Power Station is driven by a number of factors. Figure 2-8 and Figure 2-9 show the discharge from the power station for 2016–17 and 2017-18, respectively. More detailed monthly graphs are provided in Appendix A. A summary of some of the drivers of discharge conditions at Gordon Power Station is provided in Table 2-1. Significant points of interest in the 2016–17 and 2017-18 discharge data is as follows:

2016-17

- from July to late-August 2016 the discharge pattern consisted of low discharges (~ 20 m^3s^{-1}) to assist with the storage rebuild whilst also satisfying the requirements of minimum environmental flow. Discharges occasionally reduced to 0 m^3s^{-1} when downstream inflows were sufficient to fulfil the environmental flow requirement (Section 2.5.4). There were only a few minor increases in discharges over this period;
- from September to December 2016 there was an increase in power station operation that involved maintaining a low base flow of 20 m^3s^{-1} with a small amount of low to mid-range peaking discharge (80-160 m^3s^{-1});
- a period from January to late February 2017 was characterised by much more regular and high range peaking discharge typically between 160-240 m^3s^{-1};
- March to June saw a return to discharge patterns of a low base flow of 20 m^3s^{-1} with a moderate amount of low to mid-range peaking discharge (80-160 m^3s^{-1}). This period was punctuated with brief periods in mid-May and late-June 2017 of regular peaking to mid-high range discharges (160 -240 m^3s^{-1});

2017-18

- in early July 2017 the discharge consisted of the same pattern observed in late June of regular peaking to mid to high discharges (160 -240 m^3s^{-1});
- peaking regularity and size gradually reduced from mid-July through to late August 2017;
- early September to late October 2017 consisted of flow dominated by very low discharges (~ 20 m^3s^{-1}) with a few peaks at low to mid-range discharge (40-100 m^3s^{-1}) and high discharge peak (190 m^3s^{-1});
- most of November and December 2017 had discharge consisting of regular high range peaking to between (200 -240 m^3s^{-1}), whilst January 2018 returned to low discharges (~ 20 m^3s^{-1}) with a few peaks at low to mid-range discharge (40-100 m^3s^{-1});
- from February to May 2018, the discharges pattern from Gordon Power Station changed substantially to a much higher base flow of around 60-80 m^3s^{-1} with regular peaking to around 200 m^3s^{-1}. This period also consisted of two periods of around one weeks each in April of relatively constant high flow high flow (190 – 220 m^3s^{-1});
- June 2018 was characterised by regular high range peaking discharge between a low of 20 m^3s^{-1} and a high of 200-240 m^3s^{-1}.

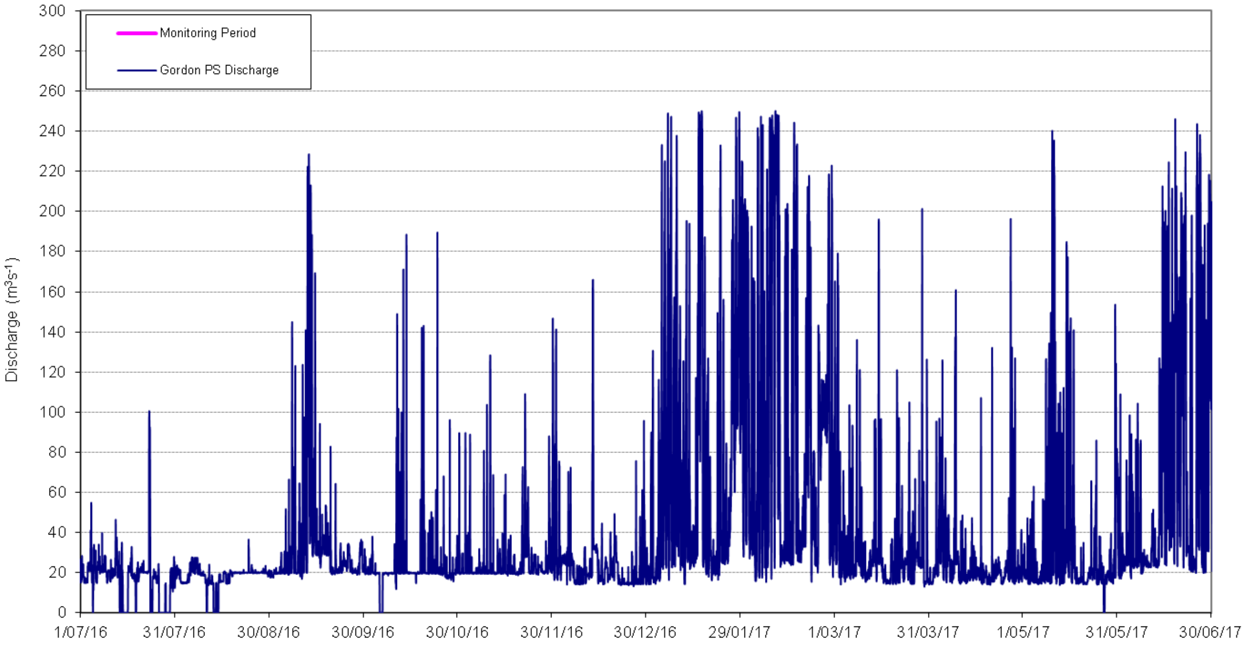


Figure 2-8: Gordon Power Station discharge (hourly data) from July 2016 to June 2017

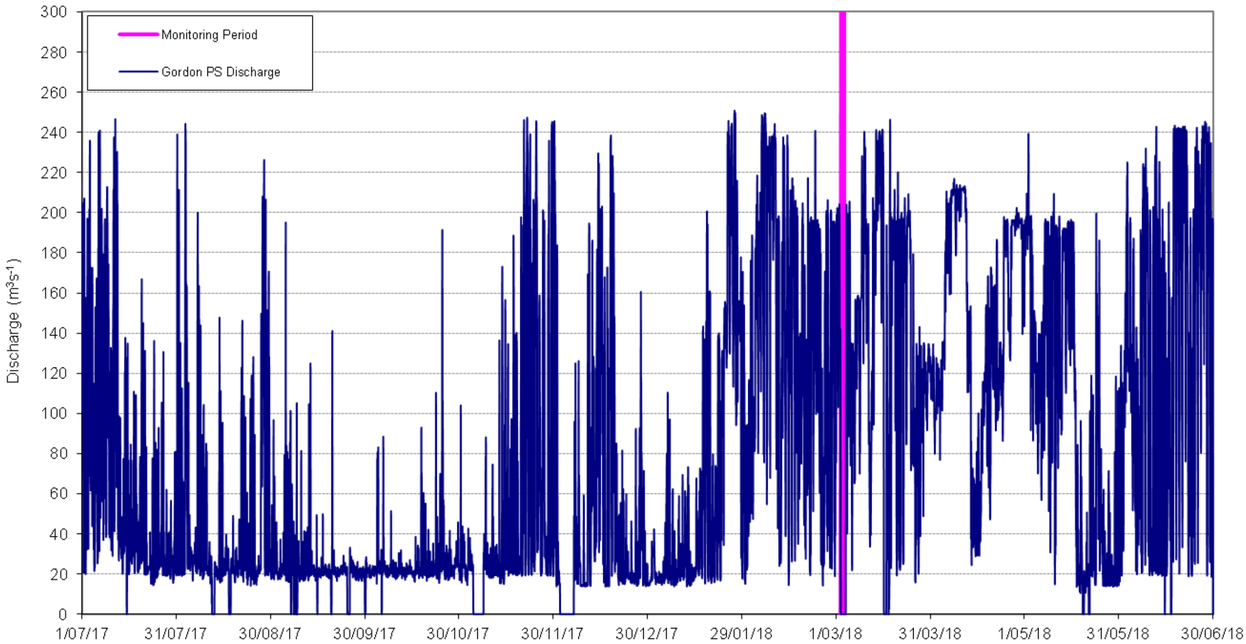


Figure 2-9: Gordon Power Station discharge (hourly data) from July 2017 to June 2018. Pink vertical line indicates the monitoring event.

Table 2-1: Summary information on discharge, weather conditions, market volatility and outages for 2016–17. Dry months are classified as months with values lower than the 20th percentile of the long-term values, and wet months are classified as months with values higher than the 80th percentile of the long-term values.

Period	0-turbine operation % time	1-turbine operation % time	2-turbine operation % time	3-turbine operation % time	Strathgordon rainfall	System yield	Gordon operation and influential factors	Basslink Net Import (GWh) (- = export, + = import)
July 2016	20.8	69.8	9.4	0.0	very wet	>>average	Minimum generation to fulfil environmental flow requirements. Storage rebuild.	-181.9
August 2016	4.8	93.7	1.3	0.1	average	< average	Minimum generation to fulfil environmental flow requirements. . Storage rebuild.	51.7
September 2016	0.0	56.1	36.8	7.1	average	< average	Minimal price triggered peaking generation. Storage rebuild.	-211.7
October 2016	3.1	85.3	8.6	3.0	very wet	>> average	Minimal price triggered peaking generation. Storage rebuild.	-65.3
November 2016	0.0	74.7	23.5	1.8	average	>> average	Minimal price triggered peaking generation. Storage rebuild.	149.8
December 2016	0.0	56.9	35.2	7.9	average	average	Minimal price triggered peaking generation. Storage rebuild.	234.0
January 2017	0.0	21.2	46.1	32.7	average	< average	Peak hour running with some offpeak support. Storage rebuild	120.5
February 2017	0.0	7.4	52.1	40.5	average	> average	Peak hour running with some offpeak support. Storage rebuild.	185.4
March 2017	0.0	52.4	41.4	6.2	very dry	<< average	Minimal price triggered peaking generation. Storage rebuild	163.7
April 2017	0.0	80.3	16.3	3.5	very dry	<< average	Minimal price triggered peaking generation. Storage rebuild	26.2
May 2017	1.1	75.8	19.1	4.0	average	< average	Minimal price triggered peaking generation. Storage rebuild.	81.1
June 2017	0.0	45.4	22.6	31.9	average	<< average	Minimal price triggered peaking generation in first half of month. Storage rebuild.	-49.3

Table 2-2: Summary information on discharge, weather conditions, market volatility and outages for 2017–18. Dry months are classified as months with values lower than the 20th percentile of the long-term values, and wet months are classified as months with values higher than the 80th percentile of the long-term values.

Period	0-turbine operation % time	1-turbine operation % time	2-turbine operation % time	3-turbine operation % time	Strathgordon rainfall	System yield	Gordon operation and influential factors	Basslink Net Import (GWh) (- = export, + = import)
July 2017	0.3	26.3	43.1	30.2	< average	< average	Marginal efficient generation in first half of month. Minimal price triggered peaking generation in second half of month.	25.5
August 2017	4.4	59.7	21.0	14.9	average	average	Minimal price triggered peaking generation	-75.1
September 2017	8.1	84.2	6.3	1.5	very wet	>> average	Minimal price triggered peaking generation	-215.5
October 2017	0.4	93.3	5.2	1.1	average	average	Minimal price triggered peaking generation	-171.8
November 2017	11.0	51.0	12.4	25.7	very dry	<<average	Price triggered peaking generation	65.4
December 2017	14.4	47.7	21.2	16.7	average	average	Peak hour running with some off-peak support. 5-day outage + Christmas	78.4
January 2018	0.0	7.6	26.2	12.4	very dry	<< average	Minimal price triggered peaking generation in first half of month. Peak hour running with some off-peak support in second half of month.	84.8
February 2018	0.0	7.6	28.4	64.0	very wet	> average	Peak hour running with some off-peak support.	77.5
March 2018	8.6	5.5	39.8	46.1	very wet	>> average	Generally on import. Running efficient to cover Tas demand. Basslink outage commenced 24/3/18	68.6
April 2018	0.0	0.0	38.1	61.9	> average	> average	BL outage. Running efficient to cover Tas Load	0.0
May 2018	2.4	32.7	21.1	43.8	> average	average	BL outage. Running efficient to cover Tas Load	0.0
June 2018	1.1	22.2	28.5	48.2	average	> average	Basslink RTS 5/6/18. Higher generation supporting export once inflows lessened	-147.2

Power station outages

Complete power station outages for 2016-17 and 2017-18 are listed in Table 2-3. There was one complete power station outage in 2016–17, a brief (9 h) outage in May 2017 for testing or maintenance purposes. There were seven complete outages in 2017-18, six for maintenance or testing purposes and one to facilitate downstream monitoring. Of these seven outages, three were less than nine hours duration while the remaining four were between 20 and 107 hours duration. The outage of the Basslink interconnector occurred between 24 March 2018 and 15 June 2018 (inclusive). During the Basslink outage, while there was no obligation under Hydro Tasmania's Special Licence Agreement to implement the Basslink mitigation measures – the ramp-down rule or the environmental flow – Hydro Tasmania continued to implement these.

Table 2-3: Complete outages at Gordon Power Station in 2016-17 and 2017-18.

Start date	End date	Duration (hours)	Reason
27/05/2017	27/05/2017	9	Testing/maintenance
15/07/2017	15/07/2017	3	Testing/maintenance
12/08/2017	12/08/2017	8	Testing/maintenance
04/11/2017	07/11/2017	81	Testing/maintenance
02/12/2017	06/12/2017	107	Testing/maintenance
02/03/2018	04/03/2018	39	Downstream Monitoring
16/03/2018	17/03/2018	20	Testing/maintenance
18/03/2018	18/03/2018	6	Testing/maintenance

Median monthly discharge

Figure 2-10 shows the median monthly discharge from the power station for 2016–17 and 2017-18 compared with long-term values (since January 1997) and the previous ten years of the post-Basslink period. The 2016-17 median values had an annual pattern that differed substantially from the long-term and other post-Basslink years. Median discharges were substantially lower than in previous years for all months except the spring months of September and October 2016. Increases in January and February 2017 medians followed the pattern of increased summer discharges, yet these were much lower in relation to the long-term and post-Basslink median discharges.

The 2017-18 median values also had an annual pattern that tended to differ for part of the year from the long-term and other post-Basslink years. The rise in median discharge typically observed in November in long-term and post-Basslink data-sets was observed later in 2017-18. Median discharges increased in February 2018 and remained elevated until June 2018 at similar high levels from the long-term record.

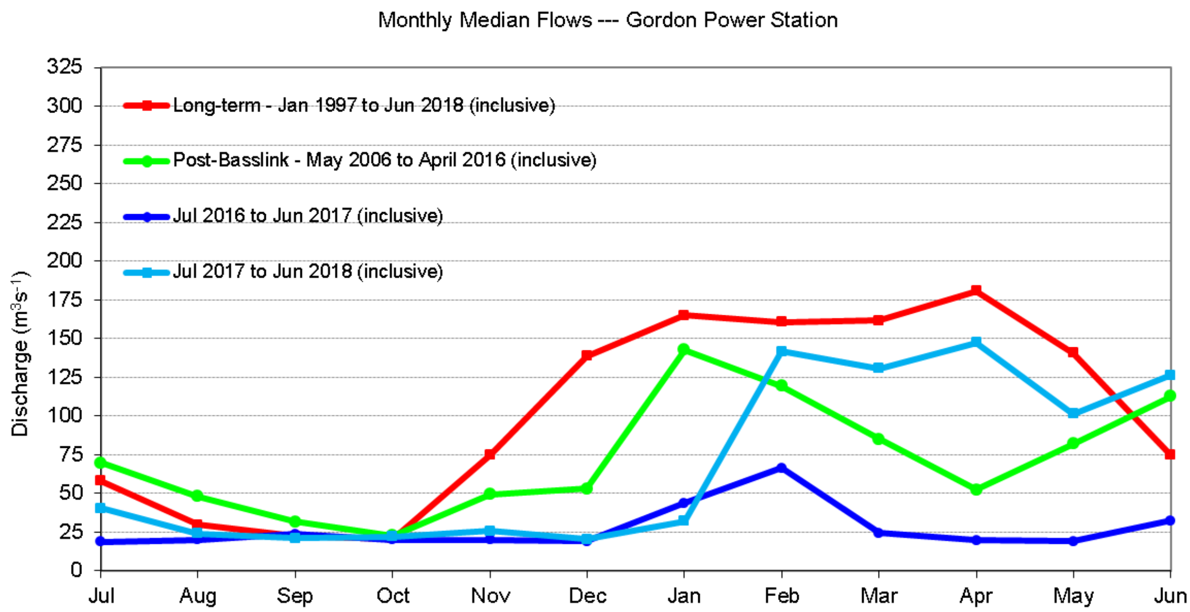


Figure 2-10: Median monthly discharge from the Gordon Power Station (site 77) for 2016-17 and 2017-18 compared with long-term monthly median values and previous post-Basslink years.

Flow duration curves

Figure 2-11 to Figure 2-14 show the duration (percentage exceedance) curve for the power station discharge for:

- whole of year (Figure 2-11)
- winter period (May–October; Figure 2-12);
- summer period (November–April; Figure 2-13); and
- years one to eight of post-Basslink annual data (Figure 2-14).

Various duration curves have been plotted against these periods (each period has been devised such that it is divisible by 12 months):

- long-term period (1 July 1997–30 June 2018);
- the historical period (1 January 1997–31 December 2000), incorporating the period when IIAS data were collected;
- the pre-Basslink period (1 January 2001–31 December 2005), when pre-Basslink data were collected;
- the post-Basslink period (1 May 2006–30 April 2016) prior to the current year; and
- 2016–17 financial year (1 July 2016–30 June 2017).
- 2017-18 financial year (1 July 2017–30 June 2018).

The annual discharge curve in 2016–17 (Figure 2-11) was indicative of the low discharge during this year, driven by the requirement to rebuild the storage in Lake Gordon. It was indicative of the pattern of operation where there was a general dominance of low flows (<40 m^3s^{-1}) with minimal mid-high range peaking (160-240 m^3s^{-1}). Its shape shows that 2016-17 was atypical relative to the longer term operations of historical, pre-Basslink operation and previous post-Basslink periods.

The annual discharge curve in 2017–18 (Figure 2-11) was also indicative of the generally lower discharge relative to the historical, pre-Basslink operation. The duration curve was very similar to that of the previous post-Basslink period with a substantial proportion of low discharge (<50 m^3s^{-1}) indicative of the regular return to low flows during peaking discharge, as well as the periods of dominant low flow. The higher flow percentiles are generally indicative of the discharge at mid-high range (100-240 m^3s^{-1}) peaking operation. The flat spot at around the 200 m^3s^{-1} flow is indicative of the short periods of continuous high flow in April 2018.

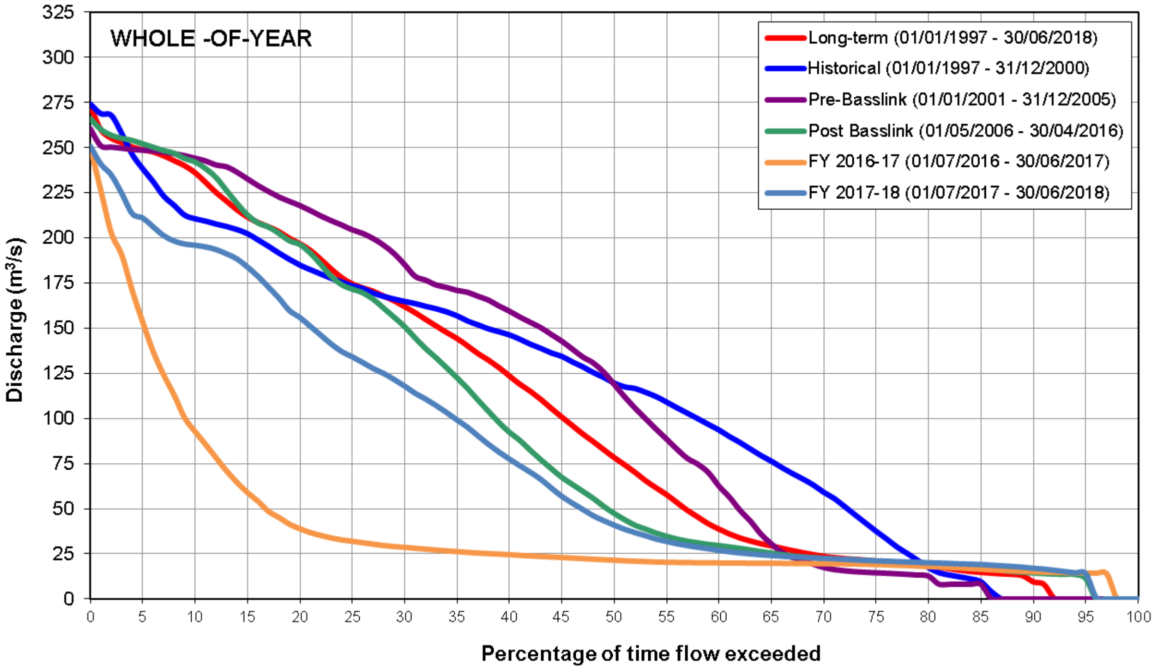


Figure 2-11: Duration curves for discharge from the power station using annual data for selected periods.

The 2016–17 winter discharge flow duration curve (Figure 2-12) was markedly different to the comparative curves. As with the annual flow duration curve, it indicates the substantial winter dominance of low flows (<50 m^3s^{-1}) and very short incidence of higher flows that occurred primarily in peaking operation in June 2017. This lower discharge was maintained to allow for the storage rebuilding of Lake Gordon.

The 2017–18 winter discharge flow duration curve (Figure 2-12) differed from the annual flow curve long-term as well as the winter historical, pre-Basslink and post-Basslink duration curves by having a greater period of low flow duration. This occurred primarily as a result of the low flow dominated discharge between August and October 2017. The general shape of the curve was very similar to the long term, historical, pre-Basslink and post-Basslink curves with reduced proportion of higher discharges.

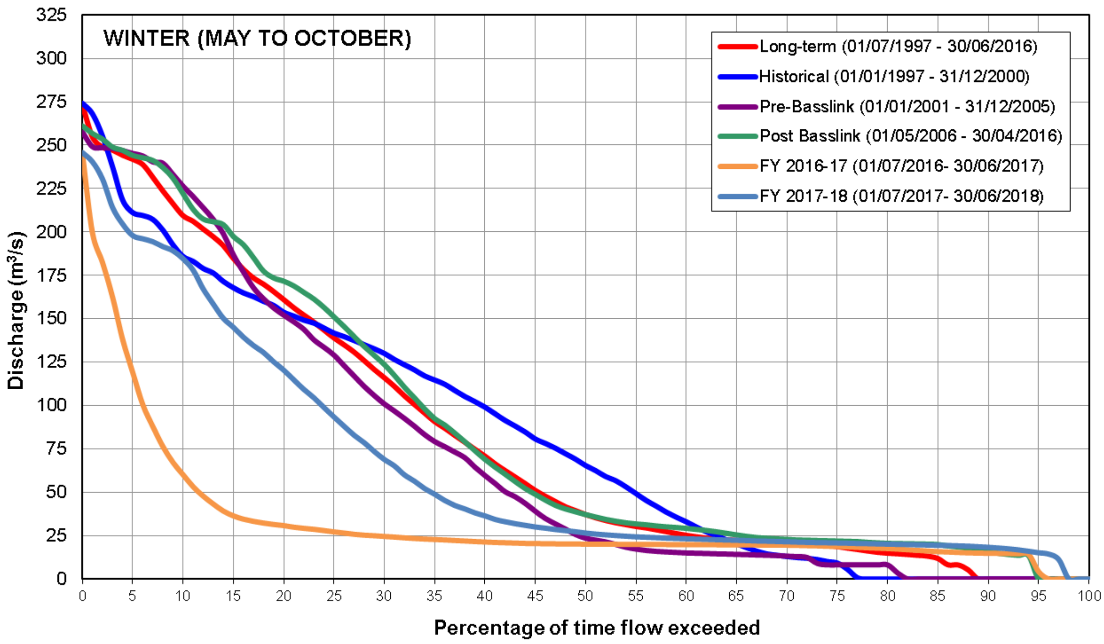


Figure 2-12: Duration curves for discharge from the Gordon Power Station using winter data (for the months of May to October inclusive) for selected periods.

The 2016–17 summer discharge flow duration curve (Figure 2-13) differed from all the comparative duration curves, having substantial dominance by the low discharges, with flows < 50 m^3s^{-1} accounting for 78% of flows. Conversely, there were only a small proportion of mid to high range flows.

The 2017-18 summer discharge flow duration curve (Figure 2-13) was similar to the previous pre-Basslink period duration curve. The combination of mid to high range peaking (100-240 m^3s^{-1}) from a low base flow is indicated by the shape of the duration curve. Low flows (< 50 m^3s^{-1}) accounted for 41% of flows, with the remainder of flows being relatively evenly distributed between 50 and 240 m^3s^{-1}. The exception to the even distribution of flows in these ranges was the flat spot at around the 200 m^3s^{-1} flow which was indicative of the short periods of continuous high flow in April 2018. A flow of 200 m^3s^{-1} corresponds to the operation of all three machines at Gordon Power Station operating at efficient load.

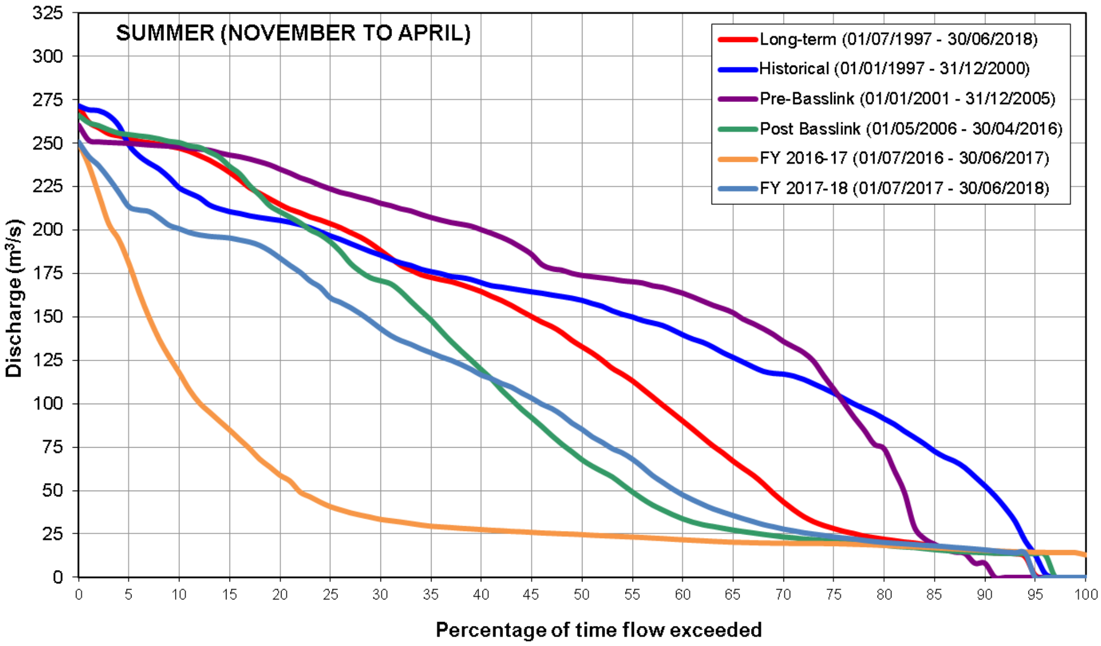


Figure 2-13: Duration curves for discharge from the Gordon Power Station using summer data (for the months of November to April inclusive) for selected periods.

Annual flow duration curves for each post-Basslink year are represented in Figure 2-14 to compare the reporting year to each of the previous post-Basslink monitoring years. As the post-Basslink period began on 1 May 2006, the annual periods for each of the post-Basslink duration curves are from May to April. Hence, the curves for 2016–17 and 2017-18 differ slightly from the annual curves (Figure 2-11) as they represent a 12-month period that is offset by two months. Comparison of the curves indicates the significant variability in flow discharge in the post-Basslink period. Compared to other years, 2016-17 had the greatest period of low flows, and minimal periods of mid and high flows. The low flow duration in 2016-17 was less than previous years of minimal power station discharge in 2010-11 and 2011-12. The flow duration curve in 2017-18 indicated that, compared to previous years, it was somewhere between years dominated by low flow and those dominated by high flow.

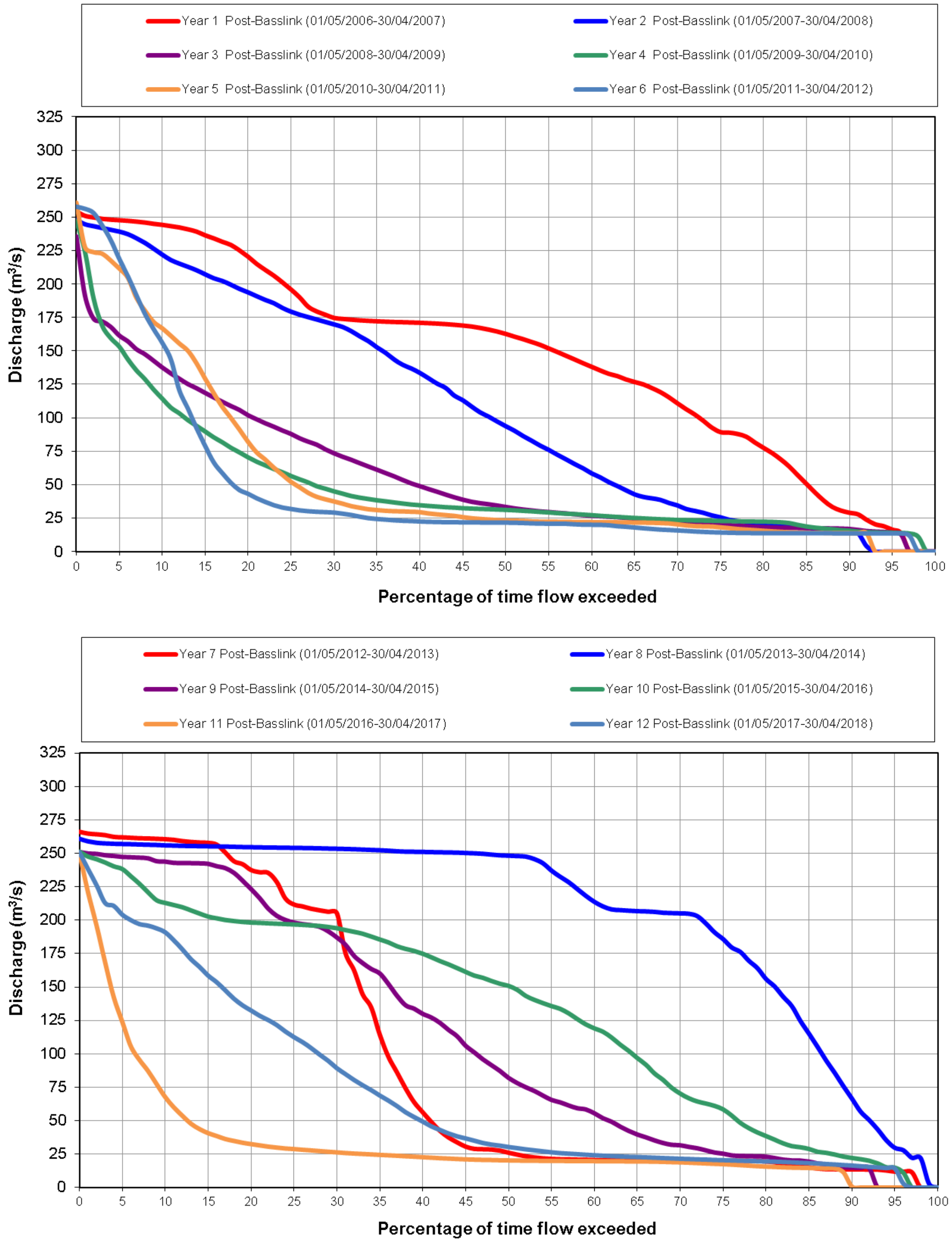


Figure 2-14: Annual duration curves for discharge from the Gordon Power Station for the twelve years post-Basslink.

Peaking hydrological triggers

Time series of peaking event trigger measures are presented in Figure 2-15 and Figure 2-16. There were no peaking event exceedances (35-100 m^3s^{-1} or 35-200 m^3s^{-1}) in 2016-17 or 2017-18. A general slow increase in the 35-100 m^3s^{-1} peaking measure was observed in 2016-17. This trend continued into August 2017, and subsequently declined sharply between October and December 2017, remaining at low levels for the remainder of 2017-18. The 35-200 m^3s^{-1} remained at low levels throughout 2016-17 and 2017-18 due to the low incidence of full-range peaking.

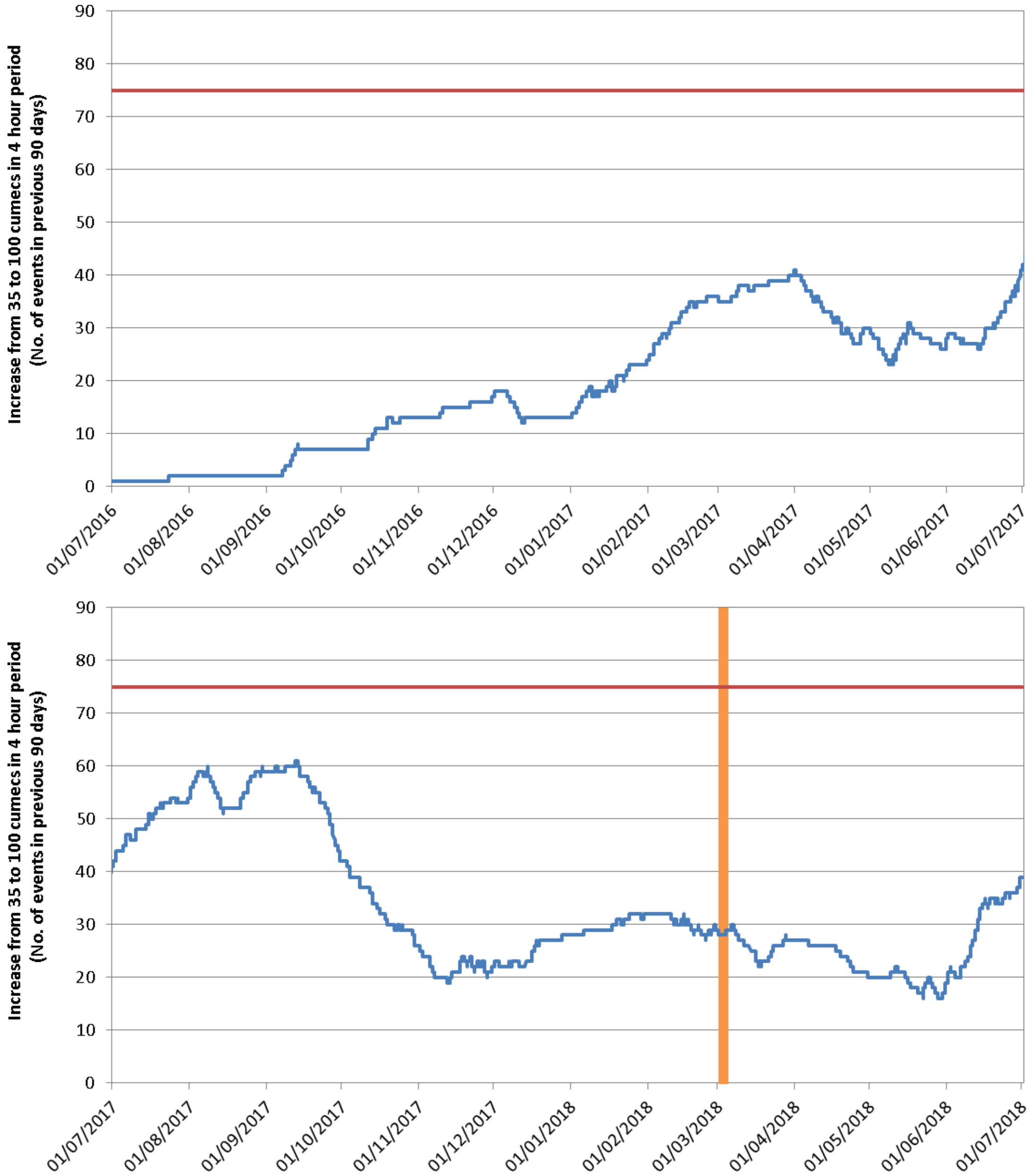


Figure 2-15: Time series for 1 July 2016 -30 June 2017 (top) and 1 July 2017 -30 June 2018 (bottom) of flow increases from 35 to 100 m^3s^{-1} in a four hour period, counted over the previous 90 days. Trigger value marked by red line, monitoring period marked by orange bar. Orange shaded area included in last year's hydrological monitoring period.

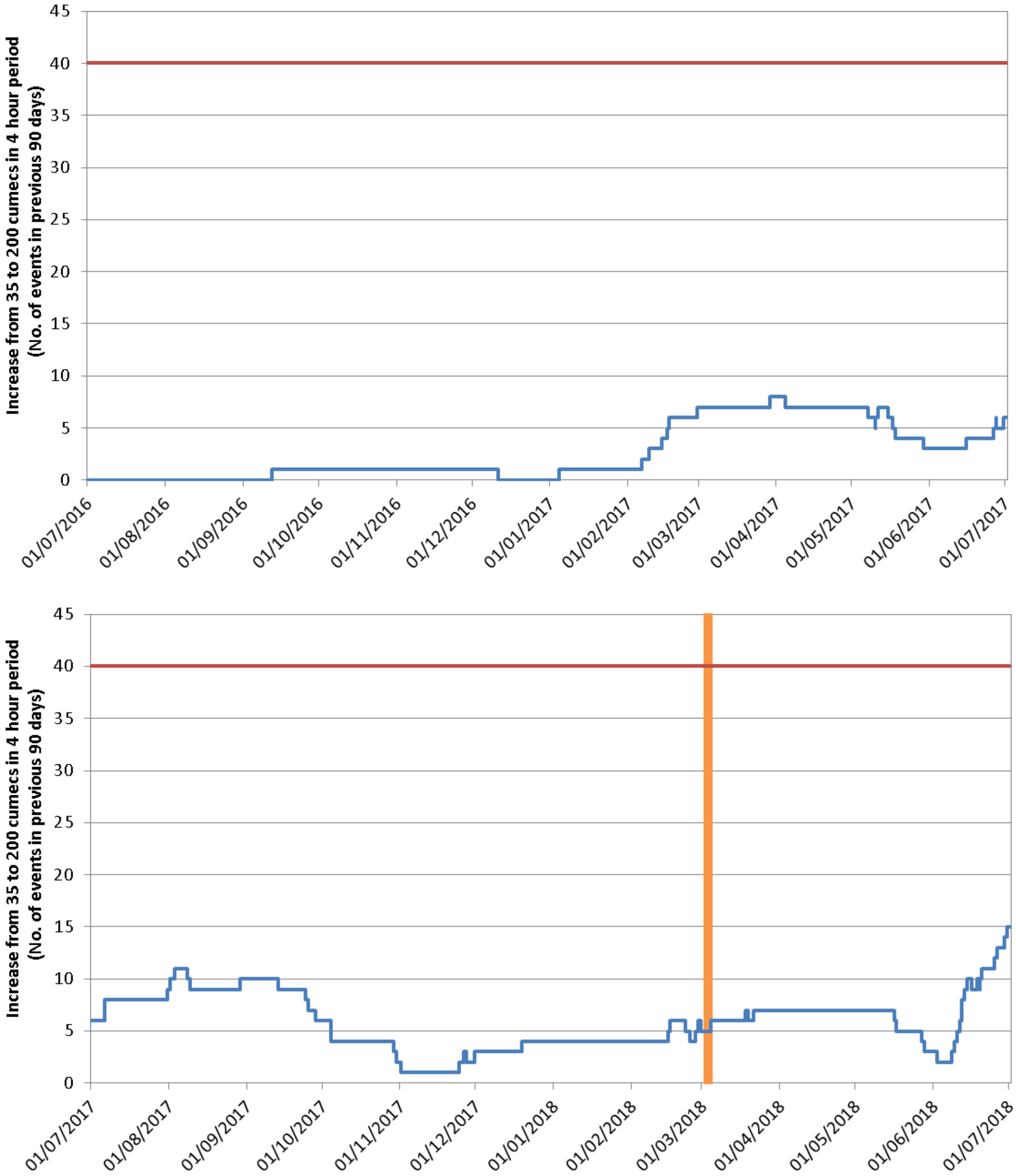


Figure 2-16: Time series for 1 July 2016 -30 June 2017 (top) and 1 July 2017 -30 June 2018 (bottom) of flow increases from 35 to 200 m^3s^{-1} in a four hour period, counted over the previous 90 days. Trigger value marked by red line, monitoring period marked by orange bar. Orange shaded area included in last year's hydrological monitoring period.

Compliance with the ramp-down rule

Mitigation measures (ramp-down rule and minimum environmental flow) were excluded from analysis for the period corresponding to the Basslink outage (24 March 2018 to 5 June 2018). They were excluded as Hydro Tasmania has no obligation under the Special Licence Agreement to implement these during the temporary or permanent outage of Basslink. However, Hydro Tasmania continued to abide by the mitigation measure requirements.

In 2016-17 and 2017-18, full compliance with the ramp-down rule was achieved. During the two year period (July 2016–June 2018) the ramp-down rule was required to be applied for 1,177 hours (i.e. while the predicted bank water level was >2.75 m and the power station discharge was >150 m^3s^{-1}). The control system was correctly set for the complete period.

Evaluation of rate of change in generation

While the control system was automatically set to reduce generation at a rate of 1 MW per minute, when the modelled saturation and flow conditions were exceeded, there were occasions when the rate of generation reduction exceeded this rate.

Of the 1,177 hours where ramping was required during flow reductions, those that exceeded 1 MW per minute occurred on 106 separate events (Appendix B), and totalled 31 hours (2.7 % of time that the ramp-down rule was applied). Whilst the proportion of exceedences of the 1 MW per minute level was higher in 2016-18 than in previous years, it remains that the measures in place to avoid fast-ramping events were effective for the vast majority of time. The exceedances of 1 MW per minute occurred as a result of over-riding causes that were beyond operator control, and are not considered to be non-conformances. There were two principal reasons for the exceedances of the target reduction rate of 1 MW per minute:

- **Frequency excursions in the NEM** can prompt a machine governor response. Common causes of such excursions include Basslink reversal, customer load reductions, and major changes in plant output anywhere in the NEM. This is a local governor response outside the 1 MW per minute control. In such instances, the power station is being used to stabilise the frequency and voltage within the NEM. This governor response is an intrinsic aspect of the machine, and an essential aspect of maintaining a stable electrical system and is beyond the control of the operators; and
- **Machine trips (sudden, automatically triggered shutdowns).** These can be triggered by fault detection at the machine or by a power system network event that will automatically trip the machine. These trips over-ride other intended operation and are beyond operator control.

A third reason for a number of these exceedances of the target reduction rate in 2017-18 was related to the initial erroneous response of the governor of Gordon No. 3 machine to a ramp-down events. It appears that this is a contributor to the higher percentage of exceedances relative to previous years. The governor on Gordon No. 3 machine is scheduled for replacement in March-April 2019, and will overcome these issues.

2.5.4 Gordon above Denison (site 65—environmental flow compliance site)

Site 65 is located in the Gordon River downstream of the power station, approximately 2 km upstream of the Denison confluence. This site monitors the minimum environmental flow required under the Special Water Licence Agreement.

Flow

Figure 2-17 and Figure 2-18 show the flow recorded at site 65 for 2016–7 and 2017-18 and indicate close concordance with power station discharge to which peak values (the result of high flows from tributary streams, such as the Albert and Orange Rivers) are added.

Notable high tributary inflows were seen in July 2016, October 2016, March 2018 and June 2018. The departure of the hydrograph from that of the Gordon Power Station discharge is indicative of these tributary inflows. The elevated flow in late July 2016 was substantially influenced by the release of water (spill) from Lake Pedder via the Serpentine River, a tributary of the Gordon River.

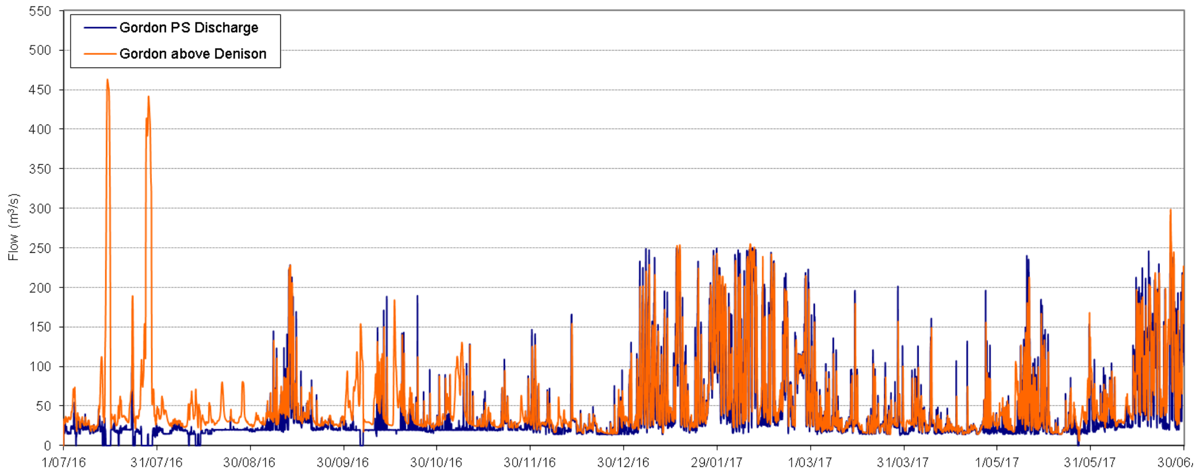


Figure 2-17: Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2016 to June 2017

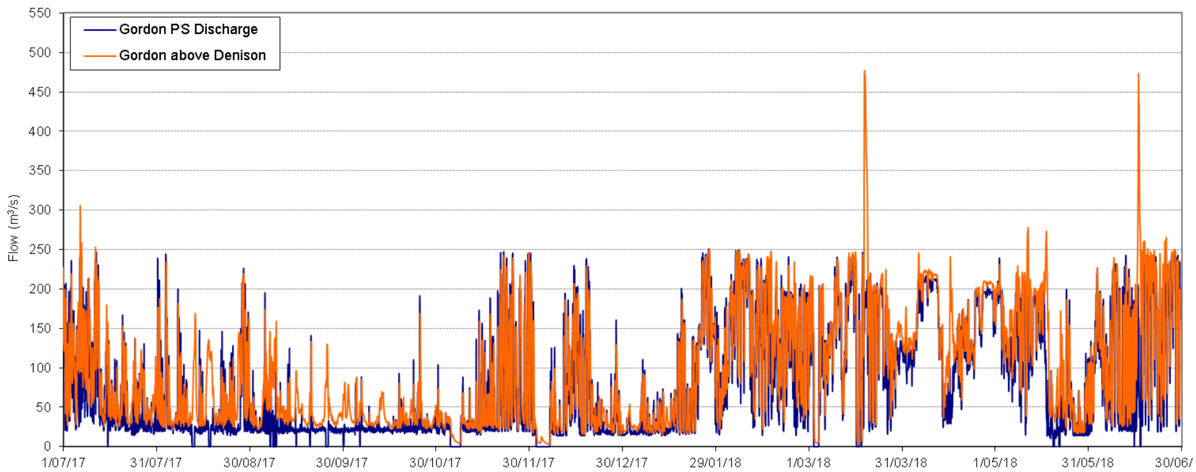


Figure 2-18: Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2017 to June 2018.

Median monthly flows

The median monthly flow for site 65 (Gordon above Denison) is shown in Figure 2-19 and compares 2016-17 and 2017-18 with historic average (2003–16) monthly median flows. These followed a very similar pattern to the median flows of the Gordon Power Station discharges.

In 2016-17, median monthly flows were generally substantially lower than the long-term and post-Basslink periods. The only exception was for the month of October, where all periods have similar median flow values.

In 2017-18, median monthly flows were somewhat lower than the long-term and post-Basslink periods for the months of July to September 2017 and November to December 2017. The median flow in January 2018 was substantially lower than previous comparative periods, however for the period of February to Jun 2018, median flows increased to levels that were marginally higher than previous comparative periods.

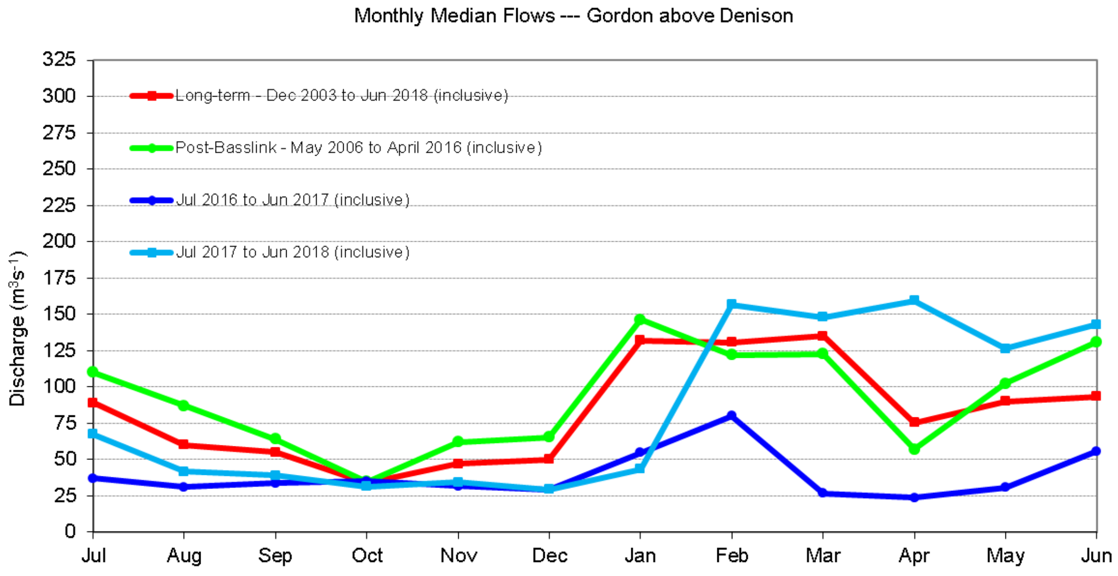


Figure 2-19: Median monthly flow at site 65 (Gordon above Denison) for 2016–17 and 2017-18 compared with long-term median values and previous post-Basslink years.

Duration curves

The duration curve for site 65 is shown in Figure 2-20. Comparison of the 2016-17 and 2017-18 duration curve with the post Basslink curve shows both curves to have substantially greater duration of lower flows, but this is particularly evident for 2016-17.

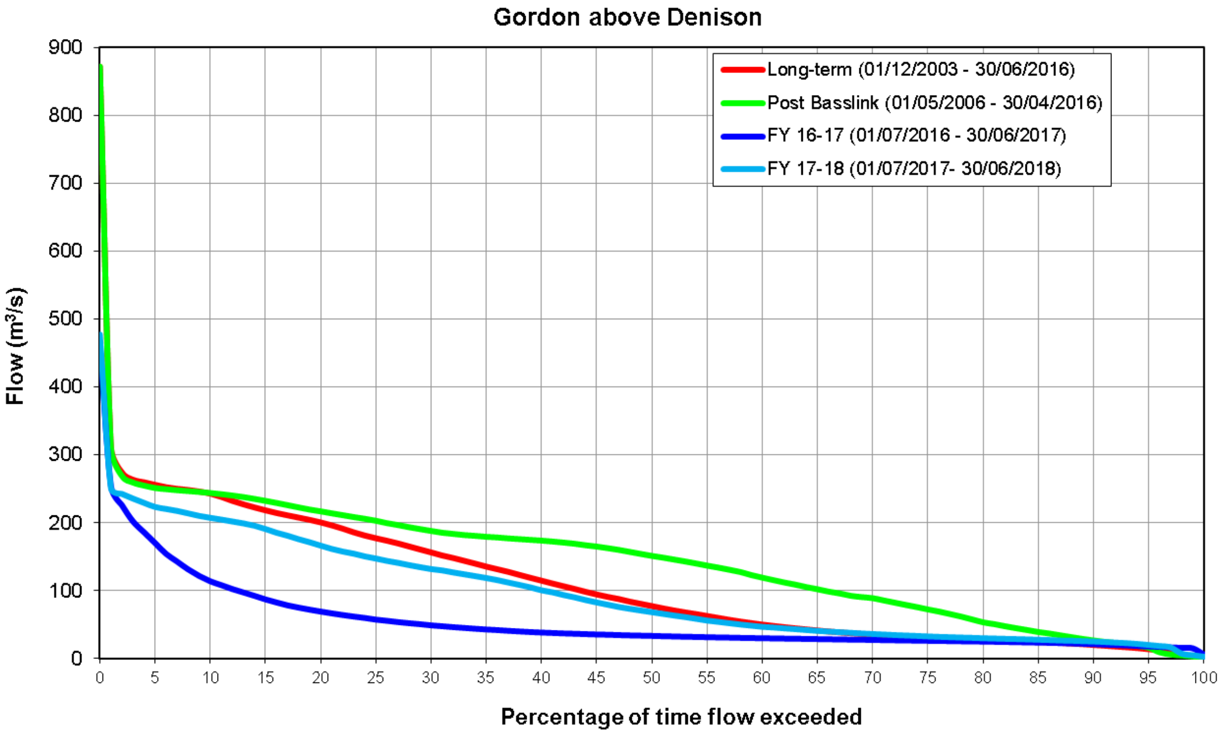


Figure 2-20: Flow duration curve for Gordon above Denison for 2016–17 and 2017-18 compared with long-term and previous post-Basslink years.

Environmental flow compliance

Mitigation measures (ramp-down rule and minimum environmental flow) were excluded from analysis for the period corresponding to the Basslink outage (24 March 2018 to 5 June 2018). They were excluded as Hydro Tasmania has no obligation under the Special Licence Agreement to implement these during the temporary or permanent outage of Basslink. Despite there being no obligation to implement the mitigation measures during this time, Hydro Tasmania maintained its compliance operations maintaining both the environmental flow and the ramp-down rule. Periods of the Basslink outage as well as other exempt conditions (shutdown of the Gordon Power Station due to maintenance, AEMO conformance testing, and/or monitoring) have been excluded from the analysis, as indicated in Figure 2-21 and Figure 2-22 by the reduction of minimum environmental flow requirement to zero.

For the period from December to May the minimum environmental flow required is 10 m^3s^{-1}, and for the periods from June to November the minimum environmental flow required is 20 m^3s^{-1}.

The analysis of hourly flows at site 65 for 2016-17, taking exempt periods into consideration (Figure 2-21), shows that during the winter periods (July–November 2016 and June 2017) the minimum 20 m^3s^{-1} flow requirement was met 99.66% of the time. A total of 15 hours were recorded where flow did not meet the requirement, and these occurred over five separate events in July, August and October 2016 with flows measured at between the range 18.1 and 19.9 m^3s^{-1} during these events. During the summer period (December 2016–May 2017), the 10 m^3s^{-1} minimum flow requirements were met 100 % of the time.

For 2017-18, the analysis of hourly flows at site 65 (Figure 2-22) shows that during the winter periods (July–November 2017 and June 2018), the minimum 20 m^3s^{-1} flow requirement was met 99.84% of the time. A total of 7 hours were recorded where flow did not meet the requirement over two separate events in mid-November 2017 with flows measured between 16.7 m^3s^{-1} and 19.9 m^3s^{-1}. During the summer period (December 2016–May 2017), the 10 m^3s^{-1} minimum flow requirement was met 100% of the time.

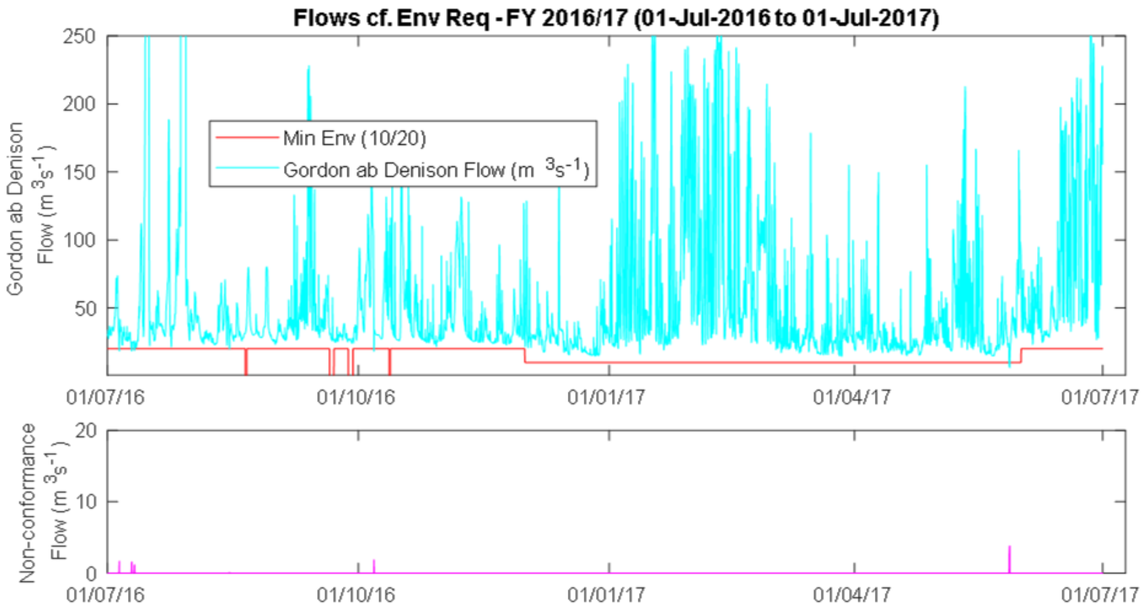


Figure 2-21: Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2016 to June 2017, and analysis of non-conforming flows. Red line indicates the flow requirement to be met.

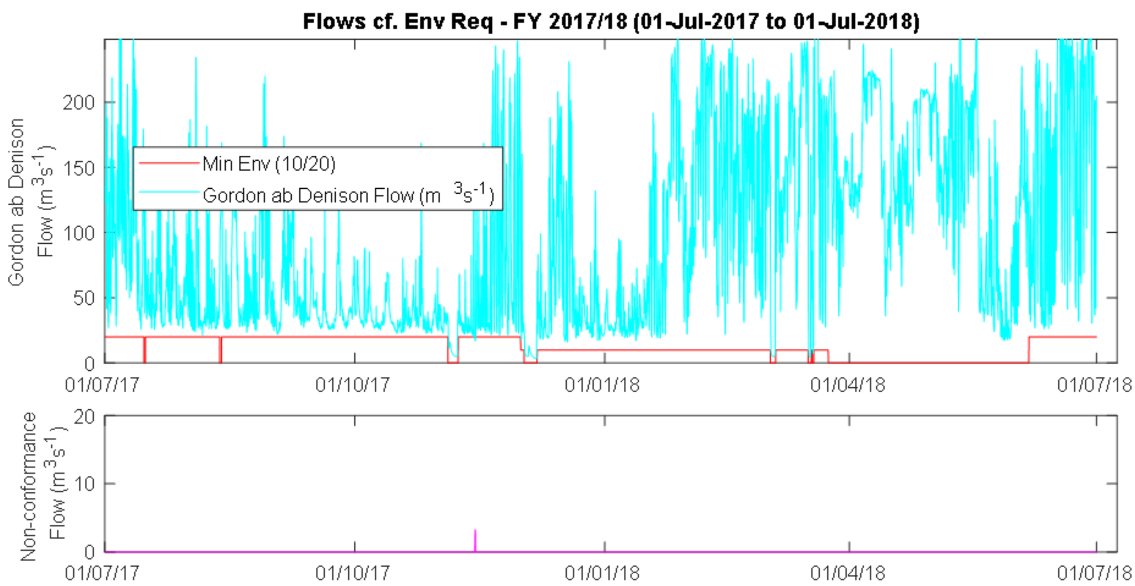
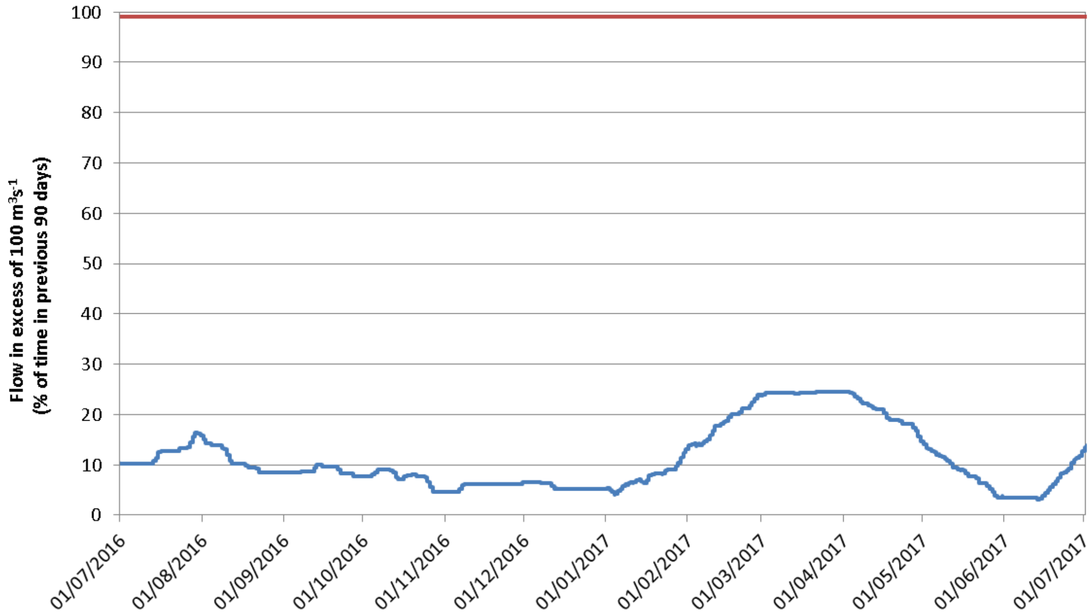


Figure 2-22: Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2017 to June 2018, and analysis of non-conforming flows. Red line indicates the flow requirement to be met.

High flow hydrological triggers

Flows at the compliance site remained below the high flow hydrological triggers for the whole of the 2016-17 and 2017-18 period (Figure 2-23, Figure 2-24).



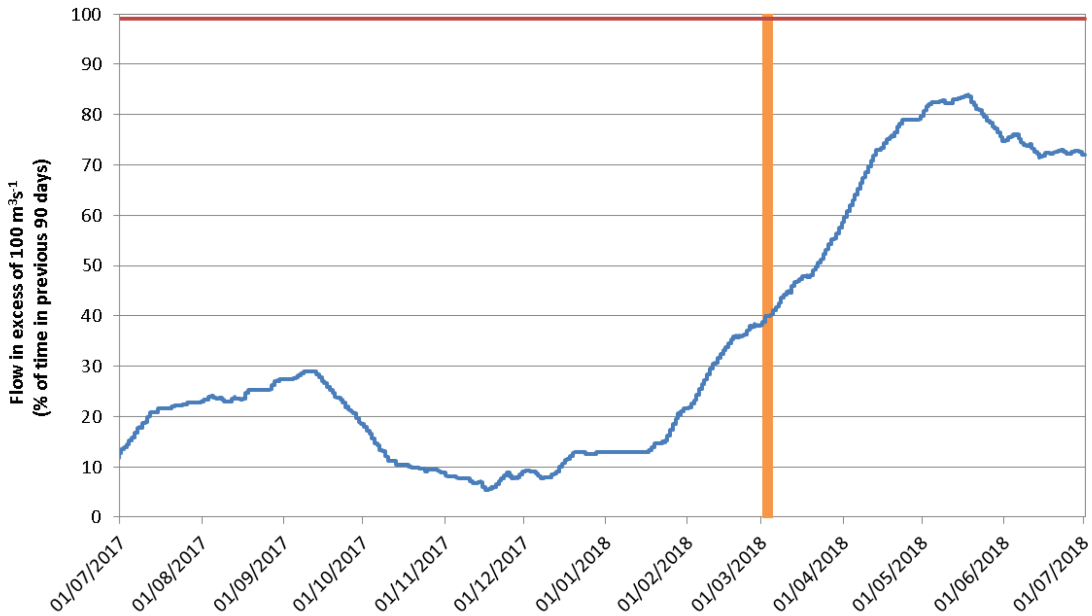


Figure 2-23: Time series of percentage of time in previous 90 days in excess of 100 m^3s^{-1} for the periods July 2016-June 2017 (Top) and July 2017-June 2018 (Bottom). The trigger value (99%) is marked by the red line and themonitoring period marked by the orange bar.

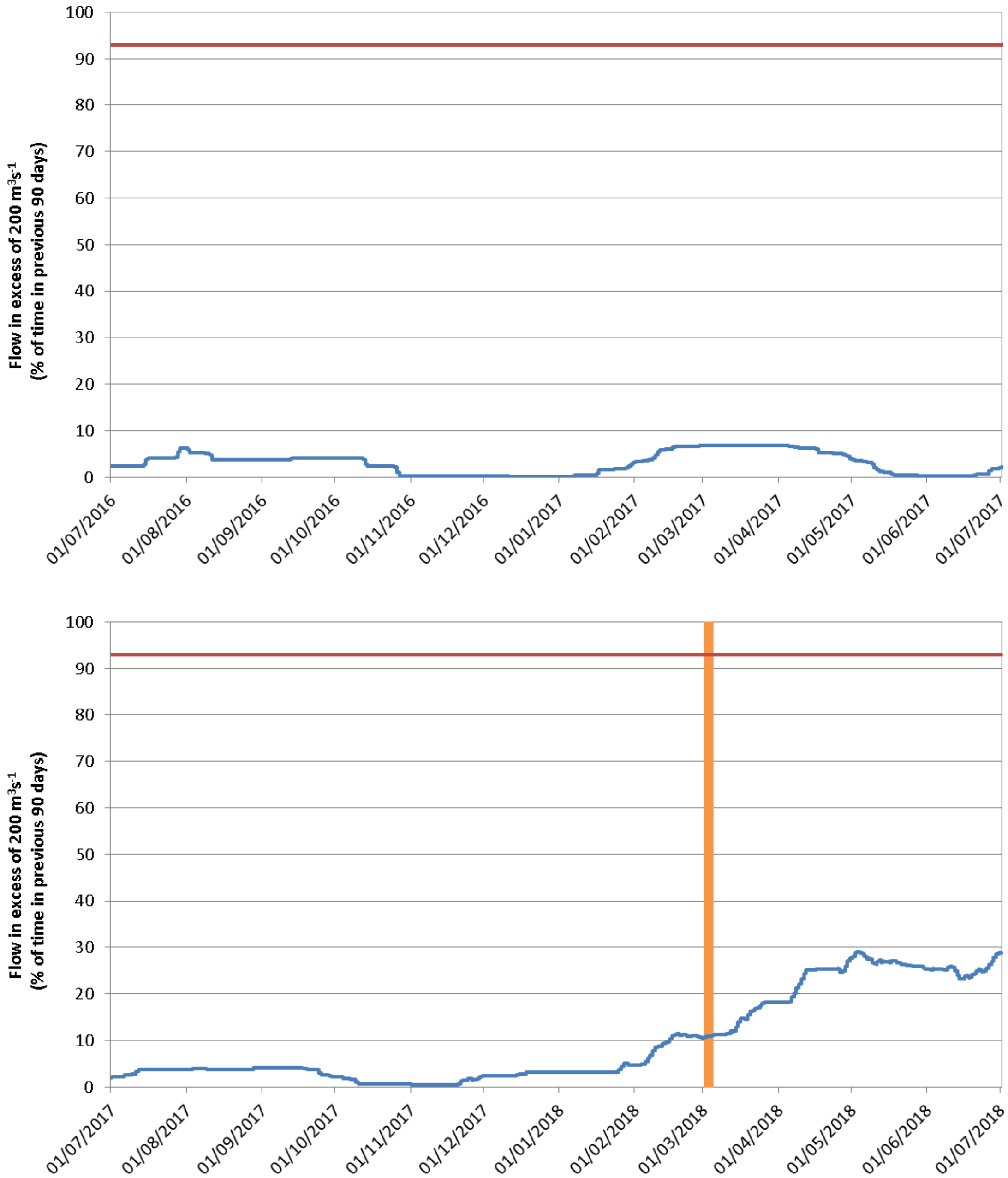


Figure 2-24: Time series of percentage of time in previous 90 days in excess of 200 m^3s^{-1} for the periods July 2016-June 2017 (Top) and July 2017-June 2018 (Bottom). The trigger value (93%) is marked by the red line and the monitoring period is marked by the orange bar.

Hydro Tasmania

2.6 Conclusions

2016-17

Discharges from Gordon Power Station were substantially lower than the long term averages for all months, with the exception of October 2016, which was similar to long term averages.

The ramp-down rule continued to be applied successfully in 2016-17. All ramping was consistent with the water licence requirements, as the system for controlling the rate of generation reduction was automatically activated under all trigger conditions (>2.75 m modelled bank level, >150 m^3s^{-1} discharge).

The minimum environmental flow requirements of 10 m^3s^{-1} in the summer period and 20 m^3s^{-1} in winter period were met 99.66 % of the time in winter and 100% of the time in summer.

2017-18

Discharges from Gordon Power Station were substantially lower than the long term averages for July to September 2017 and marginally higher than long term averages from February to June 2018.

Mitigation measures (ramp-down rule and minimum environmental flow) were excluded from analysis for the period corresponding to the Basslink outage (24 March 2018 to 5 June 2018). Mitigation measures were excluded from analysis, as Hydro Tasmania has no obligation under the Special Licence Agreement to implement these during the temporary or permanent outage of Basslink. However compliance with mitigation measures was maintained during the outage, even though there was no obligation to do so.

The ramp-down rule was also applied successfully in 2017-18. All ramping was consistent with the water licence requirements, as the system for controlling the rate of generation reduction was automatically activated under all trigger conditions (>2.75 m modelled bank level, >150 m^3s^{-1} discharge).

The minimum environmental flow requirements of 10 m^3s^{-1} in the summer period and 20 m^3s^{-1} in winter period were met 99.84 % of the time in winter and 100 % of the time in summer.

3.0 Fluvial geomorphology

3.1 Introduction

This chapter summarises the 3 March 2018 monitoring results and relates the findings to the current understanding of geomorphic processes in the middle Gordon River.

The aims of geomorphology monitoring in the Gordon River include:

- to document fluvial geomorphological processes and changes in the middle Gordon River between the power station tailrace and Sunshine Gorge (upstream of the confluence with the Olga River);
- to relate these changes to power station operations, including the ramp-down rule or other factors wherever possible; and
- to compare results with previous results to enhance the present understanding of the interaction between flow components and fluvial geomorphic response.

Twice yearly fluvial geomorphic monitoring was conducted in the middle Gordon River from October 2001 to 2014. Under the Gordon River Monitoring Program monitoring has continued at a reduced number of the geomorphic erosion pin and photo monitoring sites every 1-2 years, depending on the power station discharge regime (i.e. status of hydrological triggers). Monitoring was last completed in April 2016.

The main aim of the on-going monitoring program is to use the results to continue to validate the conceptual model and to ascertain if and how the rates and trends, tracked by the monitoring program, are changing.

Field work was completed in March 2018 and included field observations, the measurement of the long-term erosion pin monitoring sites and photo monitoring.

3.2 Methods

Basslink geomorphology monitoring methods are described in detail in the first pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2002) and the Basslink Baseline Report (Hydro Tasmania 2005a, 2005b). These documents should be consulted for a detailed description and background material pertaining to the monitoring program. Descriptions of the zones, bank types and processes operating in the middle Gordon River are contained in the initial Basslink IIAS report (Koehnken et al. 2001) and the Basslink Baseline Report (Hydro Tasmania, 2005a, 2005b). A history of monitoring in the middle Gordon associated with the Basslink monitoring program is shown in Table 3-1**.**

The current sub-set of erosion pin and photo-monitoring sites (Figure 3-1 to Figure 3-5, Table 3-1) were selected for continued monitoring based on the following criteria:

- the sites selected reflect a range of geomorphic properties considered to be representative of the middle Gordon River and monitoring results have shown a clear relationship between power station operations and geomorphic processes at these sites;
- the banks of these sites reflects one of the recognised stages of 'bank progression' linked to power station operations (e.g. stabilised by tea tree, loss of tea tree, onset of seepage/scour processes depending on bank slope, reduction in slope of bank toe, increase in slope of bank face etc.);
- a long historic monitoring record and stability of erosion pins over time; and
- their accessibility.

3.2.1 Autumn 2018 monitoring

The autumn 2018 geomorphology monitoring was undertaken on 3 March 2018. The erosion pins were measured and photo monitoring completed at the long-term sites in zones 1 to 4. Photo monitoring was completed to document changes to historic river bank disturbances (landslides and treefalls). Water level in the Gordon River was relatively low, with only two of the erosion pins located on bank toes partially submerged (site 3E and 4E). All erosion pins were located and measured.

Table 3-1: Summary of geomorphology monitoring activities in the middle Gordon River between 1999 and present.

Monitoring Type	Season	Dates	Monitoring completed
Pre-Basslink		11 December 1999 18 December 1999 4 March 2000 25 March 2000 22 July 2000 2 September 2000 4 August 2001	Investigations for IIAS: Field observations Erosion pin measurements Photo monitoring Scour chains Painted cobbles
Pre-Basslink	Spring 2001	23 November 2001 9 December 2001	Field observations Erosion pin measurements
Pre-Basslink	Autumn 2002	10 February 2002 9 March2002	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2002	5 October 2002 16 December 2002	Field observations Erosion pin measurements
Pre-Basslink	Autumn 2003	29 March 2003	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2003	18 October 2003	Field observations Erosion pin measurements
Pre-Basslink	Autumn 2004	6 March 2004	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2004	9 October 2004	Field observations Erosion pin measurements Bank profiling
Pre-Basslink	Autumn 2005	2 April 2005	Field observations Erosion pin measurements Photo monitoring
Pre-Basslink	Spring 2005	15 October 2005	Field observations Erosion pin measurements
Transition	Autumn 2006	11 March 2006	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2006	17 October 2006	Field observations Erosion pin measurements
Post-Basslink	Autumn 2007	17 March 2007	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2007	20 October 2007	Field observations Erosion pin measurements
Post-Basslink	Spring 2007	1 December 2007	Field observations
Post-Basslink	Autumn 2008	1 March 2008	Field observations Erosion pin measurements Photo monitoring

Monitoring Type	Season	Dates	Monitoring completed
Post-Basslink	Spring 2008	17 -19 October 2008	Field observations Erosion pin measurements
Post-Basslink	Autumn 2009	21-22 March 2009	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2009	17 October 2009 (zones 3&4) & 31 October 2009 (zones 1,2,5)	Field observations Erosion pin measurements
Post Basslink	Autumn 2010	12-14 March 2010	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2010	19-20 October 2010	Field observations Erosion pin measurements Establishment of vegetation transects at subset of geomorphology monitoring sites in zones 2 – 4.
Ramp-rule investigations	Summer 2011	7-days in January and March 2011	Observations of ramp-downs and draw downs at varying levels of bank saturation associated with investigations to revise ramp-rule.
Post-Basslink	Autumn 2011	26-27 February 2011	Field observations Erosion pin measurements Photo monitoring
Post-Basslink	Spring 2011	5-6 November 2011	Field observations Erosion pin measurements Combined geomorph & vegetation monitoring
Post-Basslink	Autumn 2012	25 -26 February 2012	Field observations Erosion pin measurements Photo monitoring
Interim monitoring	Spring 2012	6 October 2012	Field observations zones (1-4, limited in zone 5) Erosion pin measurements (zones 1-4 only)
Interim monitoring	Autumn 2013	17 March 2013	Field observations Erosion pin measurements Photo monitoring (zones 1-5)
Interim monitoring	Spring 2013	9 November 2013	Field observations Erosion pin measurements (zones 1-5)
Interim monitoring	Autumn 2014	29 March 2014	Field observations Erosion pin measurements Photo monitoring (zones 1-5)
On-going monitoring	Spring 2014	14 October 2014	Field observations Erosion pin measurements Photo monitoring (zones 1-4)
On-going monitoring	Autumn 2016	16 April 2016	Field observations Erosion pin measurements Photo monitoring (zones 1-4)
On-going monitoring	Autumn 2018	3 March 2018	Field observations Erosion pin measurements Photo monitoring (zones 1-4)

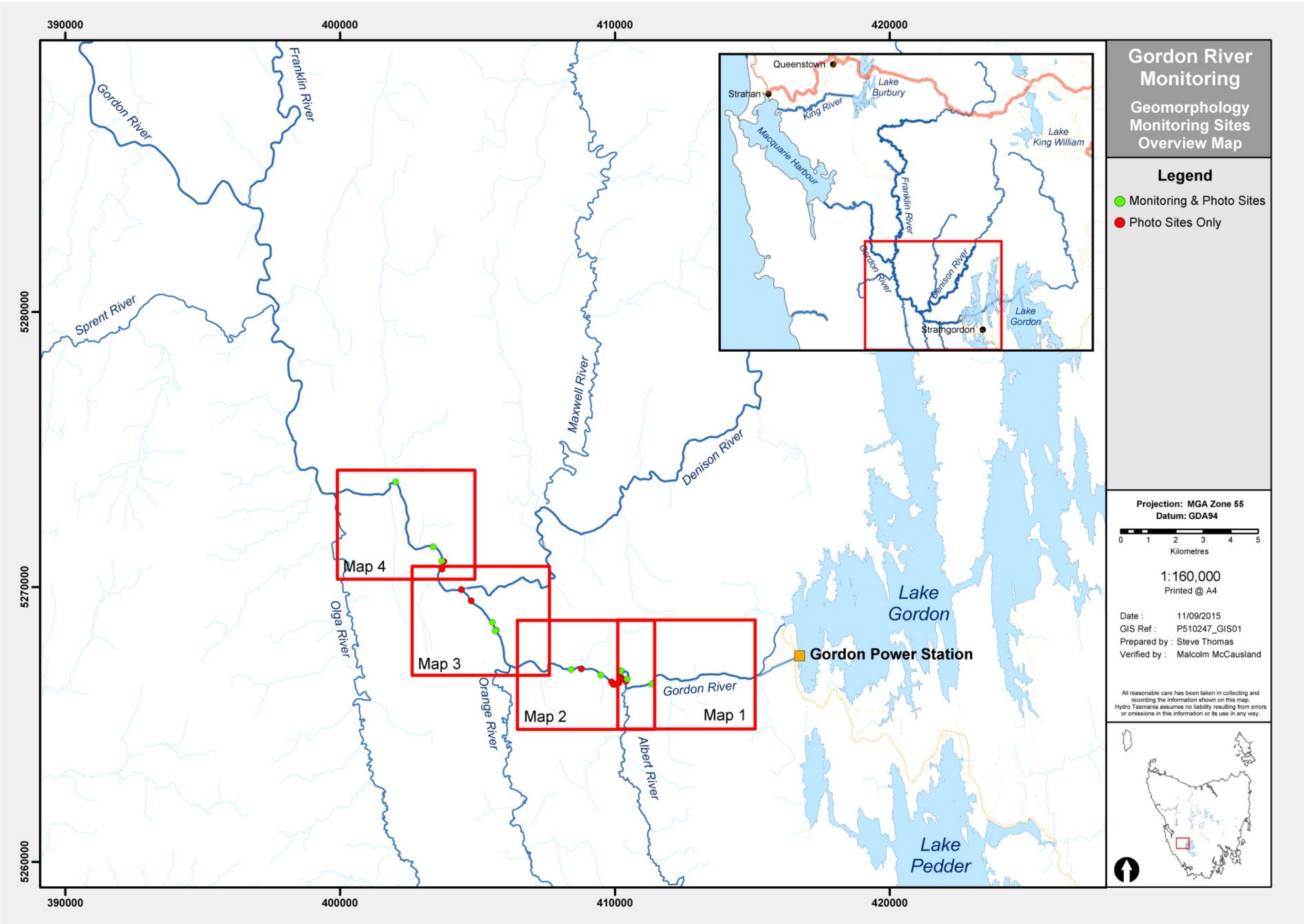


Figure 3-1: Overview of Gordon River geomorphology monitoring sites.

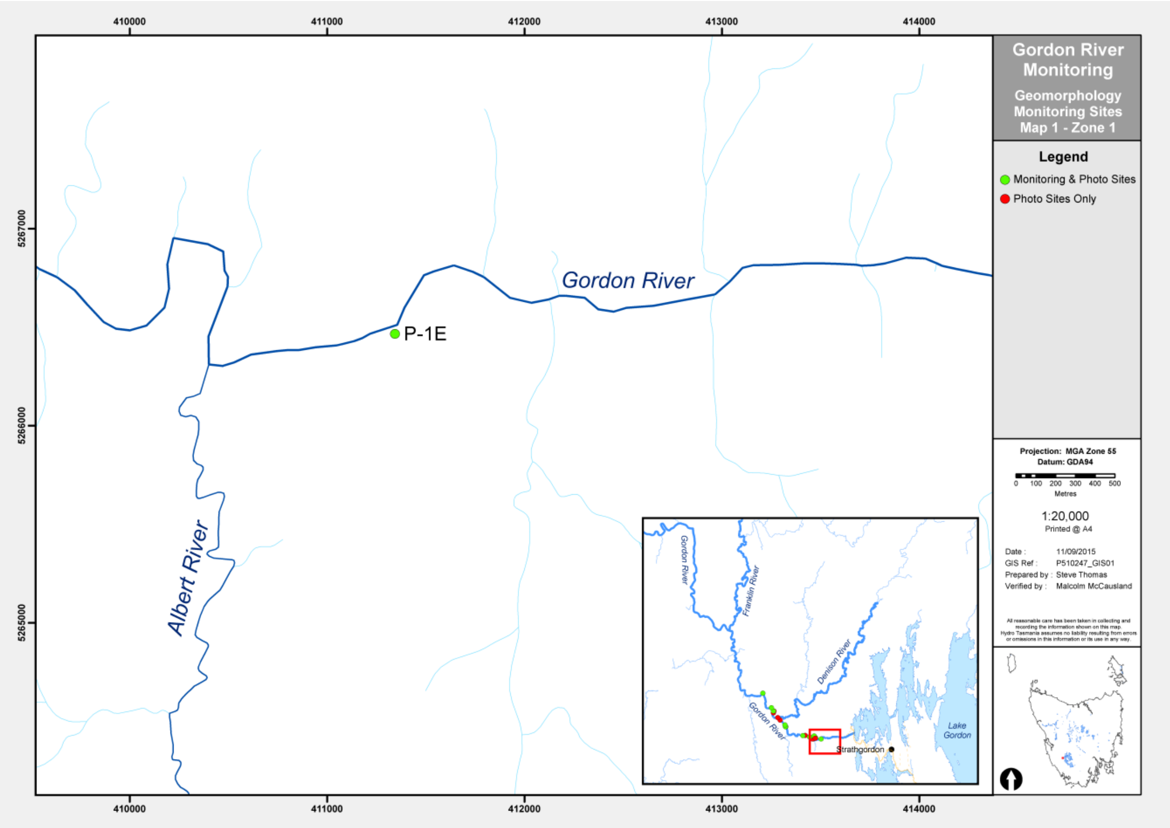


Figure 3-2: Gordon River geomorphology monitoring sites, zone 1.

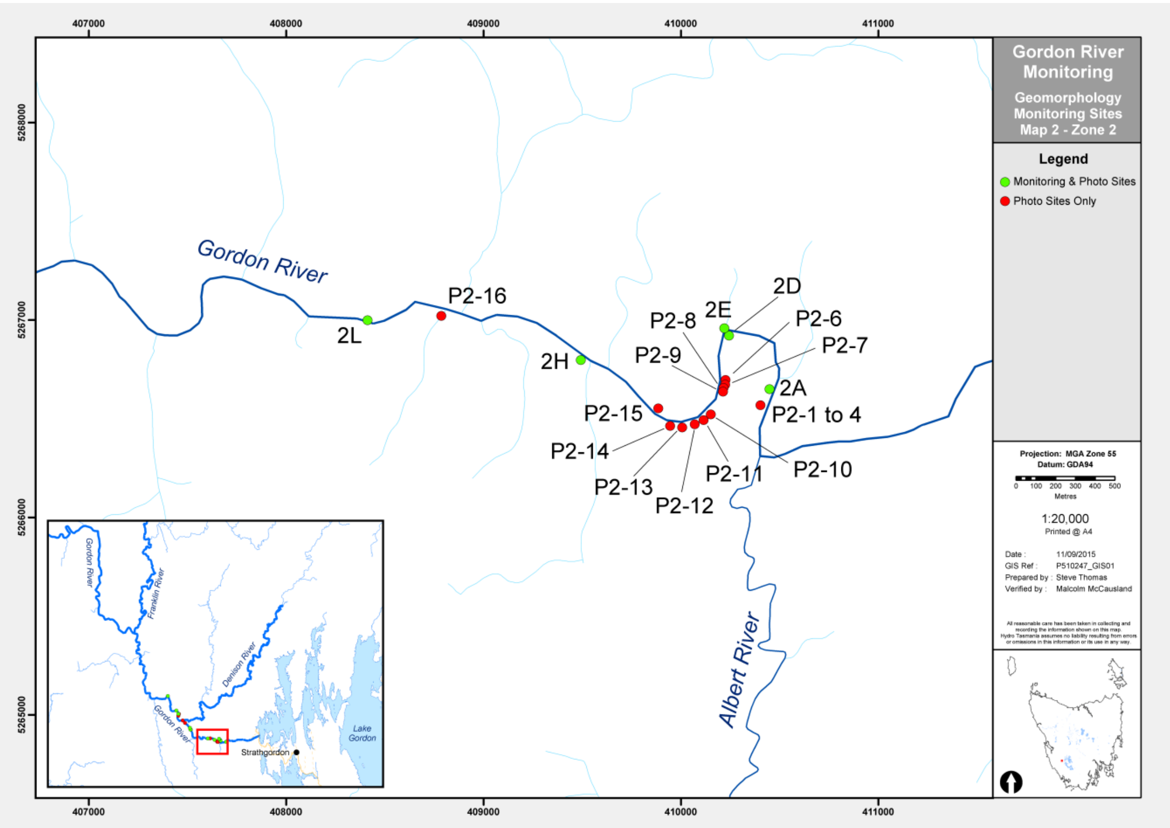


Figure 3-3: Gordon River geomorphology monitoring sites, zone 2.

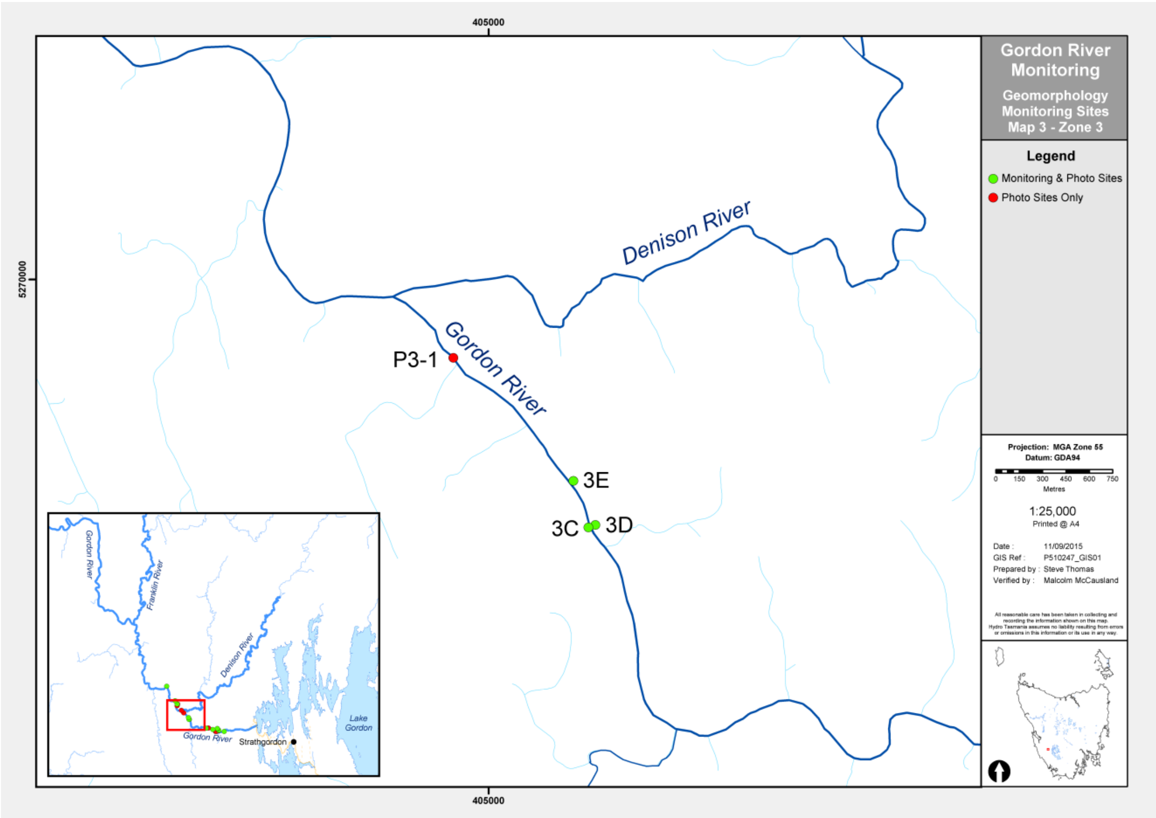


Figure 3-4: Gordon River geomorphology monitoring sites, zone 3.

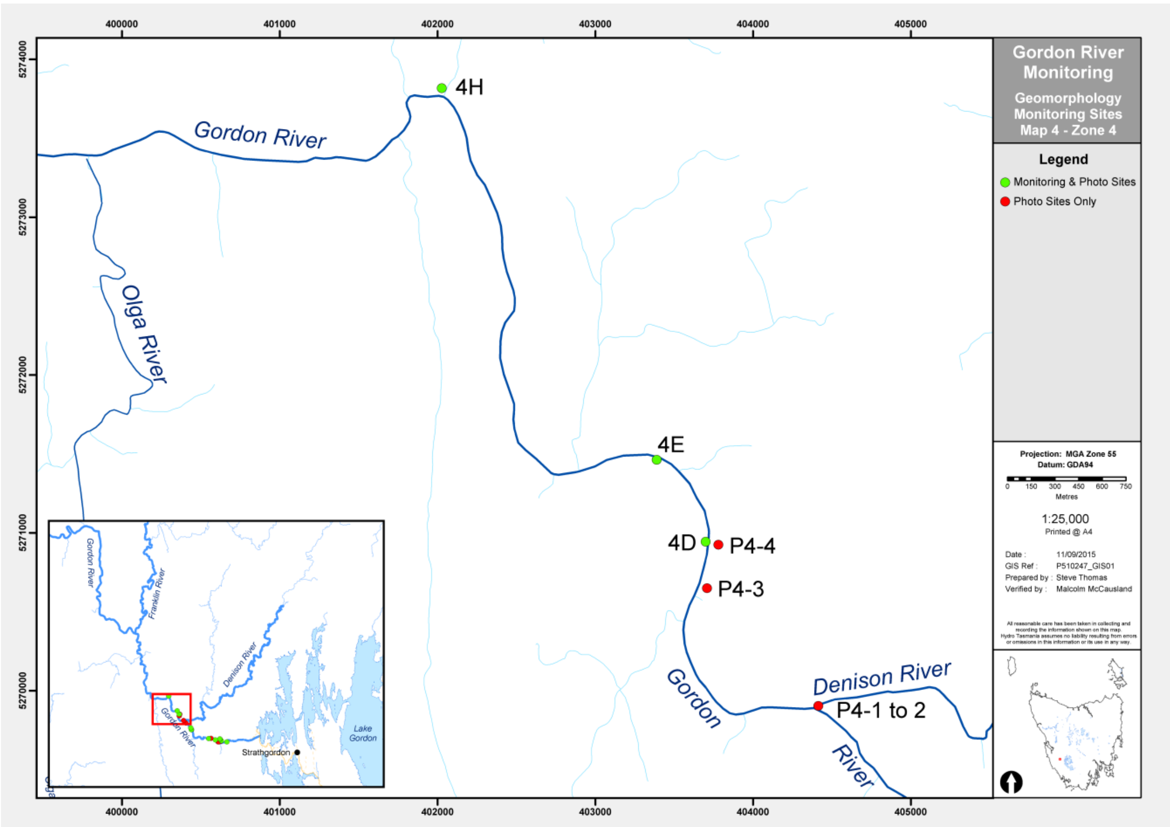


Figure 3-5: Gordon River geomorphology monitoring sites, zone 4.

Table 3-2: Number of monitoring sites and erosion pins in each geomorphology zone.

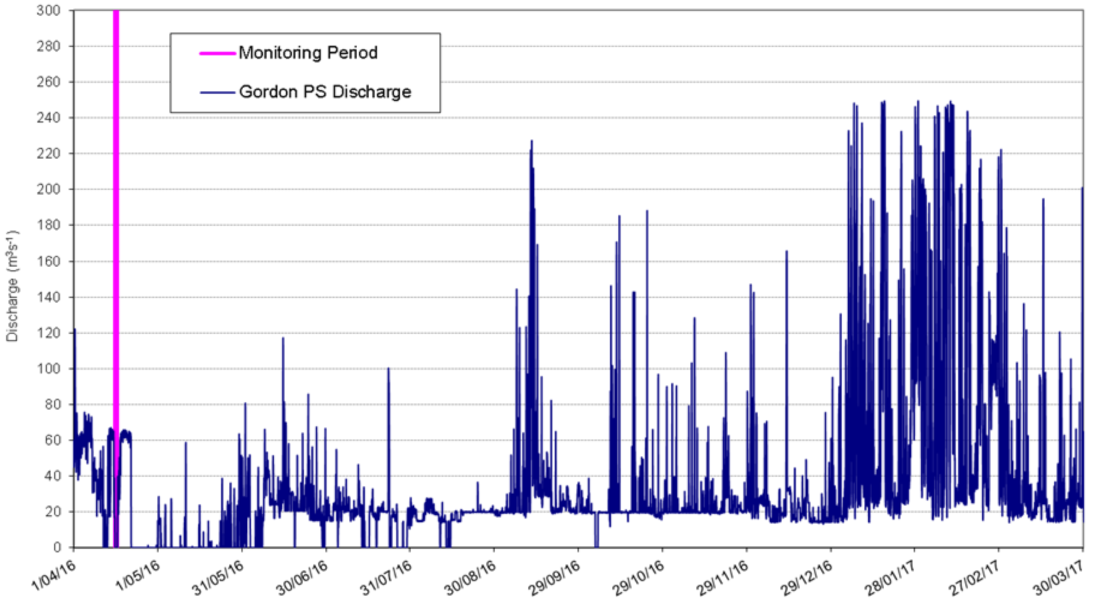
Zone	Dominant zone features	No. combined monitoring and photo sites	No. photo-only sites	No. erosion pins
Zone 1	Bedrock controlled channel with some minor alluvial sections	1	0	13
Zone 2	Extensive exposed alluvial banks.	5	16	36
Zone 3	Approximately half bedrock and half alluvial banks	3	1	22
Zone 4	Hydrology influenced by inflow of Denison. One third of banks alluvial, two thirds bedrock or cobbles.	3	4	18
Total		12	21	89

3.3 Overview of hydrology April 2016 to March 2018

The following short discussion highlights hydrologic characteristics relevant to the recent geomorphic monitoring results (Section 3.4). For a detailed discussion of the hydrology of the Gordon River during the 2016-2018 monitoring period, see Chapter 2.

Hourly discharge from the Gordon Power Station between April 2016 and March 2018 is shown in Figure 3-6, and the power station flow is compared to the Gordon above Denison Compliance in Figure 3-7. The hydrology shows the following characteristics relevant to the geomorphic monitoring results:

- Power station operation was very low in 2016 and 2017, with flow duration curves showing some of the lowest usage of the station over the period of the record. Discharge of greater than 100 m^3s^{-1} was exceeded less than 10% of the time in April 16 – April 17, and less than 25% of the time in April 2017 to April 2018 (see Hydrology Section);
- There were no prolonged periods of high discharge from the Gordon Power Station in the April 2016 to April 2018 period;
- Beginning in January 2018, discharge from the Gordon Power Station increased with short-duration high flow events increasing in frequency;
- The flow at the compliance site reflects the power station discharge with the addition of several high flow events, most notably one in May 2016 and two in July 2016. The May event and first one in July reflect very large rainfall events. The second July peak corresponds to a controlled release of water from Lake Pedder (released due to the high water level) - the first time this has occurred since monitoring was initiated in 1999;
- Flow in the Gordon River above the Denison River shows the power station operating patterns and the unregulated inflows. The first high flow in July 2016 corresponded to high rainfall, and was a very large event. The second July 2016 high flow event at the Compliance site corresponded to the release from Lake Pedder. Modelled data for sites further downstream (not indicated here) suggest that just one very large event (the first event in July) was experienced at sites downstream of the Denison River confluence in response to the rainfall inflow. The second peak in July as a result of the Lake Pedder release did not represent a large flow at sites below the Denison River;
- During the winter of 2017, there were no high flow events that exceeded 400 m^3s^{-1} at the Compliance site. In contrast, there was one such event in March 2018, which occurred after the monitoring was completed on March 3; and
- Power station discharges over the previous two years were characterised by generally low discharges interspersed with brief medium to high flows peaks over the previous two years. The conditions of the ramp-rule were not breached during this period, however, the operations would subject the lower bank faces in the river to a large number of water level changes that can contribute to the flattening of bank toes through slow seepage erosion processes. The lack of extended high flow events would be expected to limit scour.



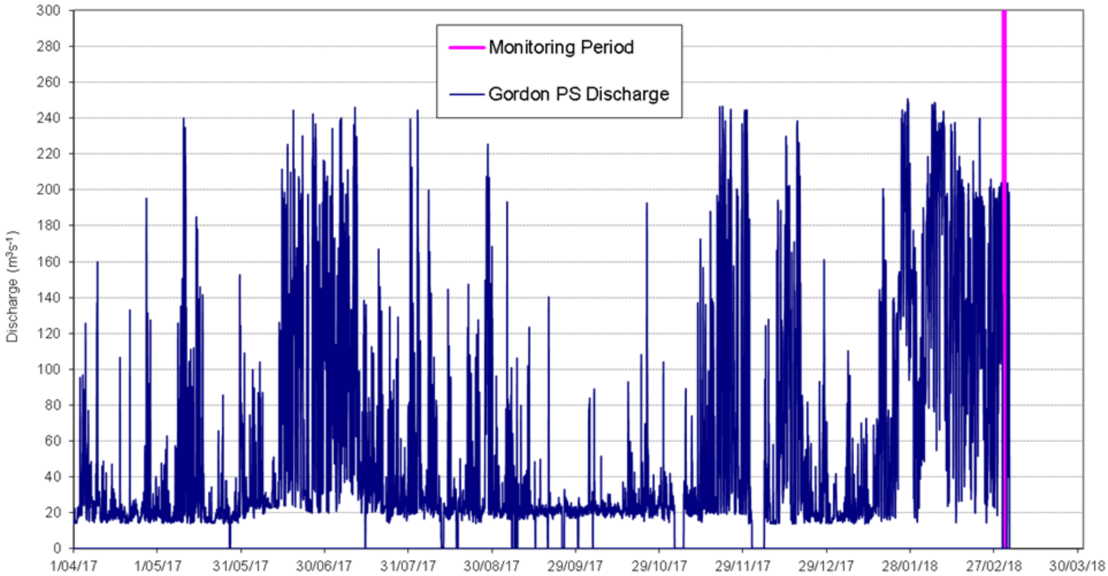


Figure 3-6: Hydrographs of discharge from the Gordon Power Station for the periods (top) 1 April 2016 to 1 April 2017, and 1 April 2017 to 1 April 2018. Monitoring periods are indicated in pink (bottom).

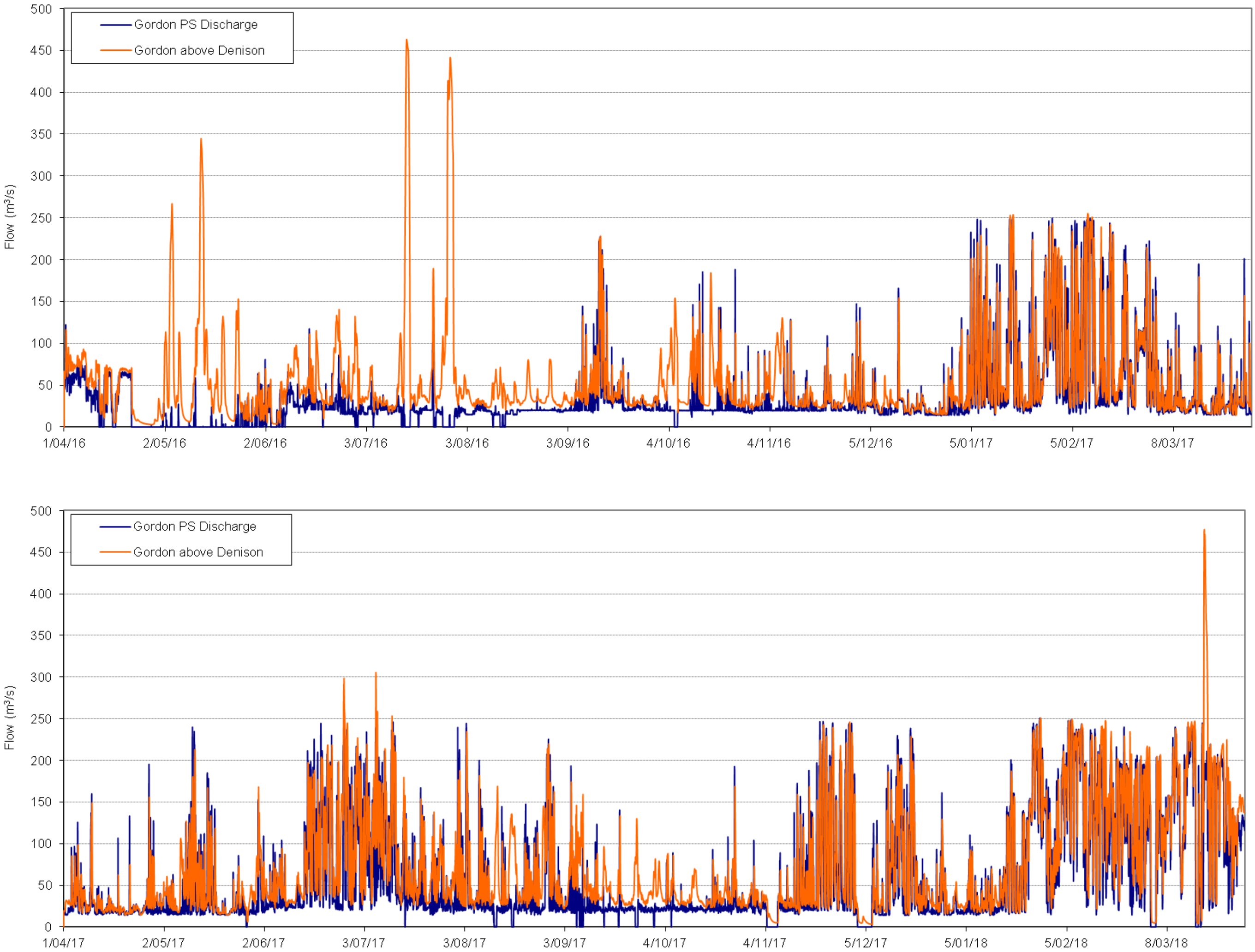


Figure 3-7 Daily flow at the Compliance site compared to discharge at the Gordon Power Station for 1 April 2016-1 April 2017(top) and 1 April 2017-1 April 2018

3.4 Monitoring results

3.4.1 Field observations in autumn 2018

Field observations in autumn 2018 included the following:

- Algae was present on bank toes in all zones, and aquatic vegetation was present in some shallow areas in zones 1 and 2, indicating that during the summer months water levels have been low enough for long enough to promote plant growth. The backwater in zone 2 behind erosion pin site 2A was well vegetated with mosses and some reeds (Figure 3-8).
- The dieback of trees that was first observed in March 2014 appears to have ceased, with no new trees along the water line observed to be browning (Figure 3-9). The dead trees remain standing;
- Flood debris was present on the G9 island in zone 4, and a large new treefall is present on the north side of the island. The level of the flood debris is above the power station operating level and may be from the July 2016 flood event. The treefall appears too recent to be directly attributable to the flood, but there is evidence of scouring on the island that may be linked to the flood event and contributed to the treefall (Figure 3-10);
- Deposits of coarse sand and gravel were observed in hydraulically quiescent areas of cobble bars in the lower section of zone 2 (upstream of the Splits) and in zones 3 and 4. The deposits are consistent with low power station usage (Figure 3-11).

Figure 3-8: Algae, mosses and rushes on the bank toe in zone 3 (left) and in the backwater behind erosion pin site 2A in zone 2 (right).

Figure 3-9: No additional trees along the power station high water level were observed as dying in 2018. The trees observed in (left) 2016 remain standing in 2018 (right). Photo from zone 2.

Figure 3-10. Flood debris on island downstream of erosion pin site 4E (G9 island) in zone 4 (left), and Large treefall on the north side of the same island(right).

Figure 3-11. Deposition of coarse sand and gravels in quiescent areas of cobble bars in (left) zone 2 upstream of the Splits and (right) in zone 3.

3.4.2 Erosion pin results

Erosion pin measurements were collected from 12 sites in geomorphic zones 1 – 4. A summary of the 2018 results compared to the 2016 results is provided in Figure 3-12 and Figure 3-13. The April 2016 results reflected changes occurring over the previous 18-months whereas the 2018 results reflect changes over a 24-month period.

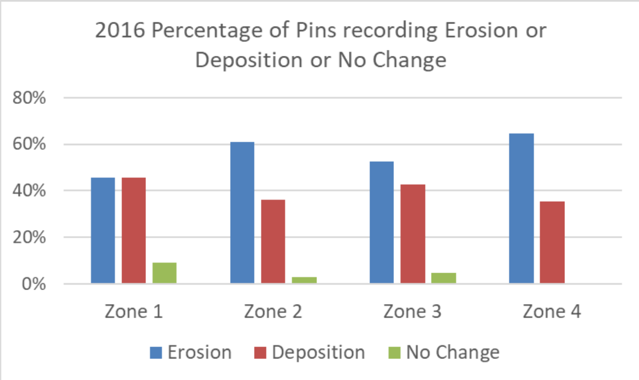
In 2016, the monitoring was completed following extended periods of power station operation, and many pins recorded erosion as compared to deposition (Figure 3-12). In 2018, the reverse occurred, with more erosion pins recording deposition as compared to erosion. Deposition in zones 1 and 2 reflects the flattening of river banks due to the seepage of sediment down slope, as there is little sediment delivery to the banks. In zones 3 and 4, deposition is attributable to a combination of seepage induced bank flattening and fluvial deposition derived from sediment derived from the unregulated tributaries.

The averages of pins recording erosion and pins recording deposition for each zone show that erosion was reduced in 2018 as compared to the results recorded in 2016 (Figure 3-13). This is consistent with the lack of extended high discharge at the power station power station reducing scour of the bank faces. In 2016, the higher rate of erosion in zones 3 and 4 was hypothesized to be partly attributable to the low rate of sediment delivery from the tributaries due to the drought. The higher rates of deposition recorded in 2018 are consistent with this theory, suggesting that sediment derived from the tributaries has been deposited and retained on the banks. Photo monitoring also supports this theory (see Appendix C).

The March 2018 results are consistent with the long-term Basslink monitoring results. During the Basslink monitoring, zones 3, 4 and 5 (which is no longer monitored) consistently recorded higher rates of deposition and erosion, reflecting a more dynamic system owing to the inflow of unregulated tributaries. The low rates of change in zones 1 and 2 are attributable to the flow being dominated by the power station discharge which transports low sediment loads, and the zones being largely adjusted to the regimented flow regime. These same attributes are present in the 2018 monitoring results.

In Figure 3-14 the average change (mm) of all erosion pins in each zone are presented for 2016 and 2018. The high rate of net erosion in 2016 is apparent, with all zones recording net erosion, and the rate of erosion increasing with distance downstream. The 2018 results show a net deposition in zone 1, and a low level of net erosion in zone 4, with zones 2 and 3 showing virtually no net change. The low level of net change in zones 3 and 4 suggest that the higher rates of erosion and deposition recorded in these zones is indicative of a dynamic equilibrium under conditions of low power station usage. Note that these net values are not necessarily representative of the overall direction of erosional trends in the river, but rather a means through which different monitoring periods can be compared.

Comments about the individual erosion pin sites in each zone are presented in the following sections.



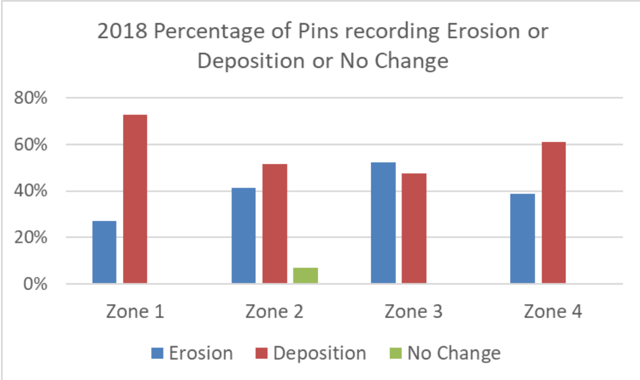
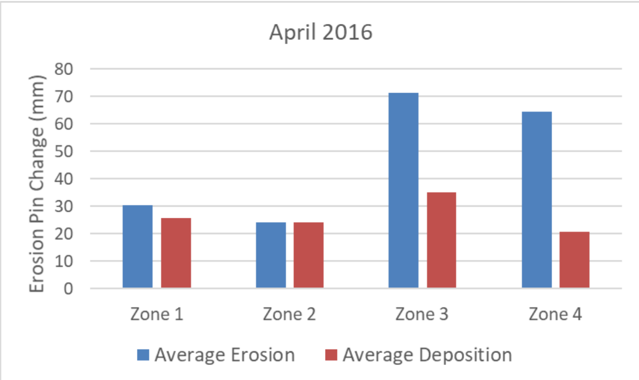


Figure 3-12. Percentage of erosion pins in each zone that recorded erosion, deposition or no change in 2016 and in 2018. The numbers of erosion pins in each zone is shown in Table 3-2.



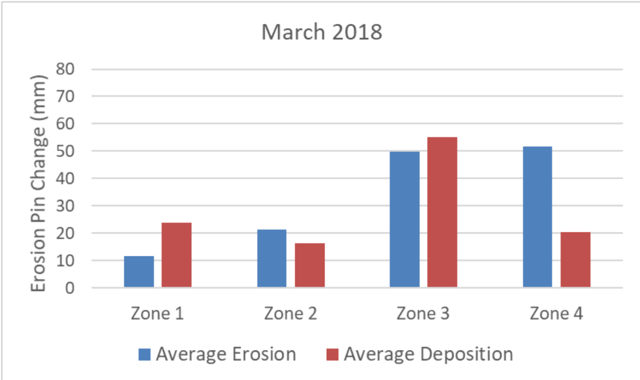


Figure 3-13 Comparison of erosion pin results in April 2016 and March 2018 by zone. Bars indicate average erosion or deposition as recorded by pins (pins recording erosion and pins recording deposition were grouped and averaged for each zone).

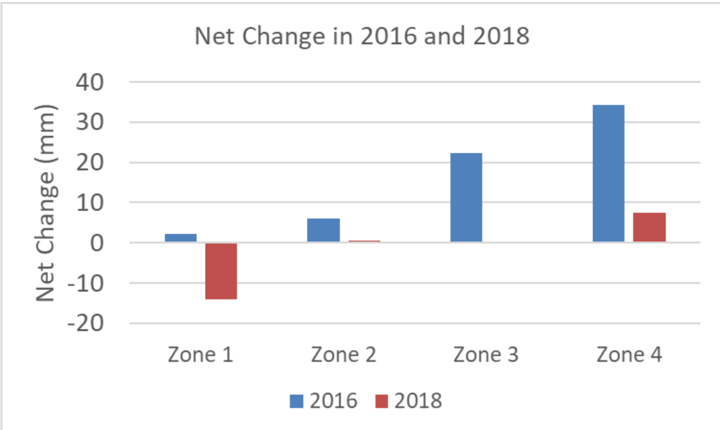


Figure 3-14: Net change based on average of all erosion pins in each zone. Positive indicates net erosion, negative indicates net deposition.

Erosion pin results by site

Photos of each of the erosion pin monitoring sites are contained within the photo monitoring results in Appendix C. In each of the erosion pin graphs, erosion is indicated by a positive change (more of the pin is exposed due to erosion of the bank) and deposition is negative. For each monitoring date, the change in the exposure of the pin relative to the date the pin was established is shown. For example, at site 1E, pin E4 has recorded a net change of -200 mm since installed in March 2001, indicating deposition at the pin site. Since the previous monitoring in 2016, when the pin showed a net change of -150 mm, an additional -50 mm of change has been recorded.

Site 1E is located on an alluvial bank which is stabilised by tea tree and a root mat which is gradually being lost through scour. Initially there were benches at discrete turbine levels present on the bank, but these have been removed as the bank reduces slope by slow seepage erosion processes. The erosion of the bank face and reduction in slope of the bank toe continues, seen in the erosion recorded by the pins on the bank face (1E1, 1E2, 1E3 and 1E7) and the deposition recorded by the lower pins (1E4, 1E5, duplicate pins 1E12, 1E13, Figure 3-15). Previously, 1E9 also recorded erosion, but showed little change between monitoring events in 2016 and 2018. This reflects the flattening of the bank following loss of the root-mat, similar to the lower pins on the bank. The trends are consistent with the long-term results at the site.

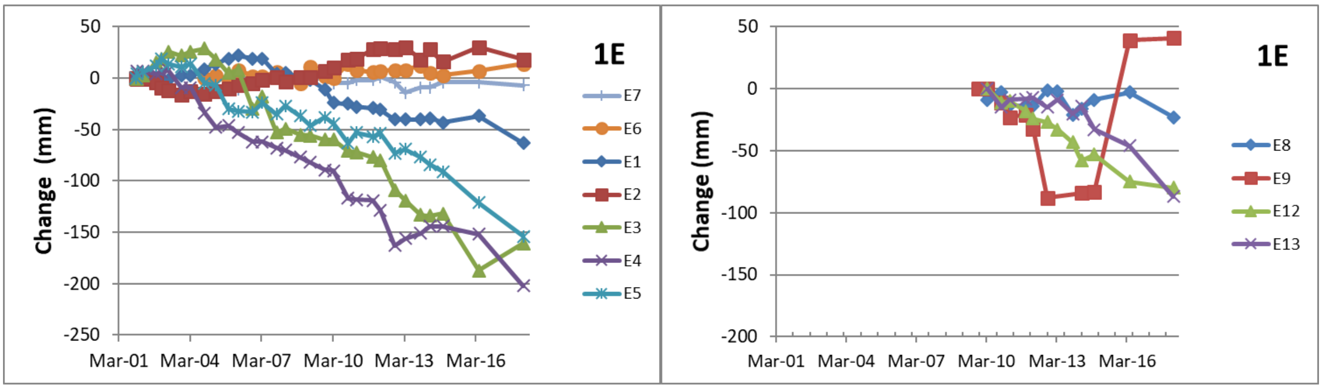


Figure 3-15: Erosion pin results for site 1E. Pins in graph on left form one profile down bank; pins in graph on right are duplicates. Legend shows approximate order of erosion pins from upslope to downslope. Graph on right shows duplicate pins due to risk of site being damaged by collapse of tree that overhangs the site.

Site 2A is also located on a bank supporting tea tree. The bank separates the main channel from a back channel which is active when the power station is in use. Pins 2A1 – 2A4 and pin 2A8 are on the river side, with pins 2A5 – 2A7 on the back-channel side (Figure 3-16). The pins on the river side have shown little change since monitoring began, except at pin 2A8 where small changes associated with the growth of vegetation and trapping of fine sediment has occurred (Figure 3-17). The pins on the back channel show low rates of change associated with slow seepage process. Pin 2A7 has recorded the greatest changes due to a scour hole forming at the base of the pin and then refilling over time. These changes are an artefact of the pin and do not reflect changes to the back channel.

Site 2D is located on the inside of a sharp bend and the site has shown cycles of flattening of the bank toe (pin D4) and erosion of the upper bank followed by erosion of the toe (Figure 3-16). In 2018 little change or deposition was recorded at any of the pins except at pin 2D7 which is located at the break in slope near the back of the bank and recorded erosion relative to April 2016. Deposition was recorded at pins located downslope of the break in slope such as 2D1, 2D2 and 2D4, consistent with the erosion of the bank face and deposition downslope.

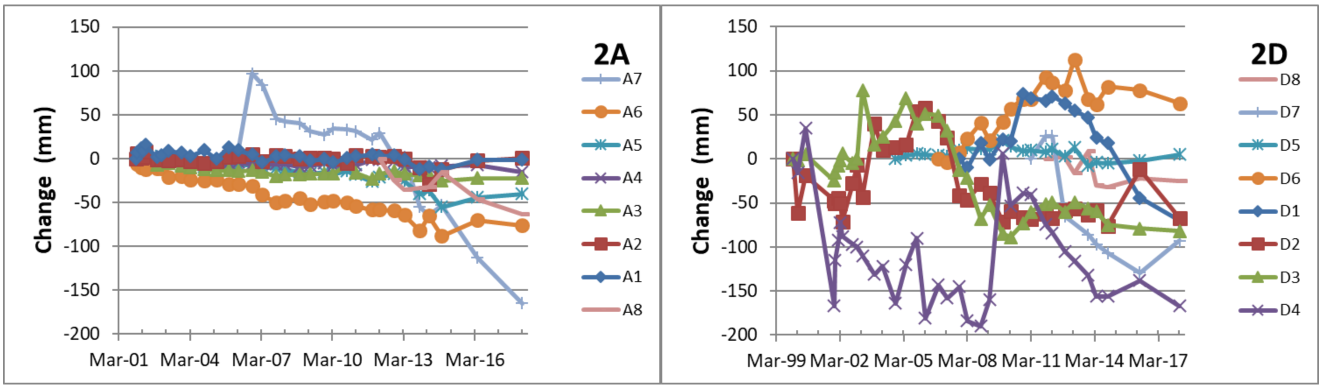


Figure 3-16: Erosion pin results for sites 2A and 2D. For site 2A, legend shows pins in order on bank from backwater to river side of the bank. For site 2D, legend shows approximate order of erosion pins from upslope to downslope.

Figure 3-17: Erosion pin site 2A showing location of pin 8 in cobbles and affected by the growth and presence of vegetation.

Site 2E is located on the opposite bank from site 2D and is on a bank where seepage erosion was active during the pre-Basslink monitoring period, with the toe (2D4) recording a long period of deposition, associated with seepage processes (Figure 3-18) followed by erosion and another cycle of deposition. Pin 2E1 is located in a cavity on the bank, and its variability is partially attributable to difficulties associated with measuring. Over the past years, the site has recorded erosion more consistently than deposition, and the site has developed a concave shape, consistent with the exhaustion of material available for transport and deposition by seepage. In 2018, the site supported wide-spread mosses and ferns, indicating a high level of stability (Figure 3-19).

Site 2H contains 2 parallel profiles of erosion pins. One set (Pins 2H1 – 2H3) is in a tea tree bank, and the other (2H4 - 2H7) is located immediately downstream in an area where the tea tree has been lost and the steep, disturbed bank is prone to seepage processes (Figure 3-18). The erosion pin results have captured the movement of a large Huon Pine down slope that buried pin 2H4, and the flattening of the seepage affected bank (2H5 – 2H6). The erosion pin results in March 2018 show continued erosion in the tea tree pins (2H1 - 2H3), and little change to the relatively flat toe at pins 2H5 and 2H6 (Figure 3-20).

Site 2L is the most downstream site in zone 2, and is subjected to the largest water level fluctuations due to backwater effects from the narrow Second Splits gorge. The site supports tea tree and there are well defined 'benches' within the banks. The erosion pins have captured the removal of a muddy root mat through erosion and reduction in slope of the upper bank as the 'benches' that were originally associated with turbine levels are removed (Figure 3-18). Pins 2L5 and 2L7, located on steeper portions of the bank are showing a slow lowering of slope (deposition).The site has recorded little change since October 2014, with the exception of pin 2L1 which is in a cavity located approximately 20 m upstream of the other erosion pins. Pin 2L is recording the slow slumping of the bank face. The occasional unusually high or low measurements associated with this pin are attributable to the presence of roots extending into the cavity which sometimes makes measurement difficult.

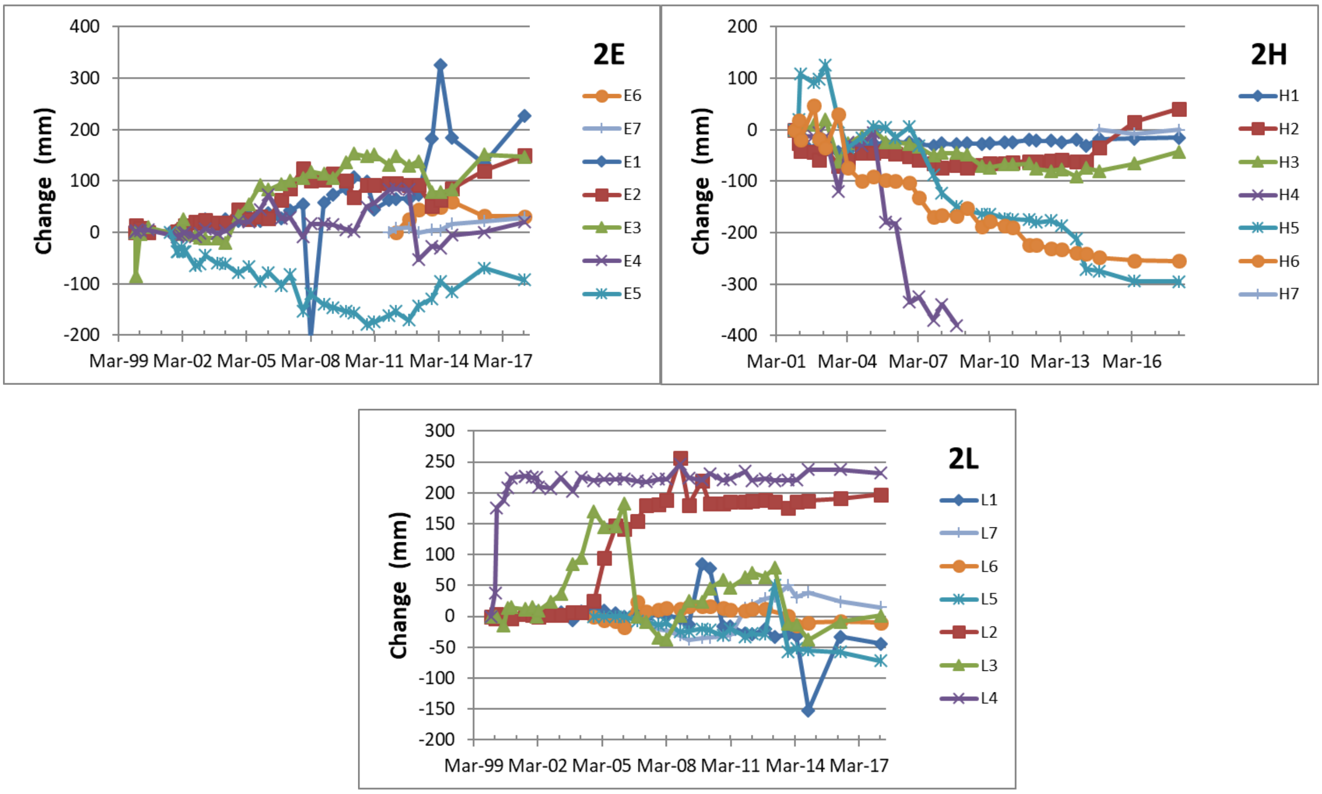


Figure 3-18: Erosion pin results for sites 2E, 2H and 2L. Legends for all sites show approximate order of erosion pins from upslope to downslope.

Figure 3-19. Photo of erosion pin site 2E showing establishment of mosses and ferns near previous seepage 'vents'.

Figure 3-20 Tea tree section of erosion pin site 2H showing steep bank face, erosion of root mat and rilling in the underlying sand bank (left), and 'seepage' section of site showing flatter bank toe and treefalls (right).

Sites 3C is located on the right bank in zone 3 just upstream of the Compliance Site. This erosion pin site is affected by power station operations, inflows from the Orange River, and backwater effects from the Denison River. Pin 3C1 is in a cavity and has been lost due to bank collapse. Pin 3C55, which was located approximately at the 55 m^3s^{-1} flow level has been lost most likely due to erosion (based on high level of erosion recorded in March 2014).

In March 2018 the lower bank (3C4) and bank toe (3C5) show erosion relative to April 2016, with the other pins recording low depositional changes or no change. A photo of the site shows that pins 3C4 and 3C5 are within the flat lying bank located within the 1-turbine level and covered with vegetation (see photo monitoring Appendix C). The upper bank shows deposition of mud, that is absent from the bank toe. It is likely that the recorded deposition is attributed to these mud deposits, which do not collect on the lower bank due to the environmental flow and power station operations, accounting for the erosion.

Site 3D is located on the left bank, opposite from site 3C upstream of the Compliance site. It is a steep, almost vertical bank with gravels at the base of the bank on the toe. Pin 3D1 is in a cavity, and Pin 3D4 is horizontal in the steep bank face, and both recorded little change, showing stability of the bank face. The remaining pins are located along the toe at the base of the steep bank and recorded erosion in March 2018. These pins recorded erosion for many years up until about 2010, after which they showed predominantly low rates of deposition (Figure 3-21).

Site 3E is located half way down zone 3 on the right bank, and is composed of a large sandy bank toe with tea tree on the higher bank. The root-mat is eroding, and since around 2013 the bank has shown higher rates of change (Figure 3-21). Most pins recorded high rates of deposition, attributable to some fluvial deposition, but also seepage processes associated with flattening of the bank face as the root-mat is lost. Pin 3E2, which recorded erosion, is located at the break in slope at the bank, near the edge of the eroding root-mat (Figure 3-22).

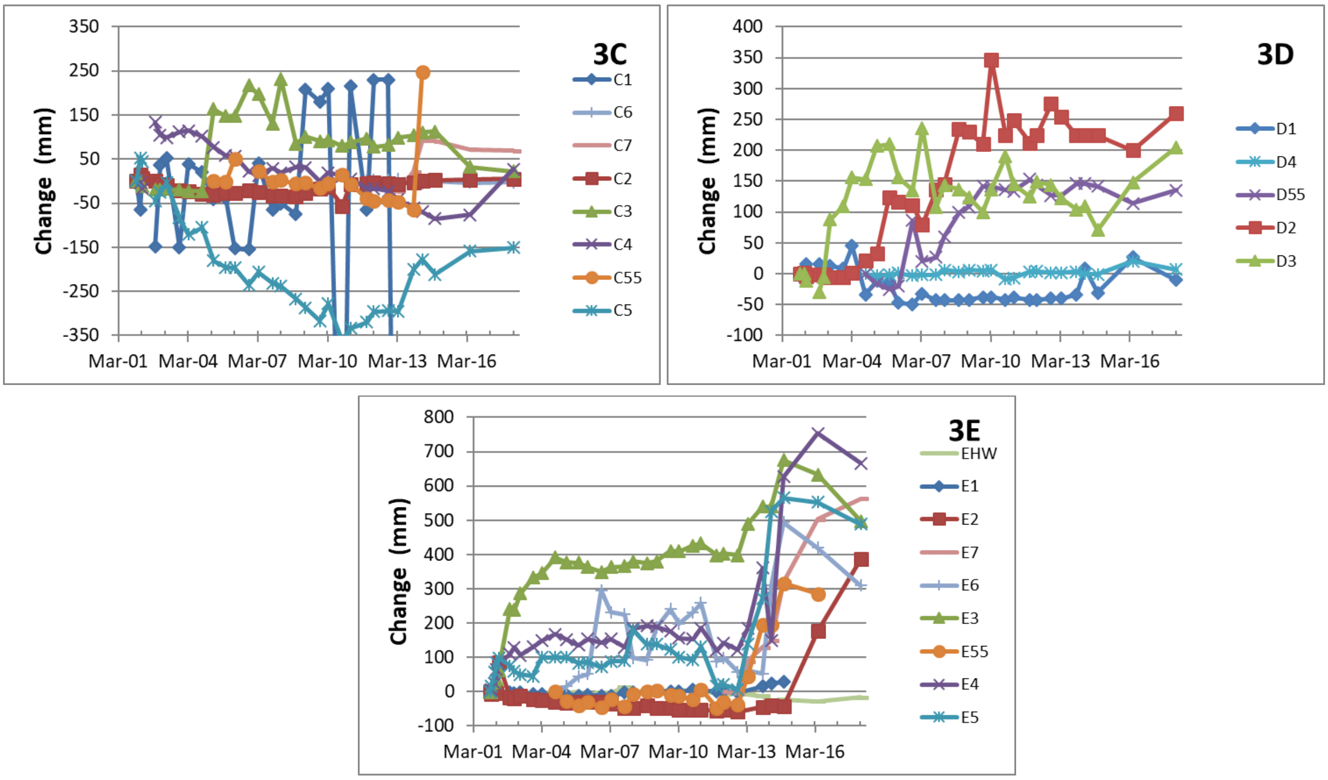


Figure 3-21: Erosion pin results for sits 3C, 3D and 3E. Legend shows approximate order of erosion pins from upslope to downslope.

Figure 3-22: Site 3C (left), showing pins 3C4 located on the flat lying lower bank, and pin 3C5 on the bank toe in an area being scoured (right) Site 3E showing location of pin 3E2 at edge of root-mat.

Site 4D is located mid-way down zone 4 on the left bank at the downstream end of a cobble bar. The toe of the bank is buttressed by a large log which in the past has stabilised the bank toe and promoted the deposition of sands. In 2016, this site experienced high rates of erosion with the removal of sands evident in the photos in the photo monitoring appendix. The lower bank (pins 4E9, 4E10, 4E2 and 4E3) continued to record erosion in 2018, with the remaining pins showing lower rates of deposition or little change (Figure 3-23). Similar to site 3E, this site appears to have increased in activity over the past 5 years. Both sites have lost vegetation during this time, consisting of small trees lost due to the erosion of the root mat. In spite of the erosion recorded by the pins, photos of the site show some increase in the deposition of sand in areas of the bank between April 2016 and March 2018.

Site 4E is located on the left bank at an inside bend across from Kayak Cavern. The upper bank on this steep site has consistently shown erosion due to scour, with pin 4E1 recording the highest rate of change of any of the erosion pins. The pin was eroded out of the bank in 2016 and reset, so the displayed cumulative change of 800 mm since 2001 is a minimum value (Figure 3-23). Pin 4E2 has recorded similar levels of erosion. The other two pins show also show net erosion since installation, but recorded deposition in 2018, suggesting the toe may have flattened under the low power station discharge operating pattern.

Site 4H is located at the downstream end of zone 4, upstream of Sunshine gorge near the confluence of the Harrison and Smith Creeks with the Gordon River. The pins show a similar trend in 2018 as recorded previously at the site (Figure 3-23). All pins except toe pin 4H5 show deposition that is partially attributable to flattening of the site over time due to seepage processes, and partially attributable to the fluvial deposition of sand. Sand in this area is likely derived from the nearby tributaries, and from the Gordon River with deposition occurring during periods of high flow when the Gordon experiences backwater effects in this area due to the proximity of Sunshine Gorge. During periods of low power station usage, vegetation increases on the banks and enhances sediment deposition. Pin 4H1 is located on a step area of the bank toe and is eroding.

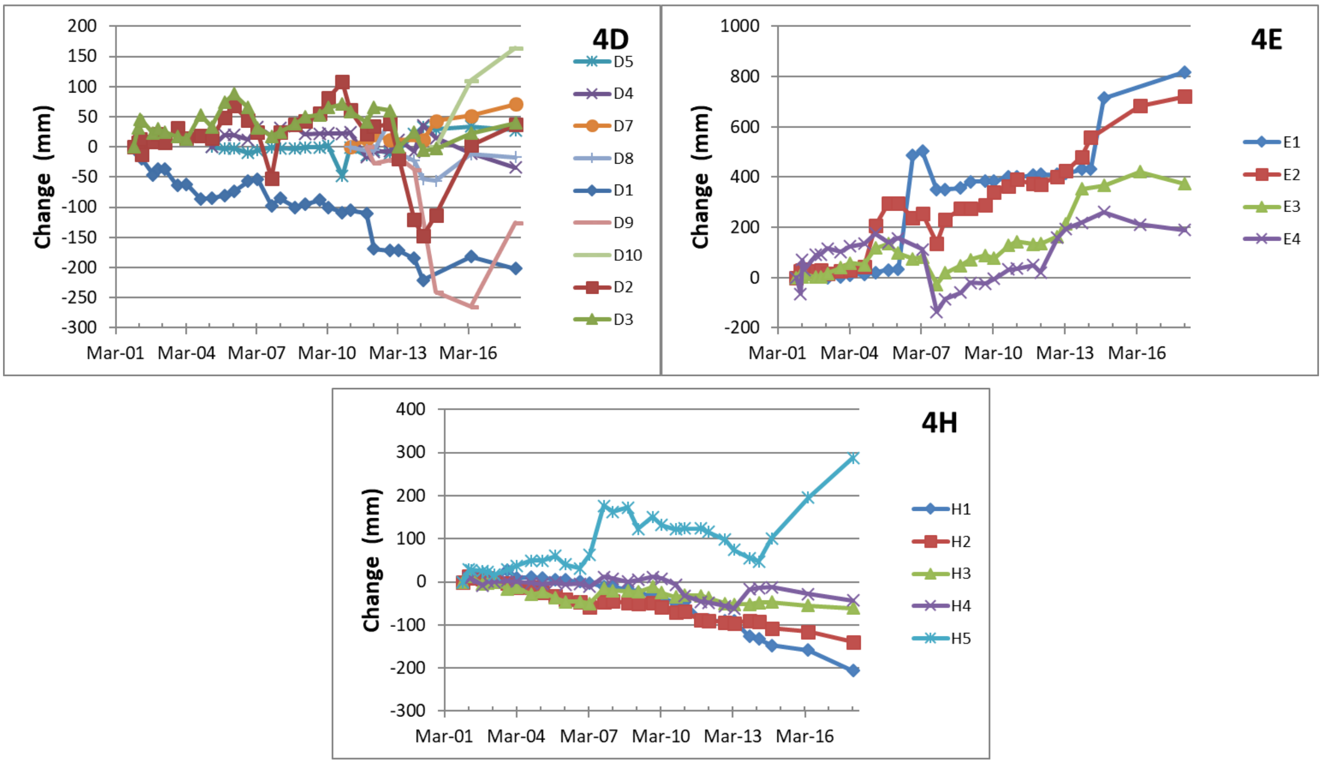


Figure 3-23: Erosion pin results for site 4D, 4E and 4H. Legend shows approximate order of erosion pins from upslope to downslope.

Figure 3-24: Erosion pin site 4H. Toe pin is located near scour chain (bottom left in photo) on steep part of bank. Vegetation is trapping sediment on the bank.

Erosion pin summary

The erosion pin results of 2018 are consistent with the understanding of geomorphic processes in the river, and the relationship between power station operations and the response of alluvial banks in the middle Gordon River. The low power station usage in the preceding 24 months limited scour of the banks, and the high frequency, short-duration increases in discharge from the power station likely promoted the flattening of bank toes through slow seepage erosion processes. Deposition of sediment derived from the unregulated tributaries also appears to be higher than 'usual' and is also attributable to the low power station usage.

Compared to 2016, the 2018 results showed lower rates of erosion, and display similar characteristics to periods of low flow during the Basslink monitoring period. Zones 1 and 2 recorded overall low average rates of erosion and deposition, with zones 3 and 4 recording higher rates of both of these processes. The higher rates reflect a dynamic equilibrium and are attributable to the combination of power station discharges and inflows of sediment and water from unregulated tributaries.

The March 2018 results did not suggest that there had been large changes associated with the very large flow event in July 2016. This contrasts to the previous very large event in July 2007 which resulted in widespread erosion and bank collapse. The lack of evidence of substantial change associated with this very large event in 2016 may suggest that the rate of river adjustment to the regulated flow and sediment regime is decreasing, however, the following needs to be recognised:

- In 2007 the greatest changes occurred in zones 4 and 5 where unregulated inflows are highest. In 2018, the highest net erosion rate was recorded in zone 4, and may reflect the large event in 2016. Zone 5 is no longer monitored so it is unknown what impact the 2016 high flow event had downstream of zone 4;
- The 2018 monitoring occurred 21 months after the 2016 high flow event, and very little power station usage occurred during the interim period. Under these conditions, some recovery of the banks would be expected. Two years after the 2007 flood event many pins had 'recovered' (Figure 3-23) and were showing trends similar to the pre-2007 results.

Photo monitoring

Photo monitoring of the erosion pin sites and prominent disturbance features, such as treefalls and land slips, was completed in March 2018. Many of the sites correspond to features included in the Basslink and Interim Monitoring programs, and historical photos are contained in the Annual Basslink Monitoring Reports (Hydro Tasmania 2014 - Photo Monitoring Appendices). Photos obtained in October 2014, March 2014, April 2016 and March 2018 are shown in Appendix C. Photos were obtained from all sites in March 2018.

Consistent with the previous years, changes in the photo monitoring sites are small. Changes that were common to most sites included an increase in the growth of mosses and other vegetation on bank toes and bank faces within the power station operating range relative to April 2016, and minor changes to the woody debris deposited on bank toes or in the river near the base of the disturbance.

Other changes observed in the March 2018 photos relative to the April 2016 photos include the following (note: letters indicate erosion pin sites and numbers indicate photo monitoring points. See Appendix C):

- Changes or addition to woody debris on bank toes, other than minor re-arrangement: 1E, 2A;
- New treefalls: downstream of 2D, upstream of P2-10;
- Collapse of or small tree fall from overhanging root-mat: P2-9, P2-14, P3-1;
- Erosion of tea tree root-mat: 2H, 3E, 2L; and
- Increased sand on bank face: 2L, 3E, 4D, 4H.

3.5 Conclusion

The geomorphic monitoring results continue to track changes in the river, with the field observations providing insights into the impact of recent power station operations (previous weeks to months) and the erosion pins and photo monitoring results capturing long-term 'net' changes.

The March 2018 monitoring results are consistent with the understanding of geomorphic processes and the influence of power station discharges in the middle Gordon River. The low power station usage limited scour of the bank faces and enabled the establishment of vegetation on bank toes and bank faces. Low power station usage allows a positive feedback with vegetation growing on the banks, and the vegetation increasing the deposition of sediment due to increasing the roughness of the banks. This process contributed to the low erosion rates that were recorded in zones 3 and 4 as compared to April 2016 when the monitoring followed a period of high volume, long duration discharge from the power station.

The short-duration power station discharge events between 2016 and 2018 affected bank toes more than bank faces, with flattening of bank toes via slow seepage processes the most common change recorded by the erosion pins and noted in field observations. These changes remain consistent with the long-term trend in the river of channel widening in alluvial reaches with low-angle bank slopes in the power station operating zone.

The very high natural flow events that occurred in May and July 2016 do not appear to have had a lasting impact on the river based on the erosion pin monitoring results. However, the monitoring was completed 21 months after the event and the low power station usage combined with high natural flows in the intervening period likely promoted deposition on bank faces. The lack of monitoring in zone 5 also prevents conclusions being made about the impacts of the flood as this zone showed the greatest impacts following the last very high flow event in 2007.

4.0 Macroinvertebrates

4.1 Introduction

Macroinvertebrate sampling was conducted in autumn (2-3 March) 2018 using the protocols established under the Basslink Monitoring Program for the Gordon River. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at monitoring sites in the Gordon River between the power station and the Franklin River confluence. This sampling was also conducted at six established reference sites located in tributaries within the Gordon River catchment.

This chapter reports on the results of field sampling for macroinvertebrates in autumn 2018, provides a comparison of these results with those for the pre-Basslink period - years (2001-2005) and describes trends over the monitoring period to date. For analysis, reporting and some interpretation the sites have been loosely grouped into the following zones (Table 4-1):

- zone 1 (Gordon River sites 75,74,72 and 69);
- zone 2 (Gordon River sites 60, 57, 48 and 42); and
- reference river sites (Fr11, FR21, De7, De35, Ma7 and Ja7).

Results were also compared with the autumn season trigger values derived from pre-Basslink period data, as detailed in the Basslink baseline report (Hydro Tasmania 2005a).

4.2 Methods

4.2.1 Sample sites

The locations of the monitoring and reference sites are shown in Figure 4-1 and listed in Table 4-1.

Table 4-1 Sites sampled in 2018 for macroinvertebrates.

River	Site Name	Zone	Site code	Distance from power station (km)	Easting	Northing
Gordon	Gordon R ds Albert Gorge (G4)	1	75	2	412980	5266630
	Gordon R ds Piguenit R (G4A)	1	74	3	412311	5266383
	Gordon R in Albert Gorge (G5)	1	72	5	410355	5266524
	Gordon R us Second Split (G6)	1	69	8	408005	5266815
	Gordon R ds Denison R (G9)	2	60	17	402896	5271211
	Gordon R us Smith R (G10)	2	57	20	402083	5273405
	Gordon R ds Olga R (G11A)	2	48	29	398178	5278476
	Gordon R @ Devil's Teapot (G15)	2	42	35	396804	5282486
Franklin	Franklin R ds Blackman's bend (G19)	Reference	Fr11	-	398562	5291239
	Franklin R @ Flat Is (G20)	Reference	Fr21	-	397939	5296733
Denison	Denison ds Maxwell R (G21)	Reference	De7	-	407206	5272718
	Denison R us Truchanas Reserve (D1)	Reference	De35	-	417400	5282900
Maxwell	Maxwell River (M1)	Reference	Ma7	-	409011	5276009
Jane	Jane R (J1)	Reference	Ja7	-	408100	5300400

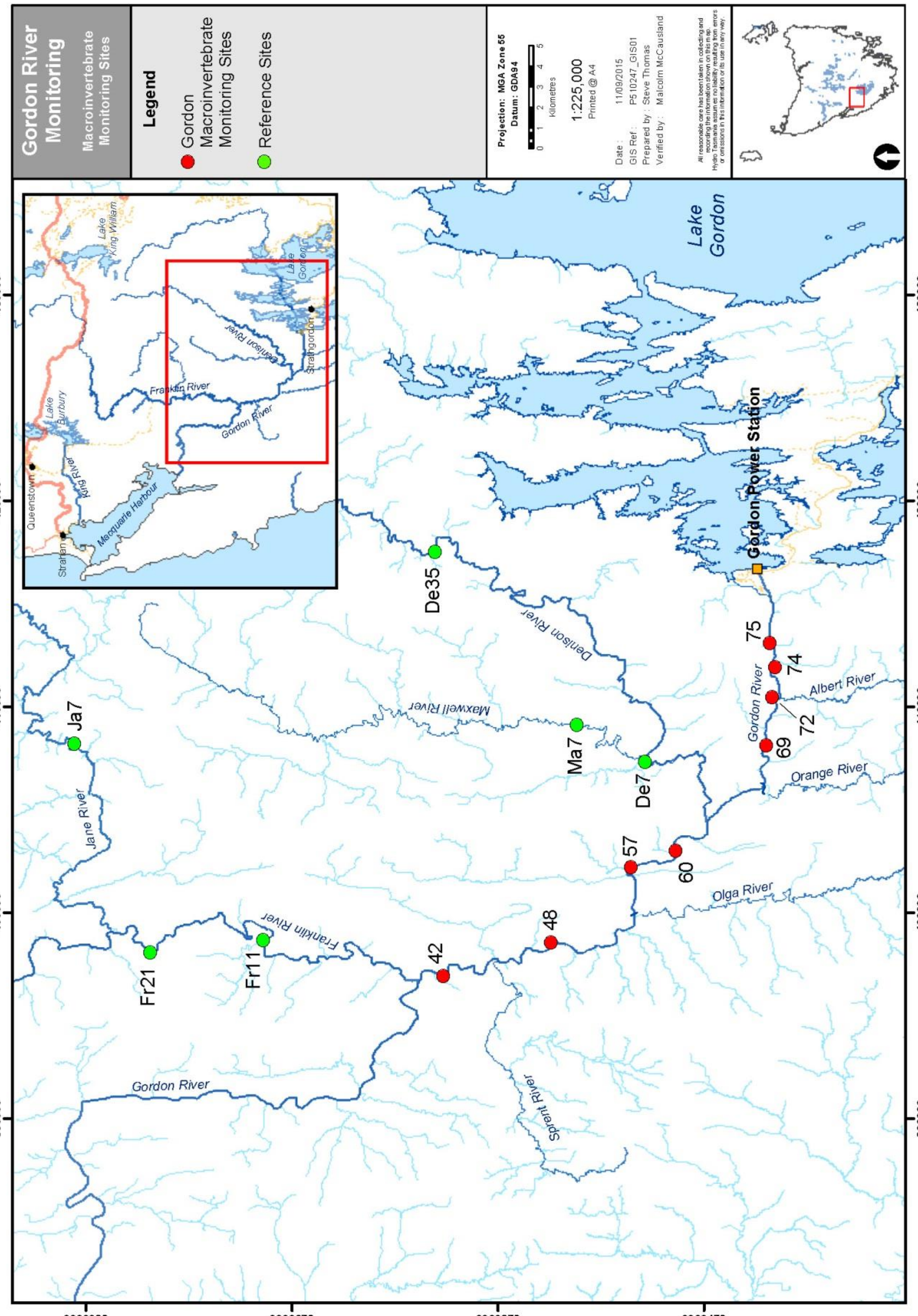


Figure 4-1: Map of locations of macroinvertebrate monitoring sites in the Gordon River and reference sites in the Denison and Franklin river catchments.

4.2.2 Macroinvertebrate sampling

Sampling of Gordon River sites was conducted on 3 March 2018 and reference sites were sampled on 2 March 2018.

Quantitative sampling (surber sampling) and rapid bioassessment kick sampling (RBA) methods were conducted. At each site during low flows riffle habitat was selected and sampled by:

- Collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by disturbing the substrate within the quadrat by hand to a depth of 10cm whereby attached macroinvertebrates are swept into the net; and
- Disturbing substrate by foot and hand immediately upstream of a standard 250 micron kick net over a distance of 10m (RBA).

All surber samples from a site were pooled and preserved (10% formalin) prior to lab processing. Samples were elutriated with a saturated calcium chloride solution and then sub-sampled to 20% (i.e. multiplied by 5 to estimate total sample) using random cell selection from a Marchant box sub-sampler. The subsamples were then hand-picked and all fauna identified to 'family level' with the exception of oligochaetes, Turbellaria, Hydrozoa, Hirudinea, Hydracarina, Copepoda and Tardigrada. Chironomids were identified to sub-family. Identification to genus and species level was conducted for the aquatic insect orders Ephemeroptera, Plecoptera, Trichoptera - the 'EPT' group fauna - using the most current taxonomic keys.

All analyses were conducted using the 20% sub-sample data (with an equivalent benthic surface area of 0.18 m^2).

Two RBA samples were collected at each site. All RBA samples were live-picked on site for 30 minutes using the standard Tasmanian AUSRIVAS live-pick protocol, with pickers maximising the number of taxa recovered for each sample. All taxa were identified to the family taxonomic level as described above.

4.2.3 Habitat variables

A set of standard habitat variables were recorded at each site and a number of variables were recorded from 1:25,000 maps. The habitat variables recorded were:

- per cent cover of substrate types (boulder, cobble, pebble, gravel, sand, silt and clay);
- per cent of site area covered by algae, moss, silt and detritus;
- site depth, temperature, conductivity, wetted width, bankfull width, flow and water clarity;
- extent of aquatic, overhanging, trailing and riparian vegetation; and
- per cent of site in habitat categories (riffle, run, pool and snag habitats).

4.2.4 Analysis

All RBA data was analysed using the autumn season Hydro RIVPACS models developed by Davies et al. (1999), with O/Epa and O/Erk values derived using the RBA macroinvertebrate data in combination with key 'predictor' habitat variables. O/Epa is derived using presence/absence data and models derived from presence/absence reference site data. O/Erk is derived using rank abundance category data and models derived from rank abundance category reference data.

O/Epa and O/Erk scores range between 0 and 1. A zero value represents the condition where no expected taxa are found in the sample and a value of 1.0 represents the condition where all expected taxa are found. This range is divided into impairment bands for reporting purposes:

- D – extremely impaired;
- C – severely impaired;
- B – significantly impaired;
- A – unimpaired, or equivalent to reference; and
- X – more diverse than reference.

Trigger values were those derived for the Basslink program as detailed in the Basslink Baseline Report (Hydro Tasmania, 2005a). Values of each metric derived from the autumn 2018 data were compared against the relevant autumn season trigger values (shown graphically in this report). Plots of temporal trends in metric values and abundances of selected families are also presented.

4.3 Results

4.3.1 Quantitative data

The Autumn 2018 season quantitative surber sample data for family and EPT species are shown in Appendix D.1 and Appendix D.2, respectively.

Diversity in the Gordon River at both family and species level was generally within or close to the range observed in previous years across most sites (Figure 4-2, Figure 4-3). Reduced diversity (<10 families and < 6 EPT species) was observed for most reference sites in the lower Franklin and Denison rivers – this was not unexpected as flows just prior and during sampling had risen substantially after a prolonged period of low summer flows. Under these high water conditions, sampling was restricted in all reference sites, with the exception of the Maxwell River, to the wadeable channel margins. Full recolonisation of these channel margins was unlikely due to recent inundation from higher flow conditions. As a result of the lack of recolonisation, the samples in most reference rivers were of sub-optmal quality.

Total abundances in the Gordon River sites were generally within historic ranges, while the abundance (absolute and proportional) of the EPT group was particularly elevated in zone 1 at sites 75 and 74 (Figure 4-3**,** Figure 4-4) – due to high densities of hydropsychid caddis of the genus Asmicridea (see Appendix D.1 and Appendix D.2). High densities of simuliid (blackfly) larvae were also recorded in the lower Gordon River sites (sites 42 to 60) and several reference rivers (Appendix D.1), indicating a substantial natural recruitment event during summer 2017-18.

The richness of EPT species was similar to the pre-Basslink means in the Gordon River sites in autumn 2018 (Figure 4-3). In contrast, EPT species richness was much lower than the pre-Basslink means at all reference sites because of the sub-optimal flow conditions experienced during sampling.

The community compositional similarity of all zone 1 (sites 69 to 75) Gordon River sites relative to the reference sites was generally similar to the pre-Basslink means, as measured by the mean Bray Curtis Similarity measure of both abundance and presence/absence EPT species data (Figure 4-5**)**. The only exception to this was site 74, which was much less similar to reference sites than pre-Basslink (Figure 4-5, upper plot), due to the very high densities of the hydropsychid caddis *Asmicridea.* All remaining sites (sites 42 to 60) had higher similarity to reference (based on the abundance Bray Curtis index) in autumn 2018 than during pre-Basslink period (Figure 4-5, lower plot).– though this is a direct artefact of the reduced abundances in the sub-optimal reference site samples, rather than an improvement in the Gordon River sites.

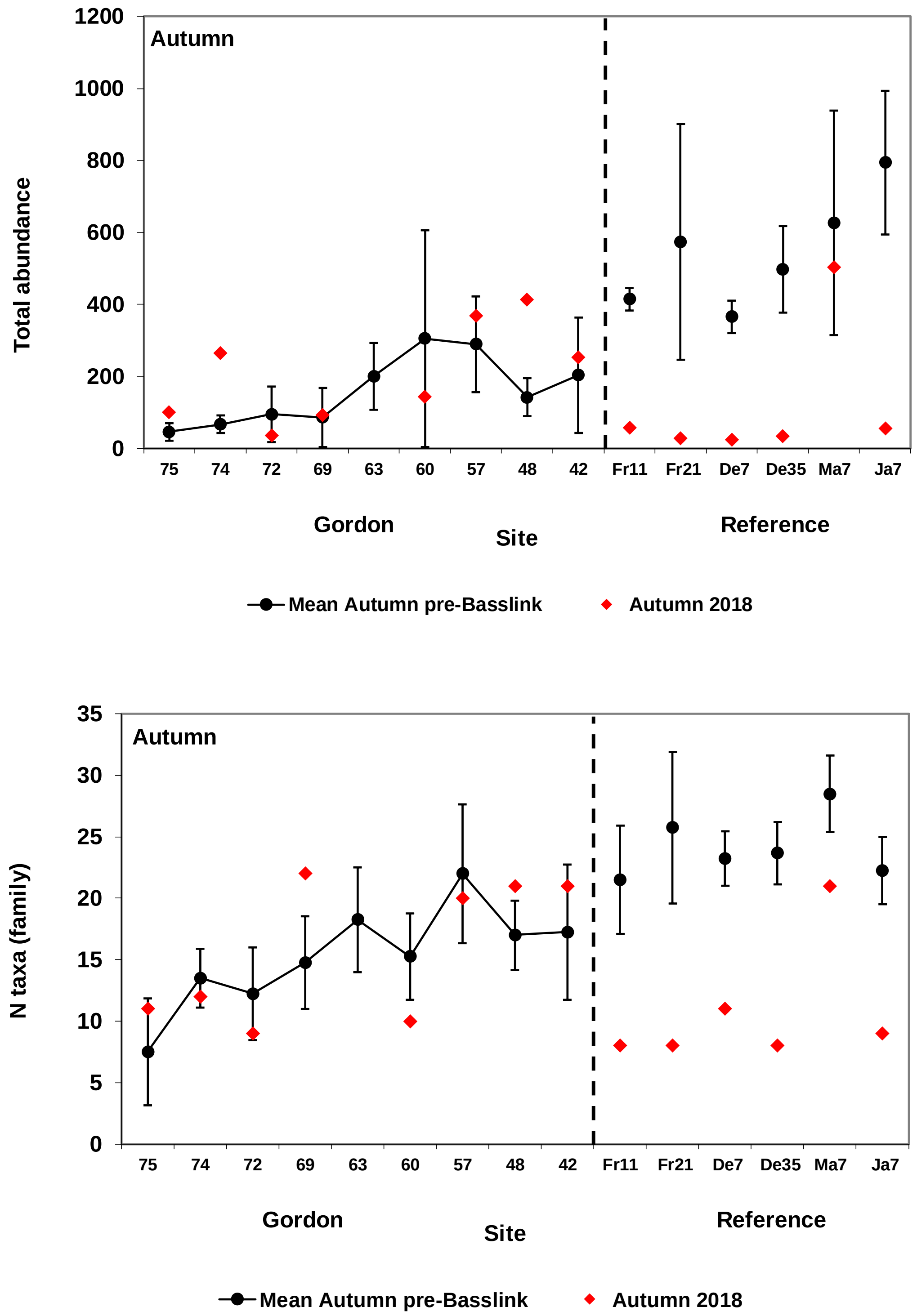


Figure 4-2 Comparison of total abundance of all benthic macroinvertebrates and diversity (number of taxa at family level) for autumn 2018 with autumn values from pre-Basslink years (2002-05). Error bars indicate standard deviations around the pre-Basslink mean. Note that the pre-Basslink values for site 63 are shown for completeness, though sampling at this site was discontinued in 2012.

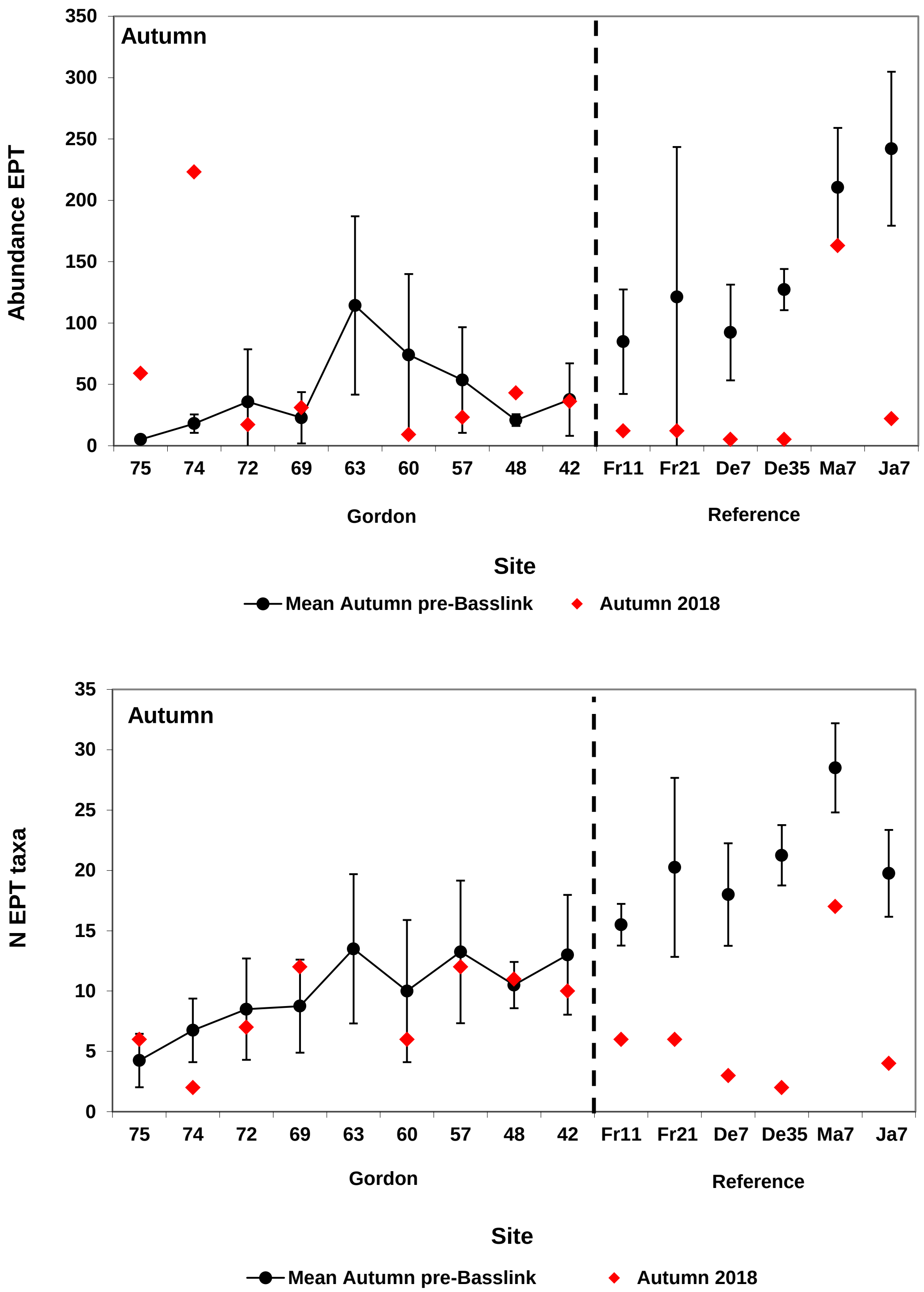


Figure 4-3 Comparison of total abundance and number of benthic EPT taxa (genus and species) for autumn 2018 with autumn values from pre-Basslink years (2002-05). Error bars indicate standard deviations around the pre-Basslink mean. Note that the pre-Basslink values for site 63 are shown for completeness, though sampling at this site was discontinued in 2012.

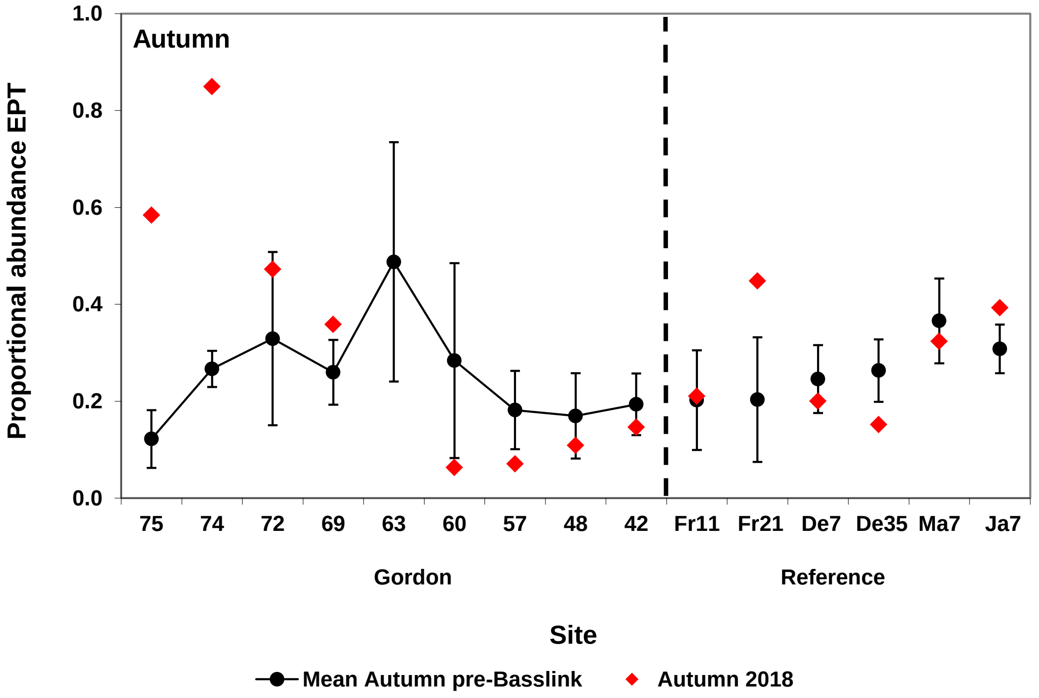
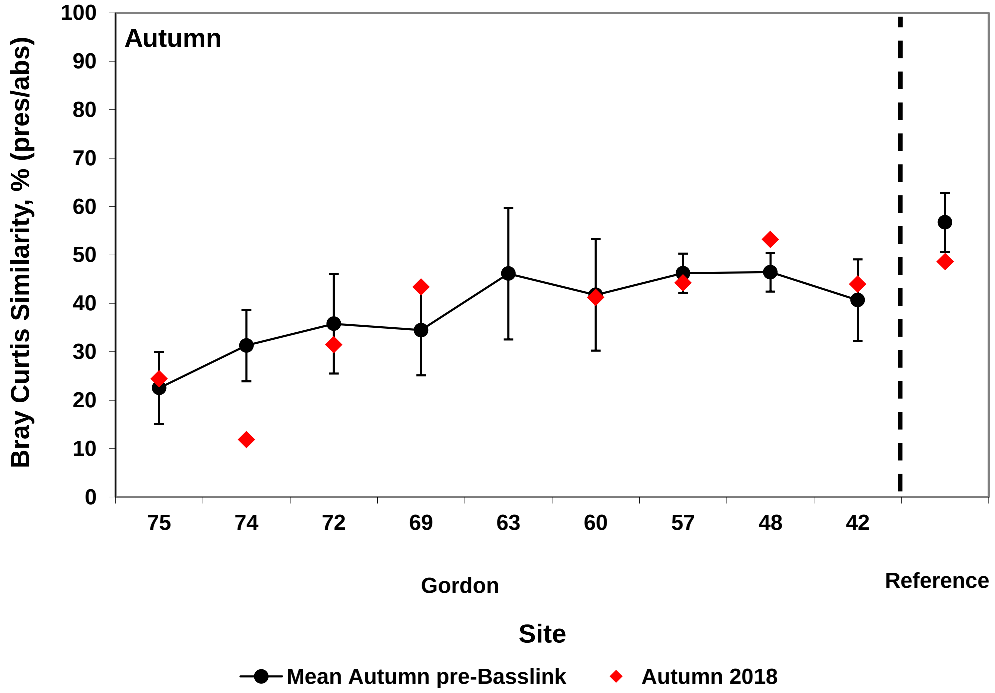


Figure 4-4 Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for autumn 2018 with autumn values from pre-Basslink years (2002-05). Error bars indicate standard deviations around the pre-Basslink mean. Note that the pre-Basslink values for site 63 are shown for completeness, though sampling at this site was discontinued in 2012.



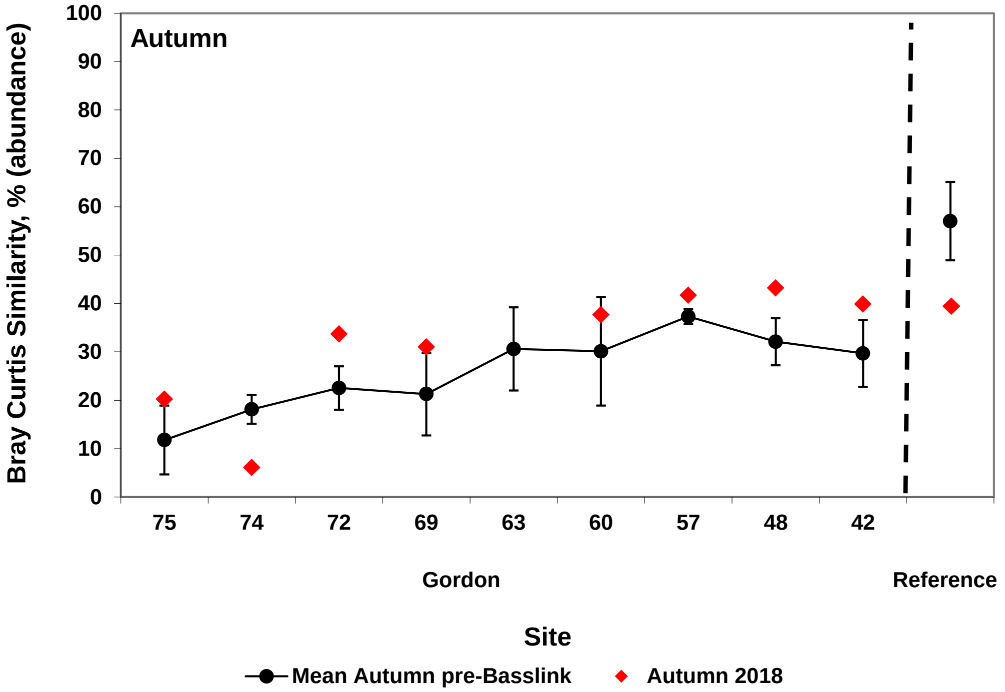


Figure 4-5 Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2018 with autumn values from pre-Basslink years (2002-05). Error bars indicate standard deviations around the pre-Basslink mean. Similarities are calculated with either abundance data (square root transformed) or presence/absence data. Note that the value for reference sites represents the mean of similarities between each reference site and the other reference sites sampled at the same time.

4.3.2 RBA data

The complete autumn season RBA data set is shown in Appendix D.3. O/Epa and O/Erk values and their impairment bands are presented in Figure 4-6 and Table 4-2.

O/Epa and O/Erk values in autumn 2018 fell below pre-Basslink means for all zone 1 Gordon River sites (72 and 74) and for zone 2 sites (42 to 57) (Figure 4-6). O/Epa and O/Erk values in the Gordon were not significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2018 values, $p > 0.03$).

Four of the six reference sites sampled had O/Epa and O/Erk values substantially below pre-Basslink means in autumn 2018 (Figure 4-6). Reference site values for O/Epa and O/Erk for autumn 2018 were significantly lower overall than pre-Basslink means (by t-test of autumn pre-Basslink means with 2018 values, $p < 0.02$ and 0.03 respectively; $df = 5$; $t = 3.54$ and 3.30 respectively). However, these differences are believed to be due to the sub-optimal quality of the reference site samples collected in autumn 2018 (refer to Section 4.3.1).

Table 4-2: O/Epa and O/Erk values for all sites sampled in autumn 2018. Individual replicate and mean values are provided with corresponding impairment bands.

River	Site	Replicate	Autumn 2018			
			O/Epa	Band	O/Erk	Band
Gordon R	75	1	0.88	A	0.61	B
		2	1.17	A	0.76	B
		Mean	**1.03**	**A**	**0.68**	**B**
	74	1	0.78	B	0.50	B
		2	0.78	B	0.50	B
		Mean	**0.78**	**B**	**0.50**	**B**
	72	1	0.78	B	0.66	B
		2	0.98	A	0.81	B
		Mean	**0.88**	**A**	**0.73**	**B**
	69	1	0.78	B	0.68	B
		2	0.98	A	0.78	B
		Mean	**0.88**	**A**	**0.73**	**B**
	60	1	0.78	B	0.71	B
		2	0.88	A	0.76	B
		Mean	**0.83**	**A**	**0.73**	**B**
	57	1	1.47	X	1.06	A
		2	1.27	X	1.01	A
		Mean	**1.37**	**X**	**1.03**	**A**
	48	1	1.17	A	0.90	A
		2	1.17	A	0.95	A
		Mean	**1.17**	**A**	**0.93**	**A**
	42	1	1.27	X	0.91	A
		2	1.08	A	0.65	B
		Mean	**1.17**	**A**	**0.78**	**B**
Franklin R	Fr11	1	1.37	X	0.91	A
		2	1.27	X	0.71	B
		Mean	**1.32**	**X**	**0.81**	**B**
	Fr21	1	0.78	B	0.60	B
		2	0.69	B	0.45	B
		Mean	**0.73**	**B**	**0.53**	**B**
Denison R	De7	1	0.98	A	0.81	B
		2	0.59	B	0.61	B
		Mean	**0.78**	**B**	**0.71**	**B**
	De35	1	1.17	A	0.91	A
		2	0.88	A	0.76	B
		Mean	**1.03**	**A**	**0.83**	**A**
Maxwell R	Ma7	1	0.88	A	0.71	B
		2	0.98	A	0.66	B
		Mean	**0.93**	**A**	**0.68**	**B**
Jane R	Ja7	1	1.76	X	1.26	X
		2	1.47	X	1.26	X
		Mean	**1.61**	**X**	**1.26**	**X**

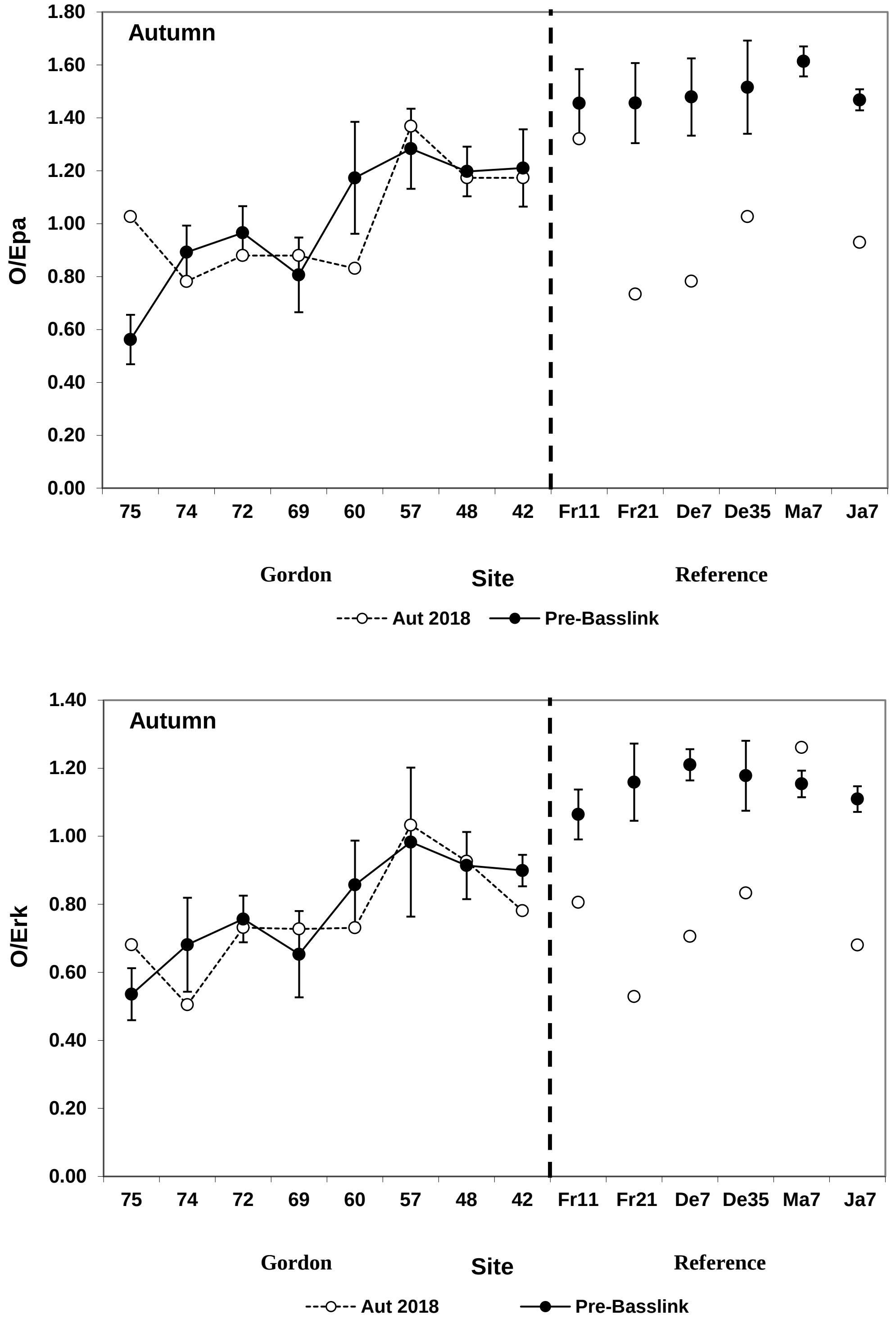


Figure 4-6 Comparison of O/Epa and O/Erk values for autumn 2018 with values from pre-Basslink (2002-05) years. Error bars indicate standard deviations around the pre-Basslink mean. Note that the OEpa point for the Maxwell River site (Ma7) was measured at the pre-Basslink mean, and is not visible on the graph.

4.3.3 Summary

Overall, the diversity at family level and the abundance and diversity of EPT species, as well as measures of compositional similarity to reference, were similar to pre-Basslink values for Gordon River sites in autumn 2018.

The previously observed decline in number and relative abundance of expected families (O/Epa and O/Erk) in the Gordon River, compared with pre-Basslink values, was reversed in autumn 2018.

Substantially reduced abundances and diversity in the reference sites was observed in autumn 2018, though this was likely due to sub-optimal sampling conditions related to rapidly rising river levels prior to sampling and is not considered to be a genuine decline in macroinvertebrate condition.

A substantial change noted in autumn 2016 – a major increase in abundance of the hydropsychid Asmicridea caddis in zone 1 – has again been observed in autumn 2018. This is likely due to the persistent periods with base flows < 50 m^3s^{-1} and fewer high peaking flows in zone 1, as compared to historic flow conditions, coupled with natural organic (‘filterable food’) inputs from the zone 1 tributaries.

High densities of simuliid (blackfly) larvae in the lower Gordon sites, coupled with relatively high representation in reference site samples (despite the sub-optimal nature of these latter samples) is likely due to a substantial natural recruitment event, favoured by the warm, dry conditions during the summer of 2017-18 (as observed in 2015-16).

4.4 Comparisons with Triggers

4.4.1 Results

Nine metrics were developed for assessing the degree of any changes in benthic macroinvertebrates in the Gordon River due to Basslink operations. These metrics are grouped into five overall components as outlined in Table 4-3.

Table 4-3 Macroinvertebrate components and metrics identified for assessing change.

Components	Metrics
Community Structure	Bray Curtis (abundance) O/Erk
Community Composition	Bray Curtis (pres/abs data) O/Epa
Taxonomic richness	N Taxa (fam) N EPT Species
Ecologically significant species	Proportion of total Abundance as EPT Abundance EPT
Biomass / productivity	Total abundance

Trigger values for these biological metrics were established based on the 95th percentile of pre-Basslink values. These trigger values are used in reporting on whether limits of acceptable change (LOAC) have been exceeded post-Basslink. Triggers were developed for each individual site in the Gordon River, as well as for the entire river ('whole of river', WOR) and zones within the river. Two zones have been described for benthic macroinvertebrates:

- zone 1-upstream of the Denison River junction (incorporating sites 69 to 75); and
- zone 2-downstream of the Denison River junction (incorporating sites 42 to 60).

Values of all metrics for autumn 2018 are shown in Appendix D.4. Plots of the trigger levels for each metric are shown in Figure 4-7 to Figure 4-11 along with the value for the metric recorded in autumn 2018 at whole of river (WOR) and zone levels.

4.4.2 Trigger status

The following section summarises and comments on the observations for autumn 2018 in comparison with the biological trigger values.

Community Structure

Bray Curtis (abundance): All values fall within trigger bounds (Figure 4-7).

Comment – Compliant with limits of acceptable change.

O/Erk: All values fall within trigger bounds (Figure 4-7**)**
Comment – Compliant with limits of acceptable change.

Community Composition

Bray Curtis (pres/abs data): All values fall within trigger bounds (Figure 4-8).

Comment – Compliant with limits of acceptable change.

O/Epa: All values fall within trigger bounds (Figure 4-8).

Comment – Compliant with limits of acceptable change.

Taxonomic richness

N Taxa (fam): Values for Zones 1 and 2 was within trigger bounds (Figure 4-9), however, the WOR case was just above the upper trigger bound.

Comment – Overall within limits of acceptable change, but with a slight exceedance for the WOR case.

N EPT Species: All values was within the trigger bounds.

Comment – Compliant with limits of acceptable change.

Ecologically significant species

Proportion of total abundance as EPT: Values for WOR and zone 2 were within trigger bounds (Figure 4-10). The value for zone 1 was once again well above the upper trigger bound, due to high densities of the hydropsychid caddis species Asmicridea sp. AV1.

Comment – Within or exceeding limits of acceptable change, with the zone 1 exceedance not of environmental concern.

Abundance EPT: Values exceeded the upper trigger bound for WOR and zone 1 (Figure 4-10**).** Very large exceedances at WOR and in zone 1 are due to sustained high densities of the hydropsychid caddis species Asmicridea sp. AV1 – as observed in 2016.

Comment – Large exceedances which represent a significant compositional shift, but which are not of environmental concern.

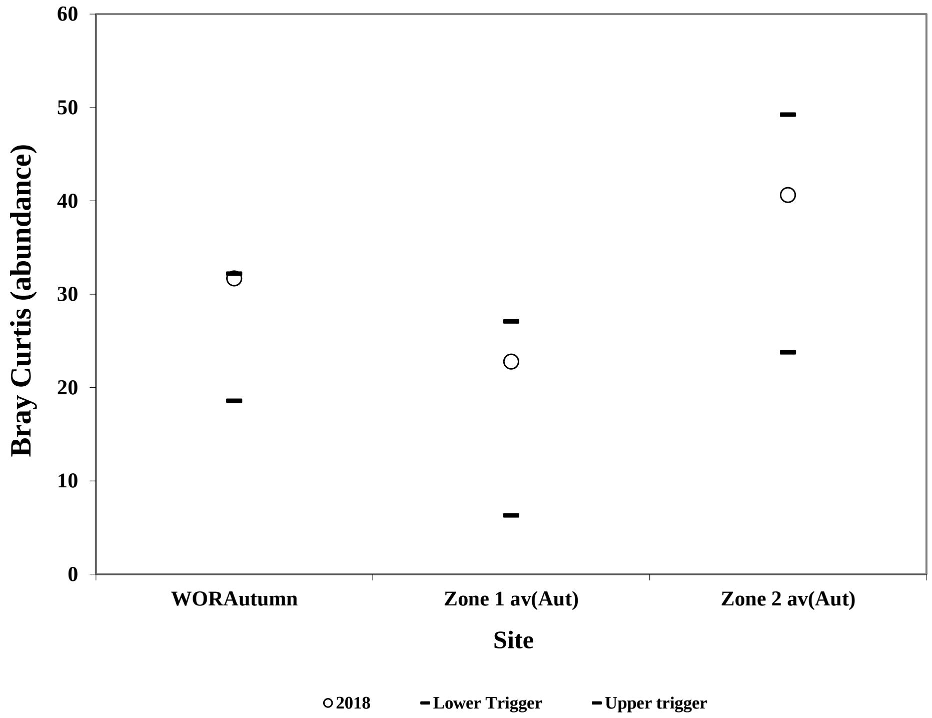
Biomass/productivity

Total abundance: Values was well within trigger bounds for zones 1 and 2 (Figure 4-11**).** The value for the WOR case slightly exceeded the upper trigger bounds. This is caused by increased densities of hydropsychid caddis Asmicridea sp. AV1 in zone 1 (due to more favourable, stable flow conditions) and of blackfly (simuliid) larvae in zone 2 (due to natural causes).

Comment – Within limits of acceptable change for both zones. WOR exceedance not of environmental concern.

Overall Summary

Status relative to trigger levels in autumn 2018 for the Gordon were very similar to those observed in autumn 2016, with no exceedances of any substance or environmental concern relative to the pre-Basslink conditions (2002-2005).



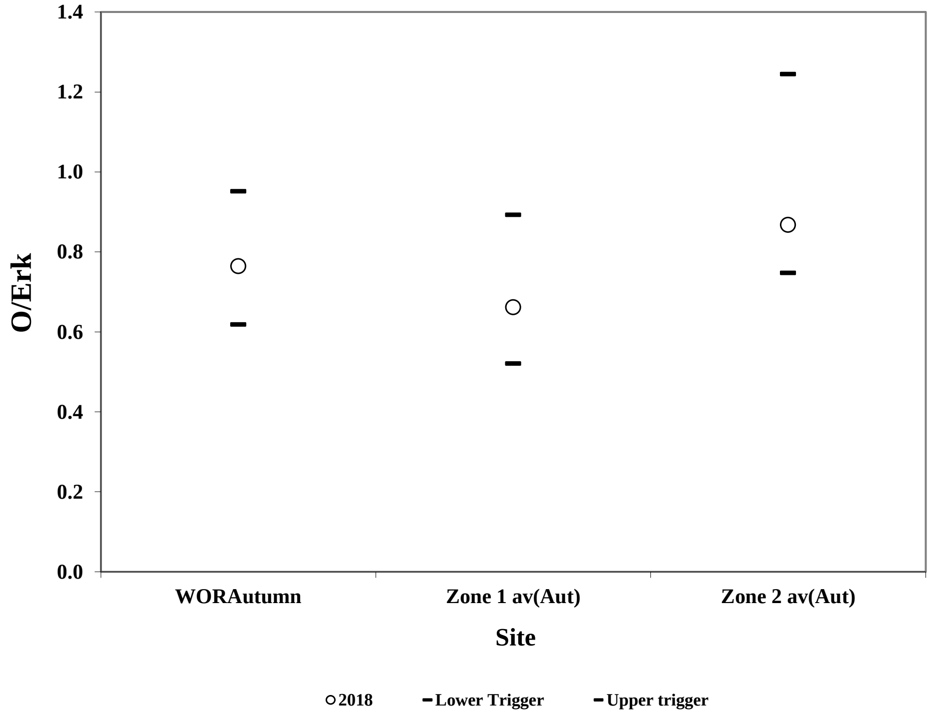


Figure 4-7 Community structure metric values for autumn 2018 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.

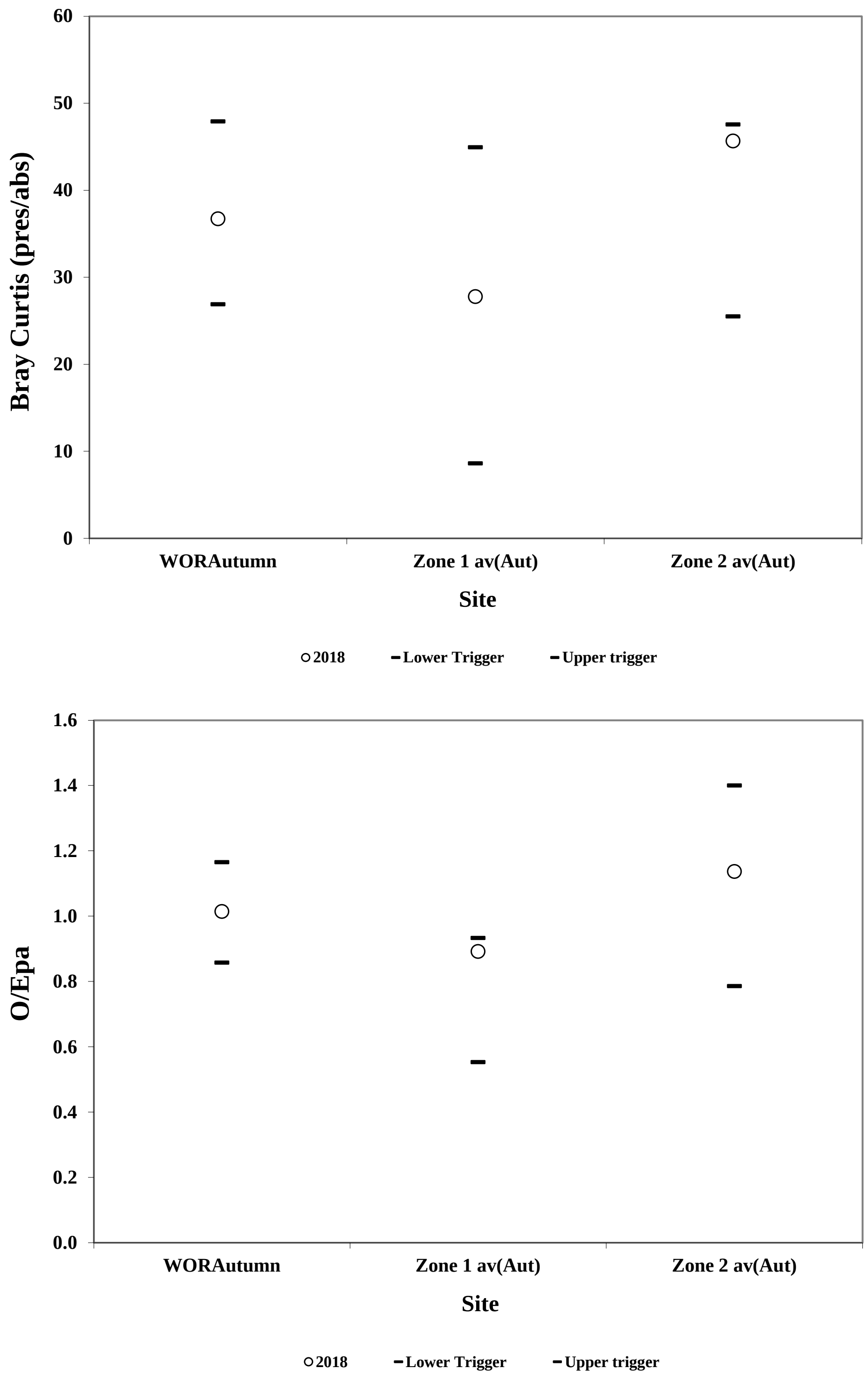
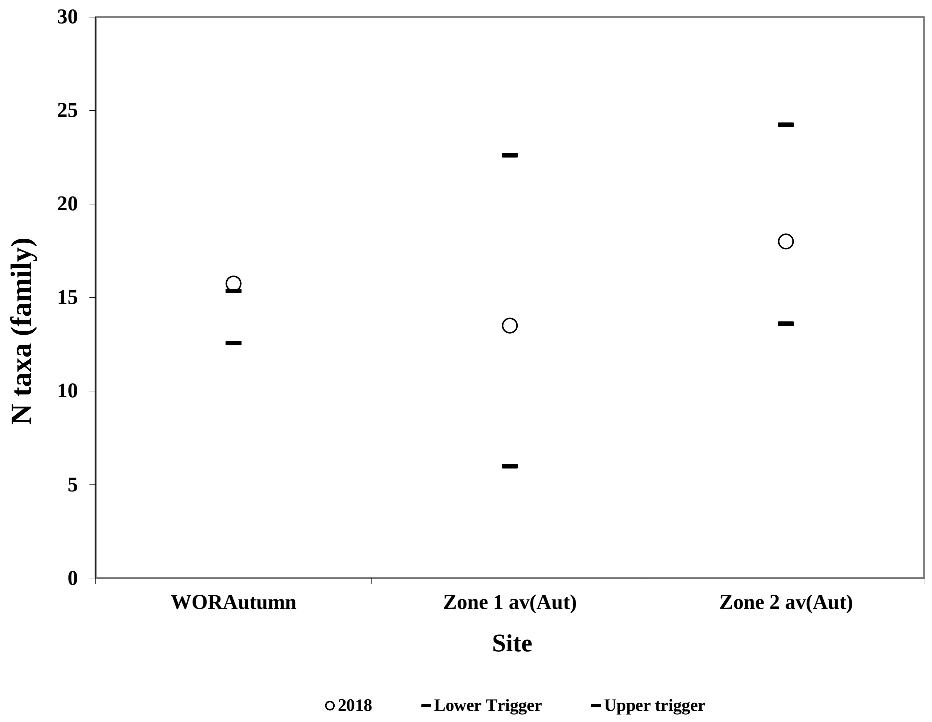


Figure 4-8 Community Composition metric values for autumn 2018 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), Zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.



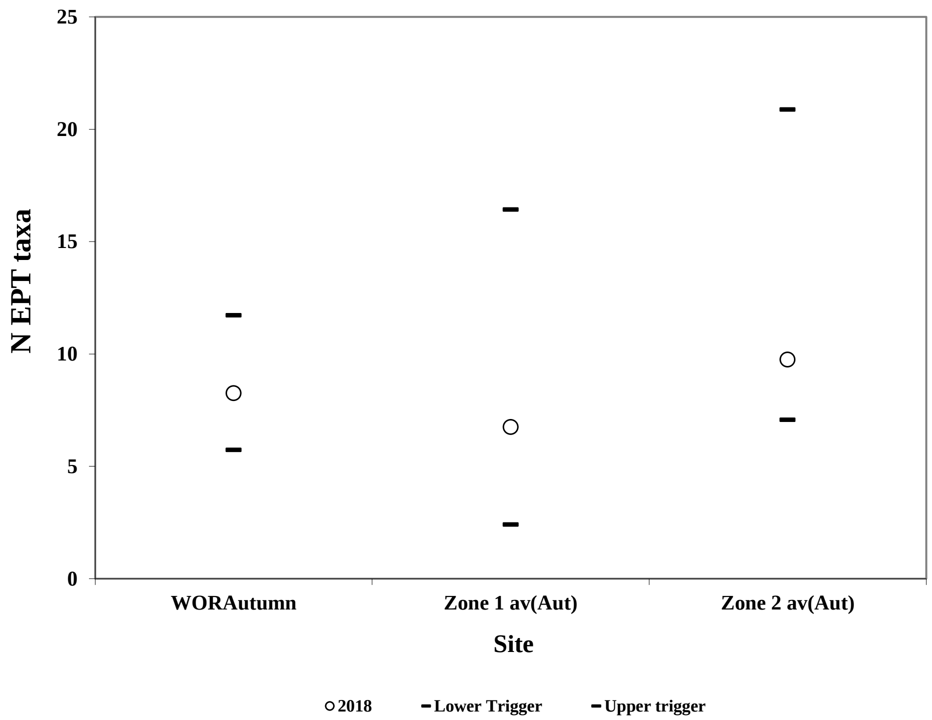
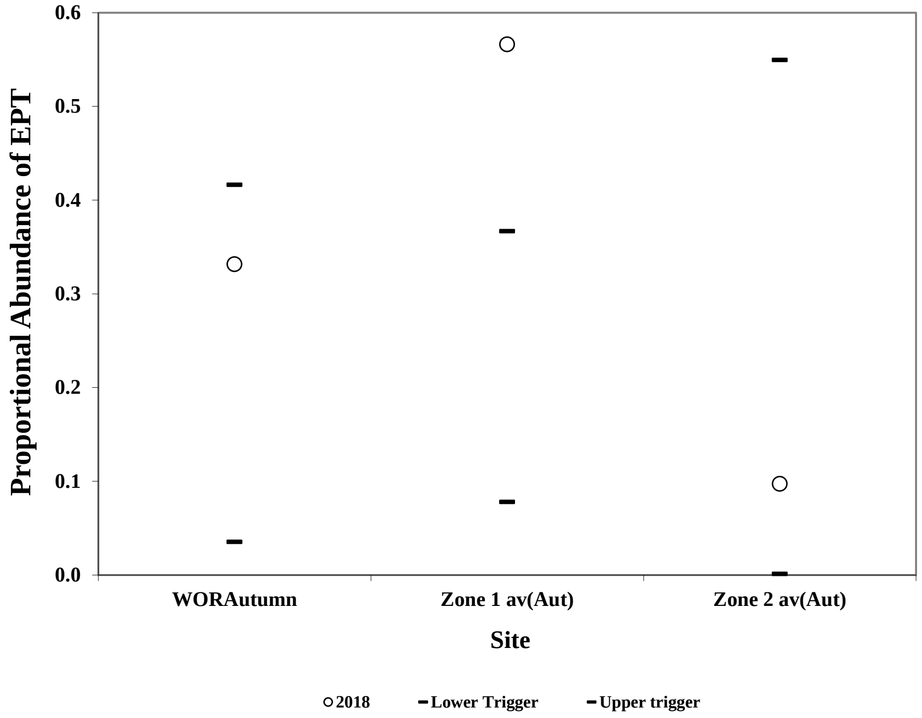


Figure 4-9 Taxonomic Richness metric values for autumn 2018 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.



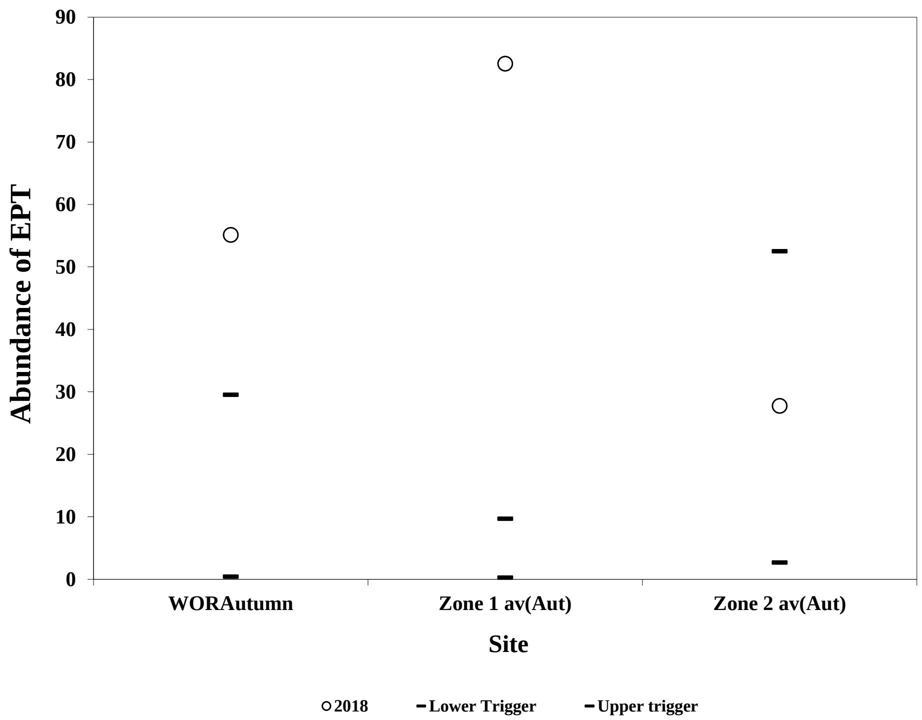


Figure 4-10 Ecologically significant species metric values for autumn 2018 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.

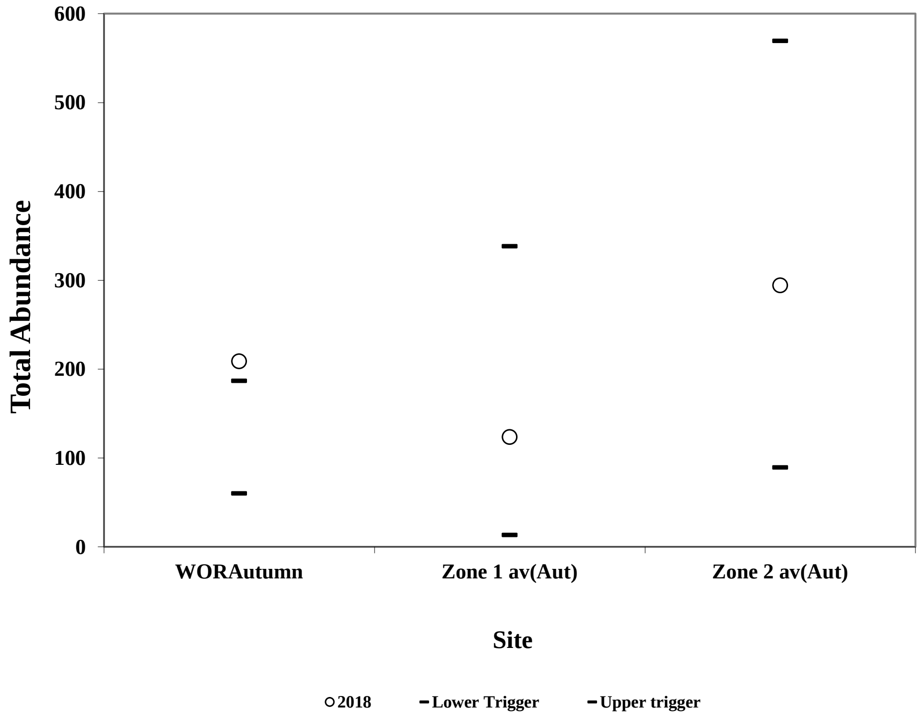


Figure 4-11 Biomass/Productivity metric values for autumn 2018 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (autumn season), zones 1 and 2 (autumn season). Trigger values based on the 95 percentile of pre-Basslink data.

4.5 Long-term trends

4.5.1 Univariate indicators

Trends in all metrics are shown in Figure 4-12 to Figure 4-16. As in previous years, the value of all metrics has been predominantly highest in reference sites, lowest in zone 1 and intermediate in zone 2. Most metrics show no overall monotonic trend over the entire sampling period in the Gordon River (with the possible exception of reference sites prior to 2016), and are broadly consistent in values with time (with zone 1 being a recent exception). Some recent post-Basslink trends are however apparent.

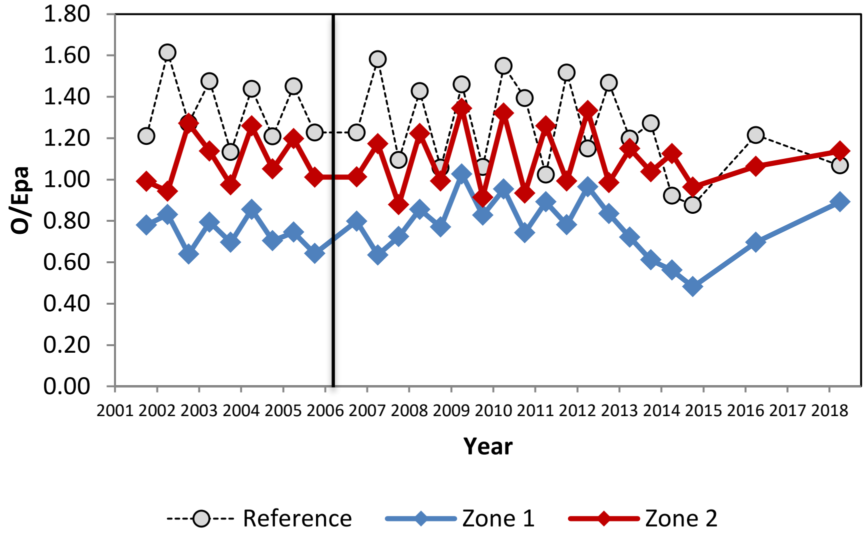
Values of O/Epa, O/Erk and the number of EPT species and their proportional abundance in 2013 - 2014 had fallen to levels not experienced previously (Figure 4-12, Figure 4-13, Figure 4-14). The zone 1 values for O/Epa showed a slight recovery in autumn 2016 from the low 2013-14 levels, while the number of EPT species remained low. O/Erk values had declined further in autumn 2016 in zone 1. All of these metrics recovered in value in autumn 2018, back to within historic and pre-Basslink ranges.

By contrast, the proportional and absolute abundance of EPT species increased dramatically in zone 1 in autumn 2016 and this is still evident in autumn 2018 (Figure 4-14). This is due to a rise in abundance of the filter feeding hydropsychid caddis Amsicridea sp. AV1, whose abundance is greatly favoured by reduced occurrence of flow peaking, sustained baseflows and a steady supply of organic food (from tributary inflows).

No substantive overall post-Basslink changes in metric values have been observed in zone 2. The decline in number of EPT species observed in spring 2014 has been reversed in autumn 2016 and 2018 (Figure 4-14). The abundance of EPT species in zone 2 increased in autumn 2016 relative to the lower levels observed in 2013-14, though fell again in 2018 (Figure 4-14).

Zone 2 continues to be biologically intermediate between zone 1 and the reference rivers in macroinvertebrate composition and temporal dynamics, reflecting the substantial influence of the Denison River and other tributary rivers. This is also reflected in its Bray Curtis similarity to reference rivers which are generally higher than for zone 1 (Figure 4-15). This greater similarity to reference is particularly reflected in the year to year changes in abundance of simuliid larvae, which are highly similar in zone 2 and the reference rivers. This latter phenomenon indicates that some of the larger scale macroinvertebrate community dynamics occurring in the larger Franklin-Gordon catchment still persist in the lower Gordon under the post-Basslink operation of the Gordon power station. It should be noted that these conclusions are slightly masked in autumn 2018 by the sub-optimal quality of the reference river samples.

Metric values for reference rivers in 2018 showed some substantial changes relative to the variability in these measures over the entire monitoring period (Figure 4-12 to Figure 4-16). The changes observed across the metrics are indicative of the poorer quality samples collected in autumn 2018.



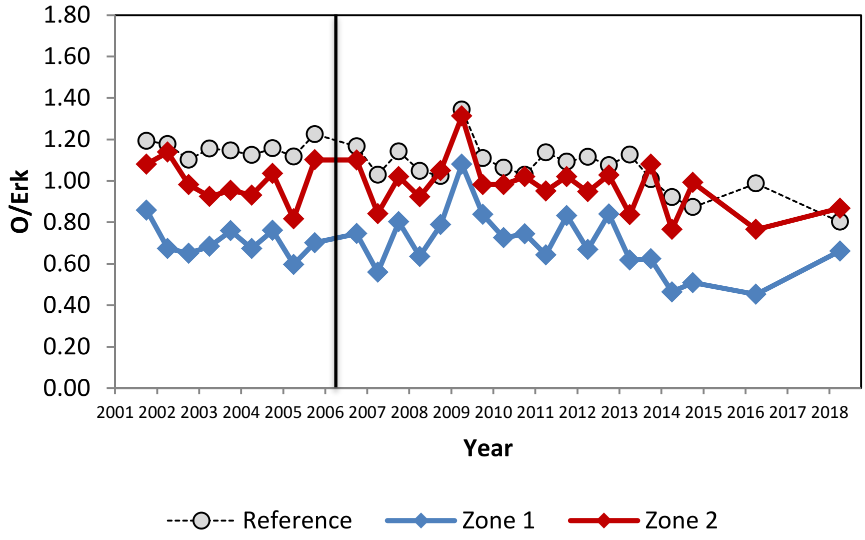
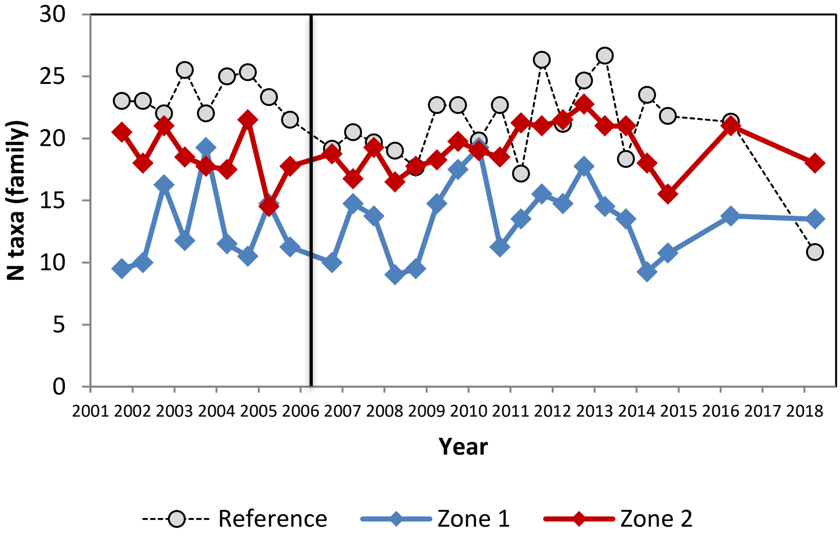


Figure 4-12 Mean O/Epa and O/Erk metric values for each zone in the Gordon river and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.



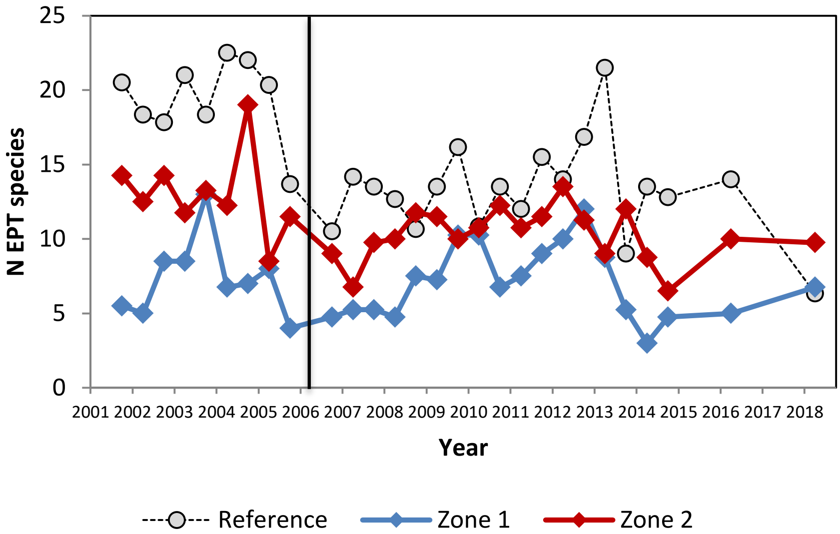


Figure 4-13 Mean N taxa (family) and N EPT species metric values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

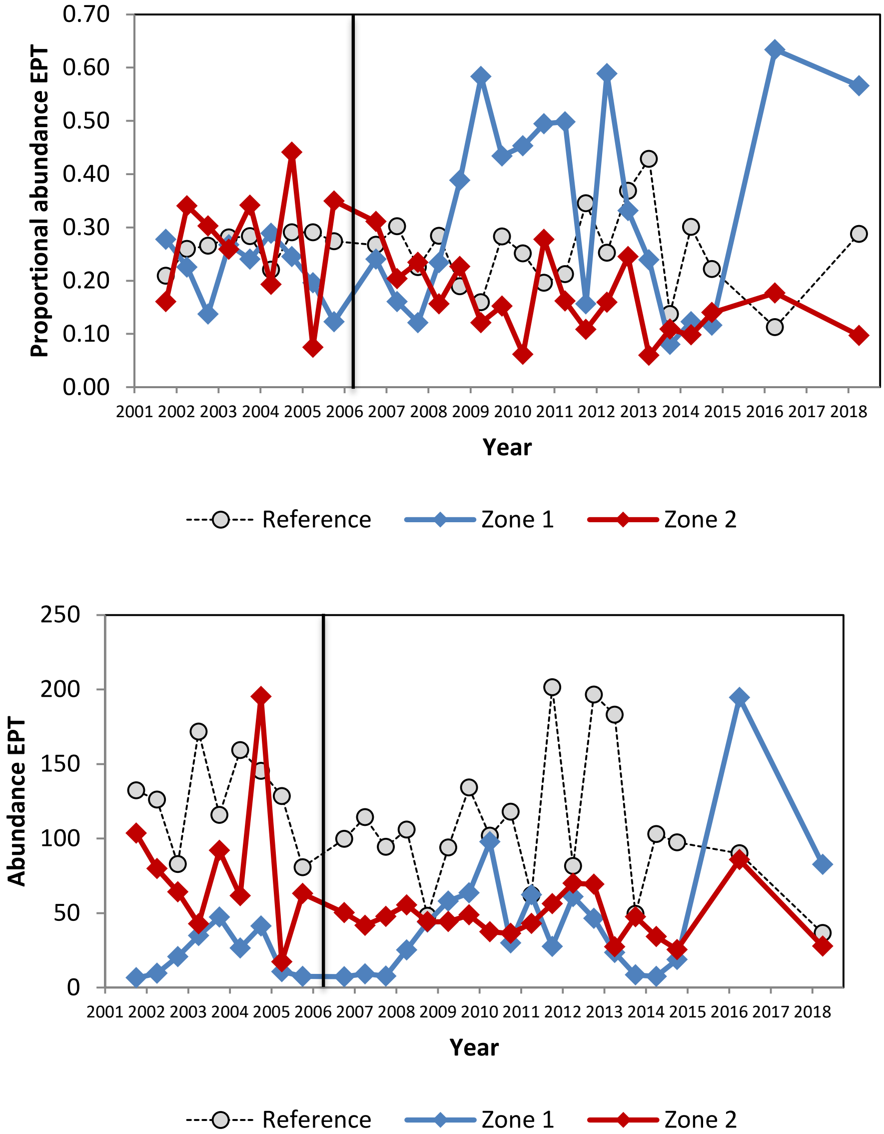


Figure 4-14 Mean Proportional abundance and absolute abundance of EPT taxa metric values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

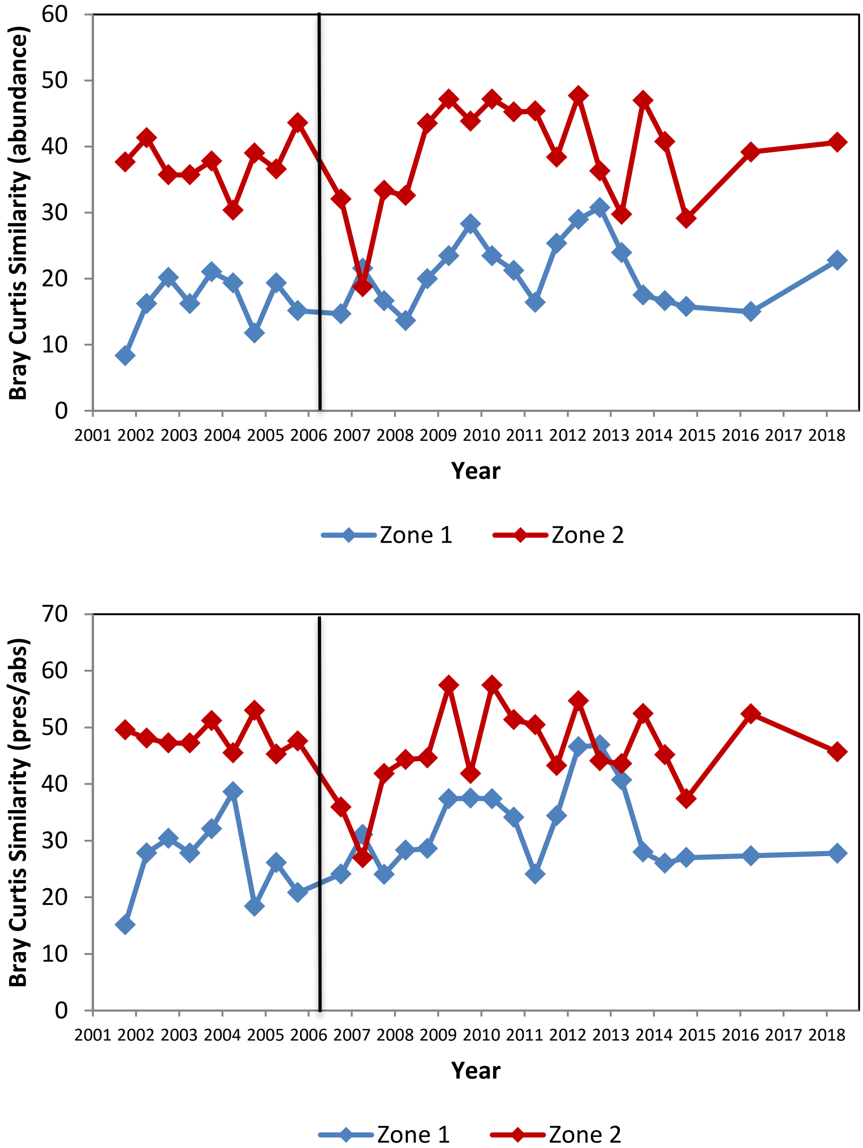


Figure 4-15 Mean Bray Curtis Similarity metric values between each zone in the Gordon River and the reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

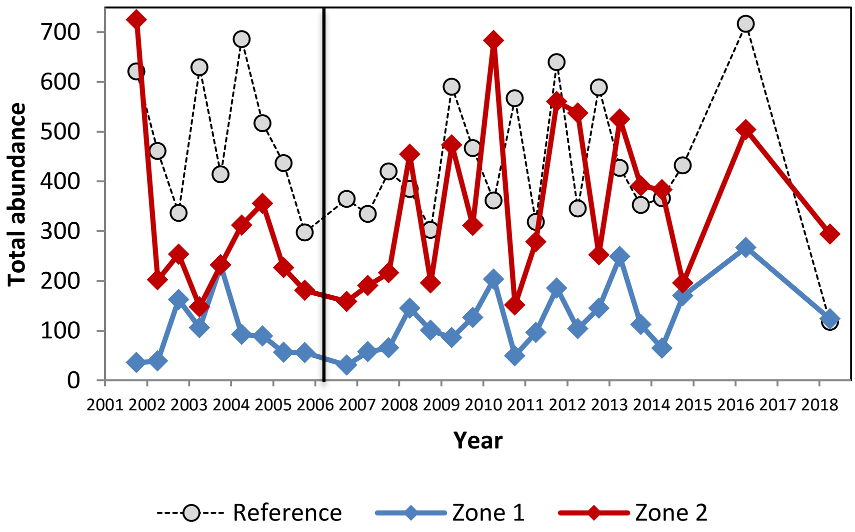


Figure 4-16 Mean total benthic macroinvertebrate abundance metric values for each zone in the Gordon River and reference rivers on each sampling occasion. Vertical line indicates initiation of Basslink operations.

4.6 Conclusion

Sampling was conducted successfully according to the requirements of the Gordon River monitoring program for all sites.

The current status for the twelfth year of the post-Basslink period is:

- five of the nine macroinvertebrate metrics had all values within trigger bounds;
- two metrics (No. of taxa, Total abundance) were slightly above their upper trigger bounds;
- a further two metrics (EPT proportional abundance, EPT total abundance) had substantial upper trigger bound exceedances due to increased hydropsychid caddis densities.

The latter two exceedances reflect a positive response to sustained low power station discharges during 2016-17 and 2017-18 and are not of ecological concern. They can be regarded as representing improvement in biological condition relative to pre-Basslink conditions, due to a spike in the abundance of the hydropsychid caddis *Asmicridea* sp. AV1. This is directly related to sustained periods of low flow < 50 m^2s^{-1} during the year before sampling in autumn 2018, combined with reduced frequency of peaking events up to 200 cumecs. These more stable flow conditions are favourable for this species.

Inter-annual variations in power station release patterns, particularly the incidence of sustained peaking and high flows, continue to drive swings in metric values. Overall, the condition of macroinvertebrate communities has been relatively stable between 2015-16 and 2017-18, reversing the previous substantial decline observed between 2012 and 2014.

5.0 References

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6.0 Appendices

A Appendix A: Power station discharges graphed per month

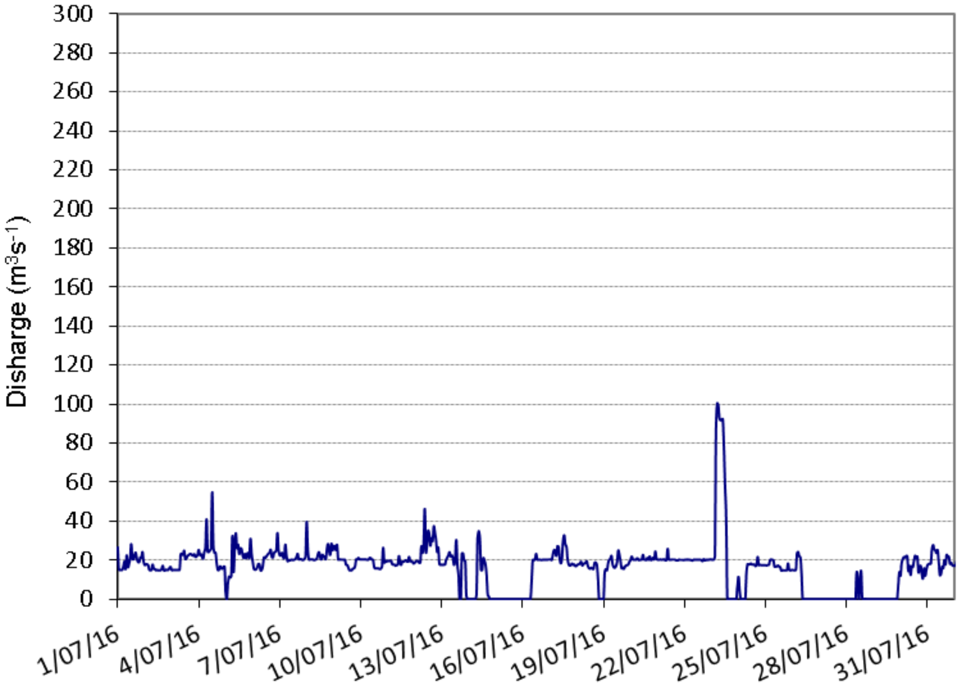

Figure A–1: Gordon Power Station discharge (hourly data) for July 2016.

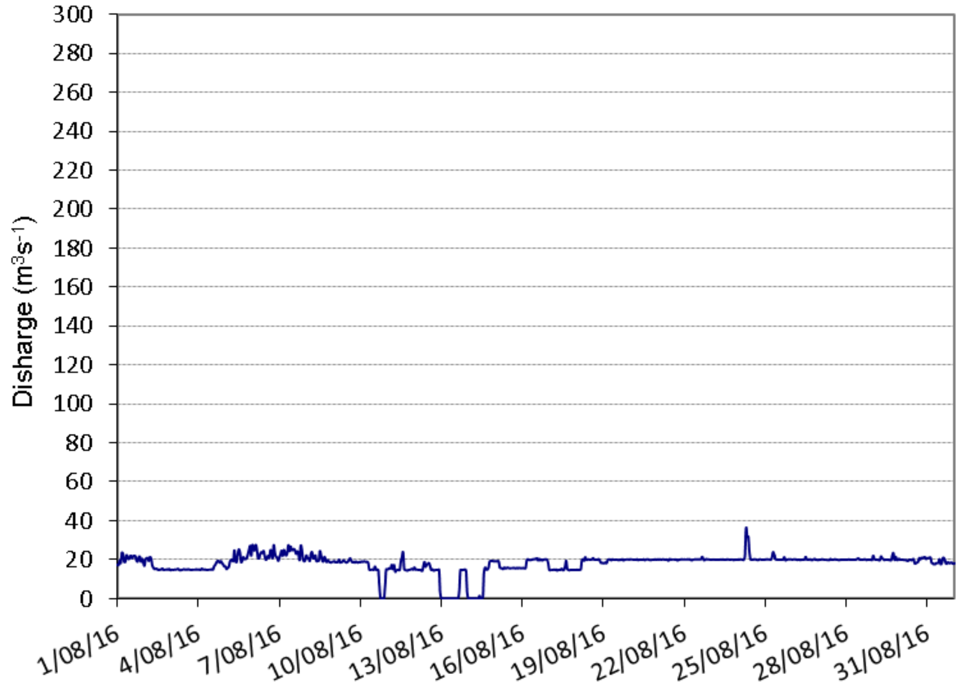

Figure A–2: Gordon Power Station discharge (hourly data) for August 2016.

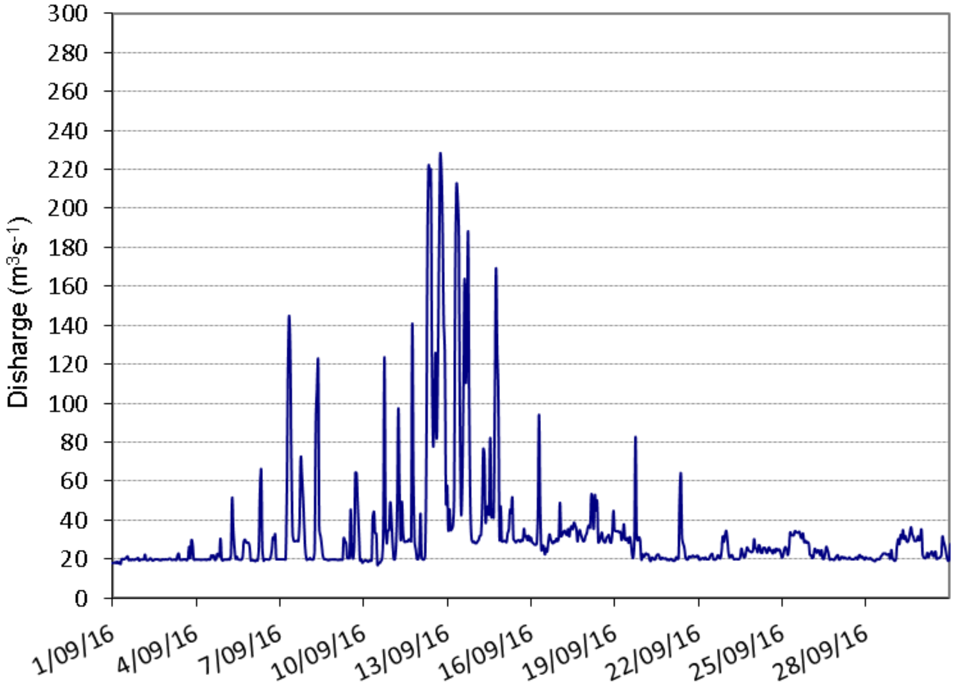

Figure A–3: Gordon Power Station discharge (hourly data) for September 2016.

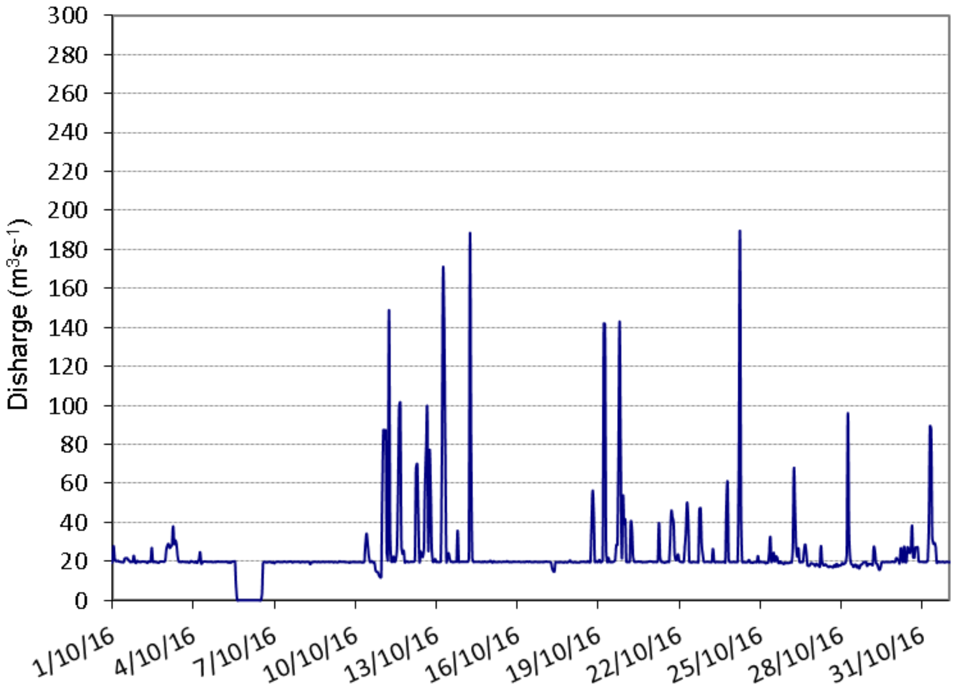

Figure A–4: Gordon Power Station discharge (hourly data) for October 2016.

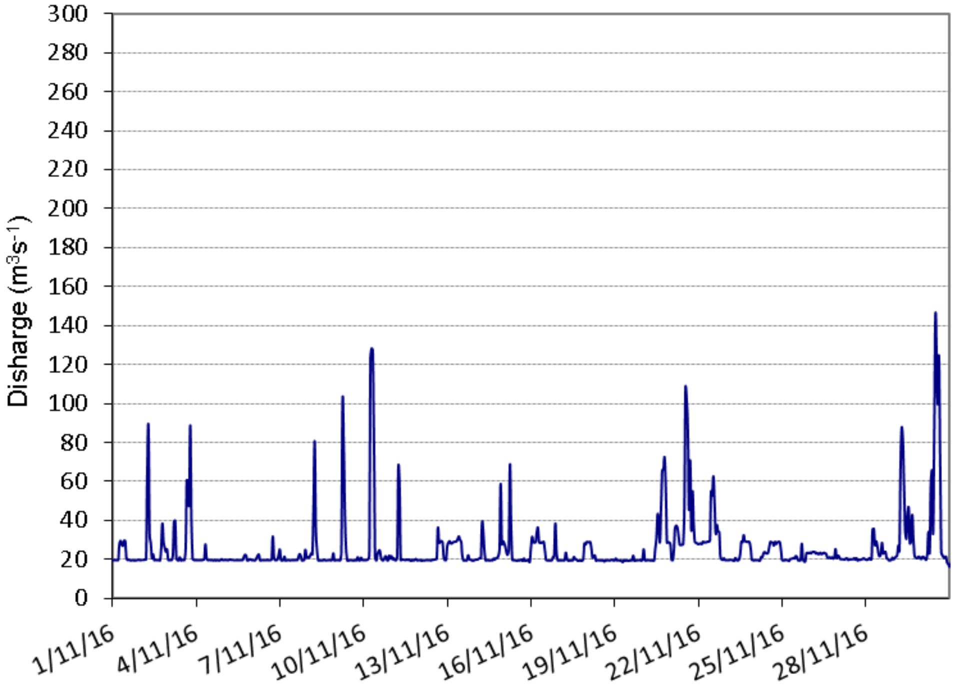

Figure A–5: Gordon Power Station discharge (hourly data) for November 2016.

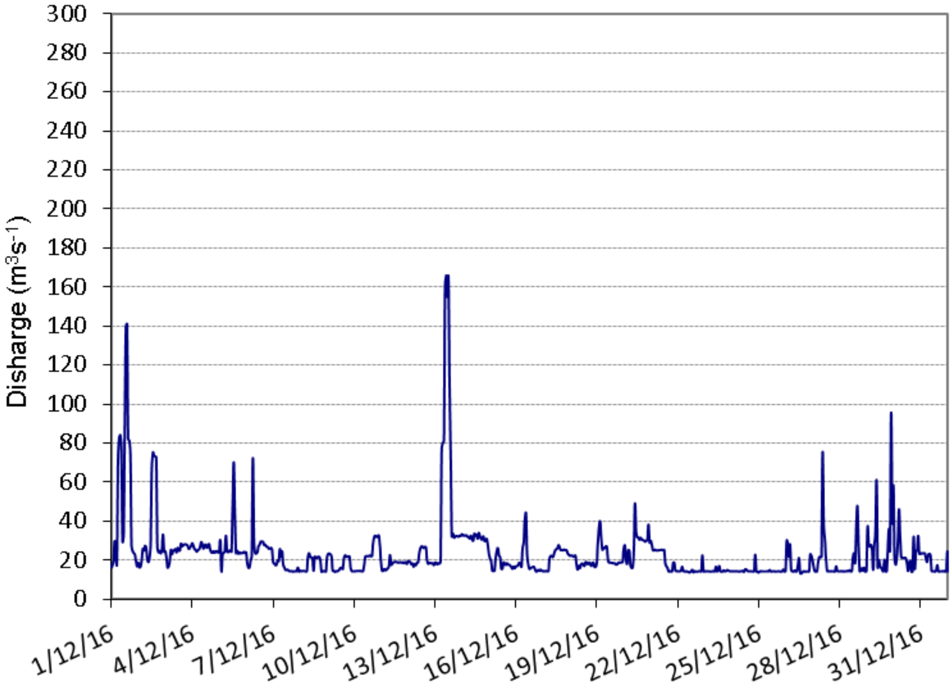

Figure A–6: Gordon Power Station discharge (hourly data) for December 2016.

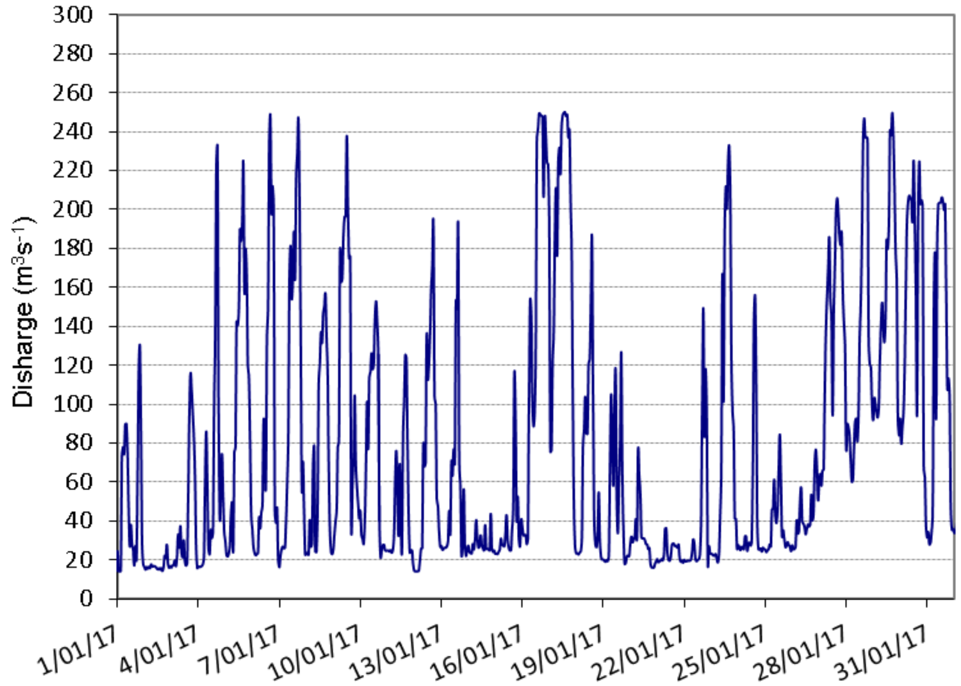

Figure A–7: Gordon Power Station discharge (hourly data) for January 2017.

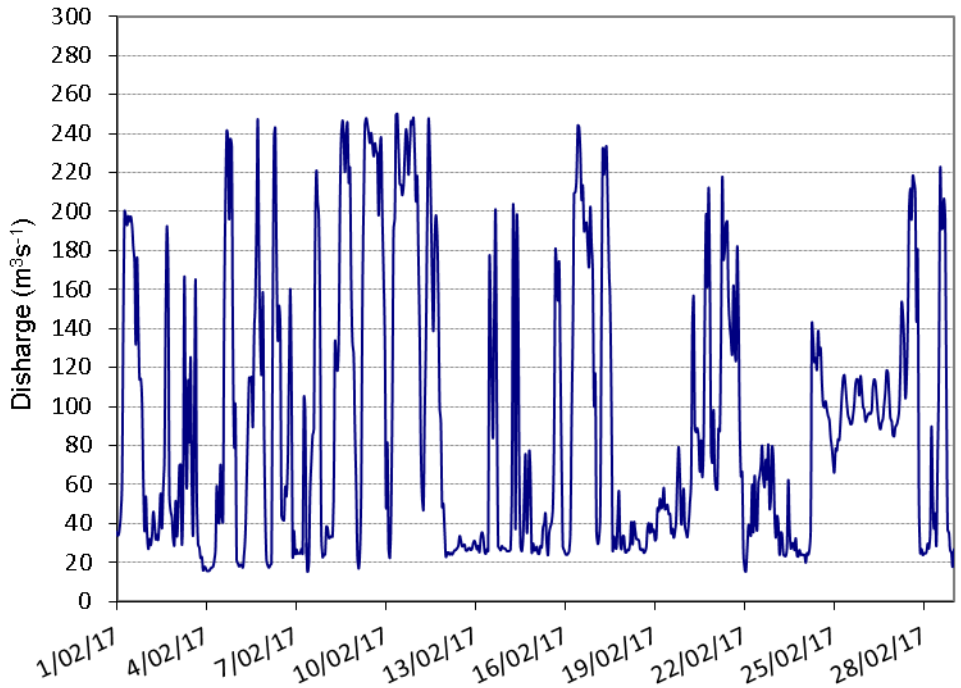

Figure A–8: Gordon Power Station discharge (hourly data) for February 2017.

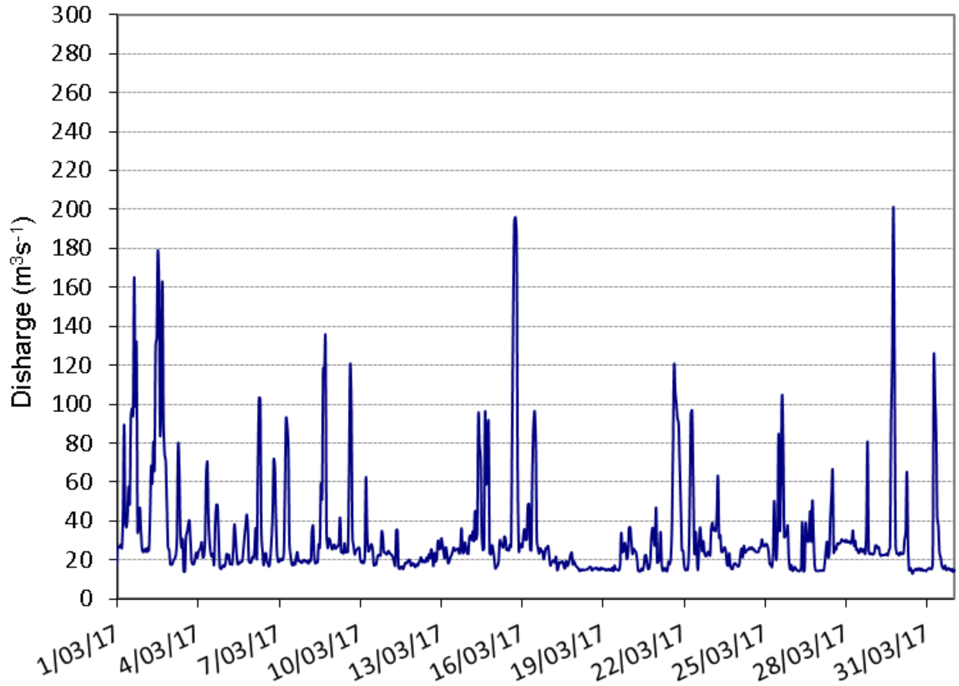

Figure A–9: Gordon Power Station discharge (hourly data) for March 2017.

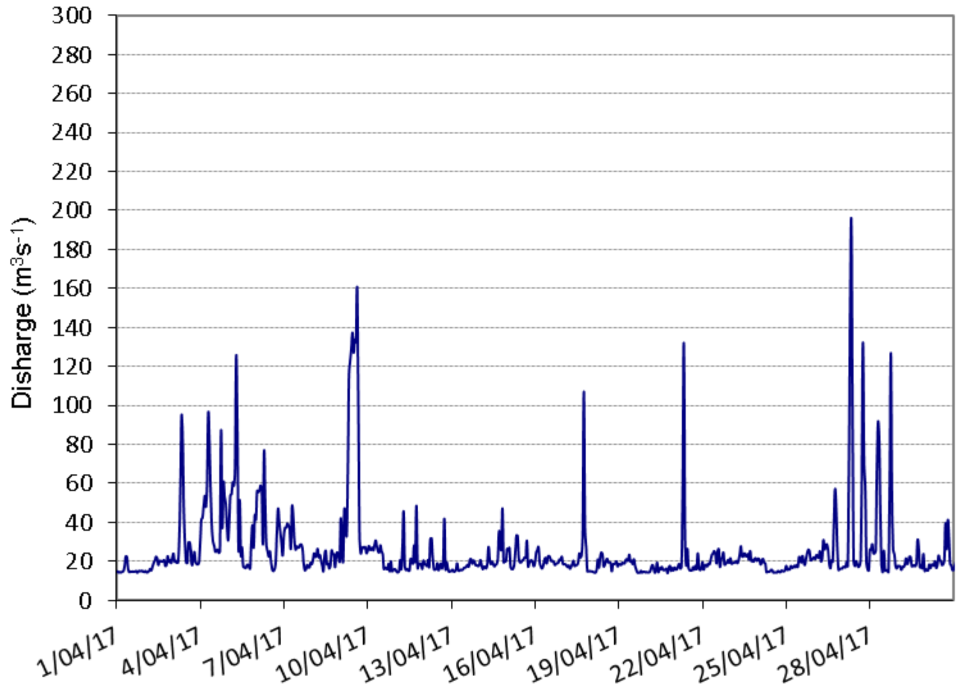

Figure A–10: Gordon Power Station discharge (hourly data) for April 2017. Pink block indicates field monitoring period.

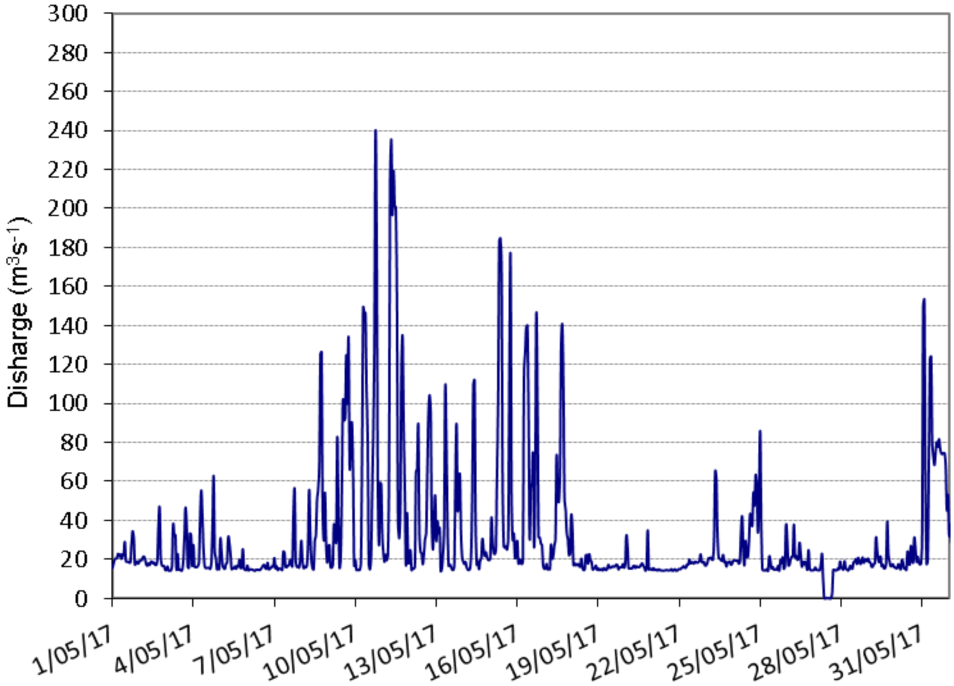

Figure A–11: Gordon Power Station discharge (hourly data) for May 2017.

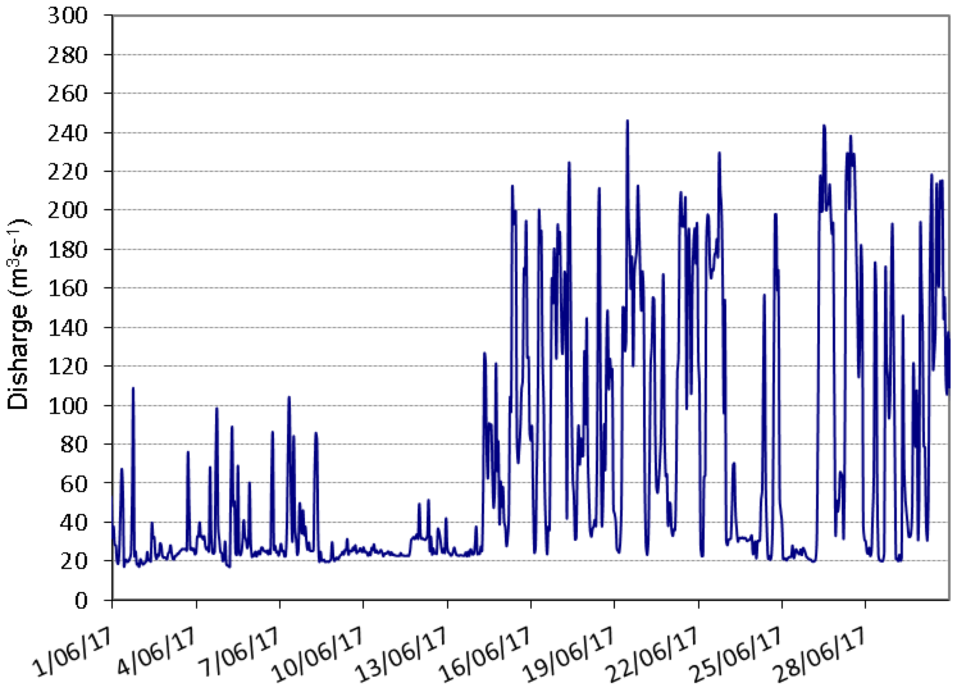

Figure A–12: Gordon Power Station discharge (hourly data) for June 2017.

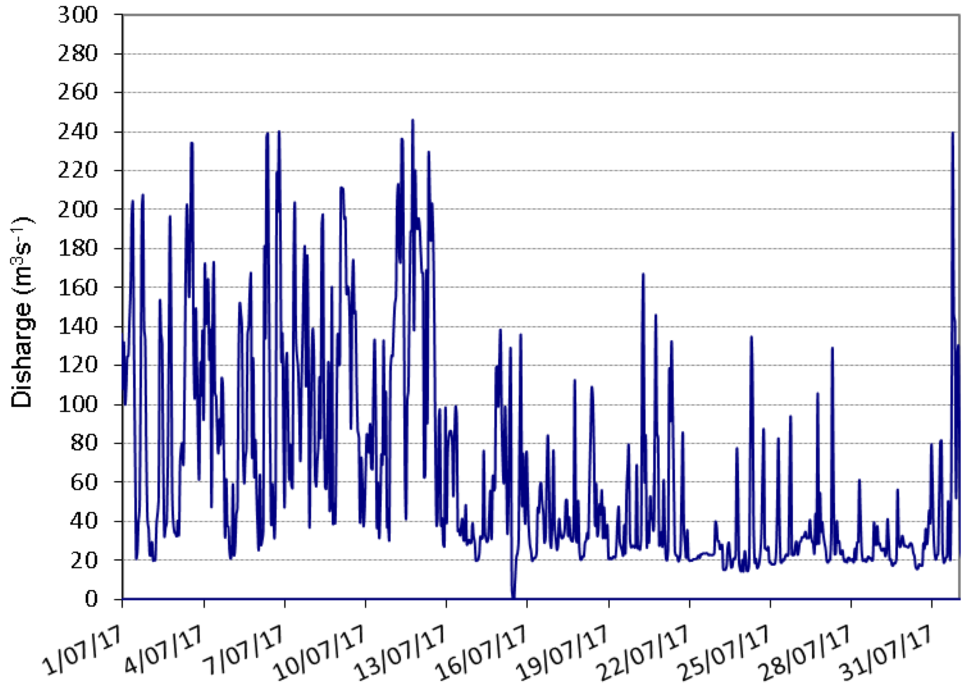

Figure A–13: Gordon Power Station discharge (hourly data) for July 2017.

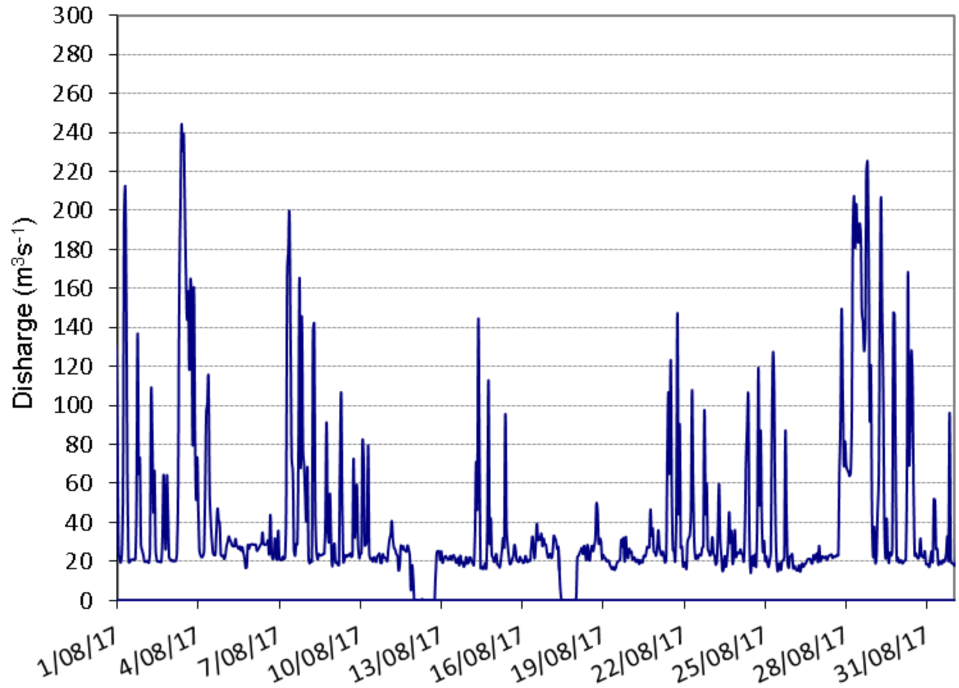

Figure A–14: Gordon Power Station discharge (hourly data) for August 2017.

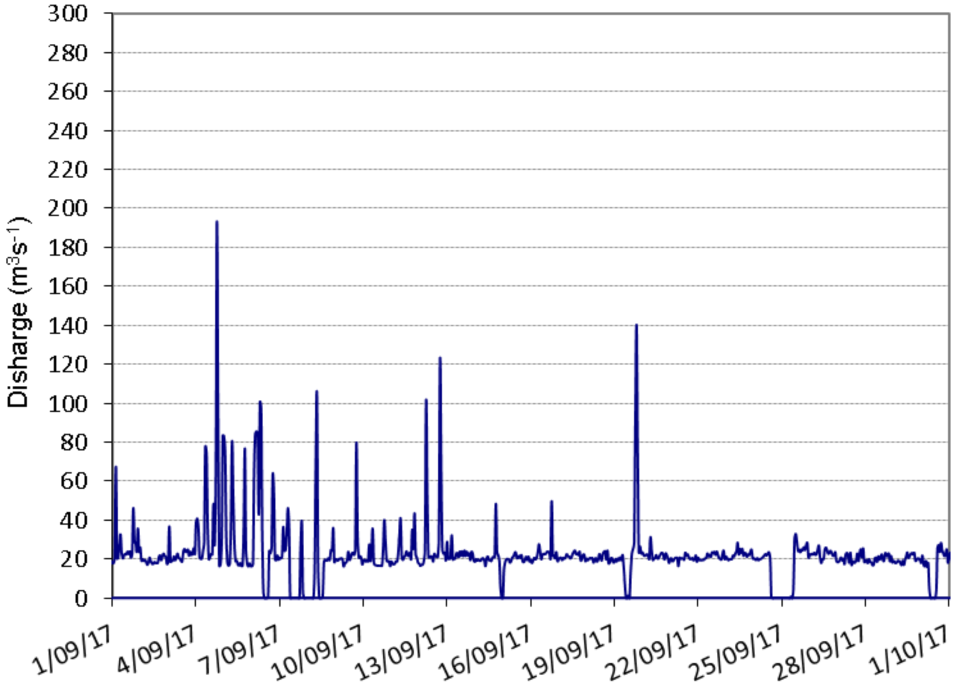

Figure A–15: Gordon Power Station discharge (hourly data) for September 2017.

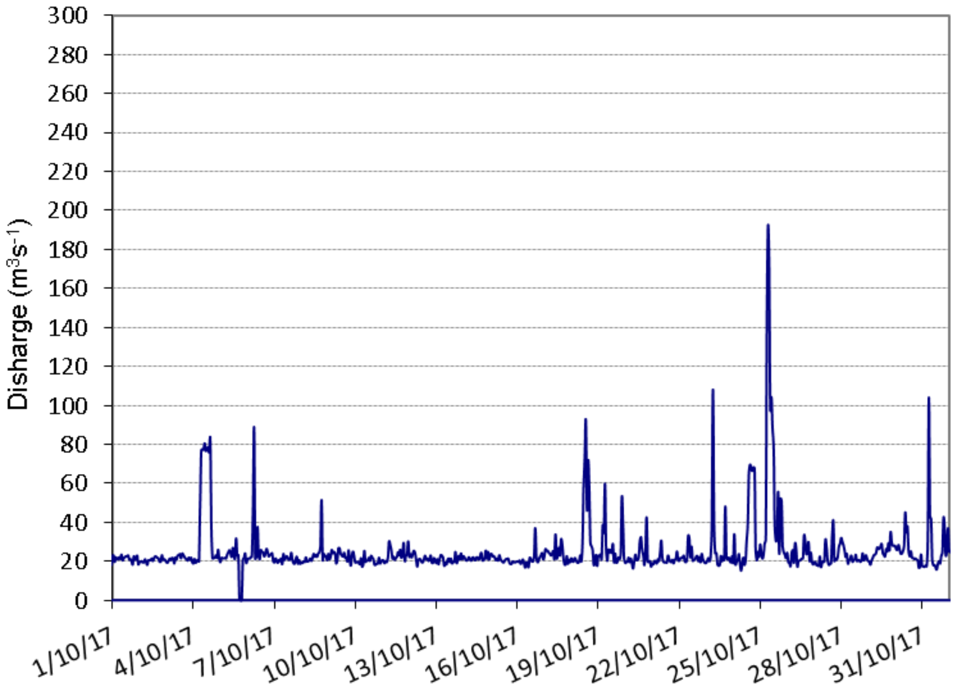

Figure A–16: Gordon Power Station discharge (hourly data) for October 2017.

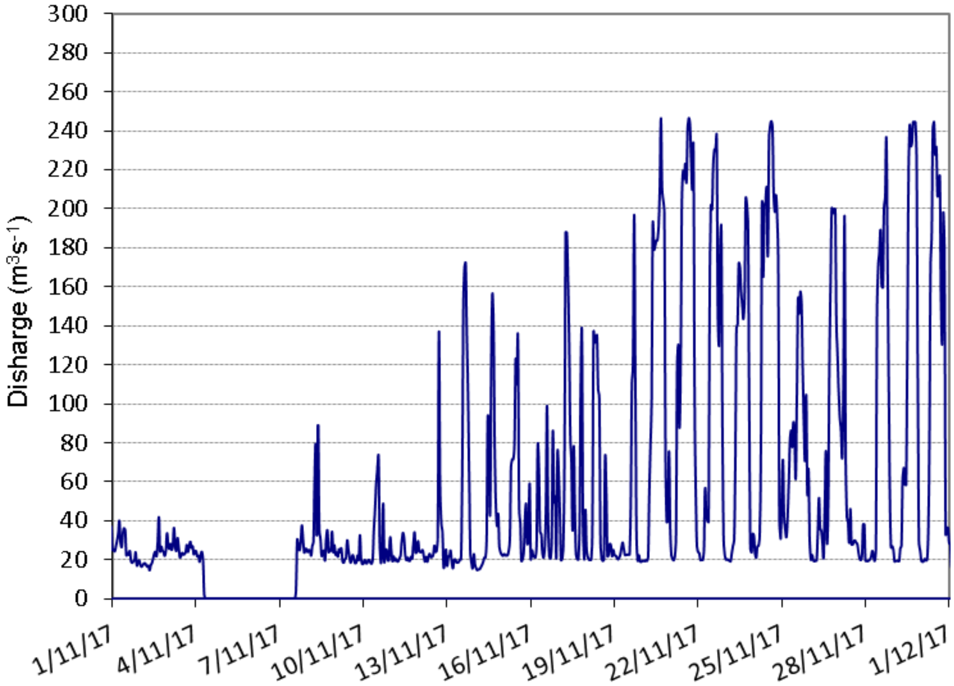

Figure A–17: Gordon Power Station discharge (hourly data) for November 2017.

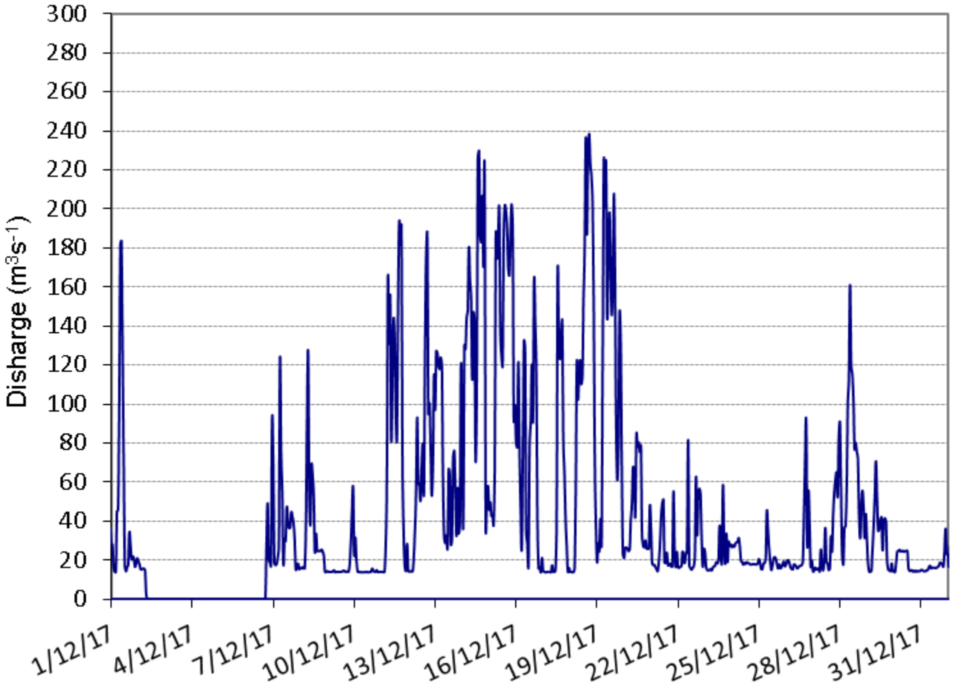

Figure A–18: Gordon Power Station discharge (hourly data) for December 2017.

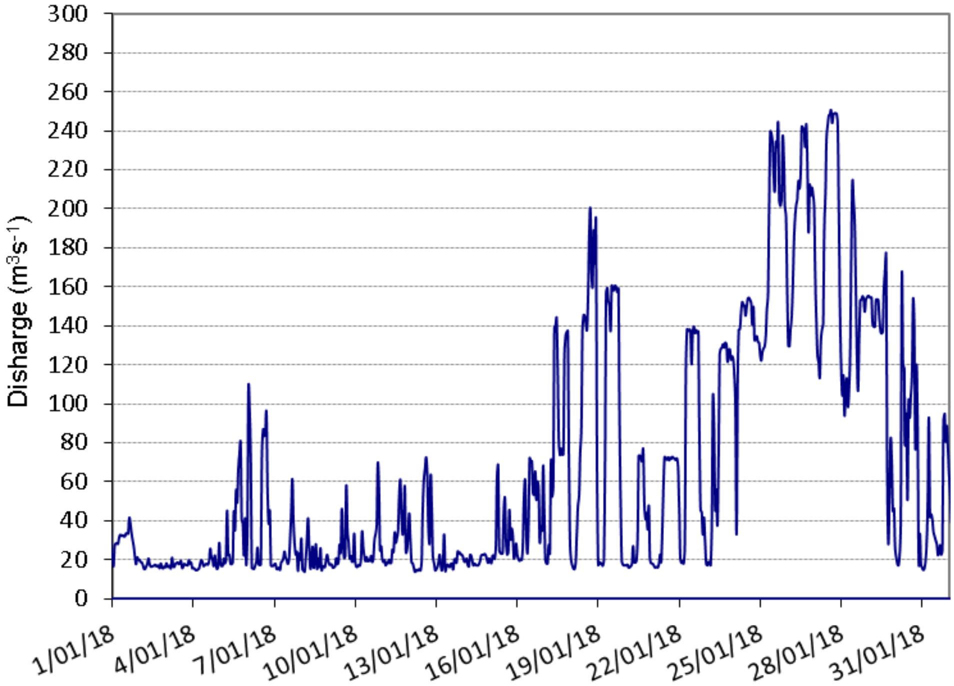

Figure A–19: Gordon Power Station discharge (hourly data) for January 2018.

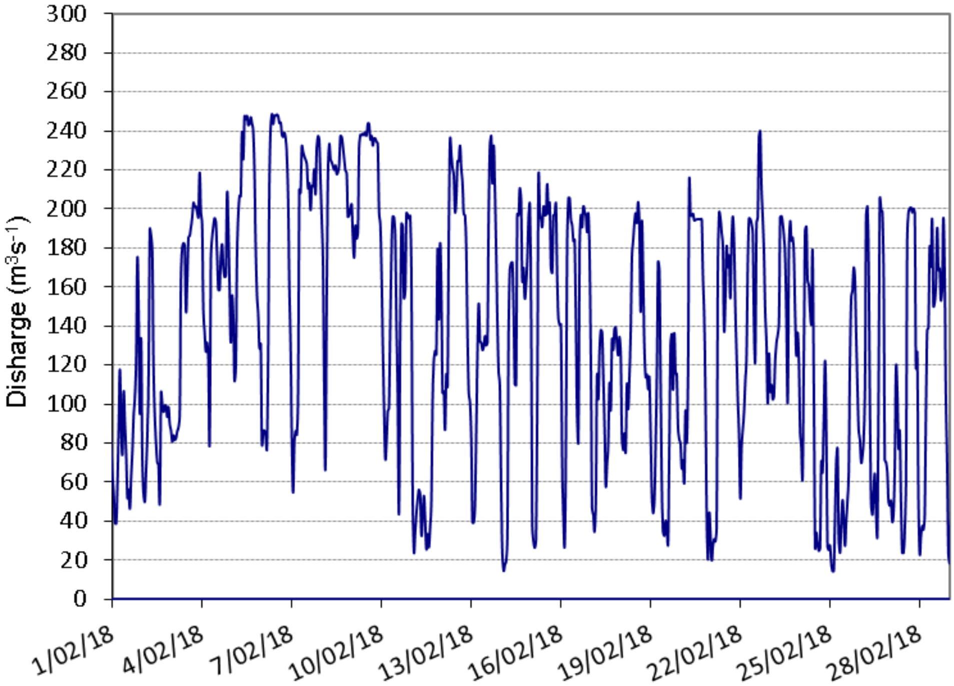

Figure A–20: Gordon Power Station discharge (hourly data) for February 2018.

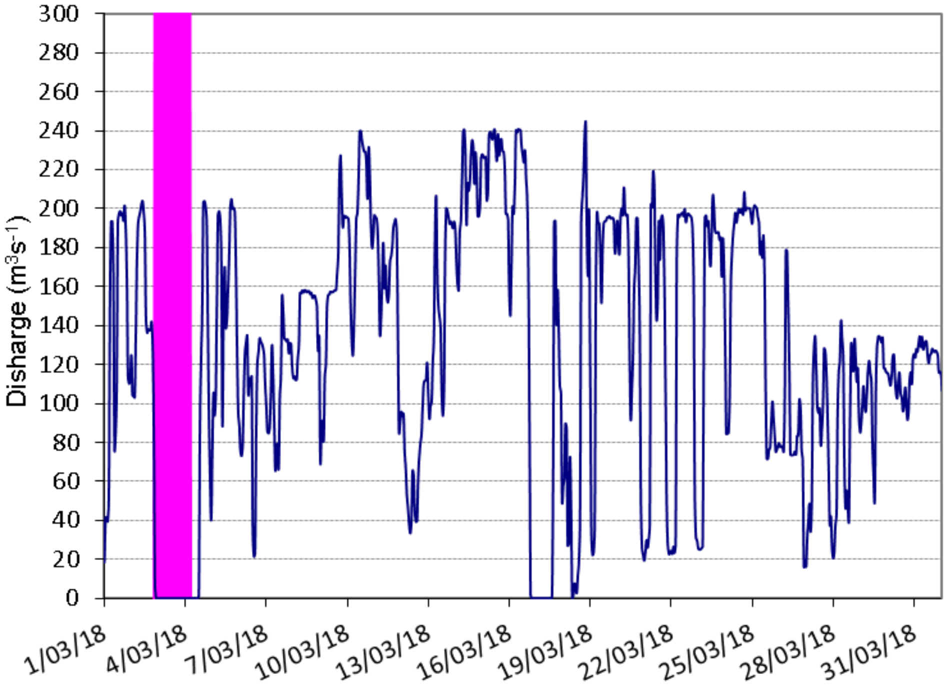

Figure A–21: Gordon Power Station discharge (hourly data) for March 2018.

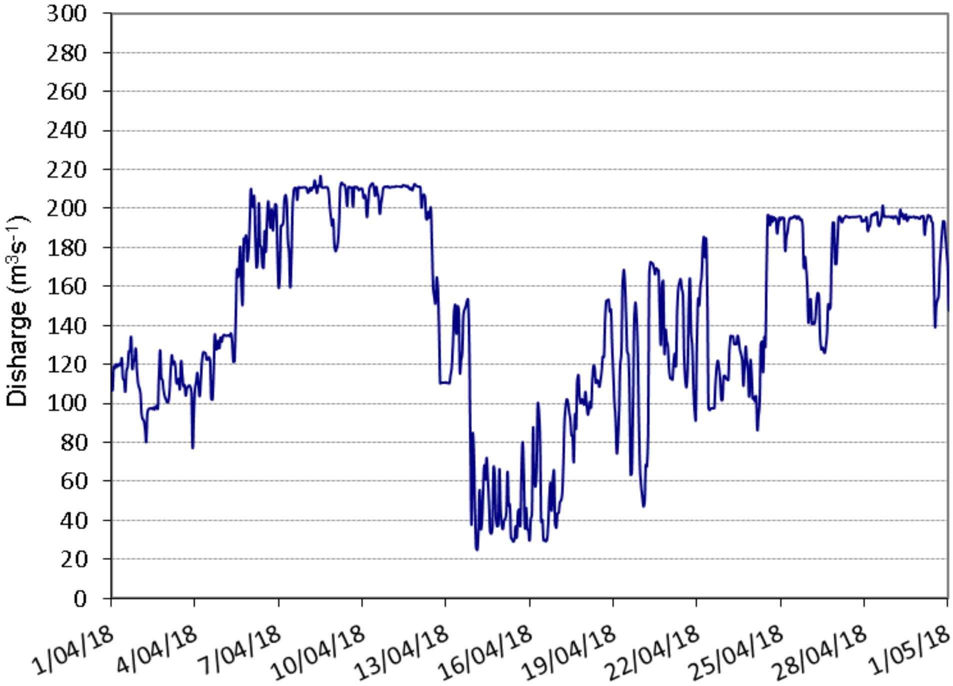

Figure A–22: Gordon Power Station discharge (hourly data) for April 2018. Pink block indicates field monitoring period.

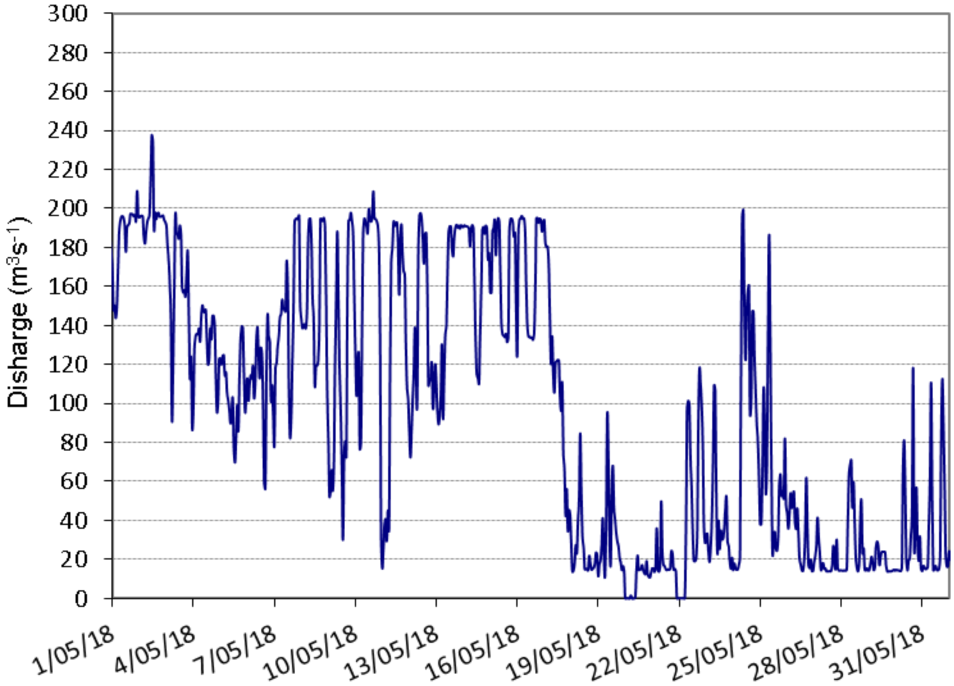

Figure A–23: Gordon Power Station discharge (hourly data) for May 2018.

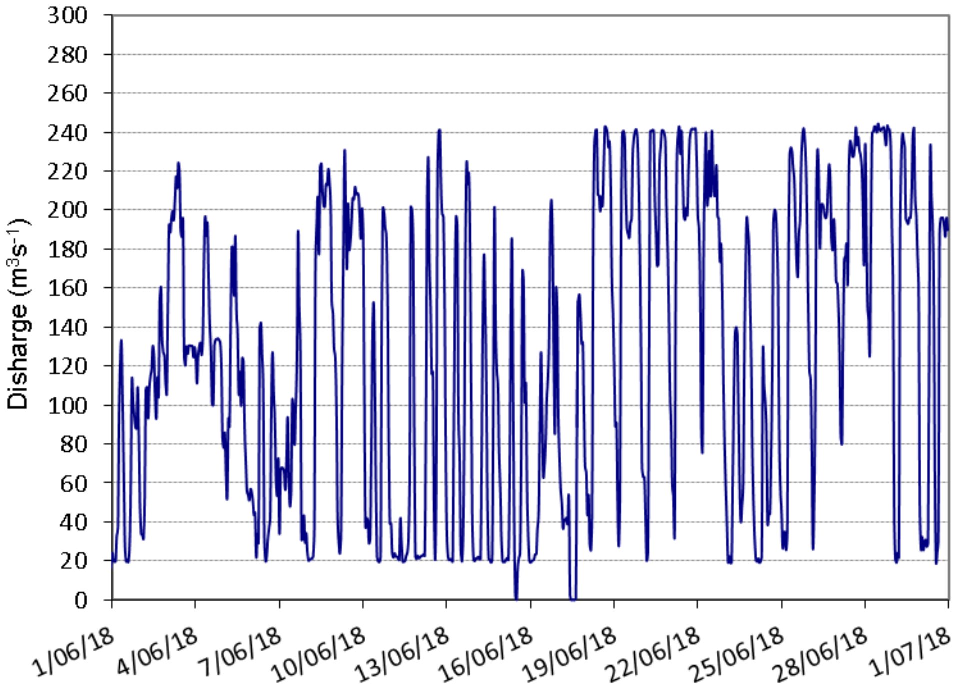

Figure A–24: Gordon Power Station discharge (hourly data) for June 2018.

B Appendix B: Fast ramp-down events

Table B–1: Fast ramp-down events at Gordon Power Station for 1 July 2016 to 30 June 2018.

Event no.	Date	Duration (h:min)	Maximum Generation reduction rate (MW/min)	Average Generation reduction rate (MW/min)	Starting level of piezometer (m)
1	17/01/2017	0:10	-1.03	-1.01	2.8
2	17/01/2017	0:15	-1.15	-1.11	2.8
3	17/01/2017	0:15	-1.12	-1.06	2.8
4	09/02/2017	0:10	-1.08	-1.06	2.88
5	09/02/2017	0:25	-1.19	-1.09	2.86
6	11/02/2017	0:45	-1.47	-1.18	3.05
7	11/02/2017	0:20	-1.32	-1.23	3.01
8	11/02/2017	0:05	-1.05	-1.05	2.89
9	17/02/2017	0:45	-1.34	-1.19	2.77
10	12/07/2017	0:50	-1.31	-1.18	2.76
11	26/01/2018	0:45	-1.84	-1.58	2.81
12	27/01/2018	0:35	-1.33	-1.2	2.77
13	27/01/2018	0:50	-1.61	-1.48	2.97
14	28/01/2018	0:05	-1.02	-1.02	2.84
15	03/02/2018	0:05	-1.04	-1.04	2.77
16	04/02/2018	0:15	-1.36	-1.25	2.8
17	04/02/2018	0:05	-1.03	-1.03	2.84
18	04/02/2018	0:10	-1.07	-1.05	2.85
19	05/02/2018	0:10	-1.03	-1.02	3.19
20	05/02/2018	0:20	-1.23	-1.11	3.19
21	06/02/2018	0:35	-1.42	-1.33	3.25
22	08/02/2018	0:05	-1.1	-1.1	3.27
23	08/02/2018	0:05	-1.1	-1.1	3.33
24	09/02/2018	0:05	-1.02	-1.02	3.24
25	10/02/2018	0:10	-1.33	-1.24	3.16
26	10/02/2018	0:40	-1.3	-1.13	2.83
27	11/02/2018	0:20	-1.3	-1.17	3.09
28	13/02/2018	0:10	-1.05	-1.04	3.09
29	13/02/2018	0:10	-1.06	-1.05	3.06
30	14/02/2018	0:10	-1.18	-1.17	2.8
31	14/02/2018	0:05	-1.08	-1.08	3.01
32	14/02/2018	0:05	-1.04	-1.04	3.03
33	15/02/2018	0:40	-1.38	-1.2	2.95
34	15/02/2018	0:10	-1.15	-1.12	3.15
35	15/02/2018	0:15	-1.09	-1.04	3.16
36	15/02/2018	0:10	-1.06	-1.05	3.09

Event no.	Date	Duration (h:min)	Maximum Generation reduction rate (MW/min)	Average Generation reduction rate (MW/min)	Starting level of piezometer (m)
37	15/02/2018	0:25	-1.56	-1.33	3.11
38	18/02/2018	0:05	-1.06	-1.06	2.95
39	18/02/2018	0:20	-1.47	-1.37	3.05
40	18/02/2018	0:15	-1.21	-1.14	3.1
41	20/02/2018	0:20	-1.29	-1.22	2.99
42	21/02/2018	0:10	-1.07	-1.04	2.93
43	21/02/2018	0:05	-1.06	-1.06	2.86
44	21/02/2018	0:05	-1	-1	2.84
45	21/02/2018	0:05	-1.01	-1.01	2.83
46	22/02/2018	0:15	-1.19	-1.13	2.94
47	22/02/2018	0:15	-1.02	-1.01	2.97
48	02/03/2018	0:25	-1.41	-1.15	2.88
49	10/03/2018	0:15	-1.26	-1.16	2.76
50	10/03/2018	0:10	-1.13	-1.07	2.98
51	11/03/2018	0:15	-1.09	-1.07	2.95
52	11/03/2018	0:25	-1.44	-1.22	2.84
53	11/03/2018	0:10	-1.29	-1.19	2.94
54	14/03/2018	0:20	-1.09	-1.05	2.83
55	14/03/2018	0:05	-1	-1	3.01
56	16/03/2018	0:10	-1.17	-1.1	3.24
57	16/03/2018	0:10	-1.05	-1.05	3.29
58	16/03/2018	0:10	-1.01	-1.01	3.29
59	18/03/2018	1:15	-1.84	-1.49	2.78
60	19/03/2018	0:20	-1.8	-1.58	2.87
61	19/03/2018	0:30	-1.32	-1.13	2.77
62	19/03/2018	0:30	-1.5	-1.24	2.94
63	20/03/2018	0:25	-1.27	-1.16	3.1
64	21/03/2018	1:00	-1.38	-1.2	2.79
65	21/03/2018	0:15	-1.3	-1.24	2.86
66	21/03/2018	0:20	-1.13	-1.08	2.97
67	22/03/2018	0:05	-1.02	-1.02	2.99
68	23/03/2018	0:05	-1.03	-1.03	2.95
69	23/03/2018	0:10	-1.18	-1.15	2.94
70	25/03/2018	0:05	-1.02	-1.02	3.12
71	06/04/2018	0:10	-1.13	-1.13	2.9
72	06/04/2018	0:10	-1.08	-1.07	2.95
73	07/04/2018	0:10	-1.12	-1.11	3.01
74	12/04/2018	0:05	-1.01	-1.01	3.34
75	22/04/2018	0:10	-1.03	-1.03	2.84

Event no.	Date	Duration (h:min)	Maximum Generation reduction rate (MW/min)	Average Generation reduction rate (MW/min)	Starting level of piezometer (m)
76	30/04/2018	0:05	-1.02	-1.02	3.19
77	02/05/2018	0:30	-1.34	-1.25	3.29
78	03/05/2018	0:25	-1.22	-1.13	3.26
79	03/05/2018	0:25	-1.2	-1.12	3.18
80	07/05/2018	0:25	-1.31	-1.28	3.07
81	08/05/2018	0:10	-1.2	-1.13	3.09
82	08/05/2018	0:15	-1.29	-1.18	3.16
83	09/05/2018	0:15	-1.15	-1.06	2.8
84	09/05/2018	0:20	-1.29	-1.13	3.02
85	11/05/2018	0:35	-1.38	-1.23	3.04
86	12/05/2018	0:15	-1.14	-1.07	3.03
87	14/05/2018	0:10	-1.04	-1.02	3.1
88	15/05/2018	0:05	-1.13	-1.13	3.09
89	15/05/2018	0:10	-1.09	-1.08	3.08
90	15/05/2018	0:15	-1.22	-1.12	3.1
91	19/06/2018	0:25	-1.24	-1.15	2.76
92	19/06/2018	0:10	-1.18	-1.13	2.88
93	20/06/2018	0:15	-1.04	-1.03	2.96
94	20/06/2018	0:05	-1.05	-1.05	2.96
95	22/06/2018	0:30	-1.34	-1.25	2.86
96	22/06/2018	0:10	-1.14	-1.08	3.12
97	25/06/2018	0:05	-1.14	-1.14	2.79
98	25/06/2018	0:40	-1.49	-1.29	2.93
99	27/06/2018	0:20	-1.11	-1.08	3.15
100	28/06/2018	1:10	-1.75	-1.51	3.13
101	28/06/2018	0:10	-1.07	-1.04	3.35
102	28/06/2018	0:05	-1.04	-1.04	3.36
103	28/06/2018	0:05	-1.01	-1.01	3.36
104	29/06/2018	0:10	-1.2	-1.16	3.36
105	29/06/2018	0:25	-1.24	-1.15	3.26
106	30/06/2018	0:15	-1.22	-1.12	3.02

C Appendix C: Geomorphology photo monitoring

C.1 Zone 1

Site 1E

March 2013

October 2014

April 2016

March 2018

C.2 Zone 2

Site 2A

March 2013 (no photo from Mar 2014)

October 2014

April 2016

March 2018

Site 2–1: Upstream view of cobble bar from site 2A


March 2014


October 2014


April 2016


March 2018

Site 2–2: Downstream view of cobble bar from site 2A


March 2014


October 2014


April 2016


March 2018

Site 2–3: Backwater view upstream at site 2A

March 2014

October 2014

April 2016

March 2018

Site 2–4: Backwater view upstream at site 2A

March 2014 (further d/s –moved to pins 6 and 7)

October 2014

April 2016

March 2018

Site 2–5: Landslip (previously P2 new 1)


March 2014


October 2014


April 2016


March 2018

Site 2D


March 2014


October 2014


April 2016


March 2018

Site 2E


March 2014


October 2014


April 2016


March 2018

Site 2–6


March 2014


October 2014


April 2016


March 2018

Site 2–7: Left bank


March 2014 (different angle)


October 2014


April 2016


March 2018

Site 2–8: Left bank – close up of 2–7


October 2014 (not obtained in March 2014)


April 2016


March 2018

Site 2–9: Left bank (old P2-2new)

March 2014

October 2014

April 2016

March 2018

Site 2–10: Left bank (old P2-2b)

March 2014

October 2014

April 2016

March 2018

Site 2–11: Left bank (old P2–4)


March 2014


October 2014


April 2016


March 2018

Site 2–12: Left bank


P2 - 12: Left bank, March 2014


P2 - 12: Left Bank, October 2014

No suitable photo obtained in April 2016


March 2018

Site 2–13: Left bank


March 2014


October 2014


April 2016


March 2018

Site 2–14: Left bank


March 2014


October 2014


April 2016


March 2018

Site 2–15: Right bank (old P2–5)

March 2014

October 2014

April 2016

March 2018

Site 2H

March 2014

October 2014

April 2016 (poor photo)

March 2018

Site 2–16: Left bank


March 2014


October 2014


April 2016


March 2018

Site 2L


March 2014


October 2014


April 2016


March 2018

C.3 Zone 3

Site 3C

March 2014

October 2014

October 2014

March 2018

Site 3D


March 2014


October 2014


April 2016


March 2018

Site 3E


March 2014


October 2014


April 2016


March 2018

Site 3–1


March 2014


October 2014


April 2016


March 2018

C.4 Zone 4

Site 4–1: Landslip at Denison confluence

November 2013

October 2014

April 2016

March 2018

Site 4–2: Landslip at Denison confluence

October 2013

October 2014

April 2016

March 2018

Site 4–3: (Old P4–1)


November 2013


October 2014


April 2016


March 2018

Site 4–4: Right bank landslip


October 2013


October 2014


April 2016


March 2018

Site 4D

March 2014

October 2014

April 2016

March 2018

Site 4E

March 2014

October 2014

April 2016

March 2018

Site 4H


October 2013


October 2014


April 2016


March 2018

D Appendix D: Macroinvertebrate data

Appendix D.1. Quantitative macroinvertebrate ‘family level’ data – autumn 2018

Table D-1: Abundances as n per 0.18 m^2 for middle Gordon River and reference sites sampled in autumn 2018

			River :	**Gordon R**								**Franklin R**		**Denison R**		**Maxwell R**	**Jane R**
			Site code:	75	74	72	69	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
			Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
Class	**Order**	**Family**	***Sub family***														
Platyhelminthes	Turbellaria							2	1		1						
Nematoda							1				3			1	1		4
Mollusca	Gastropoda	Hydrobiidae														2	
		Gastr. Unid.			1												
Annelida	Oligochaeta			4	1	7	23	9	53	53	91	14	11	6	1	4	4
Arachnida	Acarina													1			
Crustacea	Amphipoda	Paramelitidae			3		3		1	3	1			2			
	Isopoda	Janiridae					1										
		Phreatoicidea					2										
Insecta	Plecoptera	Eustheniidae							1	1	1						
		Gripopterygidae		1	11	1	4	2	4	13	6		1			9	
		Notonemouridae		1		1											
	Ephemeroptera	Leptophlebiidae		4		11	6	4	10	13	19	9	7	3	3	42	19
		Baetidae					1		2	2	3	1	1	2	2	15	2
	Diptera	Chironomidae:															
			Chironominae				1		1	3	17					1	
			Orthocladiinae	27	19	4	2	1	1	2	2			3	1	3	
			Podonominae						1		9						
		Simuliidae		1	3		16	110	261	294	81	5	4	3	22	74	
		Tipulidae					1		1							1	3
		Athericidae															1
		Blephariceridae							3	2	1						
		Dolichopodidae							1	1							
		Empididae			1						1					1	
		Dip. Unid. Pup.		6	9	1		4	6	4	4			1	1		
	Trichoptera	Calocidae					1									20	
		Conoesucidae					1									45	
		Glossosomatidae														1	1
		Helicophidae				1											
		Hydropsychidae		49	212		11	2	2	9	1		3			12	
		Hydrobiosidae		4		3	5		4	1	5					4	
		Limnephilidae					1	1		3	1	1				12	
		Philorheithridae					1			1		1				3	
		Trich. Unid. Pup.			2		2		3	2	1		1				
	Coleoptera	Elmidae A					1			1						25	
		Curculionidae A								1							
		Elmidae L		3	2		6	8	7	2	3	10		1		124	20
		Scirtidae L		1	1	7			5	2	2	16	1	2	2	101	2
		Psepheniidae L					2									5	
			Total	**101**	**265**	**36**	**92**	**143**	**368**	**413**	**253**	**57**	**29**	**25**	**33**	**504**	**56**
			N Taxa	**11**	**12**	**9**	**22**	**10**	**20**	**21**	**21**	**8**	**8**	**11**	**8**	**21**	**9**

Appendix D.2. Quantitative 'species level' data for EPT taxa – autumn 2018

Table D-2: : Ephemeroptera, Plecoptera and Trichoptera for middle Gordon River and reference sites sampled in autumn 2018 (n per 0.18 m^2).

		River :	**Gordon R**								**Franklin R**		**Denison R**		**Maxwell R**	**Jane R**
		Site code:	75	74	72	69	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
		Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
Order	**Family**	**Genus/Species**														
Ephemeroptera	Leptophlebiidae	Nousia sp. AV5/6	4		8	1	2	4	8	15	6	2		3	40	18
		Nousia sp. AV7				5		4	1		1	2	1		2	
		Tillyardophlebia sp AV2			3		2	2	4	4	2	3	2			1
	Baetidae	Offadens hickmani				1		2	2	3	1	1	2	2	15	2
Plecoptera	Eustheniidae	Eusthenia costalis						1	1	1						
	Gripopterygidae	Cardioperla media/lobata				1		2	1						4	
		Dinotoperla serricauda					1								3	
		Trinotoperla tasmanica				1										
		Trinotoperla zwicki	1	11	1	2	1	2	12	6		1			2	
	Notonemouridae	Austrocercoides sp	1		1											
Trichoptera	Calocidae	Tamasia variegata				1									20	
	Conoesucidae	Conoesucus brontensis													7	
		Conoesucus norelus													38	
		Costora rotosca				1										
	Glossosomatidaee	Agapetus sp AV1													1	1
	Helicophidae	Alloecella longispina			1											
	Hydrobiosidae	Apsilochorema obliquum						1								
		Ethochorema nesydrion														
		Moruya opora	1					1		2						
		Taschorema apobamum			2			1							2	
		Taschorema asmamum													1	
		Taschorema ferulum group	3		1	5			1	2					1	
		Ulmerochorema rubiconum						1		1						
	Hydropsychidae	Asmicridea sp AV1	49	212		11	2	2	9	1		3			12	
	Leptoceridae	Notalina sp. AV1				1	1		3	1	1				12	
	Philorheithridae	Kosreithrus remulus													1	
		Tasmanthrus sp.				1			1		1				2	
		Abundance EPT	**59**	**223**	**17**	**31**	**9**	**23**	**43**	**36**	**12**	**12**	**5**	**5**	**163**	**22**
		N EPT Taxa	**6**	**2**	**7**	**12**	**6**	**12**	**11**	**10**	**6**	**6**	**3**	**2**	**17**	**4**

Appendix D.3. RBA macroinvertebrate data – autumn 2018

Table D-3: Abundances per live picked sample for middle Gordon River and reference sites sampled in autumn 2018.

			River :	Gordon R																Franklin R				Denison R				Jane R		Maxwell R	
			Site :	75		74		72		69		60		57		48		42		Fr11		Fr21		De7		De35		Ja7		Ma7	
Class	Order	Family	*Sub-Family*	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Platyhelminthes	Turbellaria											4																1	2		1
Nematoda																			1	2											
Mollusca	Gastropoda	Hydrobiidae																													1
Annelida	Oligochaeta			4	7	5	2	24	32	14	19	16	23	6	11	7	24	30	5	16	9	17	37		3	3	1	35	11	2	1
Arachnida	Acarina																													1	1
Crustacea	Amphipoda	Paramelitidae		6	7	1			2		9			4	4	3	2	1			2		1							2	
		Ceinidae								3																					
	Ostracoda										2									1											
Insecta	Plecoptera	Eustheniidae			1	1	1					1		7		3	1			3						5	1			3	
		Austroperlidae								1																					
		Gripopterygidae		2	1	22	19		4		1		2	6	3	9	10	5	7			1				1	1	3	1	2	3
		Notonemouridae		3	2				1		1															1					
	Ephemeroptera	Leptophlebiidae		3		2	1	18	36	13	23	5	26	29	40	3	27	24	27	60	63	6	14	22	4	51	13	27	50	38	32
		Baetidae											7	1	1	1	1		3	27	10	9	8	3	1	1	4		2	15	15
	Odonata	Telephlebiidae									1																				1
	Diptera	Chironomidae:	Chironominae		1						1							3			1			1		1	1				2
		Chironomidae:	Orthocladiinae	14	17	1	2		1					4	1	1	2					2		1		9	1		2	1	1
		Chironomidae:	Podonominae										2	1	1		1		4							2	1		1	1	
		Chironomidae:	Tanypodinae																		1										
		Chironomidae:	Diamesinae		1																										
		Simuliidae		1	1		1	4		1		12	37	56	46	16	29	12	4	1		5	2	22		25	25	2		6	12
		Tipulidae								3		1		1				1		2					1				1	1	3
		Athericidae											1																		
		Blephariceridae											1			2															
		Ceratopogonidae																						1							
		Dolichopodidae									1														2						
		Empididae													1																
		Dip. Unid. Pup.				1		1		1					1		1	1								1	2				
	Trichoptera	Calocidae												1														1		1	1
		Conoesucidae			1				2					1																4	
		Glossosomatidae																	1	1	1										
		Helicopsychidae																												1	
		Hydrobiosidae		30	29	8	12	13	10	18	30	4	14	18	15	13	6	3	6	11	14	2	1	9		15	12	8	10	13	9
		Hydropsychidae		29	43	52	40	3		3	4							1												1	1
		Hydroptilidae							1																						
		Leptoceridae						1	2		1	2	1	6	10	1	3	1	3	31	35			10		12				3	4
		Philopotamidae													1		1														
		Philorheithridae								1	2			3	3		2	1	1	2	3			1				2		3	3
		Trich. Unid. Pup.			1	6	1			2			1		6		1	1	1												
	Coleoptera	Elmidae A		2	2			2	10	6	8	1		17	17	2	1	2		15	12	3	1	1	1	3	18	2	5	36	19
		Elmidae L			1										1			1	1	6	3			1		1				6	13
		Scirtidae L						1						1	2					7	10			5	2	9		2	11	3	33
		Psepheniidae L			1				1											2	2							2	1	1	5
		Dytiscidae L																							2			1			

Appendix D.4. Trigger value metrics

Table D-4: Values of all metrics for each site sampled in autumn 2018.

			Autumn 2018									
			Community Structure		Community Composition		Taxonomic richness		Ecologically significant species		Biomass / productivity
River	Site code	Old code	Bray Curtis (abundance)	O/Erk	Bray Curtis (pres/abs data)	O/Epa	N Taxa (fam)	N EPT species	Propn abundance EPT	Abundance EPT	Total abundance
Gordon											
	75	**G4**	20.22	0.68	24.41	1.03	11	6	0.584	59	101
	74	**G4a**	6.12	0.50	11.84	0.78	12	2	0.849	223	265
	72	**G5**	33.71	0.73	31.47	0.88	9	7	0.472	17	36
	69	**G6**	31.00	0.73	43.39	0.88	22	12	0.359	31	92
	60	**G9**	37.70	0.73	41.23	0.83	10	6	0.063	9	143
	57	**G10**	41.69	1.03	44.24	1.37	20	12	0.071	23	368
	48	**G11B**	43.23	0.93	53.18	1.17	21	11	0.109	43	413
	42	**G15**	39.87	0.78	43.98	1.17	21	10	0.146	36	253
Reference											
Franklin	**Fr11**	**G19**	50.02	0.81	57.36	1.32	8	6	0.211	12	57
	Fr21	**G20**	45.26	0.53	57.36	0.73	8	6	0.448	12	29
Denison	**De7**	**G21**	41.49	0.71	50.10	0.78	11	3	0.200	5	25
	De35	**D1**	26.39	0.83	38.94	1.03	8	2	0.152	5	33
Maxwell	**Ma7**	**M1**	19.92	1.26	31.32	1.61	21	17	0.323	163	504
Jane	**Ja7**	**J1**	45.26	0.68	54.48	0.93	9	4	0.393	22	56