Hydro Tasmania
The power of natural thinking

Gordon River Monitoring Annual Report 2013–14

Basslink Interim Monitoring Program

30 September 2014

Executive summary

The purpose of this Gordon River Basslink Annual Report is to present the results of the monitoring undertaken pursuant to the Gordon River Interim Basslink Monitoring Program during 2013–14.

Hydrology

The flow in the Gordon River in 2013–14 was characterised by extended periods of high discharge from the Gordon Power Station. Discharges from the power station remained in the three turbine range for most of the year. High discharges were maintained to take advantage of the ability to raise additional income following the implementation of the fixed carbon price. There were also periods of substantial natural flows in the Gordon River in 2013-14, contributing to the very large volume of water transported by the river.

In the months of July and early August 2013, the discharge from Gordon Power Station consisted mostly of a regular peaking pattern from low to mid flow ranges up to high flows. This was followed by a peaking pattern with lower peak levels generally corresponding to two-turbine operation, until October 2013. The remainder of the monitoring year (October 2013 until June 2014) saw a near-continuous high discharge (> 200 $m^3 s^{-1}$), with only few very brief periods of discharge reduction.

The application of the revised ramp-down rule was undertaken successfully in its second full year of operation, with all generation reductions being compliant with the 1 MW per minute ramping requirements. Complete compliance was achieved as the generation control system automatically applied the rule whenever the conditions requiring its use were met. Short periods of generation reduction, where implementation of ramping was required, were in excess of the 1 MW per minute target (0.26%) due to intrinsic operational factors or unforeseeable machine trips. These occurrences are not considered to be non-compliant as they were outside of operational control.

The performance of the bank saturation model, used to predict in-bank water levels, to determine when the ramp-down rule must be applied was examined for the previous 12 months of operation. This indicated that the model was operating within expectations, but with a tendency to underestimate the bank saturation levels after extended periods of high discharge. These underestimates accounted for 5.5% of all values in excess of the ramp rule trigger level being predicted by the model to be below the trigger level (i.e. false negatives). Calibrating the bank saturation model did not reduce the level of false negatives for the results in 2013-14, hence the current model will be used to provide the trigger for future operation of the ramp-down rule.

The minimum environmental flow was achieved 100% of the time, both in summer and winter.

Flow patterns at downstream sites were generally reflective of flows from the power station with the same distinctive annual pattern. In August to October 2013 there were a greater proportion of flows originating from tributaries, particularly during natural flow events in August and September 2013.

Fluvial geomorphology

Fluvial geomorphology monitoring was completed in November 2013 and March 2014. Field observations were consistent with the extended high power station usage over the year. Bank toes showed evidence of scour, with no organic debris, widespread ripple marks, and substantial changes to the shapes of some banks. Vegetation which had established over the past few years had perished, although root-balls and stems remained, providing some stability to the banks. Evidence of seepage erosion was widespread; this included rilling of bank faces, water draining from banks, and recently deposited sediment flows, all of which were likely linked to the power station shutdown to undertake the monitoring. Further effects of extended high discharge included observations of a large number of trees located on the edge of the bank, turning brown and losing foliage. In addition tea tree and associated root mats were observed to be growing adventitious roots, which are typically associated with prolonged inundation, and may also be providing stability to the banks.

Theoretical sediment transport modelling, based on the flow duration curve for the year, predicted the highest potential transport rate of any monitoring year, equivalent to almost five-times the predicted rate associated with the natural flow regime.

Piezometer results from zone 2 show that the banks were highly saturated for the periods of extended high power station discharge, and were slow to drain following reduction of flow at the station. Due to the long duration of high discharge, a large number of periods were identified with a high risk of seepage erosion, even though the station adhered to the ramp-rule.

The erosion pin results in zone 1 mostly showed little change, but deposition (associated with seepage) was recorded more frequently than scour. Similarly, in zone 2, deposition was more common than scour, although scour increased during the second half of the year. Zone 3 recorded high levels of scour over the year, with almost 40% of the pins eroding over 30 mm between March 2013 and March 2014. Zones 4 and 5 showed both deposition and erosion over the monitoring year, with most changes exceeding 30mm between March 2013 and March 2014.

When grouped by turbine bank level, the 0 – 1 turbine bank level showed high rates of scour consistent with the theoretical sediment transport modelling with almost half of the toe pins (48%) recording >30 mm erosion over the 2013 – 2014 monitoring year. The 1-2 and 2-3 turbine bank level results showed variability, but more deposition than erosion was recorded. This is attributable to both seepage processes, and possibly the deposition of sediment from unregulated tributaries during the winter.

When grouped by zone and turbine bank level, zones 2 and 3 showed a decrease in erosion and increase in deposition / seepage with increasing distance up the bank face. Zones 4 and 5 showed a similar pattern, but the magnitude of changes tended to be higher. This is consistent with previous results and is attributable to the greater flow variability in zones 4 and 5 due to the influence of unregulated inflows.

Overall, the results are consistent with the present understanding of the relationship between power station operations and geomorphic processes in the Gordon River. The major observation is that the increase in either duration or discharge volume from the power station is affecting the riparian vegetation which will likely lead to additional tree fall and bank adjustment, similar to the processes observed when extended 3-turbine power station operation was initiated in 1999 – 2000. The lack of large-scale ‘new’ sediment flows associated with this changed operation suggests that the ramp-down rule is modulating the impacts to some degree, even though it is not preventing seepage processes under all operating flow patterns.

Macroinvertebrates

Biological triggers were within trigger bounds for six of the nine macroinvertebrate indicators in 2013-14. Sustained high discharge during this period appeared to have resulted in three indicators (O/Epa, O/Erk and the proportion of total abundance as EPT species) falling to levels not previously observed, below their lower triggers.

The low level trigger exceedances for O/Epa, O/Erk and the proportion of total abundance as EPT species indicate the first time that the overall condition of the macroinvertebrate community has declined below pre-Basslink levels since the Basslink monitoring program began.

The upper level exceedances representing improvement in biological condition relative to pre-Basslink conditions have declines in number and magnitude in 2013-14. Most of the observed improvements in macroinvertebrate condition occurred prior to 2010-11, followed by large, short-term swings and subsequent decline.

The environmental flow has been observed to mitigate post-Basslink operation effects on in-stream biota in the Gordon River, however inter-annual variations in power station release patterns drive large swings in indicator values. Extended high discharge appears to have caused a general decline in 2013-14.

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Contents

List of figures

Hydro Tasmania
The power of natural thinking

Tables

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	is a 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	the O/E value calculated using an AUSRIVAS model based on presence-absence data
O/Erk	the 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
$m^3 s^{-1}$	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 brook or natural stream of water smaller than a river
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 Introduction and background

The purpose of this Gordon River Monitoring Annual Report is to present the results of the monitoring undertaken pursuant to the Gordon River Interim Basslink Monitoring Program during 2013–14. This is the eighth year of post-Basslink operation. The monitoring area is shown on Figure 1-1.

1.1 Context

The Gordon River Basslink Interim Monitoring Program was put in place after the completion of the Gordon River Basslink Monitoring Program. The aim of the Gordon River Interim Basslink Monitoring Program is to obtain additional data to confirm the continued effectiveness of the mitigation measures; the minimum environmental flow and the ramp-down rule as required by Hydro Tasmania's Special Water Licence Agreement.

The aims of the preceding 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 prevailing 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 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). Six years of data were collected post-Basslink.

The 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). The monitoring focussed on the monitoring elements of the Basslink Program for hydrology, fluvial geomorphology and macroinvertebrate disciplines. In mid 2012 the ramp-down rule was revised to better align operational and environmental objectives. Due to the short assessment period, Hydro Tasmania committed to two years of additional monitoring.

1.2 Basslink baseline and review reports

A requirement of Hydro Tasmania's Special Licence was to produce a Basslink Baseline Report (BBR) (Hydro Tasmania 2005a, 2005b) prior to Basslink commencement to provide a comprehensive assessment of pre-Basslink conditions in the Gordon River below the power station. The BBR described how post-Basslink conditions would be compared with the pre-Basslink ranges of variability and trends. The BBR consolidated and built upon knowledge gained through investigative studies undertaken during the Basslink approvals process.

Basslink Review Reports were produced in 2010 and 2013 (Hydro Tasmania 2010, 2013) and assessed the full datasets in greater detail than presented in the annual reports. The review reports included the assessment of the effectiveness of mitigation measures. The Basslink Baseline and Review Reports are available on Hydro Tasmania's website: www.hydro.com.au/environment/basslink-studies.

1.3 Logistical considerations and monitoring in 2013–14

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.

To complete the required monitoring work, the monitoring program has a schedule of at least two visits per year, each requiring the power station to be turned off for one or two consecutive days.

The 2013–14 monitoring field trips were conducted on 8 November (reference rivers), 9 November 2013 and 29-30 March 2014.

1.4 Geographic datum

Map coordinates given in this document use the 1966 Australian Geodetic Datum (AGD) as this corresponds with the topographic maps currently available for the area. A later datum, the Geocentric Datum for Australia (GDA), has recently been 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.

1.5 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 2013–14, 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 five appendices;

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

1.6 Authorship of chapters

The information presented in chapters 2–4 is based on field reports produced by scientists employed 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 Marie Egerrup, Alison Howman and Greg Carson (Hydro Tasmania), and significant assistance from the researchers.

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)

1.7 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.

Figure 1-1: Gordon River Basslink monitoring area.

2 Hydrology and water management

This section of the Gordon River Interim Basslink Monitoring Program Annual Report provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the period July 2013 to June 2014. Conformance with the two mitigation measures, environmental flow and bank saturation ramp-down rule, are presented.

2.1 Factors affecting Gordon Power Station discharge

The Gordon Power Station running regime has always been heavily influenced by a number of factors. A timeline of some of the major factors is presented in Figure 2-1. The normal factors include:

- inflows to Hydro Tasmania catchments (volume, distribution and temporal variation);
- overall storage position, in particular, the storage positions of Great Lake and Lake Gordon;
- National Electricity Market price signals;
- energy supply/demand in Tasmania; and
- power station outages.

In all but five of the last 19 years, Tasmanian electricity demand was higher than the annual yield in the hydro scheme (Figure 2-2). The annual hydro yield has had large variation between years, and in combination with variable hydro generation (Figure 2-3) the overall system storage has varied in response (Figure 2-4). The post-Basslink years (2006–2013) began with a continuation of a downward trend in overall storage position until 2007–08 (Figure 2-4). Implementation of the business storage rebuild strategy in June 2008, an opportunity made possible by Basslink, resulted in increasing storage levels as Hydro Tasmania provided less hydro-generated electricity to the market. Consequently there was significant net import of power in 2007–08 and 2008–09. In 2009–10 there was lower net import and in 2010–11, a small net export of power resulted from an increase in the system-wide hydro generation from higher inflows and greater thermal generation. In 2011–12, hydro generation was reduced from the previous year, while Tasmanian demand was very similar. The difference was met by generation from the Aurora Energy Tamar Valley (AETV), wind and a small net import of power.

In 2013–14, the highest annual hydro generation of the past 19 years (i.e. the period for which comparative records are available) was produced in Tasmania (12,033 GWh), exceeding the 2012-13 generation of 10,055 GWh. The high generation included output from Gordon Power Station, and to a lesser extent Poatina Power Station. A primary reason for such high generation was to capture additional revenue prior to the removal of the carbon price. As a result of greater generation, Basslink net export was the highest since its commissioning (3,094 GWh).

Gordon Power Station generation in 2013–14 (2,742 GWh) was the highest annual generation in the period since hourly records have been maintained (1996-2014), and was more than double the long-term average annual generation in that period (1,361 GWh). The higher hydro generation relative to yield in the Gordon catchment has resulted in a decline in water levels in Lake Gordon and Great Lake and a reduction in the overall system storage (Figure 2-4).

Based on modelling undertaken prior to Basslink commissioning it was expected that the Gordon Power Station running regime would become extremely ‘peaky’, increasing the number and severity of high to low flow reductions, as Hydro Tasmania responded to market opportunities. After eight years of Basslink operation, there have been some changes to the operation of Gordon Power Station, but the anticipated degree or pattern of peaking operation was not observed. A number of factors since commissioning Basslink have played differing roles in the power station discharge, and include:

- drought conditions and associated low water storages;
- conversion of Bell Bay Power Station to gas-fired generators, and the commissioning of the AETV gas fired power station;
- market conditions that did not match assumptions used in the initial modelling;
- the desire to hold water in storage until the carbon price was finalised; and
- high generation to capitalise on the carbon price.

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

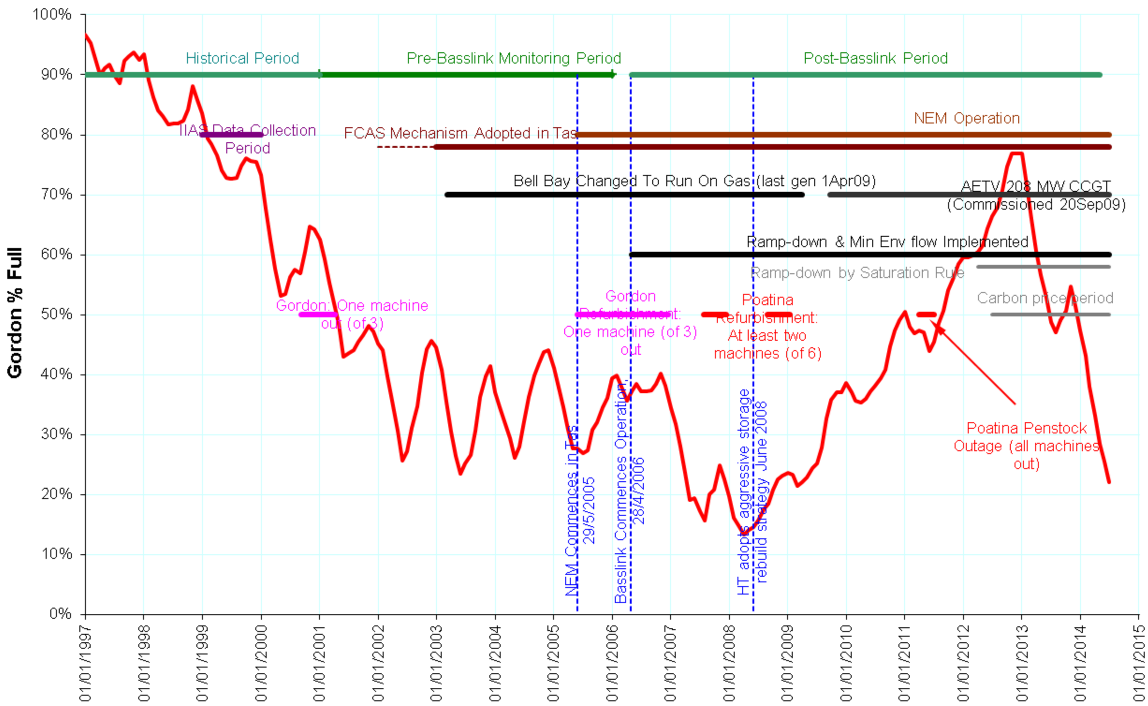

Figure 2-1: Timeline of significant factors affecting Gordon Power Station operation (including storage levels) relative to Basslink monitoring periods.

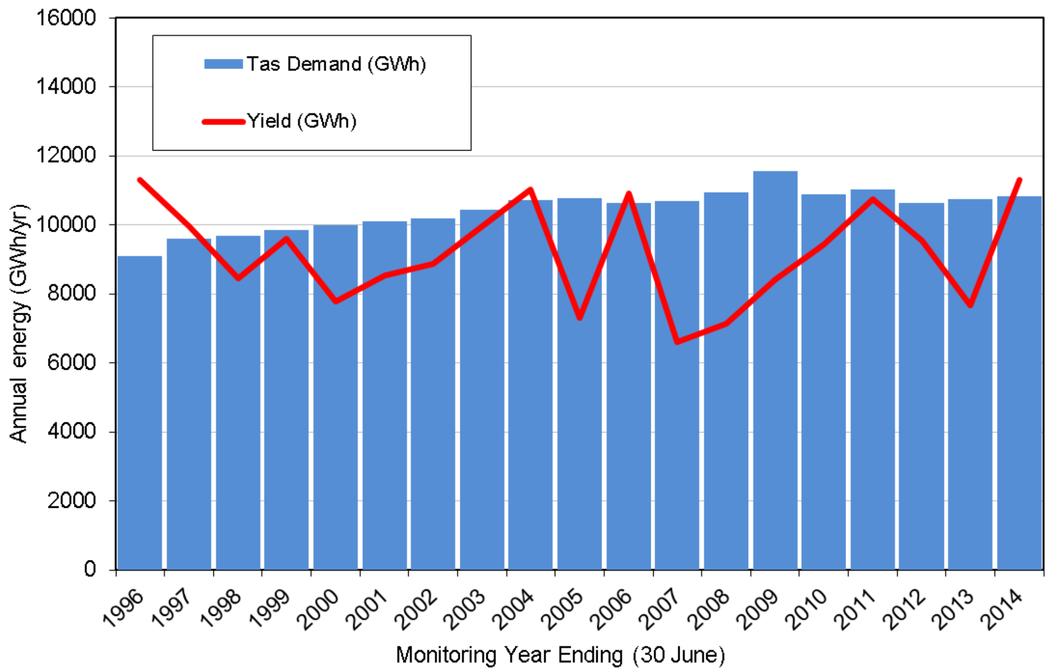

Figure 2-2: Annual Tasmanian electricity demand (total generation + import or total generation – export) and hydro energy yield representing system inflows converted to GWh.

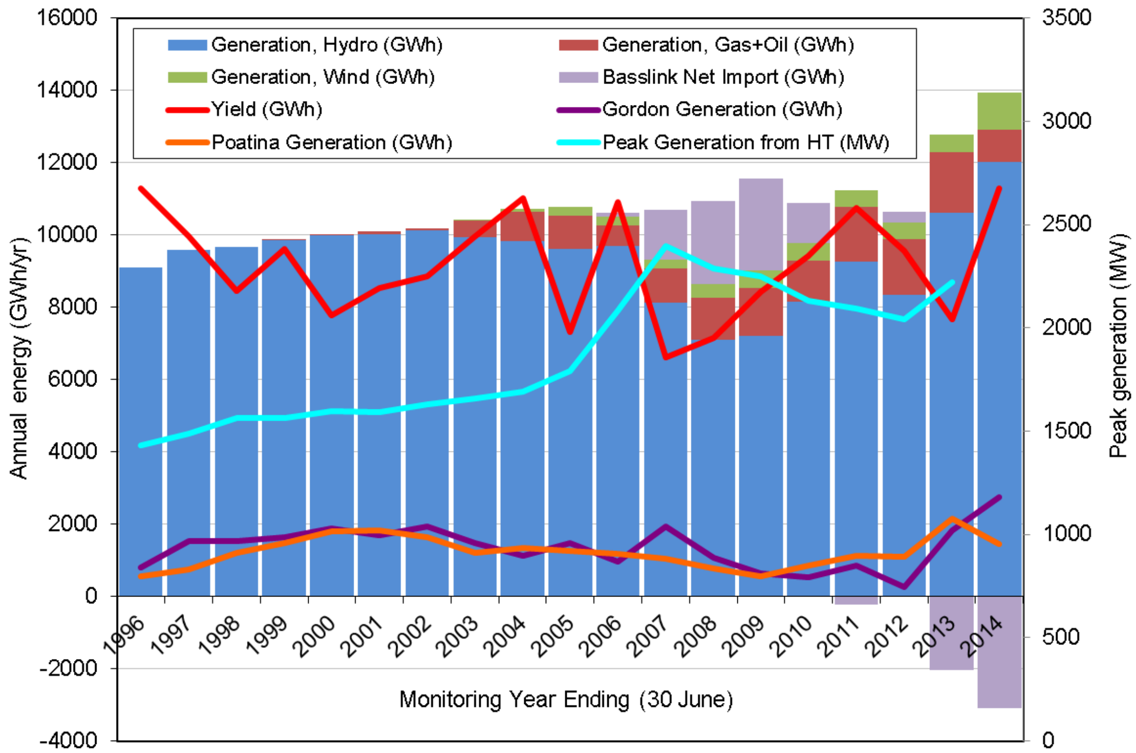

Figure 2-3: Hydro generation, wind and gas generation, Gordon and Poatina generation and net import (in GWh) and peak demand (in MW) for financial years from 1995–96 to 2013-14.

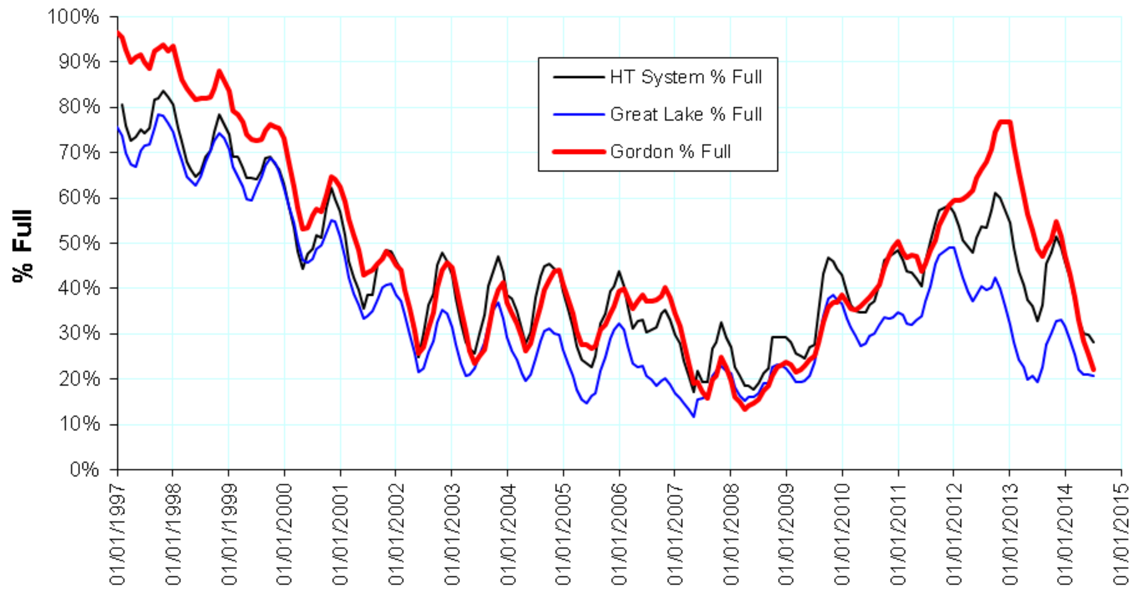

Figure 2-4: System, Lake Gordon and Great Lake water level presented as per cent full for 1997-2014.

2.2 Power output to flow ratings

Due to the difficulty in accurately measuring flow in the tailrace, flow records have been converted from power station output (MW) using a stand-alone rating application (GordonRatingApp). This application mimics the real-time application (FLOCAP) used by the operators for the measurement 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:

- Machine 1 power output;
- Machine 2 power output;
- Machine 3 power 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 gauging stations recording river levels during 2013–14 were sites 44, 62, 65, 69, 71 and 75. Power station discharge derived from the three-dimensional rating is used to estimate the flow in the tailrace (site 77). The sites reported in this chapter (and those for which data were collected but not reported here) are shown in Figure 2-5.

The flow monitoring sites reported in this chapter are Gordon above Franklin (site 44), Gordon above Denison (site 65; also known as the flow compliance site) and the Gordon Power Station tailrace (site 77).

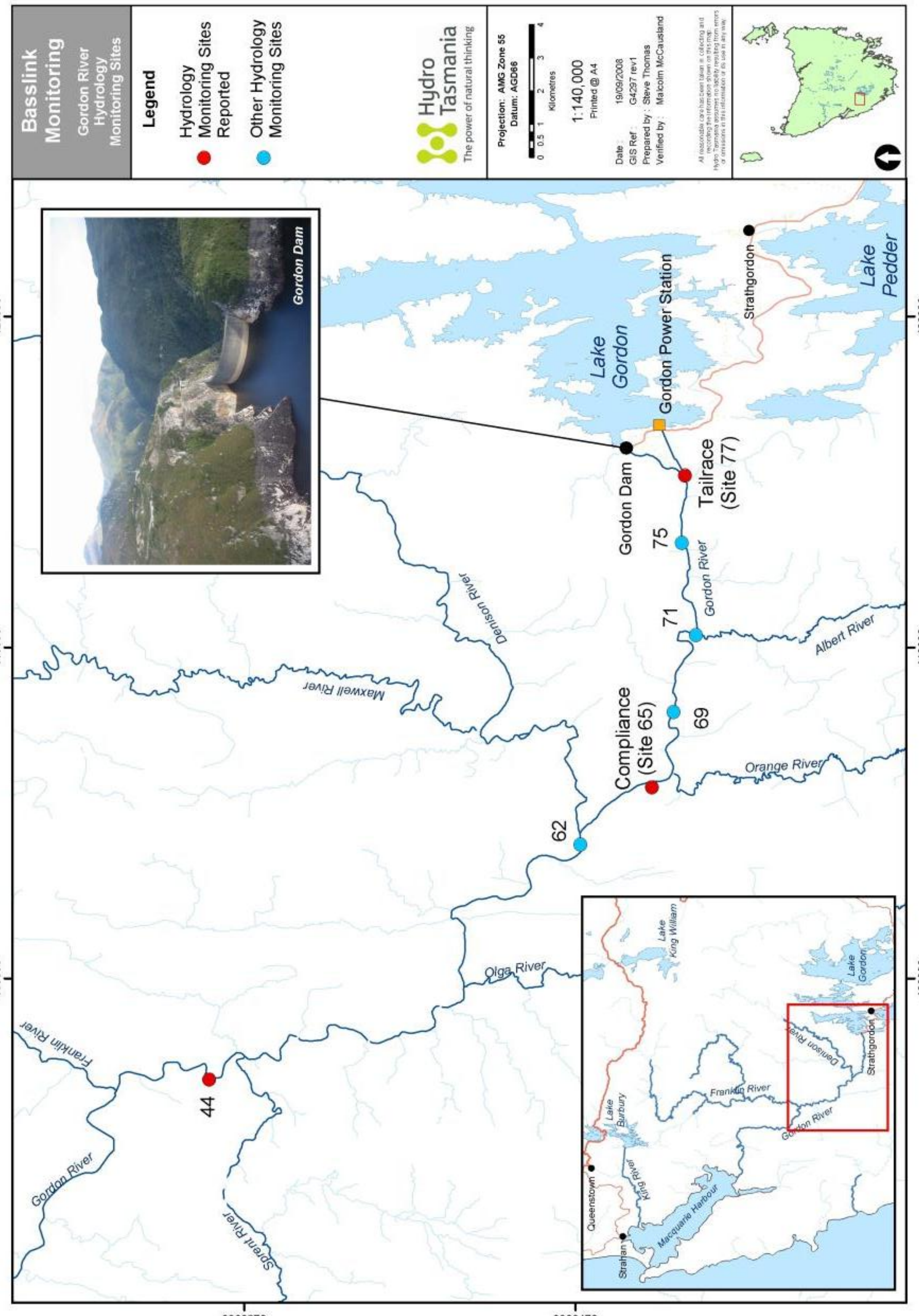

Figure 2-5: Gordon River Basslink hydrology monitoring sites.

2.4 Data analysis

2.4.1 General flow analysis

For 2013–14, the power station discharge at site 77 (the tailrace), site 65 (compliance site) and site 44 (Gordon above Franklin) hourly flow data, median monthly flow and annual duration curves were plotted. These three sites are considered representative of the various river sections below the power station (data from sites 75, 71, 69, 62 were recorded hourly but are not presented in this report). The data available from all sites are a resource available to assist researchers in the interpretation of their data. 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.

Analyses at sites 77, 65 and 44 have provided the comparison of data from the 2013–14 year to the long-term average at that site. 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 figures will change for each site depending on when data records commenced.

2.4.2 High flow change frequency analysis

Analysis of changes in flow in the 2–3 turbine operation is presented. This information shows how individual periods vary with regard to flow changes above 180 $m^3 s^{-1}$. The information assists with the interpretation of data in the discipline sections, in particular chapter 3 - Fluvial geomorphology. Flow change frequency analysis was conducted on the data to determine the frequency with which different flow changes occurred, i.e. between one hour's average and the next hour's average[1].

The calculation of the one-hour lag difference was conducted applying the following rules:

- missing data was eliminated;
- only data where the start flow was above 180 $m^3 s^{-1}$ was selected; and
- data was ranked and plotted.

2.4.3 Low range discharge 'peakiness' analysis

An analysis of the frequency of flow variation or 'peakiness' was undertaken for low range discharges for the Gordon Power Station discharge and for the Gordon above Denison site. This was undertaken with specific relevance to understanding the influence of a variable flow regime on the macroinvertebrates at the lower flow ranges. This examined the number of occasions when:

- flow reduced below 25 $m^3 s^{-1}$; and
- subsequently increased to greater than 100 $m^3 s^{-1}$ within a two-hour period.

The number of instances where this flow pattern was observed is presented for each year for which hourly data is available for the Gordon Power Station and Gordon below Denison site, and for each month in 2013–14.

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[1] This method cannot be used to determine conformance with ramp-down rule.

2.4.4 Ramp-down rule

2.4.4.1 Background

A ramp-down rule mitigation measure has been in place at Gordon Power Station since the commissioning of Basslink in April 2006, under the terms of Hydro Tasmania's Special Water Licence Agreement. A revised and improved ramp-down rule has been developed following modelling and field investigations.

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).

The revised rule was implemented from 1 April 2012 and 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 $m^3 s^{-1}$, 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 $m^3 s^{-1}$.

2.4.4.2 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 $m^3 s^{-1}$.

Hence the testing approach identified such periods (on a 5-minute basis) and, for them, determined if the plant control system was in place. 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.

2.4.4.3 Performance of Bank Saturation Model

The integral component for the implementation of the ramp-down rule is the Bank Saturation Model. Its continued good performance is important to ensure that un-ramped flow reductions do not occur while saturation in the banks is high. The performance of the model was assessed in a comparison of observed and modelled water level. In addition, the percentage of false positives (modelled values higher than actual level of 2.75 m) and false negatives (modelled values lower than actual level of 2.75 m) is reported.

2.5 Results

2.5.1 Data availability

Data was collected at all the water level (flow measurement) sites (Table 2-1). There was one brief period of missing data for site 69. This period of missing data was of less than 24 hours duration due to site instrument calibration. There were no periods of missing data at any of the sites, however site 65 utilised both of its level sensors to create a complete data record. Non-telemetered sites 62 and 75 were manually downloaded on 29 March 2014, during the most recent field visit to these sites.

Table 2-1: Data availability for water level sites on the Gordon River 2013–14.

Site no.	Site name	Periods of missing data	Reason	Comment
75	Gordon River at G4	none to last download	---	Data manually downloaded. Currently available to 29/03/14
71	Gordon River below Albert (G5A)	none	---	Nil.
69	Gordon River above 2nd Split (G6)	13-14 July 2013	Site calibration	Nil
65	Gordon above Denison (compliance site)	none	---	Secondary level sensor used at times in Nov and Dec 2013, Jan and Mar 2014.
62	Gordon River below Denison	none to last download	---	Data manually downloaded. Currently available to 29/03/14
44	Gordon River above Franklin	none	---	Nil

2.5.2 General analysis

2.5.2.1 System yield

The inflows to Hydro Tasmania's state-wide system during the 2013–14 was the greatest since 1996. The total system inflows (system yield) of 11,302 GWh were 124% of the long-term mean (1976–2013). The inflows in 2013–14 were less (by the equivalent of 731 GWh) than the hydro generation which contributed to the continued reduction in storage in Lake Gordon and the state-wide system.

Figure 2-6 shows the total system yield during 2013–14 compared with the long-term (1976–2013) median, 20th and 80th percentile inflows. The most pronounced above average inflows were observed in July, August and October 2013, while only two months (February and June 2014) had below median yields.

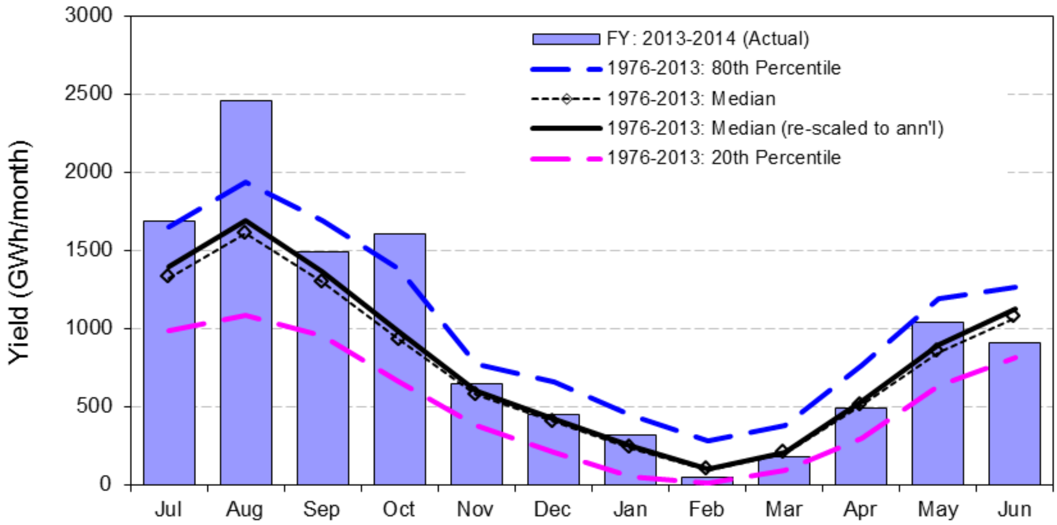

Figure 2-6: Monthly total system yield for 2013–14 compared to the long-term median, 20th and 80th percentiles for 1976–2013.

2.5.2.2 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records dating back to 1970. These allow the calculation of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2013–14.

Figure 2-7 shows the total monthly and long-term average monthly rainfall values. In 2013–14 it was a wet year in Strathgordon receiving 2,875 mm. The annual rainfall was appreciably more than the long-term 80th percentile figure (2,680 mm). The 2013–14 annual pattern of rainfall in Strathgordon was similar to the pattern of system inflows. August and October 2013 had rainfall well above the monthly long term 80th percentile. There were no months where the total rainfall was lower than the long term 20th percentile, however the months of November 2013 and June 2014 had rainfall totals just in excess of the 20th percentile value. In all, eight months of the years had rainfall greater than the average.

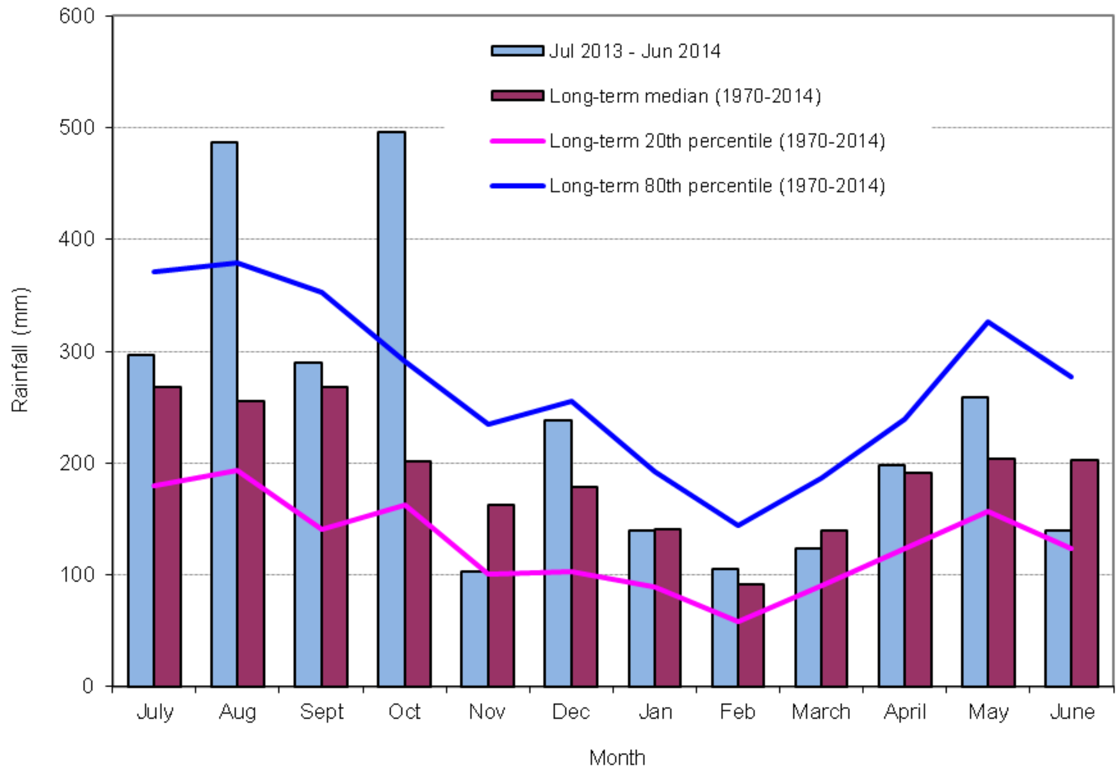

Figure 2-7: Total monthly rainfall values recorded at Strathgordon for 2013–14 compared with the long-term median (1970–2014).

2.5.3 Gordon Power Station operation

2.5.3.1 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 shows the discharge from the power station for 2013–14. More detailed monthly graphs are provided in Appendix A. A summary of significant points of interest in the 2013–14 discharge data is as follows:

- In July and early August 2013 the discharge pattern consisted of periods of peaking between high (> 200 $m^3 s^{-1}$) and low-mid range discharges (30-120 $m^3 s^{-1}$) interspersed with a pattern of near continuous high discharge (>200 $m^3 s^{-1}$);
- for the remainder of August until late October 2013, the discharge was highly variable, with only short periods of high flow (>200 $m^3 s^{-1}$). The variable flow that occurred was generally a peaking discharge with a base in low-mid discharges (20-100 $m^3 s^{-1}$) and a peak in mid-high ranges (120-200 $m^3 s^{-1}$); and
- the most dominant flow pattern for the year was seen from late October 2013 until the end of the monitoring period in June 2014. This pattern was characterised by near-continuous high discharge (> 200 $m^3 s^{-1}$) for this eight month period, with only few very brief periods of flow reduction.

Table 2-2 and Table 2-3 show the percentage of time zero, one, two and three turbines were running annually and on a monthly basis, respectively, along with a description of shorter term influencing factors (Table 2-3). The monthly breakdown of power station operating pattern throughout the year provides an indication of the downstream hydrological regime, as efficient discharge for operating one, two or three turbines is approximately 70, 140 and 210 $m^3 s^{-1}$, respectively. The use of three turbines is generally related to higher discharge, however since joining the National Electricity Market, there has been greater use of three turbines at low to moderate discharge. In 2013–14 there was high use of all three turbines (83.1 % of the time) compared to previous operations. The use of just one turbine occurred infrequently, while two turbine operation had a greater, though modest period of operation.

Table 2-2: Percentage of time that each configuration of turbines was in operation during 2013–14, in each of the financial years post-Basslink and in all previous records.

No. of turbines	Percentage of time operating								
	Jul 13–Jun 14	Jul 12–Jun 13	Jul 11–Jun 12	Jul 10 – Jun 11	Jul 09 – Jun 10	Jul 08 – Jun 09	Jul 07 – Jun 08	Jul 06 – Jun 07	Sep 96 – Jun 13
0 turbines running	1.1	2.6	2.8	6.9	2.6	3.1	7.5	3.6	12.1
1 turbine running	4.0	34.9	74.8	42.0	33.1	34.3	22.7	9.0	26.2
2 turbines running	11.8	13.4	17.3	24.5	49.9	38.1	30.8	40.1	31.3
3 turbines running	83.1	49.2	5.1	26.6	14.4	24.5	39.1	47.3	30.4

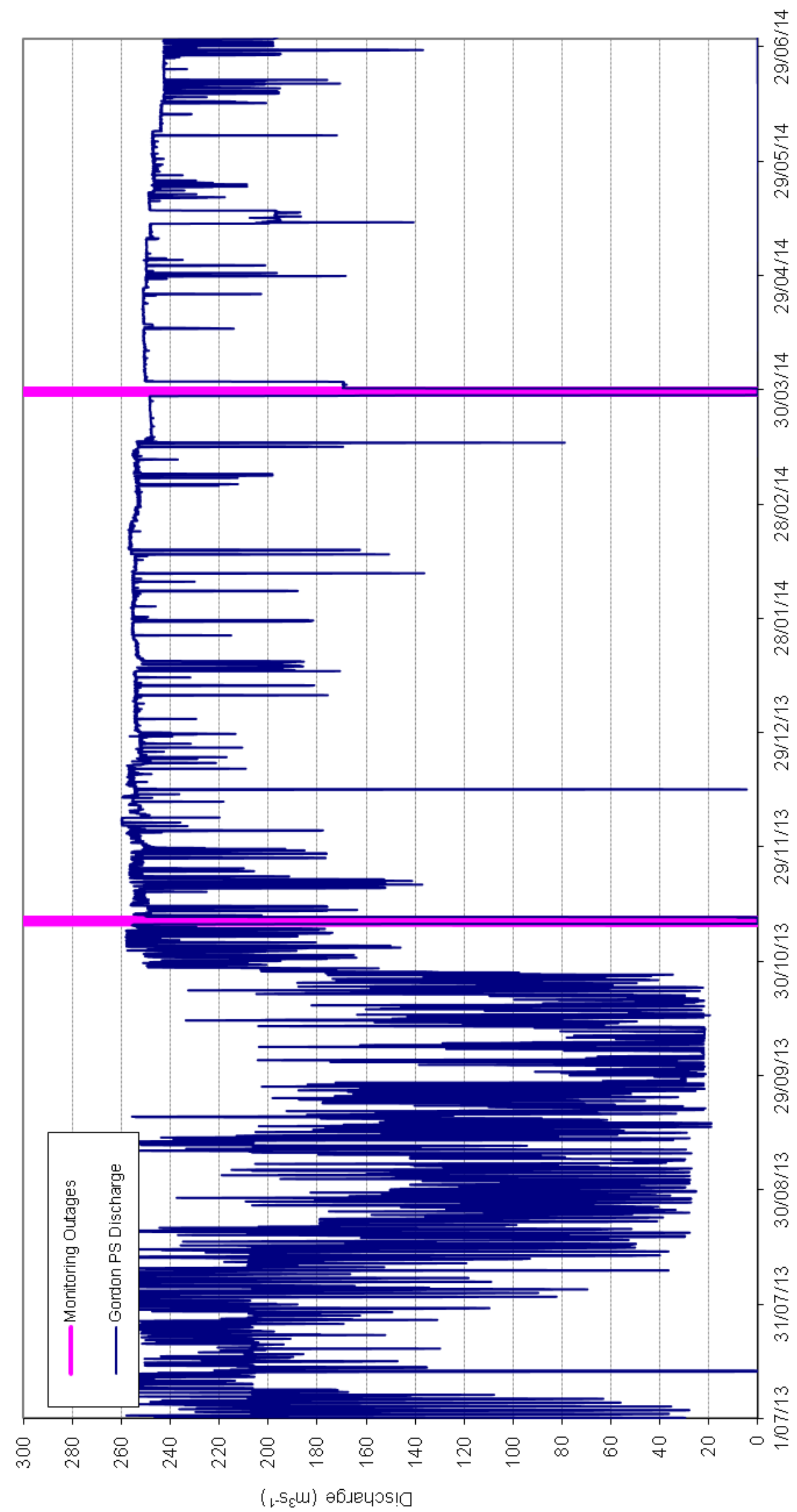

Figure 2-8: Gordon Power Station discharge (hourly data) from July 2013 to June 2014. Pink vertical lines indicate monitoring events.

Table 2-3: Summary information on discharge, weather conditions, market volatility and outages for 2013–14. 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. Market volatility is based on daily average price and 30 minute prices.

Period	0-turbine operation % time	1-turbine operation % time	2-turbine operation % time	3-turbine operation % time	Strathgordon rainfall	System yield	Market volatility, inflows and outages	Basslink Net Import (GWh) (negative = export, positive = import)
July 2013	0.9	0.0	3.9	95.2	> average	> average	Gordon peaking for the first half of the month, loaded after Poatina. Loaded before Poatina for second half of the month to maintain high export on Basslink.	-238.9
August 2013	0.0	0.5	33.6	65.9	wet	high	One Gordon machine out for a week, running to Basslink export limits, loading Gordon before Poatina but after run of river.	-273.7
September 2013	0.0	10.8	52.6	36.5	> average	> average	Running to Bass link export limits, loading Gordon before Poatina but after run of river.	-296.5
October 2013	0.0	36.0	36.3	27.7	wet	high	Running to Basslink export limits, loading Gordon after Poatina for first half of month then changed back to loading Gordon before Poatina but after run of river.	-308.5
November 2013	5.8	0.1	7.8	86.3	< average	> average	Base load Gordon to full output with reduced run of river operation. A number of single machine outages through this month as well as a two day station outage.	-212.6
December 2013	0.3	0.0	0.4	99.3	> average	> average	Baseload Gordon to full output with reduced run of river.	-264.1
January 2014	0.0	0.0	0.1	99.9	< average	> average	Base load Gordon to full output with reduced run of river.	-236
February 2014	0.0	0.0	0.3	99.7	> average	< average	Baseload Gordon to full output with reduced run of river.	-204.9
March 2014	5.8	0.0	5.0	89.2	< average	average	Baseload Gordon to full output with reduced run of river. Two day Gordon station outage.	-152.6
April 2014	0.0	0.1	1.3	98.6	> average	average	Baseload Gordon to full output with reduced run of river.	-274.9
May 2014	0.0	0.0	0.0	100.0	> average	> average	Baseload Gordon to full output. Basslink outage 13/05/14 to 16/05/14, Gordon output reduced to 290MW for this period.	-356.8
June 2014	0.0	0.0	0.1	99.9	< average	< average	Baseload Gordon to full output.	-274.2

2.5.3.2 Power station outages

There were four power station maintenance and inspection outages in 2013–14. All of these were only a few hours' duration, and these were all consistent with the Licence requirements.

Basslink monitoring power station outages took place on:

- 22:00, 8 November 2013 – 15:00, 10 November 2013; and
- 20:00, 28 March 2014 – 16:00, 30 March 2014.

2.5.3.3 Median monthly discharge

Figure 2-9 shows the median monthly discharge from the power station for 2013–14 compared with long-term values (since January 1997) and the previous seven years of the post-Basslink period. This figure illustrates the extended period of high discharge that was the dominant hydrological feature in 2013–14. The median discharge values in all months of 2013-14 were substantially higher than long term and previous post-Basslink values. The 2013-14 median values indicated an annual pattern of gradually decreasing discharges between July and October 2013. This was followed in November 2013 by an abrupt increase in median discharge values equivalent to near-maximum discharge values, and was maintained at these high levels for the remainder of the monitoring period to June 2014.

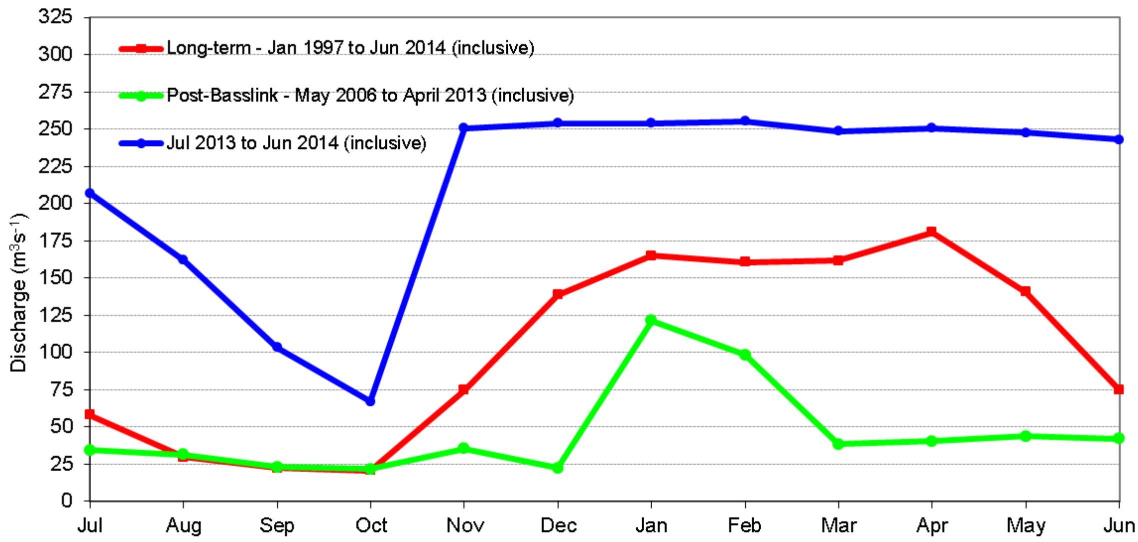

Figure 2-9: Median monthly discharge from the Gordon Power Station (site 77) for 2013–14 compared with long-term monthly median values and previous post-Basslink years.

2.5.3.4 Flow duration curves

Figure 2-10 to Figure 2-13 show the duration (percentage exceedance) curve for the power station discharge for:

- Whole of year (Figure 2-10);
- winter period (May–October; Figure 2-11);
- summer period (November–April; Figure 2-12); and
- years one to eight of post-Basslink annual data (Figure 2-13).

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 2014);
- 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 2013) prior to the current year ; and
- 2013–14 financial year (1 July 2013–30 June 2014).

The annual 2013–14 discharge (Figure 2-10) was defined by the extended period of high flow, and the lack of flow in the low to mid-ranges. The annual discharge in 2013–14 had greater periods of high flow, relative to long-term, historical and all previous post-Basslink years. In 2013–14 flow discharges greater than 200 $m^3 s^{-1}$ accounted for 72% of flows which was greater than long-term (19%), historical (15%), pre-Basslink (26%) and previous post-Basslink (12%) periods. Discharges less than 30 $m^3 s^{-1}$ were observed for 5% of the time in 2013–14. This was lower than the long-term record which had 34% of discharges less than 30 $m^3 s^{-1}$.

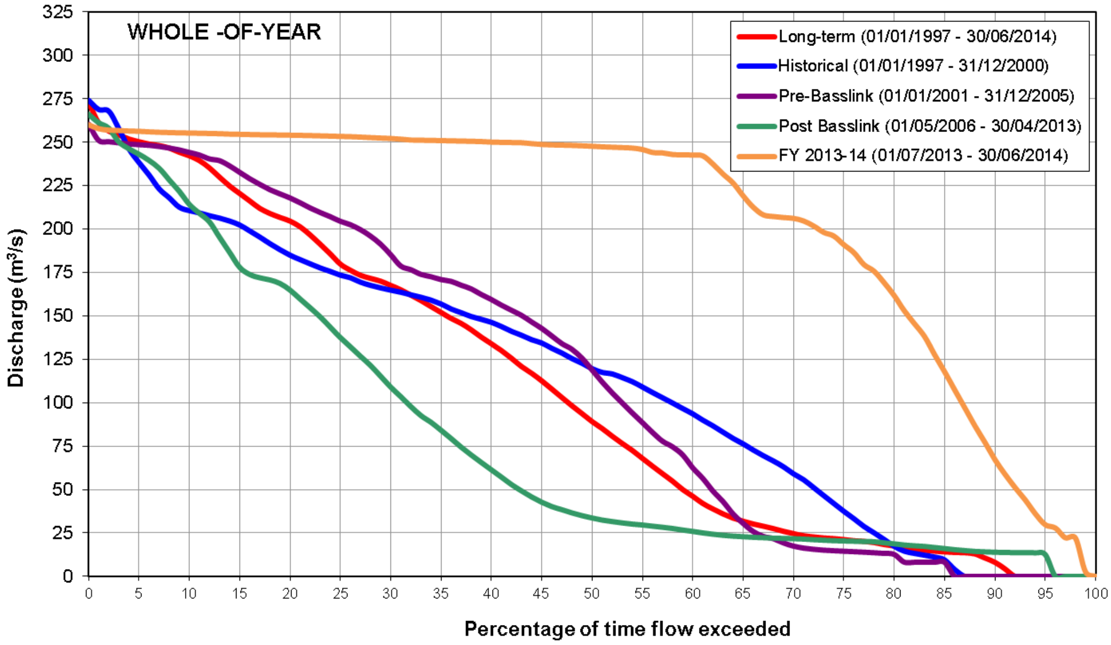

Figure 2-10: Duration curves for discharge from the power station tailrace using annual data for selected periods.

The 2013–14 winter discharge flow duration curve (Figure 2-11) was a similar shape to that of the annual duration curve, with a high but shorter duration of high discharge. The winter flows had a high proportion of discharges > 200 $m^3 s^{-1}$ (53%), which exceeded the proportion of discharge >200 $m^3 s^{-1}$ for all other periods for comparison (e.g. 11% of all long term flow >200 $m^3 s^{-1}$). Despite following the long-term annual pattern of reduced discharge during winter, there were very few low flows in winter 2013-14, which was very similar to the annual duration curve. Discharge <30 $m^3 s^{-1}$ accounted for only 8% of all winter flows in 2013–14 and 44% of all long-term winter flows.

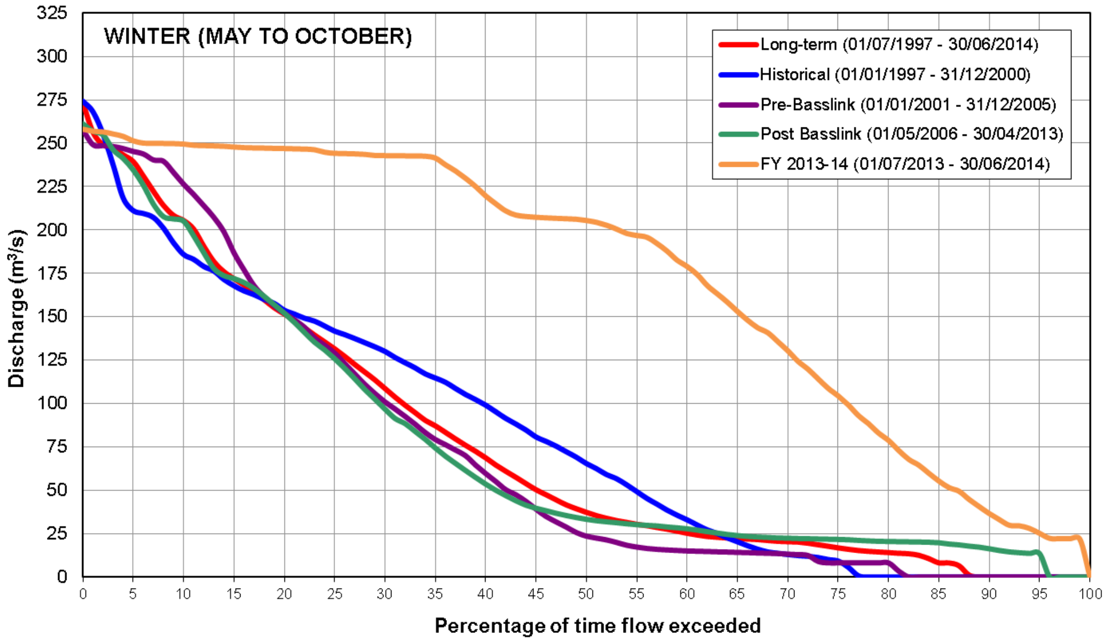

Figure 2-11: Duration curves for discharge from the Gordon Power Station using winter data (for the months of May to October inclusive) for selected periods.

The 2013–14 summer discharge flow duration curve (Figure 2-12) was also a similar shape to that of the annual duration curve, but with extended period of high flow. It had a distinctive flat-line appearance at high discharge for the majority of the plot due to the dominance of high flow discharge during the summer period. There were very few periods of low and mid-range flows. Summer 2013–14 had a proportion of flows >200 $m^3 s^{-1}$ (92%) which exceeded any of the comparison periods (long-term: 28%; historical: 23%; pre-Basslink: 40%; previous post-Basslink years: 13%).

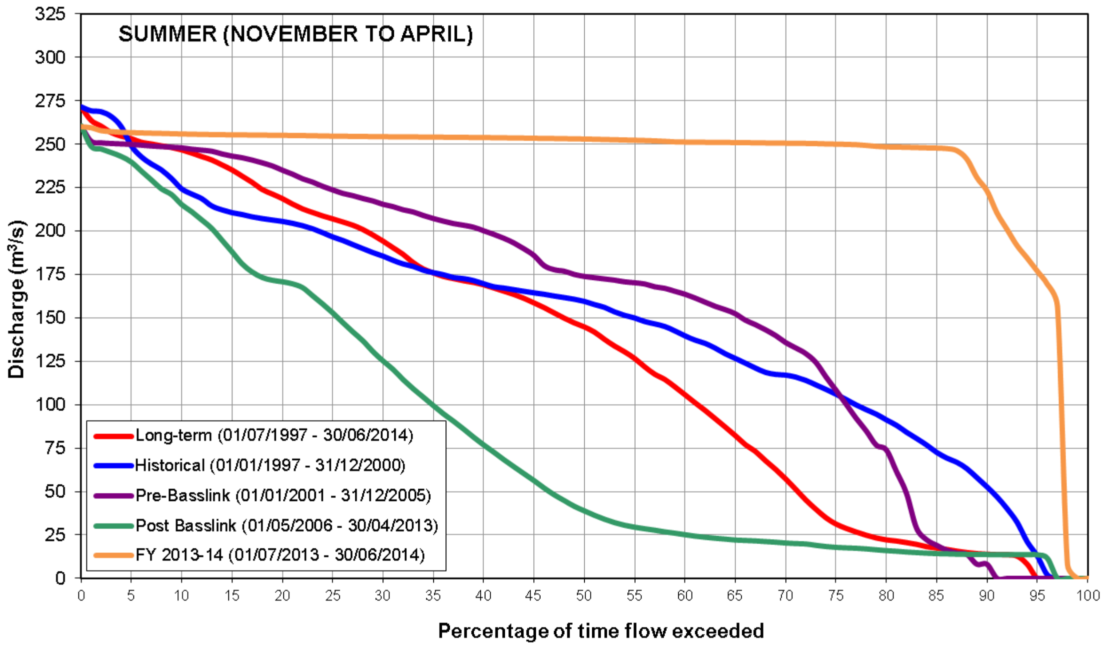

Figure 2-12: Duration curves for discharge from the Gordon Power Station using summer data (for the months of November to April inclusive) for selected periods.

Annual flow duration curves for each post-Basslink year are represented in Figure 2-13 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 curve for 2013–14 differs slightly from the annual curve in Figure 2-10 as it represents a 12-month period that is offset by two months. It is clear that 2013–14 had the highest and longest periods of high flows (>200 $m^3 s^{-1}$) in the post-Basslink period, which also exceeded all previous years from which data is available for comparison (i.e . since 1997).

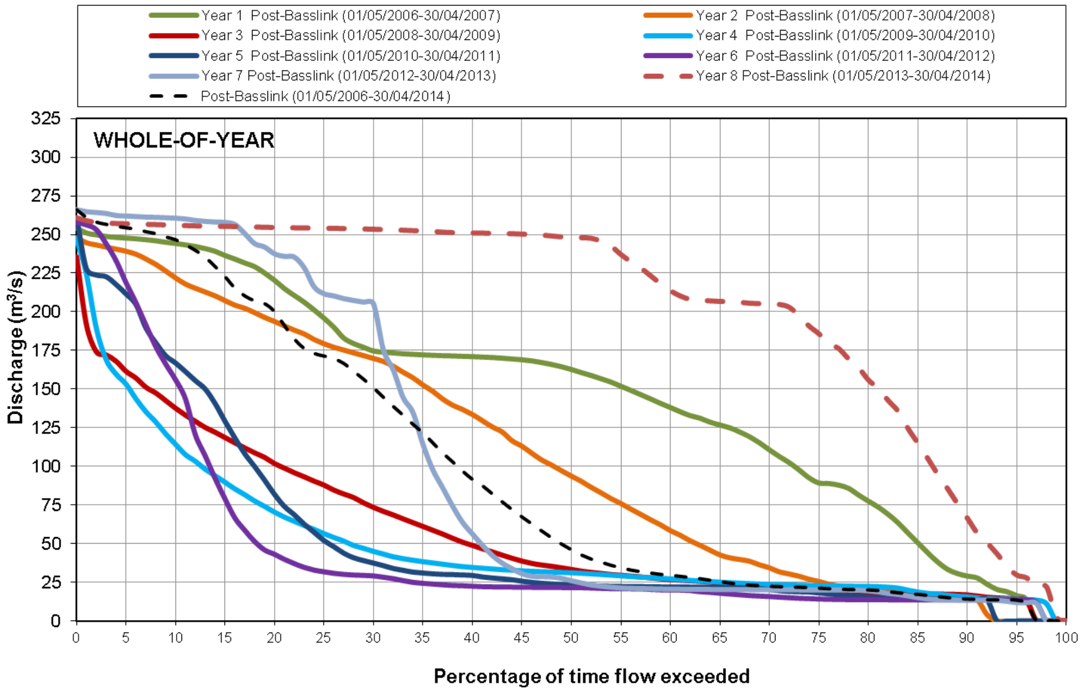

Figure 2-13: Annual duration curves for discharge from the Gordon Power Station for the eight years post-Basslink.

2.5.3.5 Flow change frequency analysis

The results of the flow change frequency analysis are shown in Figure 2-14 to Figure 2-16. The data for 2013–14 indicate that the six months up to 1 October 2013 had a larger number of hours (107 hours) of flow reduction in excess of 30 $m^3 s^{-1}$ per hour while discharge was > 180 $m^3 s^{-1}$ than in the six months up to April 2013 (48 hours) (Figure 2-15). The April to October 2013 period had the second highest on record, and is indicative of variable flow whilst power station discharges were in excess of 180 $m^3 s^{-1}$. The 48 hours of flow reductions >30 $m^3 s^{-1}$ per hour from 1 October 2013 to 1 April 2014 was slightly above the average of 33 hours for all periods since 1997. The extended period of high discharge during this period was the main cause the elevated occurrence, however the lower occurrence compared to the previous six months appears to be due to the very steady high discharge.

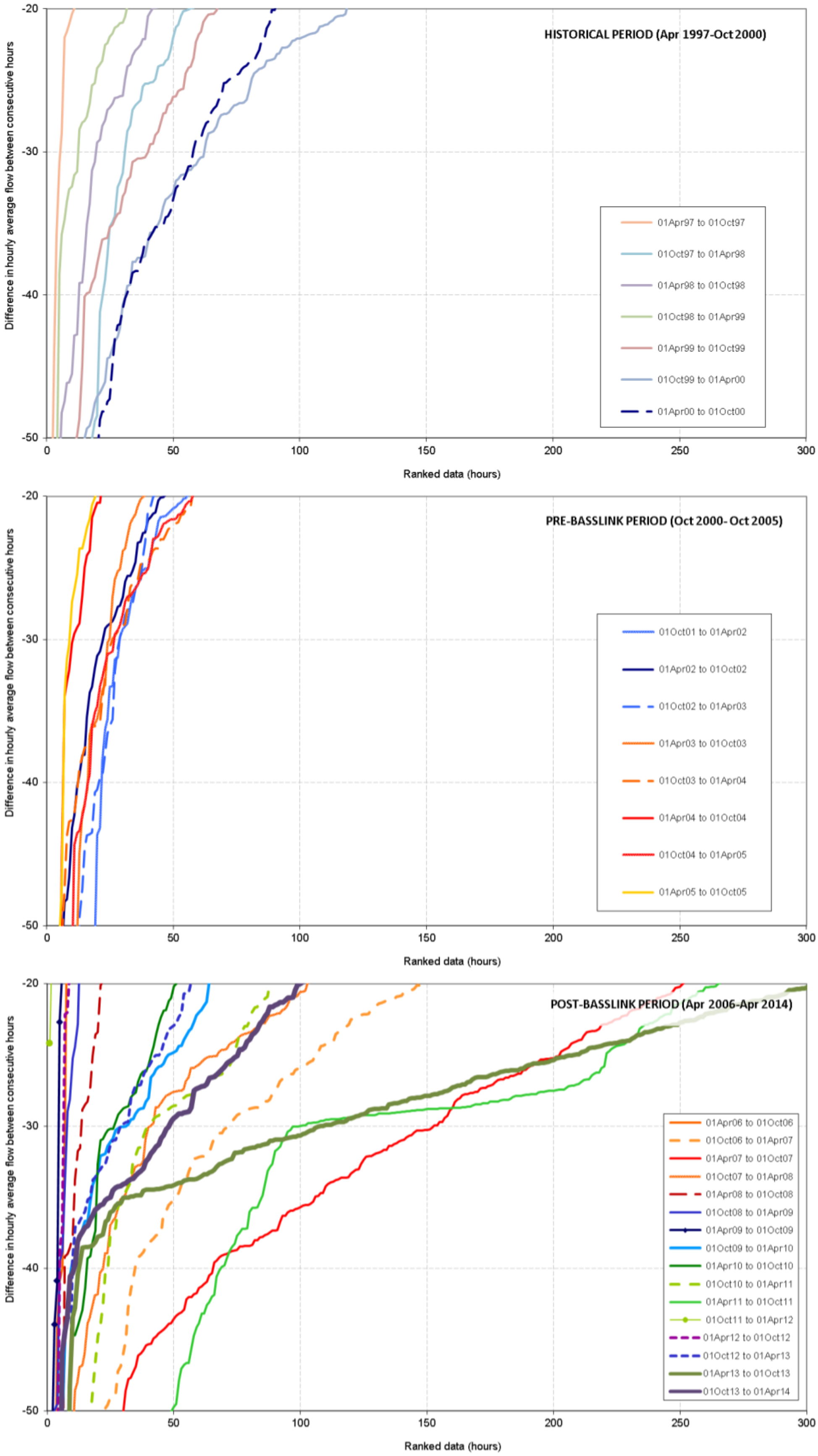

Figure 2-14: Flow change frequency for six month periods of ranked flow rate reductions while power station discharge was more than 180 $m^3 s^{-1}$.for historical, pre-Basslink and post-Basslink periods.

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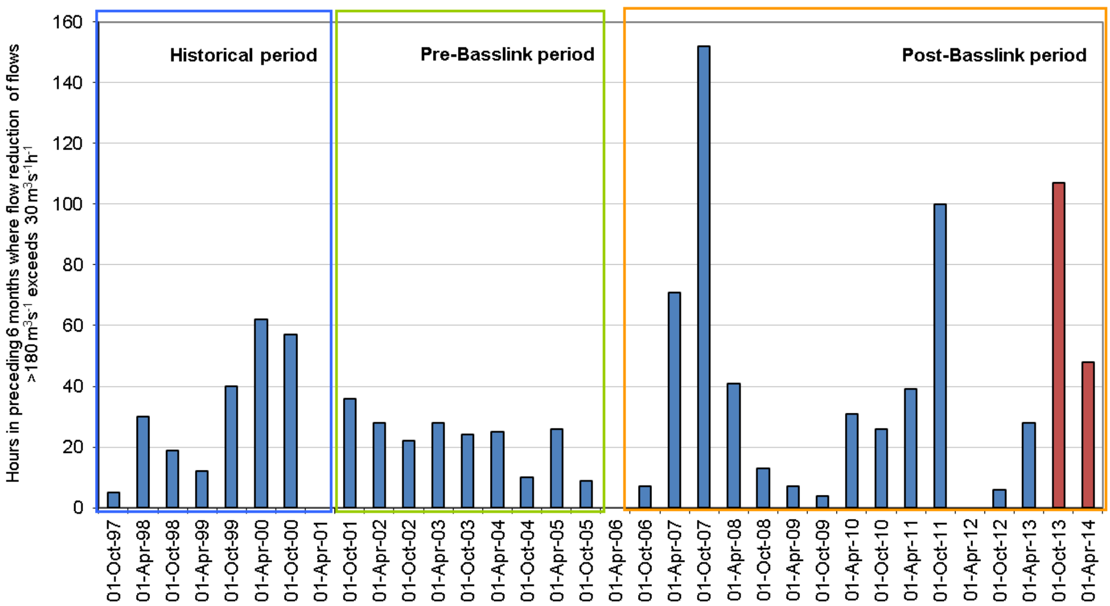

Figure 2-15: Number of hours for each prior six-month period where flow reductions from >180 $m^3 s^{-1}$ exceed 30 $m^3 s^{-1}$ per hour. The most recent periods are indicated by red columns.

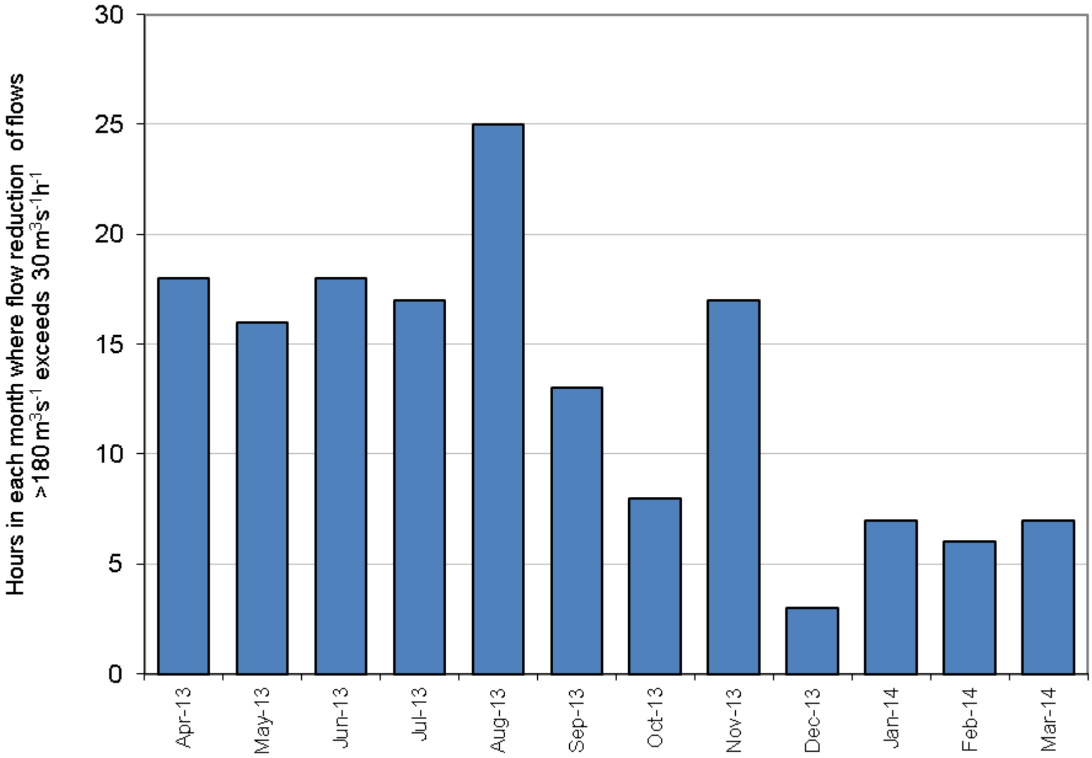

Figure 2-16: Number of hours for each month between April 2013 and March 2014 where flow reductions from >180 m^3s^{-1} exceed 30 m^3s^{-1} per hour.

2.5.3.6 Low to mid-range flow variability analysis at the power station

Figure 2-17 presents analysis of rapid increases between low and mid-range flows, and provides a measure of flow variability that is at a scale of relevance to macroinvertebrates and fish. The rapid increases are not indicative of full-range hydro-peaking, just rapid low-mid range variations in flow. This analysis presents data for the number of occasions when flows have increased rapidly (within two hours) from low flows in the vicinity of the environmental flow (<25 $m^3 s^{-1}$) to greater than 100 $m^3 s^{-1}$. Since 1997, when hourly data became available, 2013–14 had the lowest number of such events (8 instances). This was less than half the previously lowest annual occurrences in 2007-08 (18 instances).

There were two rapid flow increase events in July and one each in September, October, November, December 2013 and March 2014 (Figure 2-18). The very low number of these events was the result of there having been very few periods where flow reduced below 25 $m^3 s^{-1}$.

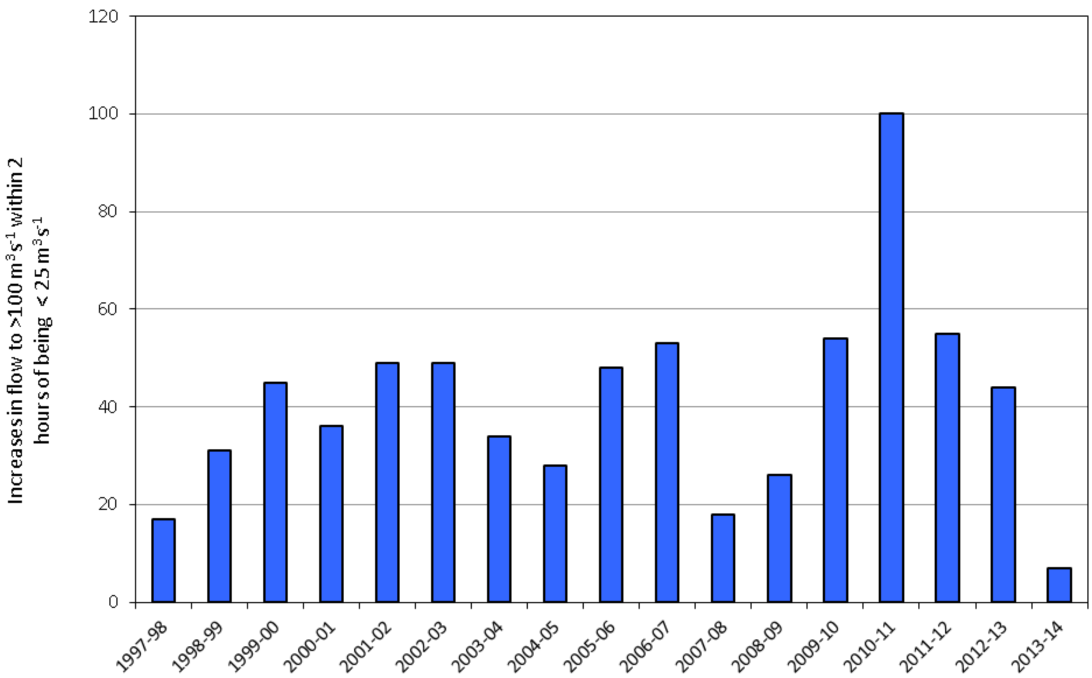

Figure 2-17: Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each year where hourly data are available.

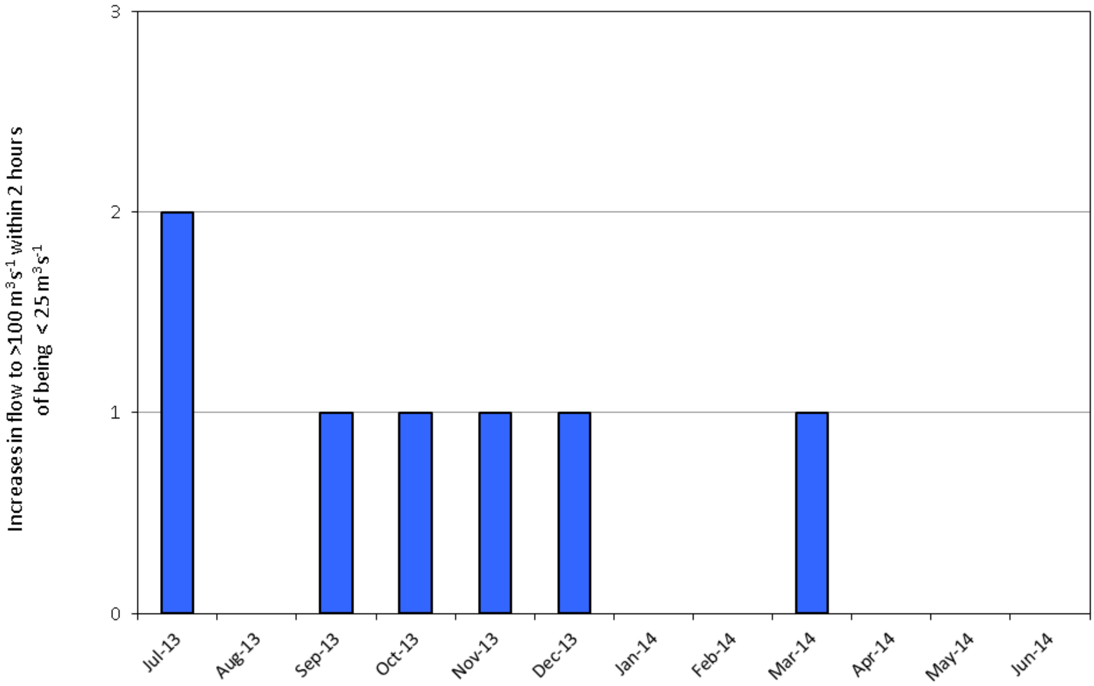

Figure 2-18: Rapid flow increases (<25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each month during 2013–14.

2.5.3.7 Compliance with ramp-down rule

In 2013-14, there were no non-compliances with the ramp-down rule. During the audit period (July 2013–June 2014) the ramp down rule was required to be applied for 6883 hours (i.e. while the bank water level was >2.75 m and the power station discharge was >150 m^3s^{-1}). The control system was correctly (automatically) set for all of those periods and so it follows that there were no ramp-down rule non-conformances.

2.5.3.8 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 6883 hours where ramping was required during flow reductions, those that exceeded 1 MW per minute occurred on 99 separate events (Appendix B), and totalled a little less than 23 hours (0.26% of time that the ramp-down rule was applied). Of these events, the majority (74% or 73 events) had a maximum reduction rate that was less than 1.1 MW per minute. 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 exceedences 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.

The greatest exceedances of the 1 MW per minute reduction target were seen during events 17 (31 Jul 2013) and 84 (14 Jan 2014) (Appendix B). These two large exceedences occurred as a result of simultaneous machine protection trips on machines 2 and 3 due to a Basslink trip fault. Both of these events were beyond the control of operators.

2.5.3.9 Performance of Bank Saturation Model

The bank saturation model provides estimates of the water level in the river banks to determine when the trigger level of 2.75 m was exceeded (Figure 2-19). The analysis of 30 minute aggregated data indicated that over the audit period (1 July 2013 to 30 June 2014) the modelled data provided 827 false negatives (5.4% of observed positives) where water levels were greater than the trigger level of 2.75 m, while the model indicated that they were less than this level. There were only 63 false positives (0.4% of compared values) for the audit period, however these are of little concern.

The comparison of the prevalence of false positives and false negatives indicates that the model has tended to underestimate the water level in the vicinity of the trigger level more regularly in 2013-14. This underestimation is also clear when comparing the 1:1 line in Figure 2-19 with the spread of the data points. The large number of observations in the vicinity of the 2.75 m trigger level mostly occurred during the period of August to September 2013. At this time, the discharge from the power station had been reduced from near maximum discharge to a mid-range peaking pattern. It appears that during the unusual operating pattern of 2013-14, the model was prone to underestimate the bank water level following periods of high bank saturation. This is most likely related to the propensity of the banks to drain slowly in response to high in-bank water storage following periods of extended high bank inundation (chapter 3: Fluvial geomorphology).

The model was initially developed with a period of data that encompassed a range of power station operations (1 July 2007 to 1 July 2010). The regression model was evaluated, to determine whether improvements in the number of false negative values could be achieved by incorporating the most recent piezometer data. The current model formulation was retained without alteration of the regression variables. The regression coefficients were re-calculated utilising all good quality data (July 2007 to July 2014), incorporating an additional four years of data than the previous calculation.

The model is as follows:

$$\begin{aligned} Level_{Site\ G5A,\ Piezo\ 2} &= a_0 \\ &+ a_1 * Q\_PS\_Advanced_{FMA\ 2hour} \\ &+ a_2 * Q\_PS\_Advanced_{FMA\ 24hour} \\ &+ a_3 * Q\_PS\_Advanced_{FMA\ 3day} \\ &+ a_4 * Q\_PS\_Advanced_{FMA\ 14day} \end{aligned}$$

Where:

a_i = *Regression coefficients.*

Q_PS_Advanced = *PS Flow advanced 2.5 hours from TSM(254.1/111.00/2); Aggregate(0:30:00)*

FMA t = *Flat Moving Average Filter applied over the preceding period t.*

The recalculation of co-efficients (a_i) provided only minor improvement in the number of false negatives calculated for 2013-14, from 5.4 % to 5.2 % of observed positive values. Given this improvement is very small and the operation during 2013-14 was unusual, the regression coefficients in the current model will be maintained.

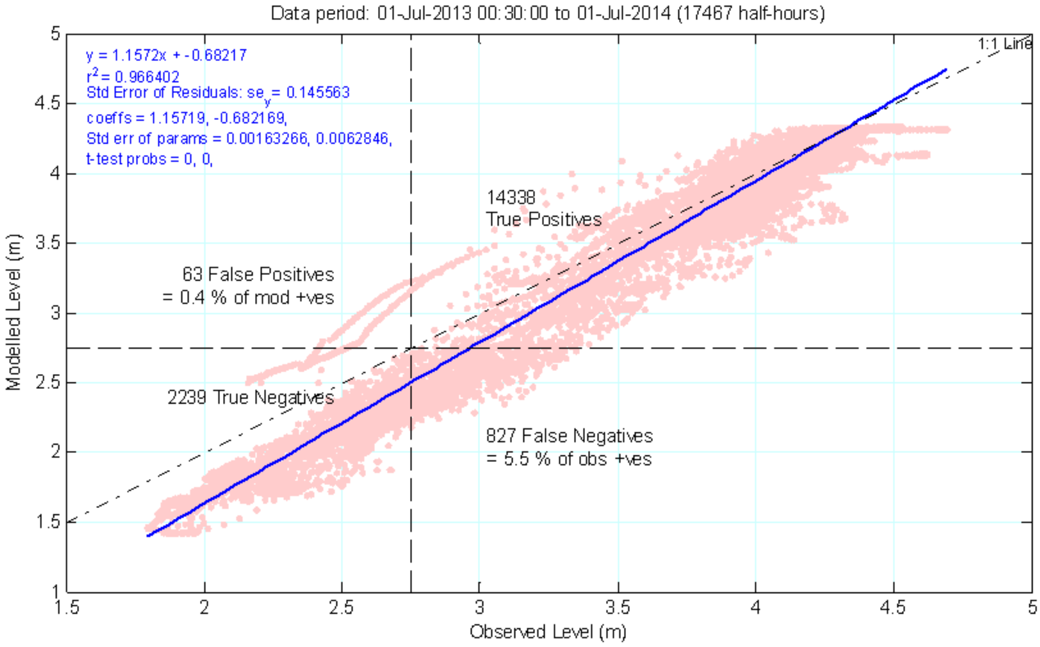

Figure 2-19: Observed versus modelled water levels for period 1 July 2013 to 30 June 2014 based on 30 minute aggregated data.

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.

2.5.4.1 Flow

Figure 2-20 shows the flow recorded at site 65 for 2013–14 and indicates 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 from a number of events from July to October 2013 as well as events in January, May and June 2014. The departure of the hydrograph from that of the Gordon Power Station discharge is indicative of these tributary inflows from such rainfall events.

A backwater effect has been observed at this site. When the Denison River floods and Gordon discharge is low, Denison River water may backflow up past site 65. The result of this effect at site 65 would be an over-estimation of the flows during the period of Denison River flooding. The primary function of this site is to monitor the minimum environmental flow, so the backwater effect will not interfere with this function as it only occurs during periods of high tributary flow (i.e. when the minimum environmental flow is met by tributary inputs). The maximum flow for 2013-14 at site 65 was measured as 558 m^3s^{-1} on 22 May 2014.

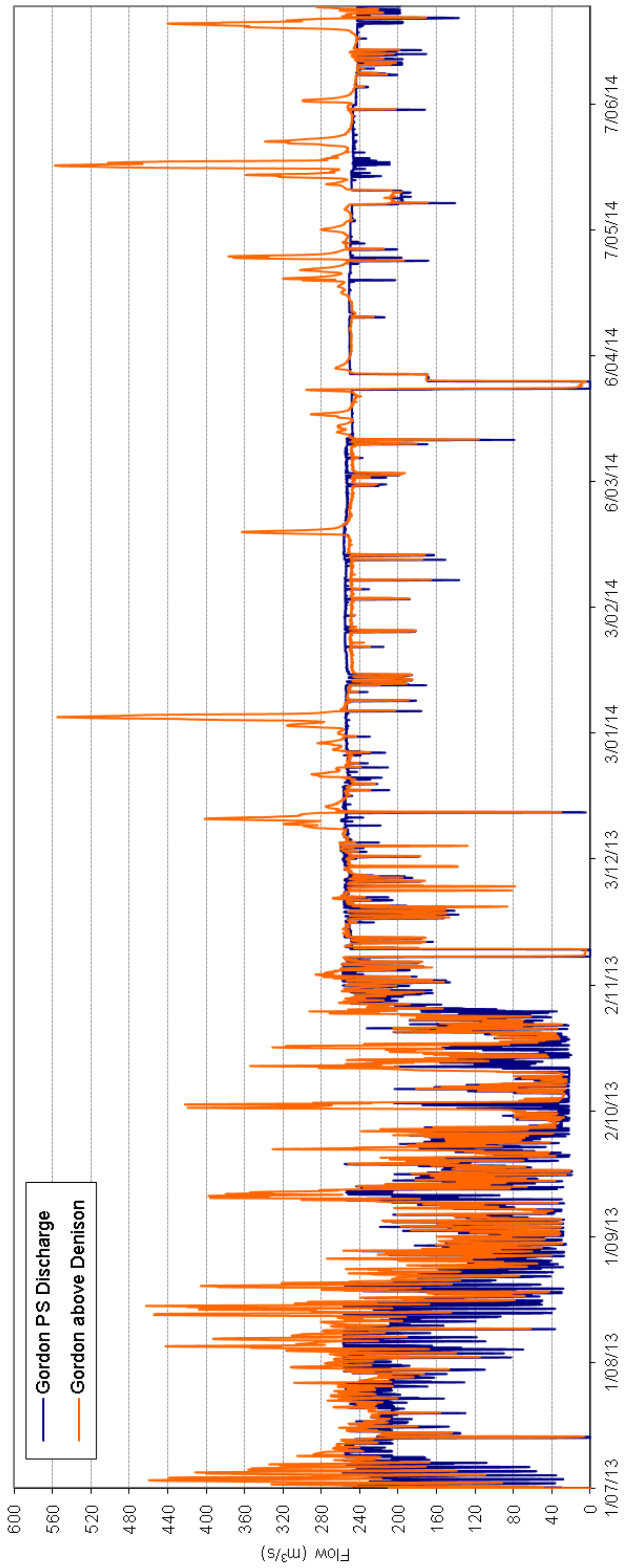

Figure 2-20: Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2013 to June 2014.

2.5.4.2 Median monthly flows

The median monthly flow for site 65 (Gordon above Denison) is shown in Figure 2-21. Comparison with historic average (2003–14) patterns shows monthly median flows from all months were well above average. These followed a very similar pattern to those of the Gordon Power Station discharges.

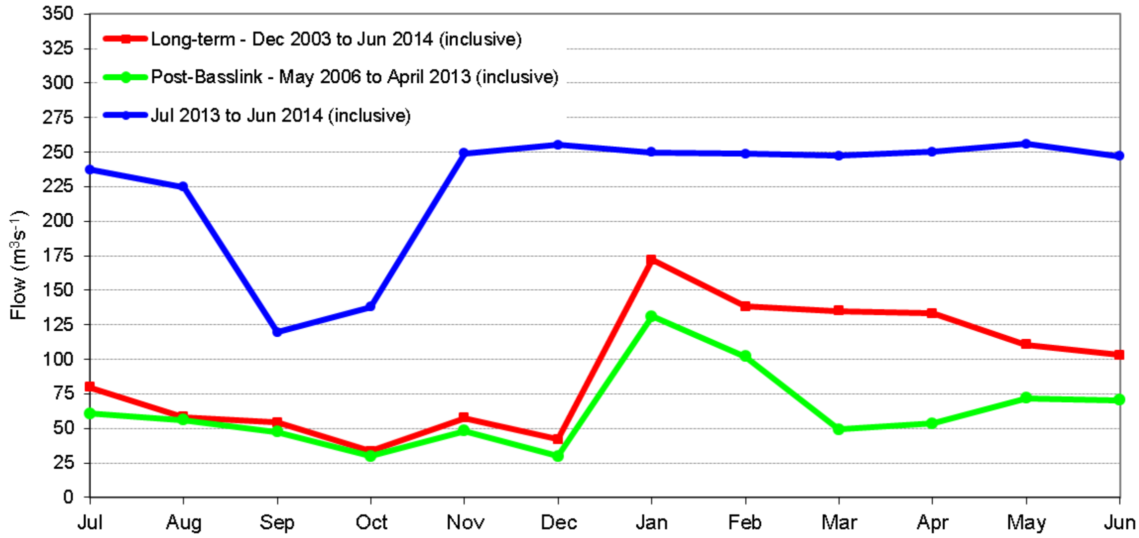

Figure 2-21: Median monthly flow at site 65 (Gordon above Denison) for 2013–14 compared with long-term median values and previous post-Basslink years.

2.5.4.3 Duration curves

The duration curve for site 65 is shown in Figure 2-22. Comparison with the long-term curve shows an extended period of high flow, reflective of the power station discharge flow duration curve (Figure 2-12). This high duration of high flows was evident with 78% of flows in excess of 200 m^3s^{-1}, and consequently there were very few periods of low flow. Flows in excess of 260 m^3s^{-1} are indicative of combined discharge and tributary flows in the Gordon River and account for approximately 15% of flows in 2013-14.

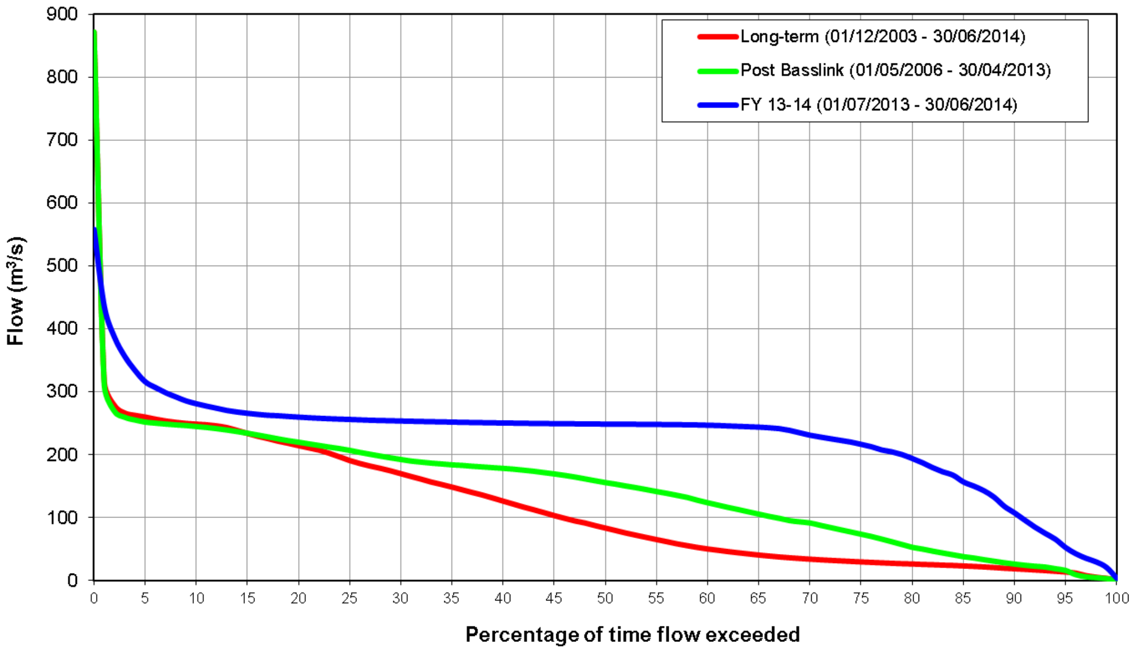

Figure 2-22: Flow duration curve for Gordon above Denison for 2013–14 compared with long-term and previous post-Basslink years.

2.5.4.4 Environmental flow compliance

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

An analysis of hourly flows at site 65 (Figure 2-23) shows that for the winter periods (July–November 2012 and June 2013), the minimum flow requirement of 20 $m^3 s^{-1}$ was met 100 % of the time. The minimum summer (December 2012–May 2013) flow requirement of 10 $m^3 s^{-1}$ was also met 100 % of the time (Table 2-4). Note that times of shutdown of the Gordon Power Station due to maintenance, AEMO conformance testing, and/or monitoring have been excluded from the analysis, as per the licence conditions.

Table 2-4: Environmental low flow non-conformance events at site 65 for 2013–14.

Period	Minimum environmental flow	Non-compliant events	Non-compliant hours	Compliance rate
Winter (July–Nov 2013)	20	0	0	100%
Summer (Dec 2013–May 2014)	10	0	0	100%
Winter (June 2014)	20	0	0	100%

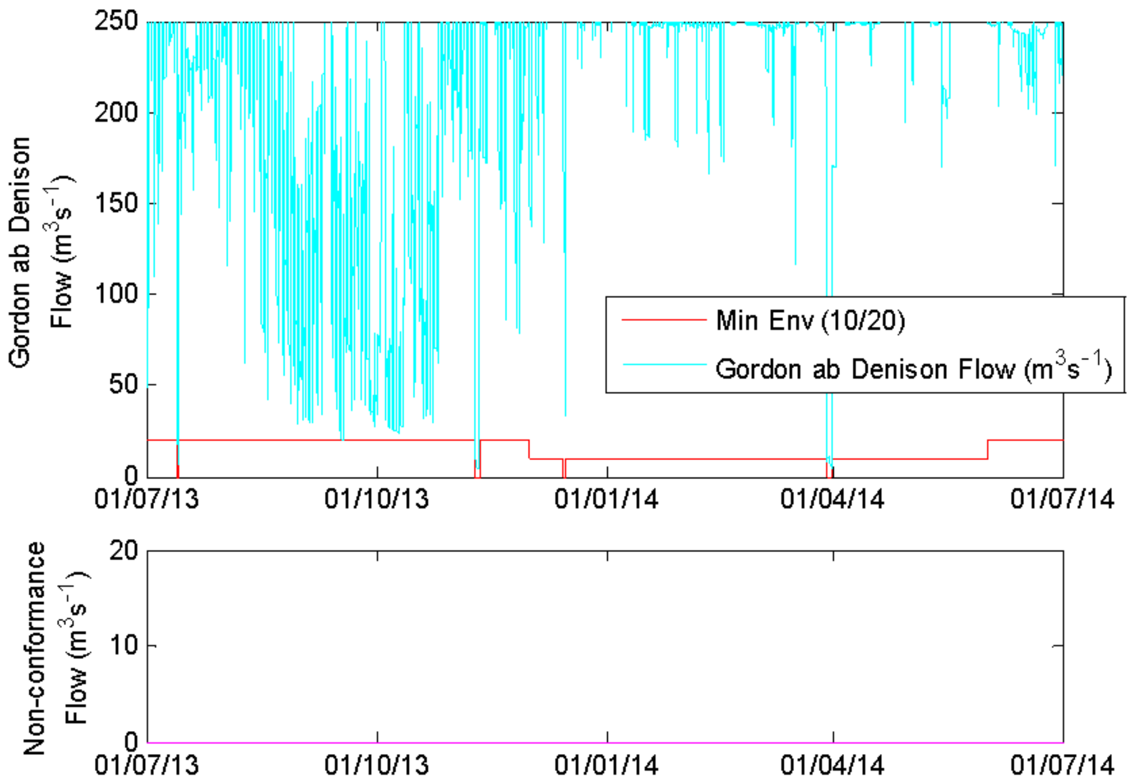

Figure 2-23: Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2013 to June 2014, and analysis of non-conforming flows.

2.5.4.5 Low to mid-range flow variability analysis at Gordon above Denison

Figure 2-24 presents analysis of rapid increases between low and mid-range flows at the Gordon above Denison site, and provides a measure of flow variability that is at a scale of relevance to macroinvertebrates and fish. This measure is not indicative of full-range hydro-peaking, but rapid low-mid range variations in flow. This analysis presents data for the number of occasions when flows have increased rapidly in the post-Basslink period (within two hours) from low flows in the vicinity of the environmental flow (<25 $m^3 s^{-1}$) to greater than 100 $m^3 s^{-1}$. In 2013–14 there were three instances, which was one of the lowest occurrences since the commissioning of Basslink. The annual number of events for most years including 2013-14, is less than half of that recorded for the Gordon Power Station discharge (Figure 2-17) and is due to the downstream attenuation of flows and tributary inputs.

In 2013–14, the three rapid flow increases occurred one in each of the months of July 2013, November 2013 and March 2014. The latter two occurred at the return to higher discharges following each of the monitoring outages (Figure 2-25).

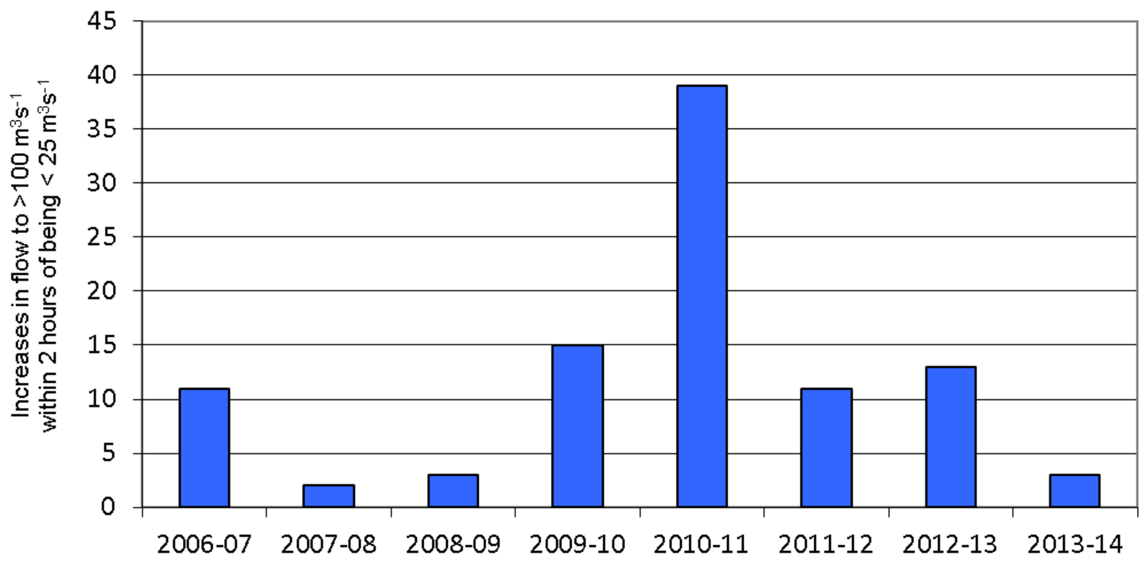

Figure 2-24: Rapid flow increases (<25 to >100 m3 s-1 in two hours) at the Gordon above Denison for each post-Basslink year.

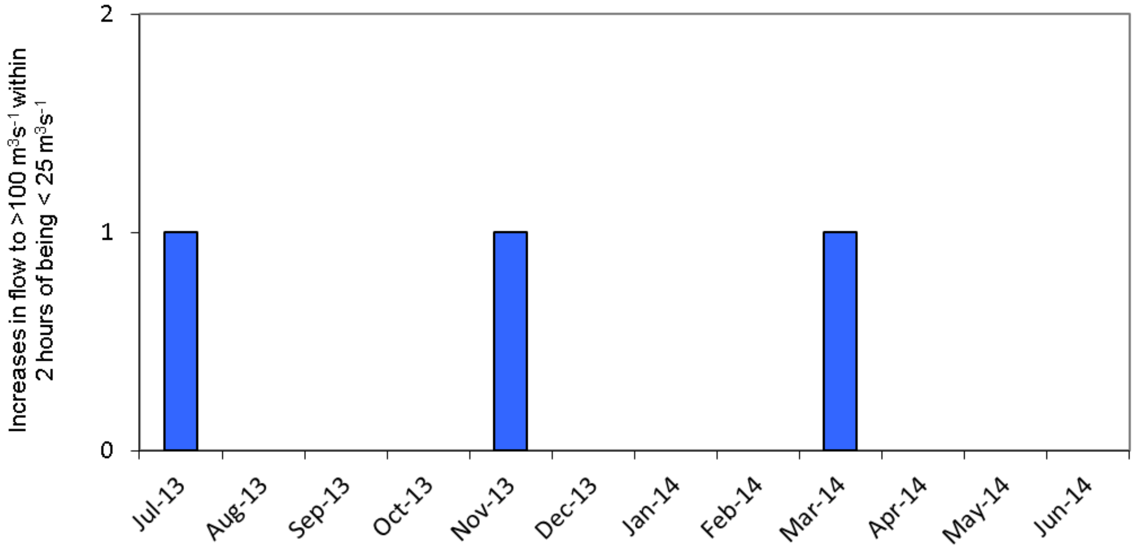

Figure 2-25: Rapid flow increases (<25 to >100 m3 s-1 in two hours) at the Gordon above Denison for each month during 2013–14.

2.5.5 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the most downstream monitoring site on the Gordon River. Power station releases travel 33 km down the Gordon River before passing the gauge at site 44. The measured flow at this point is a combination of the power station discharge as well as the input from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent rivers. The Franklin River joins the Gordon downstream of site 44 and therefore is not included in the gauged data. Data from site 44 provides an indication of the influence of tributary streams and flow attenuation of the power station discharge on hydrology of the lower reaches of the river.

2.5.5.1 Flow

Figure 2-26 shows the hourly flows at site 44 for 2013–14 compared with discharge from the Gordon Power Station.

The flow rating at this site is based on only a small number of gaugings undertaken during monitoring periods. Of these, few gaugings have been taken at high flows, and it is acknowledged that the flow estimation, particularly at higher flows, is an under-estimate. In 2013–14, power station discharge was a large flow component at site 44. However, there were many divergences in hydrographs on a number of occasions where tributary flows (i.e. Denison River) provided a major proportion of the flow. High tributary flows were most common in July-October 2013. Other periods where significant tributary contributions occurred were in December 2013-January 2014 and April-June 2014. The maximum flow of 881 $m^3 s^{-1}$ for the year occurred on 2 October 2013.

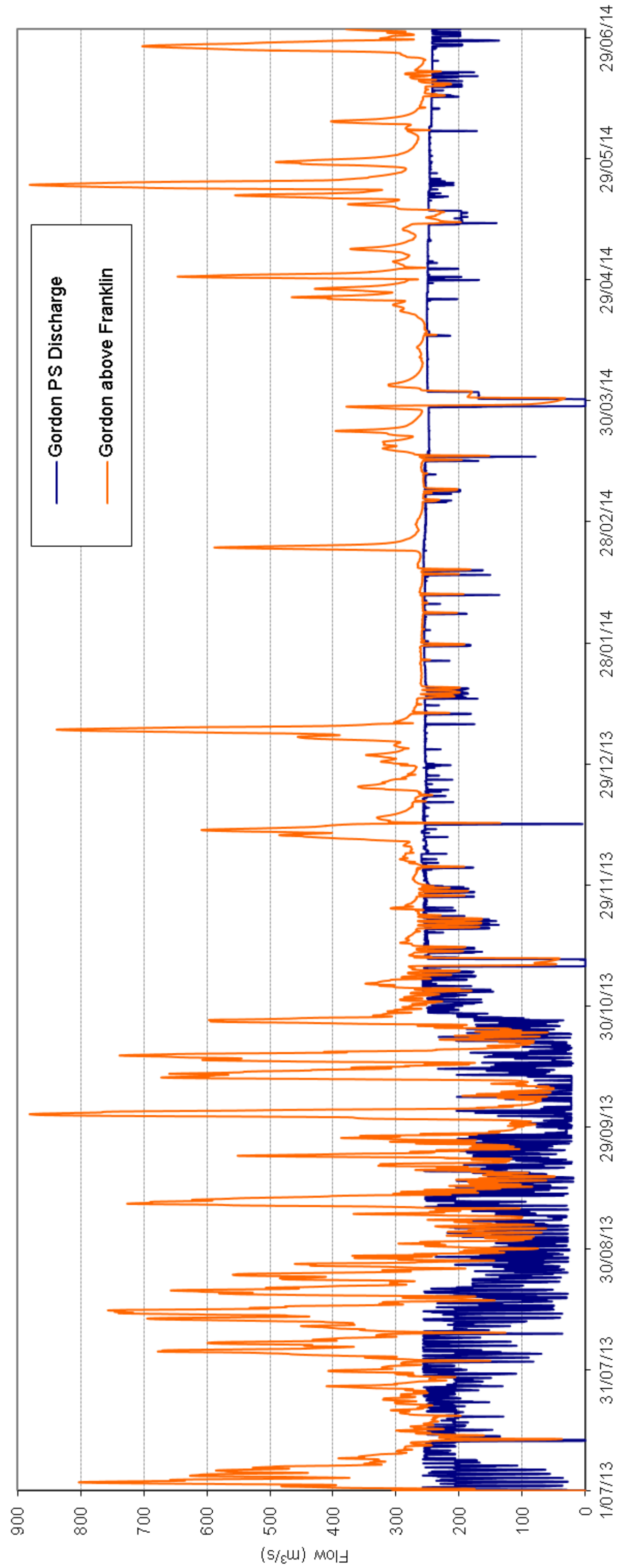

Figure 2-26: Flow recorded (hourly data) at site 44 (Gordon above Franklin) and Gordon Power Station discharge derived from the simplified three-dimensional rating during 2013–14.

2.5.5.2 Median monthly flows

Figure 2-27 shows the median monthly flow for the data at site 44 over the 2013–14 year, compared with the long-term post-dam (since January 1978) patterns. All months in the monitoring year had median values well in excess of long term and previous post-Basslink periods. The high median values were driven by two main factors; high catchment inflows and high power station discharge. The high catchment inflows had a major influence on the median values from July to October 2013, while the sustained high discharge from the power station from November 2013 to June 2014, maintained the median flow values at this time.

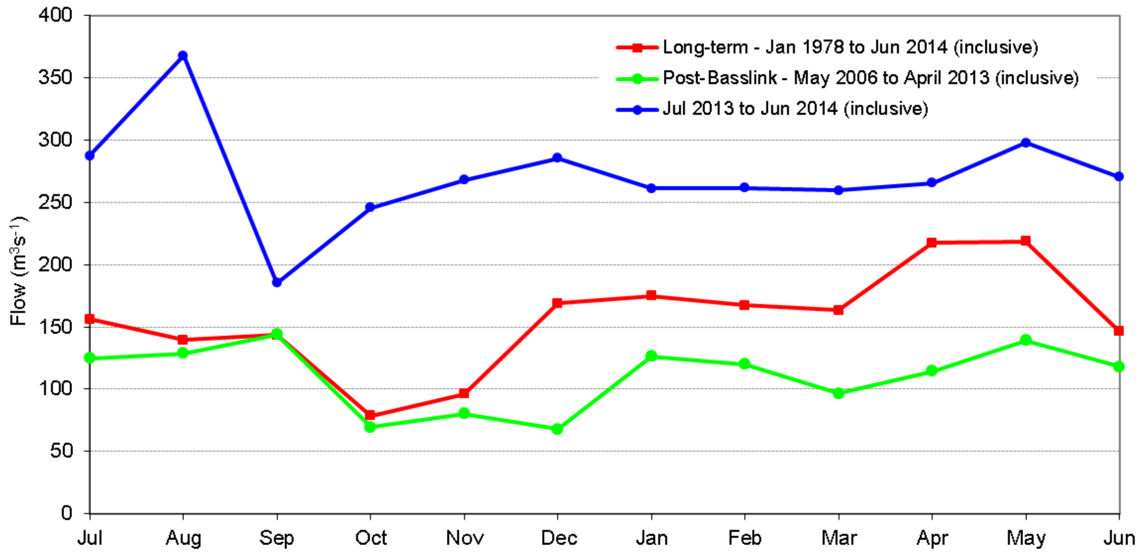

Figure 2-27: Median monthly flow at site 44 (Gordon above Franklin) for 2013–14 compared with long-term median values and previous post-Basslink years.

2.5.5.3 Duration curves

The duration curve for site 44 is shown in Figure 2-28. Comparison with the long-term curve is indicative of the significantly higher flows for most of the year as a result of the high power station discharge and high tributary inputs. The extended section of the duration curve between 250-300 $m^3 s^{-1}$ is primarily due to the extended period of high power station discharge in 2013-14.

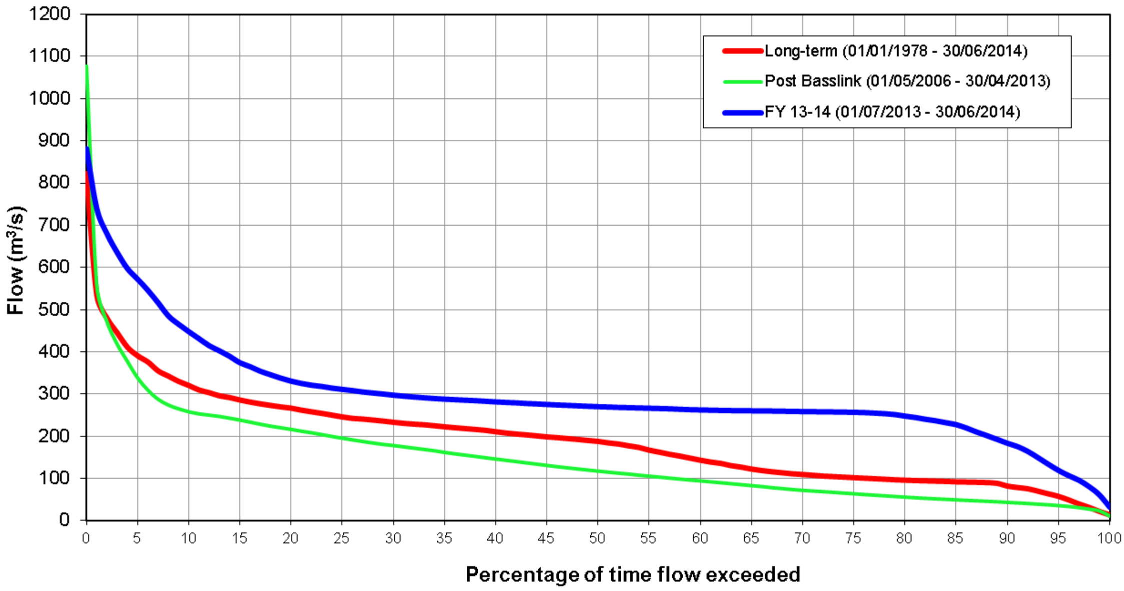

Figure 2-28: Flow duration curve for Gordon above Franklin (Site 44) for 2013–14 compared with long-term and previous post-Basslink years.

2.6 Conclusions

The flow in the Gordon River in 2013–14 was influenced by extended high discharge from the power station. High discharges were maintained to take advantage of the capacity to raise additional revenues following the implementation of the fixed carbon price.

Under the conditions of high discharge and subsequent reductions in flow, while the banks were saturated, the operation of the newly implemented ramp-down rule was applied successfully. 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 $m^3 s^{-1}$ discharge).

The bank saturation regression model performed within expectations, modelling water level at the piezometer site. The model under estimated water levels a small proportion of the time (5.4%) following extended periods of high flow, when banks subsequently drained more slowly than the model predicted. Re-calibration of the model using all available data provided only minor improvements in the accuracy of the model. The model will continue to be used in its current form considering the unusual operation regime in 2013-14.

The minimum environmental flow was achieved 100 % of the time both in summer and winter.

3 Fluvial geomorphology

3.1 Introduction

This report summarises the 2013–14 monitoring results and relates the findings to the current understanding of geomorphic processes in the middle Gordon River.

3.1.1 Aims of monitoring program

The aims of fluvial geomorphology monitoring in the Gordon River include:

- to document fluvial geomorphological processes and changes in the Gordon River between the power station tailrace and the mouth of the Franklin River (defined as the middle Gordon River);
- to relate these changes, where possible, to power station operations, including the ramp-down rule or other factors; 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 has been routinely completed in the middle Gordon River since October 2001

3.2 Methods

Basslink geomorphology monitoring is 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) and 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). The following is a brief summary of the monitoring components which have been included in the interim monitoring program (October 2012 – March 2014).

The monitoring included field observations and the measurement of ~250 erosion pins located at 47 monitoring sites in the middle Gordon River (Table 3-1). The monitoring sites are distributed over five geomorphic zones in the river, which have been identified based on hydrologic and hydraulic attributes (Figure 3-1 to Figure 3-6). Erosion pins are located in sandy alluvial banks along the middle Gordon River within the height affected by power station operation. The location of pins at each site have also been classified according to the typical turbine discharge required for inundation (<1 turbine indicates that the operation of one turbine is likely to inundate the pin, 1-2 turbine bank level requires the operation of two turbines for inundation and 2-3 turbine bank is inundated when all three turbines are in operation). These levels are approximate and based on field observations under low-flow conditions only as no hydraulic model is available for the river and observations during periods of power station discharge are extremely limited. A history of monitoring in the middle Gordon River associated with the Gordon River Basslink monitoring program is shown in Table 3-2.

A summary of all geomorphology sampling activities can be found in Table 3-2. In the current monitoring year, erosion pins in zones 2-4 were measured both in spring 2013 and autumn 2014, as required for the Interim Monitoring Program. In addition, time in the field allowed for the measurement of erosion pins in zones 1 and 5 in both trips. The 2013-2014 monitoring has allowed results to be compared to historical results on an annual basis, with the spring results providing an indication of changes over the winter period. The statistical analysis of the monitoring results has been altered due to the number of pins which were not found (due to inundation or loss of pin through deposition or scour), with histograms of change used to summarise the erosion pin results.

The field observations, erosion pin measurements and photo monitoring were completed by boat based teams. In addition to the field monitoring results, ground water levels were continuously recorded by the piezometer array in zone 2 originally installed for the Basslink monitoring.

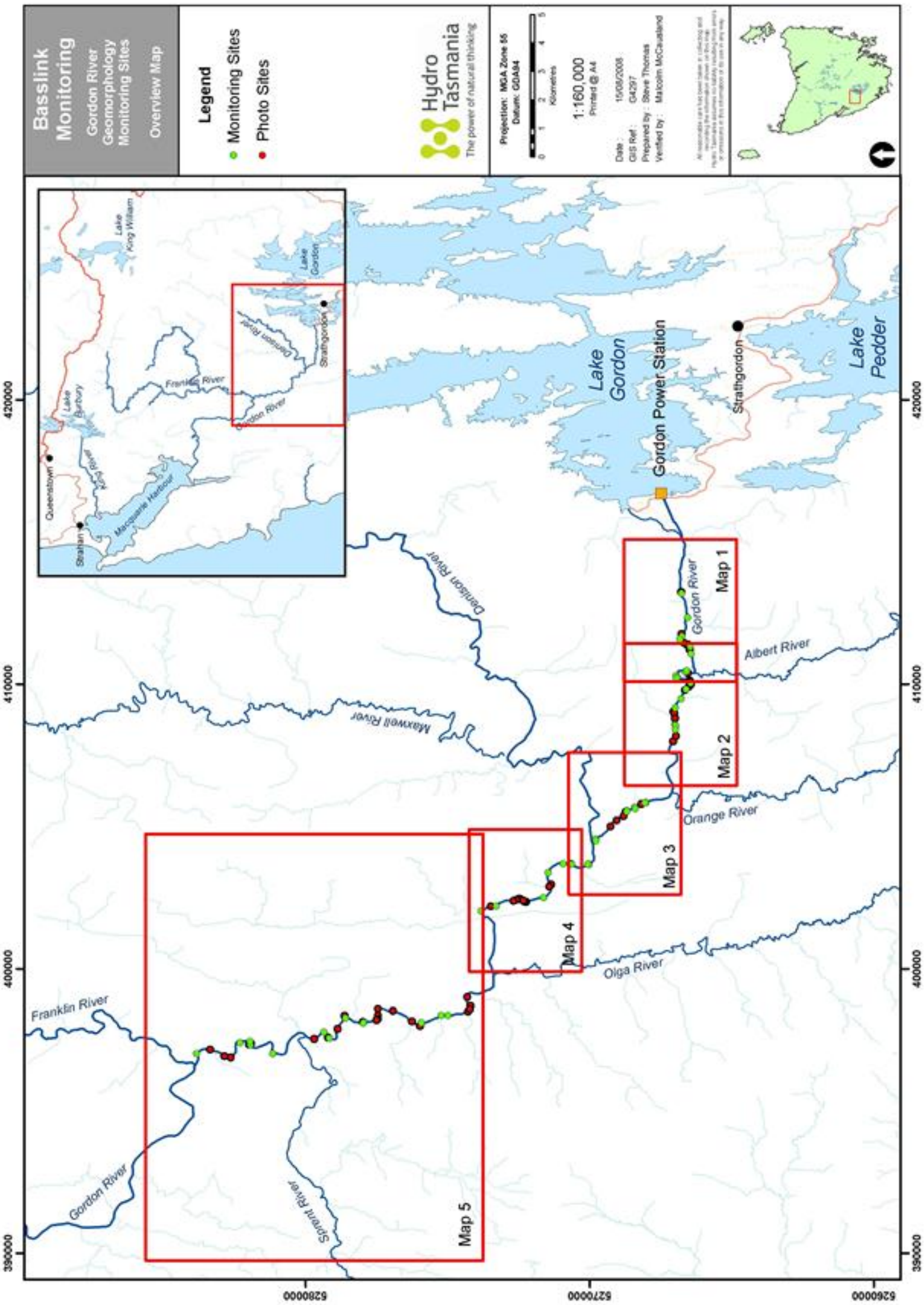

Figure 3-1: Overview of Gordon River geomorphology monitoring sites.

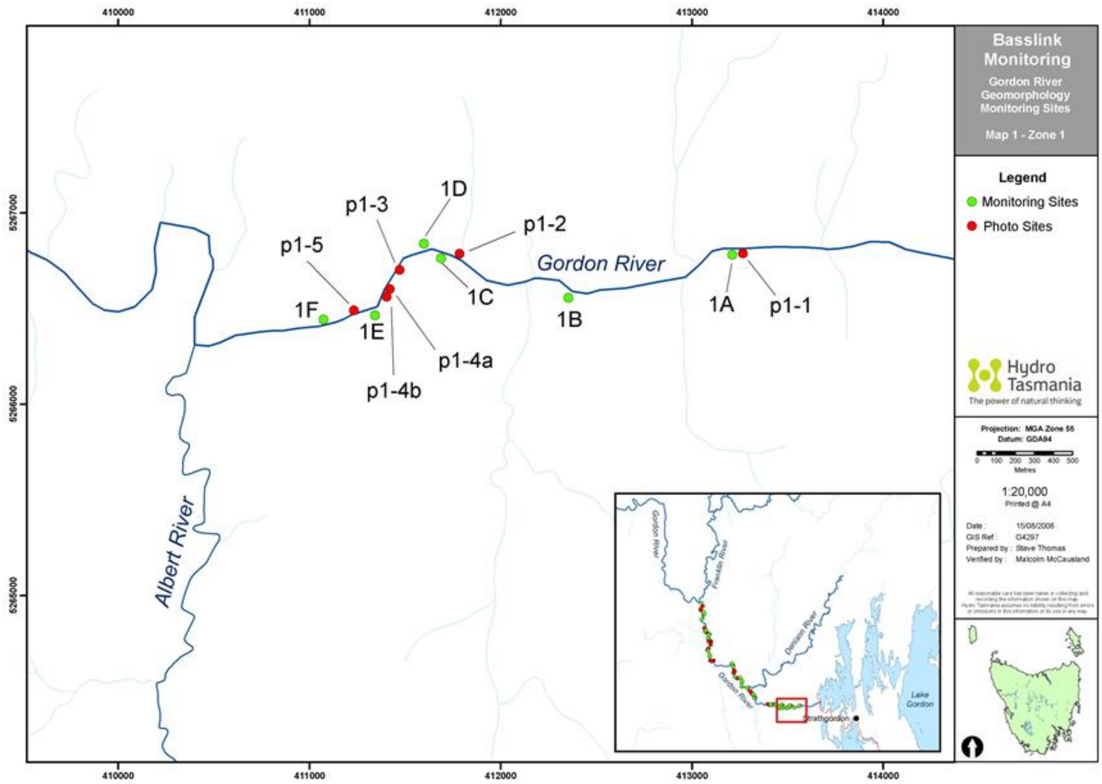

Figure 3-2: Gordon River geomorphology monitoring sites, zone 1.

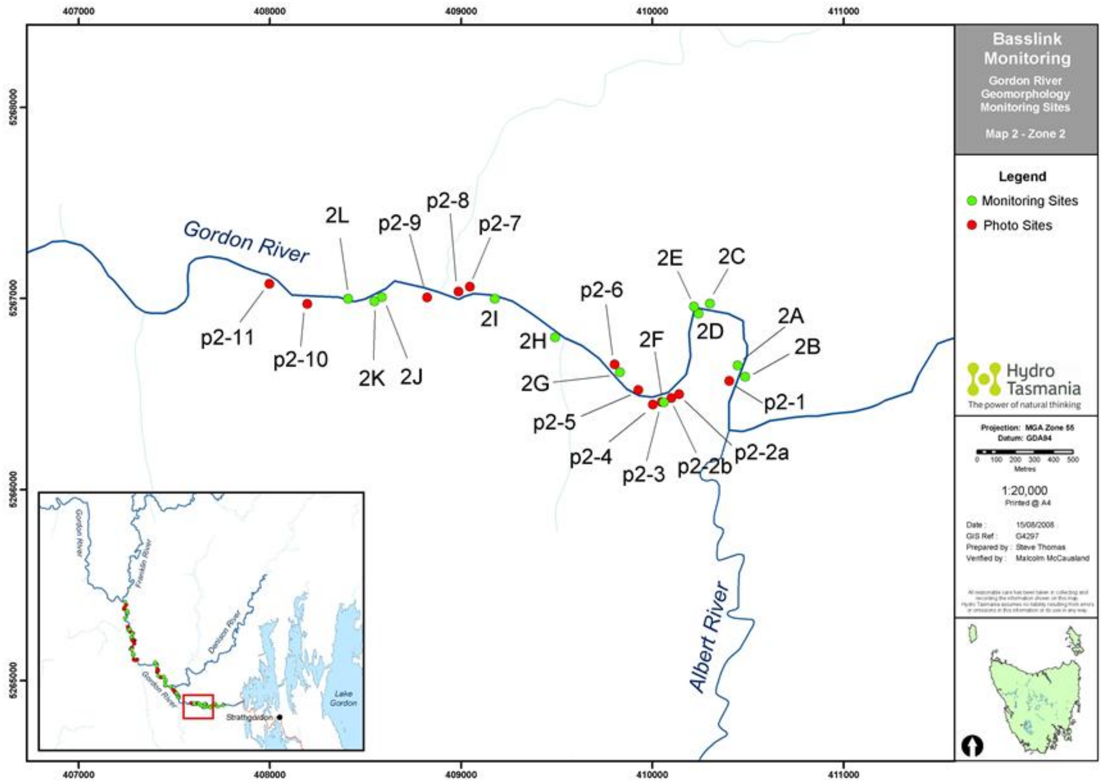

Figure 3-3: Gordon River geomorphology monitoring sites, zone 2.

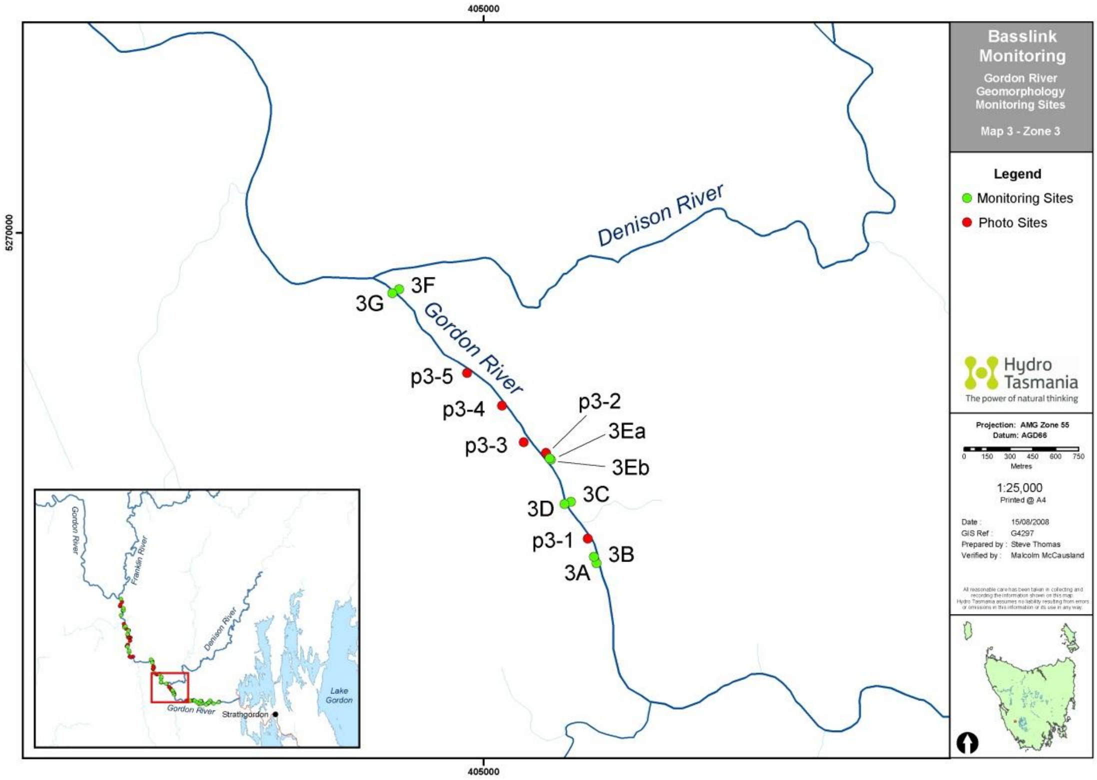

Figure 3-4: Gordon River geomorphology monitoring sites, zone 3.

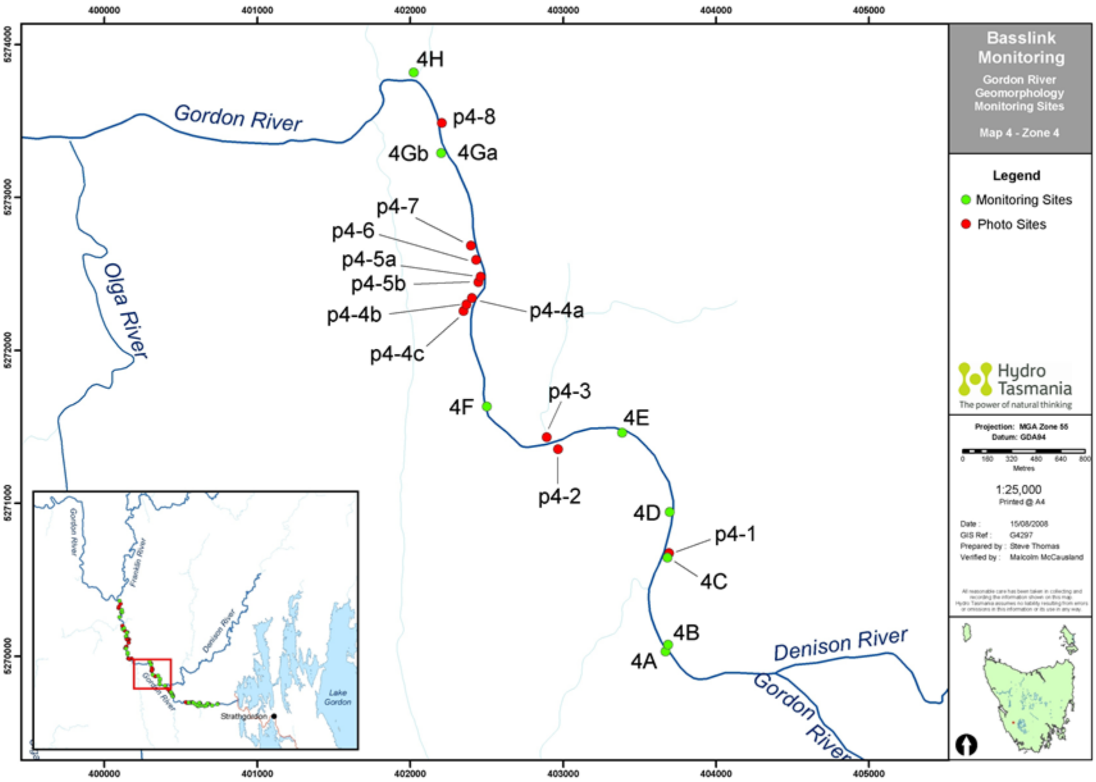

Figure 3-5: Gordon River geomorphology monitoring sites, zone 4.

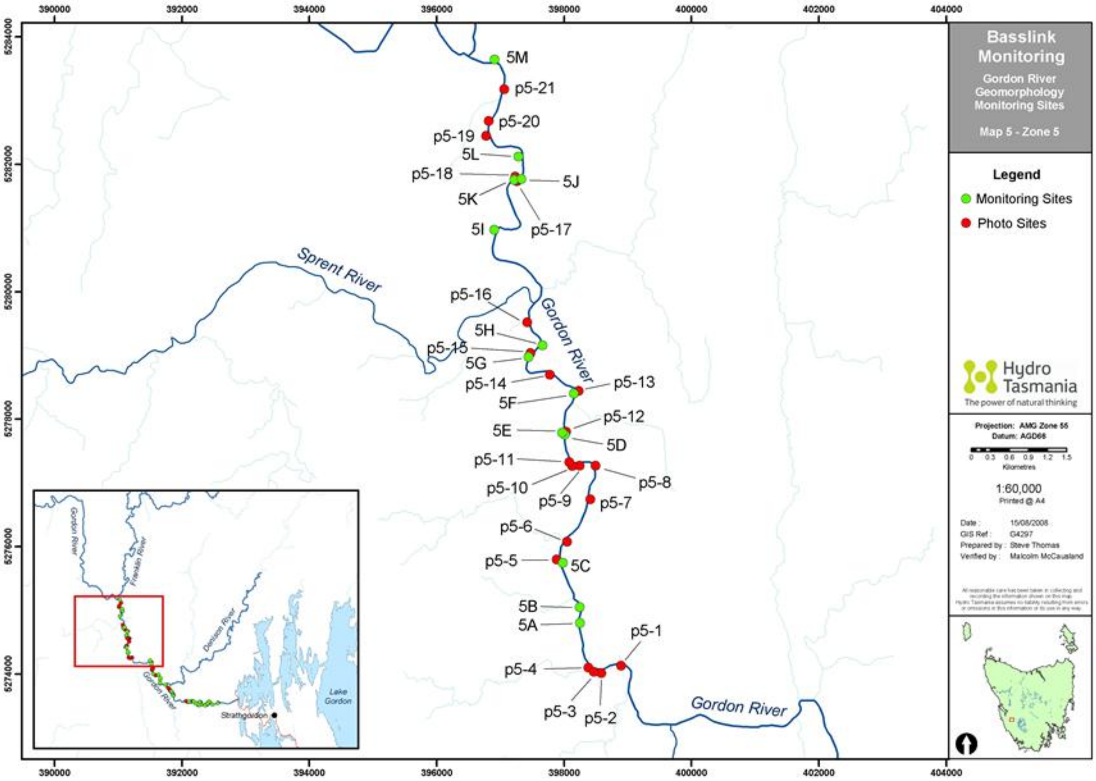

Figure 3-6: Gordon River geomorphology monitoring sites, zone 5.

Table 3-1: Number of monitoring sites and erosion pins in each geomorphology zone.

Zone	#Sites	#Erosion Pins
Zone 1	6	35
Zone 2	12	63
Zone 3	8	47
Zone 4	8	39
Zone 5	13	63
Total	**47**	**247**

Table 3-2: Summary of geomorphology monitoring activities in the middle Gordon River between 1999 and present. Derivation indicates that the data was used in the formulation of trigger values, 'test' indicates that the erosion pin results from that monitoring period have been compared with the trigger values or the conceptual model of the river.

Monitoring Type	Triggers: Derivation or Test	Season	Dates	Monitoring completed
Pre-Basslink	Initial investigations		11 Dec 99 18 Dec 99 4 Mar 00 25 Mar 00 22 Jul 00 2 Sep 00 4 Aug 01	Investigations for IIAS: Field observations Erosion pin measurements Photo-monitoring Scour chains Painted cobbles
Pre-Basslink	Derivation	Spring 2001	23 Nov 01 9 Dec 01	Field observations Erosion pin measurements
Pre-Basslink	Derivation	Autumn 2002	10 Feb 02 9 Mar 02	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2002	5 Oct 02 16 Dec 02	Field observations Erosion pin measurements
Pre-Basslink	Derivation	Autumn 2003	29 Mar 03	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2003	18 Oct 03	Field observations Erosion pin measurements
Pre-Basslink	Derivation	Autumn 2004	6 Mar 04	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2004	9 Oct 04	Field observations Erosion pin measurements Bank profiling
Pre-Basslink	Derivation	Autumn 2005	2 Apr 05	Field observations Erosion pin measurements Photo-monitoring
Pre-Basslink	Derivation	Spring 2005	15 Oct 05	Field observations Erosion pin measurements
Transition	Test	Autumn 2006	11 Mar 06	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2006	17 Oct 06	Field observations Erosion pin measurements
Post-Basslink	Test	Autumn 2007	17 Mar 07	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2007	20 Oct 07	Field observations Erosion pin measurements
Post-Basslink	No	Spring 2007	1 Dec 07	Field observations
Post-Basslink	Test	Autumn 2008	1 Mar 08	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2008	17-19 Oct 08	Field observations Erosion pin measurements
Post-Basslink	Test	Autumn 2009	21–22 Mar 09	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2009	17 Oct 09 (zones 3&4) 31 Oct 09 (zones 1,2,5)	Field observations Erosion pin measurements

Monitoring Type	Triggers: Derivation or Test	Season	Dates	Monitoring completed
Post Basslink	Test	Autumn 2010	12–14 Mar 10	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2010	19-20 Oct 10	Field observations Erosion pin measurements Establishment of vegetation transects at subset of geomorphology monitoring sites in zones 2 – 4.
Ramp-down rule investigations	No	Summer 2011	7-days in Jan – Mar 11	Observations of ramp-downs and drawdowns at varying levels of bank saturation associated with investigations to revise ramp-down rule.
Post-Basslink	Test	Autumn 2011	26–27 Feb 11	Field observations Erosion pin measurements Photo-monitoring
Post-Basslink	Test	Spring 2011	5–6 Nov 11	Field observations Erosion pin measurements Combined geomorph & vegetation monitoring
Post-Basslink	Test	Autumn 2012	25–26 Feb 12	Field observations Erosion pin measurements Photo-monitoring
Interim monitoring	Test	Spring 2012	6-Oct 12	Field observations zones (1-4, limited in zone 5) Erosion pin measurements (zones 1-4 only)
Interim monitoring	Test	Autumn 2013	17 Mar 13	Field observations Erosion pin measurements Photo- monitoring (zones 1-5)
Interim monitoring	Test	Spring 2013	9 Nov 2013	Field observations Erosion pin measurements (zones 1-5)
Interim monitoring	Test	Autumn 2014	29 Mar 2014	Field observations Erosion pin measurements Photo monitoring (zones 1 – 5)

Table 3-2 continued.

3.2.1 Monitoring in spring 2013

The spring 2013 geomorphology monitoring was completed on 9 November 2013. Although only zones 2 through 4 were scheduled for monitoring, the field teams were able to visit and measure erosion pins in all five geomorphic zones. Inflows to the Gordon River from the Denison River and other tributaries were high and water levels increased rapidly throughout the day, resulting in the inundation of many erosion pins located on the lower bank of zones 3, 4 and 5 (Figure 3-7). Erosion pins located in the bank toes in zone 5 were generally completely submerged, resulting in 10 pins and one erosion pin site not being located or measured. Pins which were not located or unable to be measured in spring 2013 are described in Table 3-3.

Figure 3-7: Erosion pin site 4A downstream of Denison River confluence showing inundation of erosion pins.

3.2.2 Monitoring in autumn 2014

The final interim monitoring mission (autumn 2014) was completed on 29 March 2014. Erosion pin measurements and photo monitoring were completed, along with the recording of field observations. Inflows to the Gordon River were high, leading to the inundation of some pins. Several pins were found lying on the ground, presumably either knocked down, or in some cases eroded out of the bank. A summary of the pins which were not located or unable to be measured in autumn 2014 is found in Table 3-3.

Table 3-3: List of erosion pins not located in spring 2013 and autumn 2014.

Pin	Monitoring period	Change(s) to site (eg. treefall, etc)	Comment
1D/3	Spring 2013	Not found	Semi-buried by root mat. Found in March 2013 using a metal detector
1F/1	Spring 2013	Unable to be measured	Completely buried under slump
2B/8	Spring 2013	Missing	Located on toe of bank. Missed by field party but later present in March 2014
4D/9	Spring 2013	Not found	Water too deep. Pin is part of veg profile, not 'core' erosion pin
4Ga/4	Spring 2013	Not found	Toe pin. Water too deep to locate pin.
5B/6	Spring 2013	Not found	Presumed buried, almost buried in March 2013
5E/1	Spring 2013	Not found	Presumed buried, almost buried in March 2013
5J/7	Spring 2013	Not found	Duplicate toe pin, possibly knocked out as original pin shows erosion
Site 5K	Spring 2013	Site not located	Team unable to located site using GPS. In March 2013 a bank slump had been observed at site and site tends to be a depositional area for woody debris so pins might have been buried
5L/4	Spring 2013	Not found	Water too deep to locate toe pin
5M/2	Spring 2013	Not found	Possibly dislodged
5M/4	Spring 2013	Not found	Water too deep to located toe pin
3G/6	Autumn 2014	Not found	Underwater and not located
4A/3	Autumn 2014	Not found	Presumed buried -previous measurement very low
4D/1	Autumn 2014	Not found	Presumed buried – previous measurement very low
4E/3	Autumn 2014	Pin laying on ground	Reset in same location
4E/4	Autumn 2014	Not found	Underwater
4Ga/4	Autumn 2014	Not found	Underwater
4Gb/5	Autumn 2014	Not found	Probably underwater
5F/3	Autumn 2014	Not found	
5G/1	Autumn 2014	Laying on bank – eroded out	Reset in same location
5H/4	Autumn 2014	Not found	Abundant small and large woody debris at site
5I/1	Autumn 2014	Not found	Active site – evidence of seepage erosion and head cut

3.3 Overview of hydrology, April 2013 – March 2014

A detailed discussion of the hydrology of the Gordon River during the 2013-14 monitoring year is presented in Chapter 2 Hydrology and water management. The following short discussion highlights hydrologic characteristics of the monitoring year relevant to the geomorphology monitoring results.

Discharge from the Gordon Power Station between April 2013 and April 2014 is shown in Figure 3-8, with discharge from the station compared to flow at the Gordon above Denison (Compliance site) and Gordon above Franklin gauging site in Figure 3-9. The hydrographs show the following features relevant to the geomorphic investigations:

- discharge was high from Gordon Power Station from April 2013 through to mid-June 2013, with only a few periods of discharge <200 m^3s^{-1};
- during the winter 2013, the discharge from Gordon Power Station was variable, with short duration, medium to high flow events common;
- continual high discharge resumed in late October/early November 2013, with flow reduction only occurring to facilitate monitoring (spring 2013, autumn 2014) or when required due to bushfires near the transmission lines (early summer 2013);
- during the reporting period a number of high flow events occurred which ranged from 500-900 m^3s^{-1} associated with high tributary inflows. Several of these high flow events coincided with high discharge from Gordon Power Station. Concurrent high discharge and high tributary flows is unusual, as historically high inflows coincide with low Gordon discharge/generation due to run-of-river schemes elsewhere in Tasmania being used for generation in preference to Gordon following periods of high statewide inflow; and
- maximum discharge from the power station over the reporting period was about ~260 m^3s^{-1}.

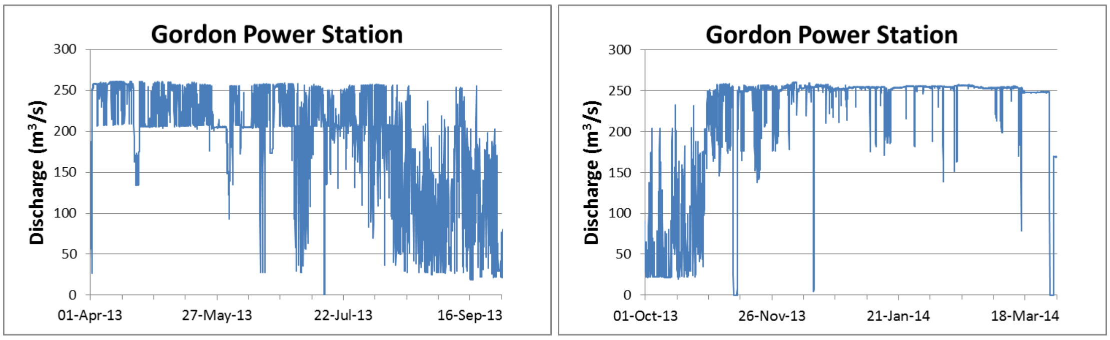

Figure 3-8: Hydrograph of discharge from the Gordon Power Station between 1 April 2013 and 1 April 2014.

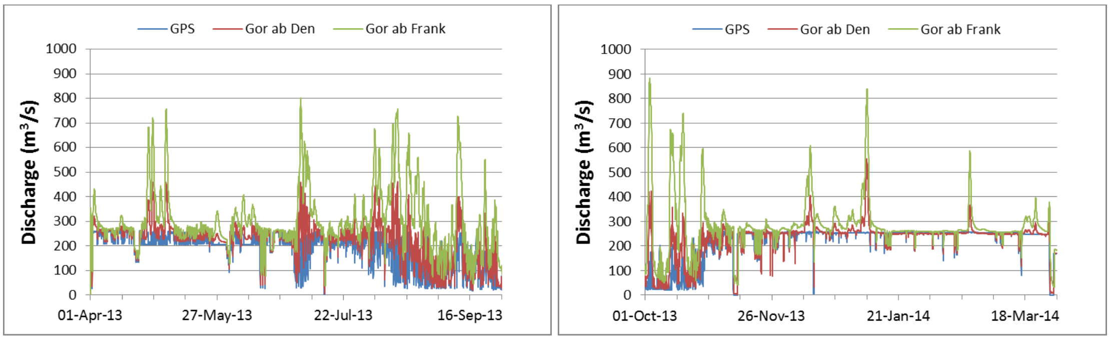

Figure 3-9: Hydrographs from the Gordon Power Station, the Gordon above Denison (Compliance site) and the Gordon above Franklin gauging station for the period 1 April 2013 and 1 April 2014.

3.4 Sediment transport capacity modelling

A theoretical sediment transport model for zone 1 in the Gordon River was developed by S. Wilkinson and I. Rutherfurd during the IIAS investigations (Koehnken *et al.* 2001). The model is based on the calculated shear stress at the toe of the bank using the river cross-section and water surface slopes measured in zone 1 (at site 1A; Figure 3-2). Site 1A is used as it is the first monitoring site downstream from the power station, so unregulated inflows are minimal. The input to the model is the flow duration curve for power station discharge for the year, with the output divided into flow brackets. Actual results from the model are not particularly meaningful, but changes between years provide a relative indication of how the potential for scour in the river varies as a function of power station discharge. Figure 3-10 compares the model results for the 2013-14 monitoring year with previous years and the modelled unregulated (natural) flow regime.

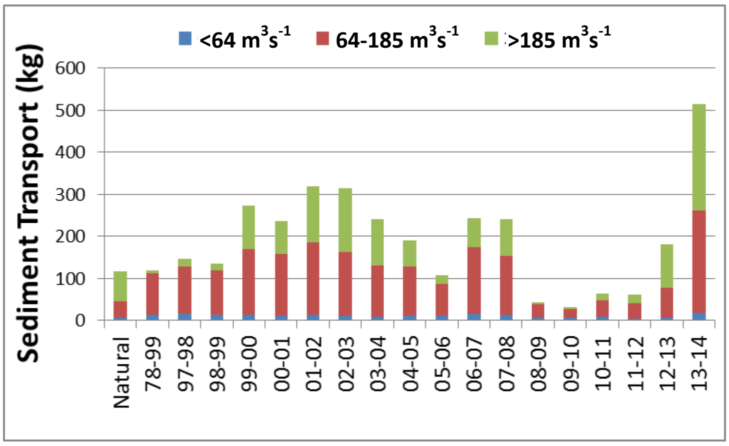

Figure 3-10: Theoretical sediment transport in zone 1 of the Gordon River due to power station discharge. Total calculated sediment transport is divided into flow levels approximately equivalent to 1, 2 and 3 turbine power station operation.

The model results show that the extended period of high discharge from the power station over the 2013-14 monitoring year has resulted in the highest calculated sediment transport capacity of any of the pre- or post-Basslink years, and greatly exceeds the 2000 to 2003 values which were the previous maxima. The 2013-14 result of 515 kg is about 15 times greater than the minimum result obtained in 2009-10 of 32 kg, and almost five-times the 'natural' flow regime value. The sediment transport capacity is split relatively evenly between high flows (185 m^3s^{-1} equivalent to three turbines), and 64 to 185 m^3 s^{-1} (roughly equates to two turbines). Similar to previous years, flow rates <64 m^3s^{-1} contribute very little to the transport capacity of the river.

3.5 Monitoring results

3.5.1 Field observations: spring 2013

Field observations in spring 2013 included the following:

- bank toes showed evidence of scour, with ripple marks and low quantities of sand on banks where deposition had been previously observed. This was especially pronounced upstream of the Denison River and is shown in comparative photos of such sites relative to previous observations (e.g. site 1E in Figure 3-11, and site 3A in Figure 3-12 , Figure 3-13);
- downstream of the Denison River, some bank faces (not toes) showed evidence of deposition, most likely attributable to high winter inflows from the unregulated tributaries (e.g. site 4D, Figure 3-14);
- considerably less vegetation was observed on the banks relative to autumn 2013, with the green algae that was prominent in autumn, absent. There was also a lack of organic matter or mud veneers on the bank toes or bank faces consistent with the high power station discharge which preceded monitoring;

- a few erosion pins which were previously located above the power station controlled high water level showed evidence of inundation, consistent with the higher power station discharge relative to previous years (due to generator refurbishment); and
- water was observed draining from the lower banks and there was evidence of seepage processes (rilling of bank toes, tension cracks, Figure 3-15) and saturated banks (expelled sediment clasts, Figure 3-16), but no active sediment flows were observed during monitoring.


Figure 3-11: Site 1E, previous observation in autumn 2013 (left) showing presence of sand on bank face compared with the reporting period observation in spring 2013 (right) showing a reduction in sand.


Figure 3-12: Site 3A, previous observation in spring 2012 (left) showing extent of sand deposition compared with the reporting period observation in spring 2013 (right) showing loss of sand.

Figure 3-13: Break in slope on bank at erosion pin site 3A showing scour of root mat and lack of deposition of organic matter in spring 2013.


Figure 3-14: Site 4D, previous observation in spring 2012 (left) shows less sand than in the reporting period observation in spring 2013(right) indicating an increase in sand deposition.

Figure 3-15: Tension cracks at erosion pin site 5A, autumn 2013.

Figure 3-16: Sediment clasts expelled from bank due to high water pressure in saturated bank.

3.5.2 Field observations: autumn 2014

Field observations in autumn 2014 were consistent with prolonged high flow contributing to both scour and seepage erosion in the middle Gordon River. Observations are summarised below:

- the extended high flow has resulted in a pronounced plimsoll line along the banks of the river. This is not a new feature, but was more pronounced than in the past few years (Figure 3-17);
- seepage erosion processes were active, with water draining from the banks during the monitoring trip (Figure 3-18, Figure 3-19). Areas prone to seepage processes tended to be saturated and showed signs of water draining from banks and some sediment flows. At some sites, the banks were stained by organic compounds which had drained from the bank with the water flow. It is likely the organic compounds were derived from the prolonged inundation of vegetation associated with the higher power station discharge. The increased rate of discharge from the power station has, most likely, resulted in the inundation of vegetation previously not inundated by power station operations.

  Other evidence of seepage processes included piping, tension cracks and bank slumping which were observed in all zones (Figure 3-20, Figure 3-21).

- Sediment flows were present in areas prone to seepage processes and small sediment flows were observed at the toe of banks supporting tea tree, where sand had been deposited by water draining from the banks (Figure 3-22, Figure 3-23). Small sediment flows were observed at the base of the cobble banks downstream of the zone 2 piezometer site. This is the first time sediment flows have been observed in this location; and
- scouring of the banks was evident throughout the river. Examples include a lack of leaf litter on the bank faces, undercutting of a cobble bank in zone 1 (Figure 3-24) and scouring of a prominent sandy bank in zone, resulting in the bank profile going from convex in autumn 2013 to concave in autumn 2014 (Figure 3-25). Other evidence of scour included the collapse of vegetation and ripple marks on banks toes (Figure 3-26, Figure 3-27).

Vegetation is closely linked with fluvial geomorphology in the middle Gordon River. Observations of vegetation relevant to bank stability include:

- a number of trees located at the edge of the river appear to be dying. The location of the trees at the water's edge suggests that either the prolonged duration of inundation or the increased water levels associated with the higher power station discharge (or a combination of both) are affecting the trees. The field teams in zones 1 and 2 noted numerous trees showing signs of dieback (Figure 3-28, Figure 3-29). The other field parties did not specifically note any, but photos of other features in zone 5 included evidence of dieback of trees on the banks (Figure 3-30);
- the extended period of inundation has led to tea trees growing adventitious roots. These are present on the trees, with root mats covering the banks. Based on previous discussions with vegetation experts, these roots are formed in response to inundation. The 'white beards' on the tea trees were prominent in all zones (Figure 3-31). These roots, where present as a root-mat, may increase bank stability through physical protection of the bank and increasing the roughness of the bank surface; and
- vegetation which had established over the past few years on the banks below the power station controlled high water level has died, but the root balls remain intact. The root structures of these plants likely provide stability to the bank. Examples are shown in Figure 3-32 and Figure 3-33.

Figure 3-17: Pronounced plimsoll line in zone 1.

Figure 3-18: Rilling in zones 1 and 2: Water draining through sediment flow composed of white sands (photo cloudy due to moisture in camera).

Figure 3-19: Rilling in zones 1 and 2: Rilling in zone 2 with organic oils present in drainage.

Figure 3-20: Piping in zone 1 (left) and zone 5 (right).

Figure 3-21: Tension cracks and bank slumping in zone 5.

Figure 3-22: Sediment flows in zone 2 (erosion pin site 2H) on bank with tea trees.

Figure 3-23: Sediment flow from under cobble bank in zone 2, just downstream of piezometer site.

Figure 3-24: Comparison of undercutting at cobble bank in zone 1 in autumn 2013 (left) and autumn 2014 (right).

Figure 3-25: Scour of a sandy bank toe in zone 3 (site 3Eb) in autumn 2013 (left) and autumn 2014 (right).

Figure 3-26: Undercutting and collapse of vegetation in zone 1.

Figure 3-27: Scouring of bank and ripple marks at the upstream end of zone 3.

Figure 3-28: Brown Huon pine trees in zone 1.

Figure 3-29: Brown Huon pine trees in zone 2.

Figure 3-30: Brown Huon pine trees in zone 5.

Figure 3-31: Adventitious roots on tea tree and root mat in response to extended inundation.

Figure 3-32: Dieback of vegetation on banks in power station operating level.

Figure 3-33: Changes in vegetation to the backwater channel in zone 2 (site 2A) in autumn 2012 (top left), autumn 2013 (top right) and autumn 2014 (bottom).

3.5.3 Zone 2 piezometer results

The results from the zone 2 piezometers are shown in Figure 3-34. Only results from probes 1 (river level), 2 (10 m inland), and 3 (20 m inland) are shown as the data from probes 4 and 5 is no longer considered reliable.

The river level at the piezometer site reflects the operation of the Gordon Power Station, as there is limited tributary inflow between the station and the probes. The results clearly show that for a substantial portion of the monitoring year, the river level, and ground water level in the bank exceeded 4 m, with the only break being July to September 2013.

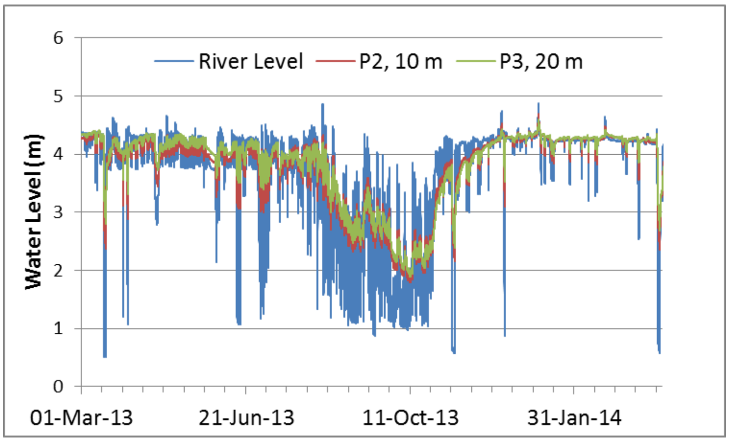

Figure 3-34: Piezometer results for 1 March 2013 to 1 April 2014. River level is probe 1.

The piezometer results have been analysed to identify periods when the risk of seepage erosion is high. The criteria used in this analysis are: the slope of water between probe 2 and probe 1 (river level) exceeds 0.1, *and* the ground water level at probe 2 exceeds 2.75 m. Under these conditions, ground water level in the bank is high, and there is a sufficient slope to potentially mobilise sediment. These criteria were identified prior to the development of a detailed bank saturation model and should be considered indicative only.

In Figure 3-35, the power station discharge is compared to water slopes in the bank (grey lines). The black lines indicate when the water slope in the bank exceeded 0.1 and the ground water level at probe 2 exceeded 2.75 m. These periods are associated with flow reductions at the power station following prolonged periods of high discharge.

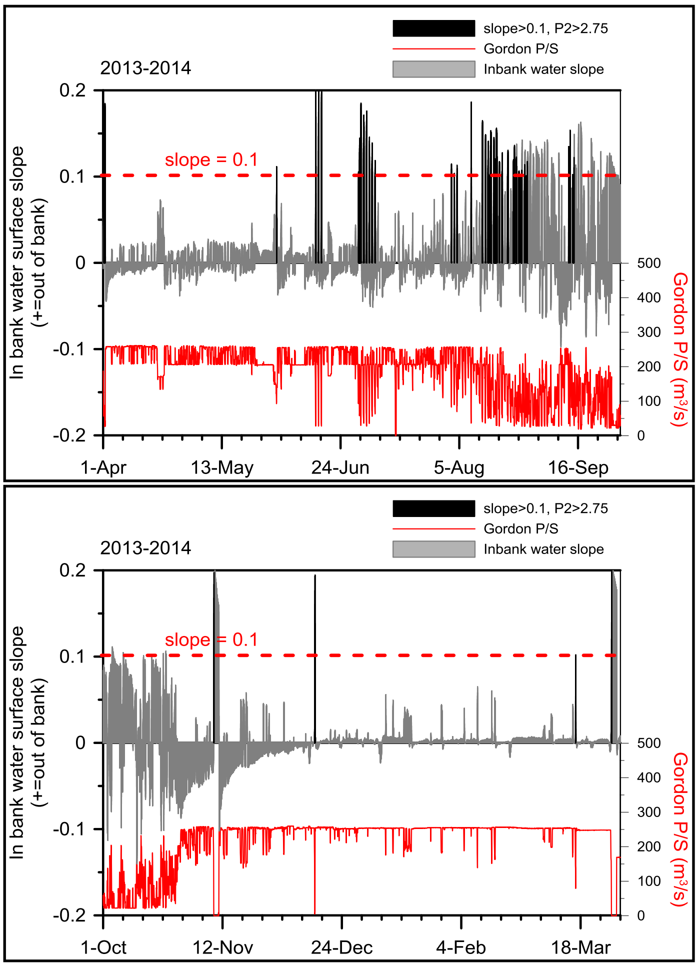

Figure 3-35: Comparison of power station discharge (red line) with ground water slopes (grey bars). Black bars show slopes corresponding to possible periods of high seepage erosion risk.

There were several periods during the year when the power station operated in a ‘peaking’ pattern following prolonged high discharge (Figure 3-36, Figure 3-37 and Figure 3-38). In Figure 3-36, two periods are shown when there was high discharge from the power station during the day, and flow was reduced but not stopped at night. During these periods, ground water levels at probes 2 and 3 fluctuated by ~1 m and 0.5 m respectively, but did not show any trends towards decreasing over the period of peaking.

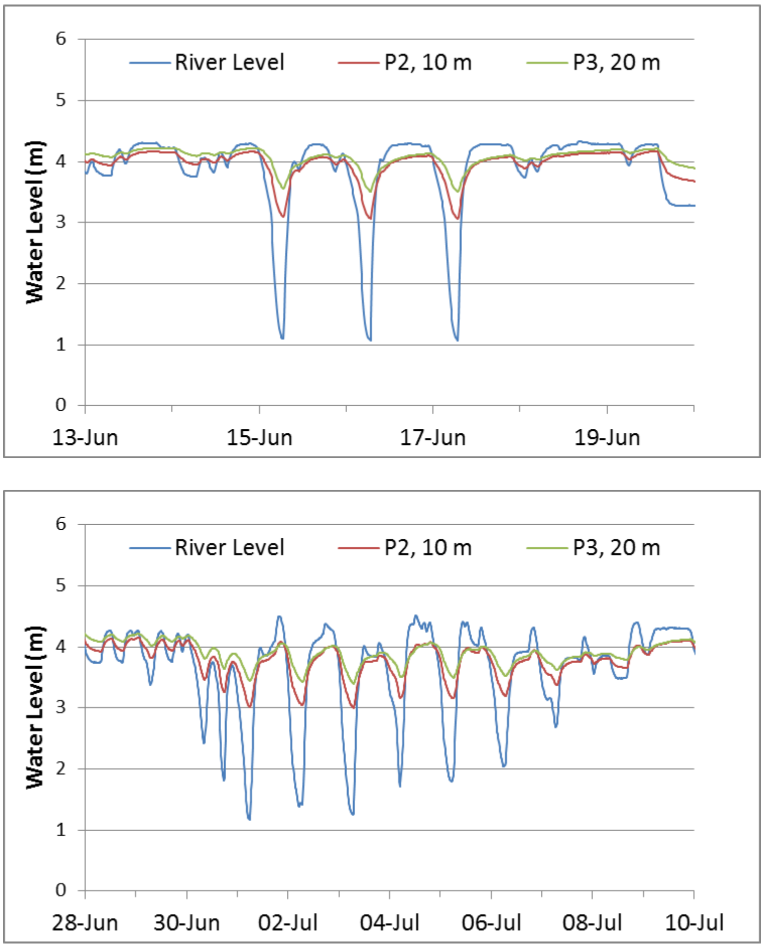

Figure 3-36: Piezometer results for 13 to 20 June, 2013 and 28 Jun 2013 to 10 Jul 2013 showing the piezometer results associated with peaking operations.

During the peaking period in August and September 2013 (Figure 3-37), the ground water levels at probes 2 and 3 gradually decreased, but only as the maximum discharge from the power station during the day decreased. These examples demonstrate that once the banks are fully saturated, a relatively long period of reduced flow is required to promote bank drainage, and the reductions associated with daily peaking are not sufficient to reduce bank saturation.
The reverse case also appears to hold, with relatively low ground water levels at probes 2 and 3 maintained during periods of daily peaking when the initial bank saturation level was low. This is demonstrated in Figure 3-38, which shows that ground water levels in the bank remained constant, but relatively low during peaking operations in mid-October 2013.

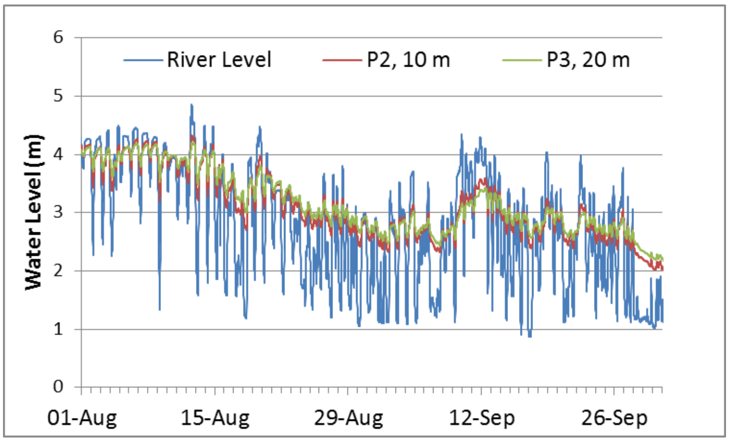

Figure 3-37: Piezometer results for 1 Aug 2013 to 1 Oct 2013.

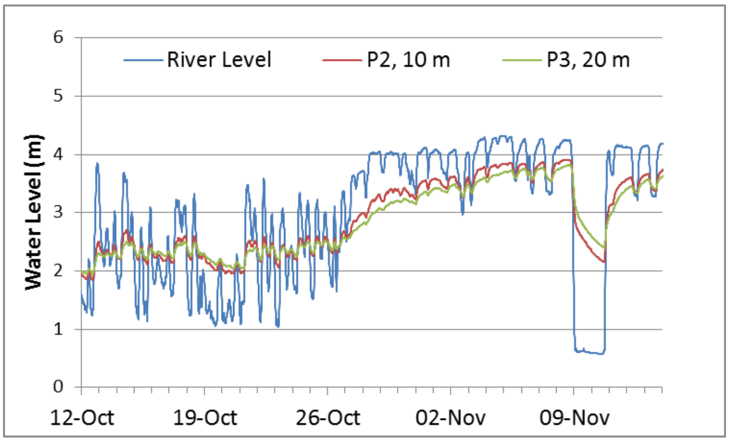

Figure 3-38: Piezometer results for 12 October 2013 to 15 November 2013.

The piezometer results and examples presented here are consistent with the understanding of the relationship between power station operation and bank saturation in the middle Gordon River that has been gained over the past 13 years of monitoring. The high number of 'high risk' seepage erosion periods identified by the analysis over 2013-14 is due to prolonged power station discharge leading to high levels of bank saturation, with few opportunities for the bank to drain.

The ramp-down rule is aimed at reducing seepage erosion associated with hydro-peaking operations at the power station, with the base case scenario having the station operated Monday to Friday during the day, and then reduced over weekends. The present rule results in low levels of bank saturation in the base case scenario, or during periods when the banks are starting from a moderate to low level of bank saturation. A moderate saturation level includes a ground water level at probe 2 in excess of 2.75 m. However, when ground water levels are >4 m extending back for a distance in excess of 50 m, the rule does not achieve the desired outcome, as there is insufficient time for the banks to drain during the ramping period. This is attributable to the large volume of water that needs to drain from the banks in order to lower ground water levels at probe 3 (or further inland) to levels which minimise sediment transport.

In spite of this short-coming, the ramp-down rule appears to be reducing large seepage events in the 2-3 turbine bank level associated with the increased discharge from the power station and resultant higher water levels. No new large seepage 'events' or sediment flows have been identified in the high 3 turbine bank level.

3.5.4 Erosion pin results

3.5.4.1 Introduction

Erosion pin measurements were collected from all zones in spring 2013 and autumn 2014, and graphs for each monitoring site are contained in Appendix C. In spring 2013 and autumn 2014, a large number of toe pins were inundated and unable to be located and measured, so the usual statistical analysis was not completed.

Data analysis included the erosion pin results presented as histograms based on the same data groupings as previously presented; erosion pins grouped by zones, turbine levels and by a combination of zones and turbine levels (zones 2 and 3, and zones 4 and 5). In addition, the analysis has been extended to examine annual changes (autumn 2013 to autumn 2014) and the entire monitoring period, (2001 to 2014). This analysis does not allow direct comparison with past results, but does provide a good summary of how the zones and turbine levels have responded to recent power station operations. To provide an indication of how the results compare with historic statistics, histograms for net changes since the inception of monitoring are also presented.

3.5.4.2 Results grouped by zones

The erosion pin results grouped by zones are shown in Figure 3-39 to Figure 3-43. In each set of graphs for each zone, four graphs are shown, which display the distribution of results for the periods: autumn 2013 to spring 2013, spring 2013 to autumn 2014, autumn 2013 to autumn 2014, and 2001 to 2014. A further comparison between the five zones is presented in Figure 3-44.

Similar to previous results, the erosion pins in zone 1 (Figure 3-39) showed low levels of change between spring 2013 and autumn 2014, with most pins showing -10 mm to +10 mm of change. Comparing the first and second graphs suggests that scour decreased during the most recent monitoring period, with more pins recording low levels of deposition (most likely related to seepage processes). The annual results for autumn 2013 to autumn 2014 period also show more deposition than scour. The results for the entire monitoring period, 2001 to 2014, show a normal distribution of results centered around -25 mm to 0 mm change, with almost half of all pins recording between -25 mm to +25 mm of change over the 13 year period.

The pins in zone 2 (Figure 3-40) recorded more deposition than erosion in both the autumn 2013 to spring 2013 and spring 2013 to autumn 2014 periods, although there was a shift towards erosion during the second monitoring period. The erosion pin results are consistent with field results which found evidence of both seepage processes (resulting in deposition) and scouring. The annual change recorded in zone 2 shows predominantly deposition reflecting seepage processes, with 10 pins recording greater than 30 mm change over the year. The results for the entire 2001 to 2014 monitoring period, show higher levels of deposition than erosion, although the results are distributed more evenly compared to the annual change recorded in 2013 to 2014. This reflects periods when scour dominated the zone, which occurred during the prolonged period of low power station usage from 2008 to 2012.

Zone 3 (Figure 3-41) shows the opposite trends to zone 2, with erosion being the dominant process recorded during both of the 2013-14 monitoring periods, with an increase in the number of pins recording high levels of erosion (>30 mm change) in autumn 2014 as compared to spring 2013. In autumn 2014, pins that recorded erosion tended to record low (0-10 mm) or high levels (>30 mm) with only a few pins recording between 10 mm and 30 mm erosion. The annual results showed that about 40% of the pins recorded greater than 30 mm of erosion over the year. Since the inception of monitoring, scour has been the dominant process in the zone, with about 40% of the pins registering 100 mm or more of erosion over the 13 years.

Zone 4 results (Figure 3-42) show that from autumn to spring 2013, the zone experienced more erosion than deposition, while from spring 2013 to autumn 2014 there was a reduction in pins recording erosion and a corresponding increase in deposition. These results suggest that the high winter flow events combined with prolonged power station flow led to bank scour, while the prolonged power station flows over the summer led to seepage induced deposition. The annual results reflect both processes, with about 50% of the pins recording either greater than 30 mm or less than – 30 mm of change. Over the entire monitoring period (2001 to 2014) the distribution of results is very even, with slightly more erosion recorded than deposition.

Zone 5 erosion pins (Figure 3-43) have always recorded the highest rates of erosion and deposition, with overall net rates being low. This is attributable to natural inflows in the zone leading to flow variability, modulating the influence of the power station. In both the autumn to spring 2013 and spring 2013 to autumn 2014 results, the most commonly recorded change was either >30 mm or <-30 mm. This trend is accentuated in the annual results, with only 25% of the pins recording values between these two extremes. The entire monitoring period results also show an even distribution between erosion and deposition.

The results are compared across the zones as percentages of pins in each bin (Figure 3-44). The comparison shows that zone 1 has the highest proportion of pins recording low rates of change during both of the 2013 - 2014 monitoring periods. The comparison also indicates that during spring 2013 to autumn 2014, pins generally recorded either quite low levels of change, or changes in excess of ± 30 mm. Since monitoring began in 2001, zone 3 has a higher percentage of pins recorded relatively high rates of erosion, whereas deposition has been most pronounced in zone 5.

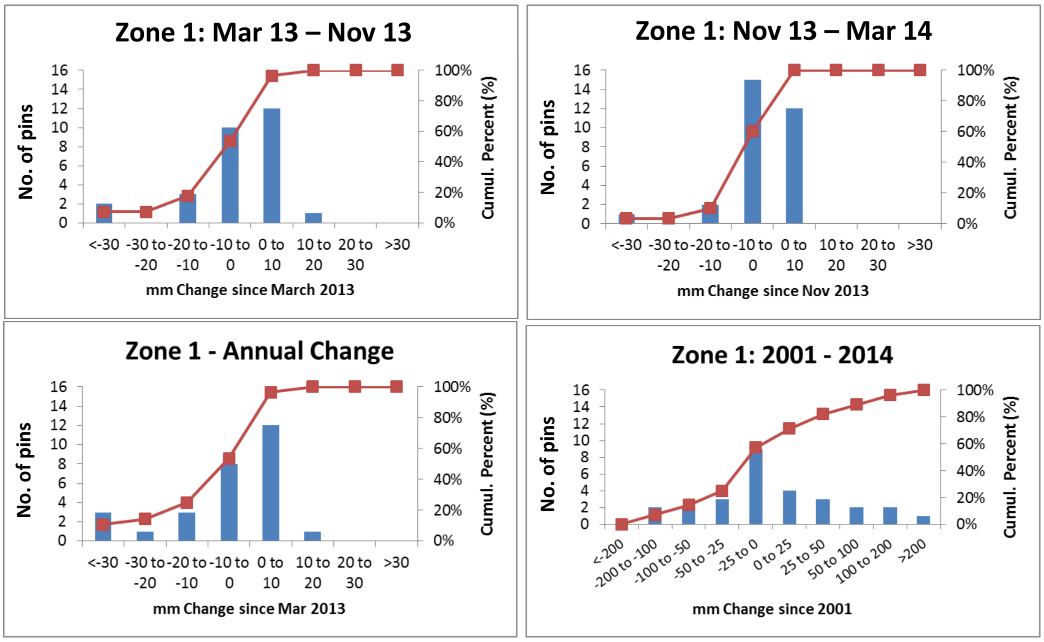

Figure 3-39: Erosion pin results for zone 1. Bins indicate changes to erosion pins relative to the monitoring period indicated in the title, with negative values indicating deposition (e.g. less of the pin is exposed), and positive values indicating erosion (e.g. more of the pin in exposed).

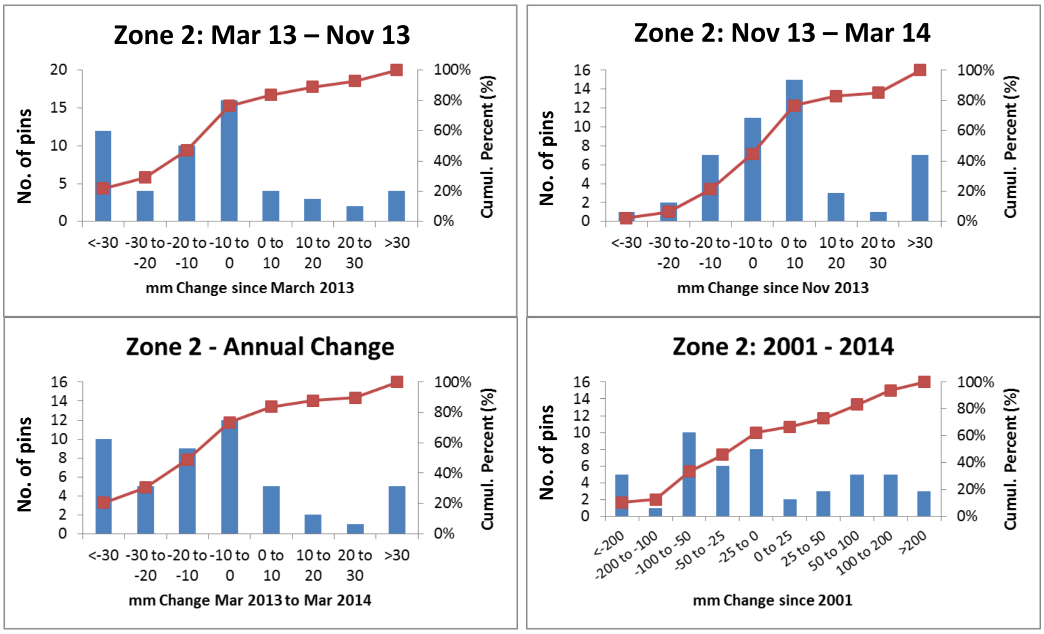

Figure 3-40: Erosion pin results for zone 2. Bins indicate changes to erosion pins relative to the monitoring period indicated in the title, with negative values indicating deposition (e.g. less of the pin is exposed), and positive values indicating erosion (e.g. more of the pin in exposed).

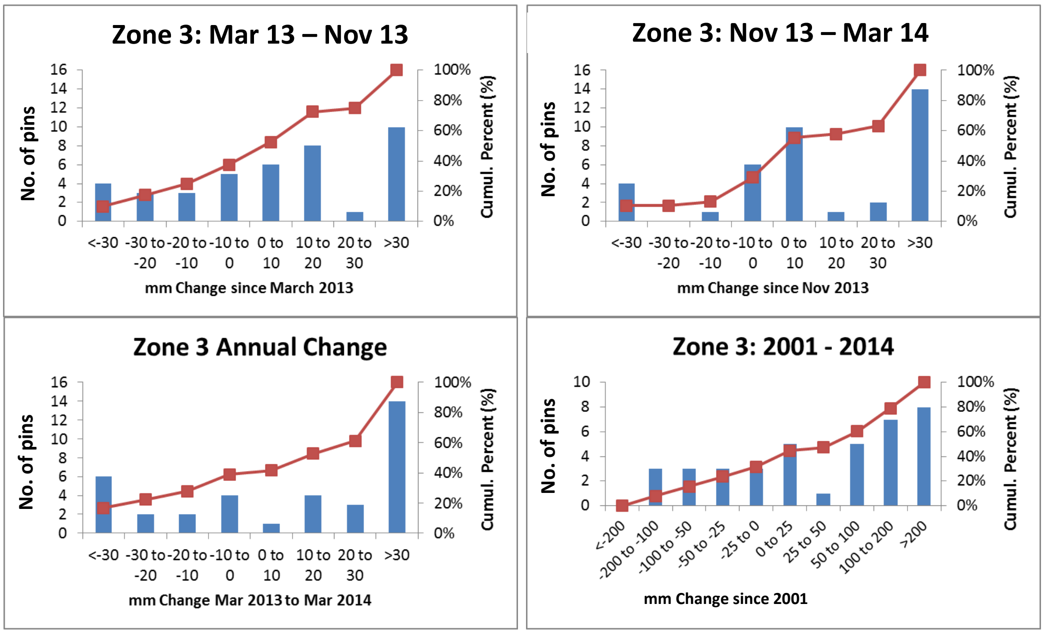

Figure 3-41: Erosion pin results for zone 3. Bins indicate changes to erosion pins relative to the monitoring period indicated in the title, with negative values indicating deposition (e.g. less of the pin is exposed), and positive values indicating erosion (e.g. more of the pin in exposed).

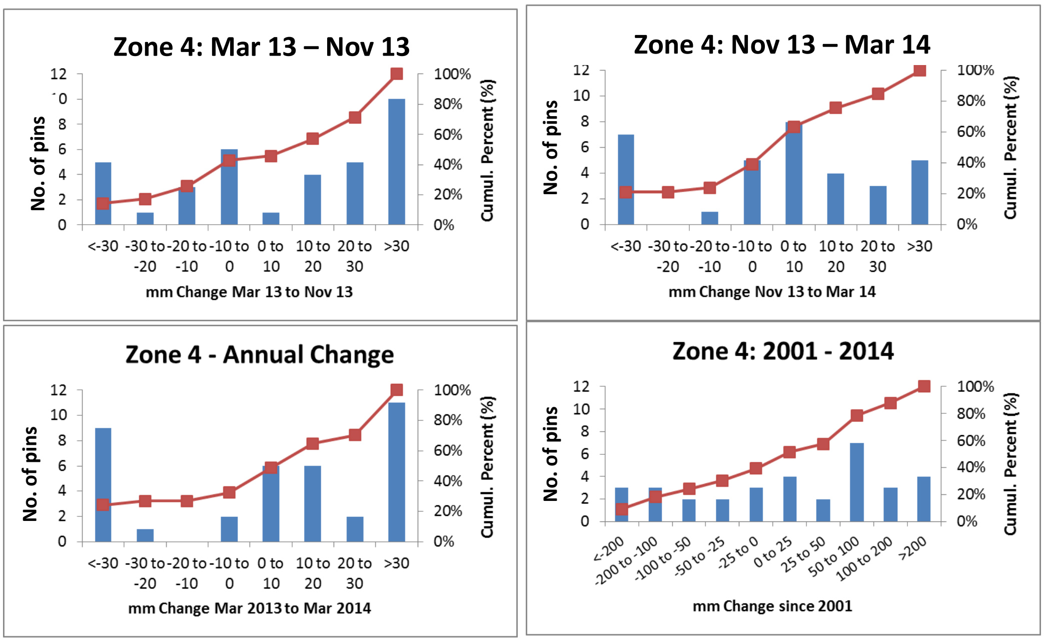

Figure 3-42: Erosion pin results for zone 4. Bins indicate changes to erosion pins relative to each monitoring period indicated in the title, with negative values indicating deposition (e.g. less of the pin is exposed), and positive values indicating erosion (e.g. more of the pin in exposed).

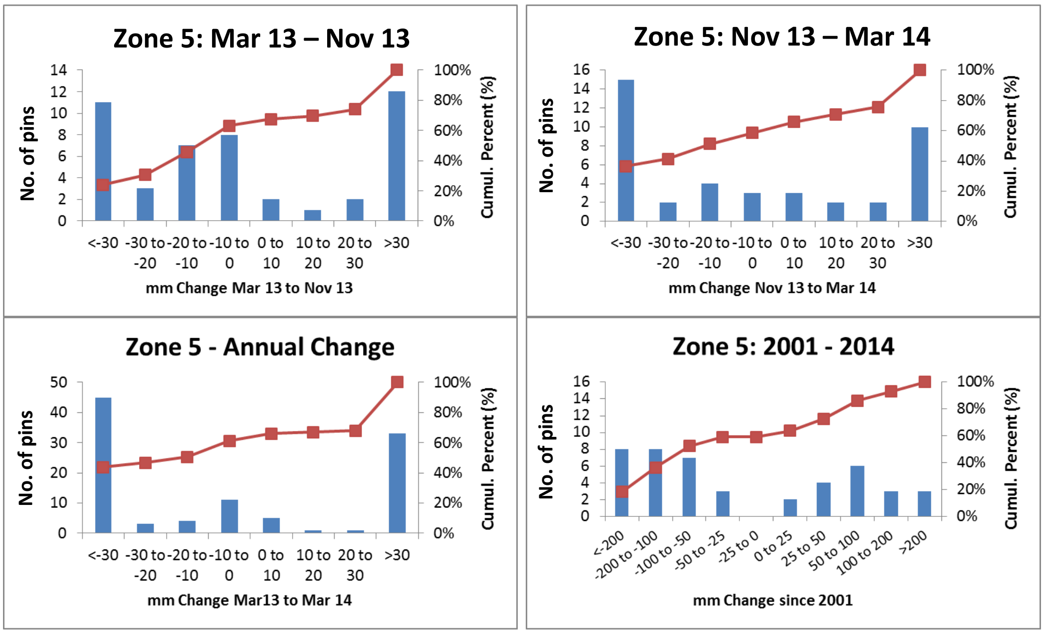

Figure 3-43: Erosion pin results for zone 5. Bins indicate changes to erosion pins relative to monitoring period indicated in the title, with negative values indicating deposition (e.g. less of the pin is exposed), and positive values indicating erosion (e.g. more of the pin in exposed).

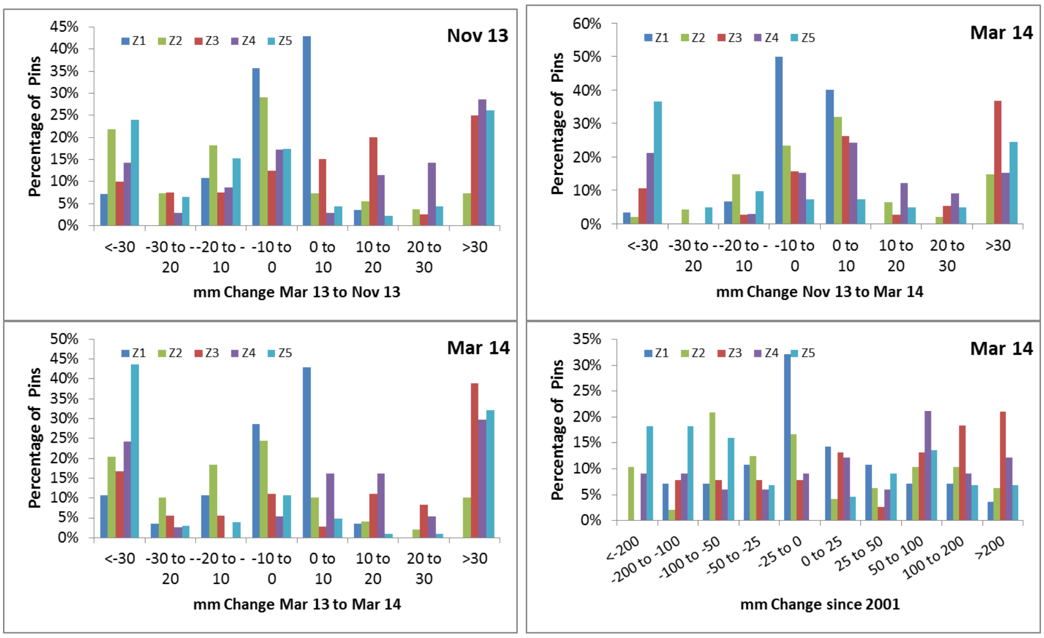

Figure 3-44: Comparison or erosion pin results between zones. Results presented as percentage of total pins in each zone for comparison.

3.5.4.3 Erosion pin results by turbine levels

The same erosion pin results are grouped by turbine levels for all zones in Figure 3-45 to Figure 3-47, with the turbine level groupings compared in Figure 3-48.

In the <1 turbine bank level (Figure 3-45), >30 mm of erosion was recorded by approximately 40% of the erosion pins for each monitoring period, and over the course of the year almost 50% of the pins at the base of the banks recorded >30 mm. This is not surprising as the shear stress of the river flow is greatest on the bank toe and the erosion pin results are consistent with the theoretical sediment transport model results which indicated high levels of shear stress on the bank toes.

The 1-2 turbine bank level (Figure 3-46) showed a range of results, but more pins recorded deposition than erosion in the first monitoring period (autumn to spring 2013), with an increase in pins recording low levels of activity in spring 2013 to autumn 2014. Overall, greater deposition than erosion was recorded during the monitoring year. The findings are consistent with the conceptual model for the middle Gordon River, with the 1-2 turbine bank level subjected to erosion and/or deposition, depending on whether the site is prone to seepage processes (which promote deposition), scour (erosion) or deposition from tributary inflows.

The 2-3 turbine bank level (Figure 3-47) showed similar results to the 1-2 turbine bank level, with a high percentage of pins recording deposition during the first monitoring period, and a shift towards less deposition/more erosion during the second. Some of the deposition in the zones during the winter period may be associated with unregulated winter inflows as the power station was not operating at full capacity for much of this period.

The comparison of results between zones (Figure 3-48) shows very clear trends within and between the turbine levels. Overall, erosion was highest on the bank toes and generally decreased with distance up the bank face, whereas deposition/seepage processes were more common on the upper banks. The results also show that a substantial number of pins in each of the turbine levels recorded between -10 to +10 mm changes. The final summary graph for the turbine levels shows the range of net change since monitoring began in 2001. The average change of pins showing net erosion and net deposition are shown along with the average change for all pins over the entire period for each turbine level. All turbine levels show net erosion, with the <1 turbine level showing the highest average erosional and depositional changes, and the highest net erosion (42 mm). The 1-2 and 2-3 turbine levels averaged 15 mm and 22 mm change respectively, with average erosion being slightly higher and deposition being slightly lower in the 2-3 turbine level compared to the 1-2 turbine level.

Overall the results show that in spite of local deposition on the banks from tributary inflows or upslope seepage processes, the overall trend in the river is one of erosion. Annualising the average rate of change over the period of monitoring, net erosion in the middle Gordon River is 3.2 mm yr^{-1} in the <1 turbine bank level, 1.1 mm yr^{-1} in the 1-2 turbine level, and 1.7 mm yr^{-1} in the 2-3 turbine bank level.

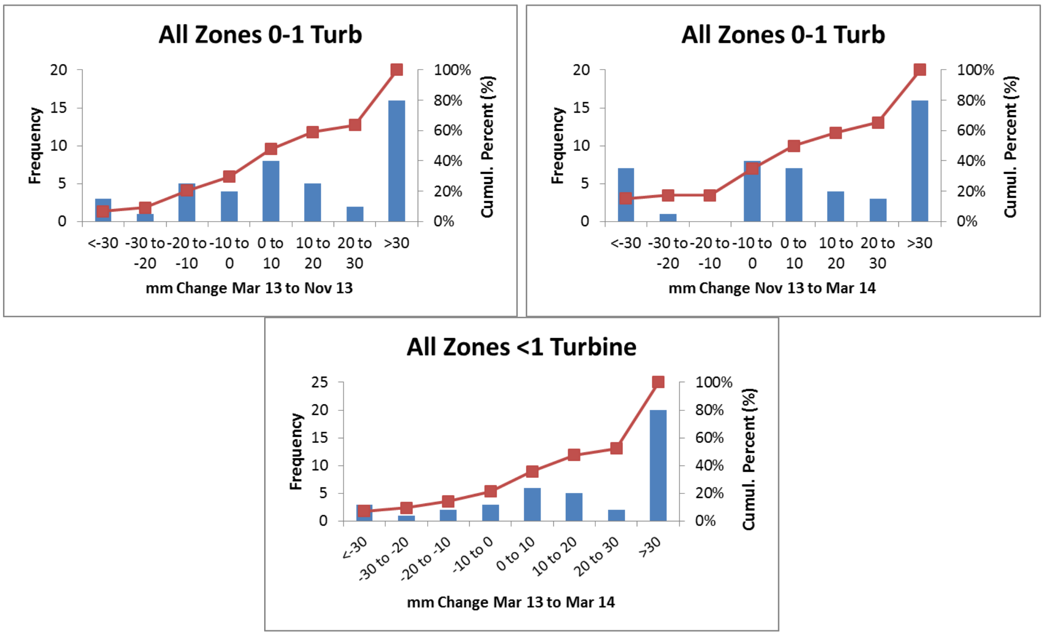

Figure 3-45: Distribution of erosion pin results from all zones in the 0-1 turbine bank level.

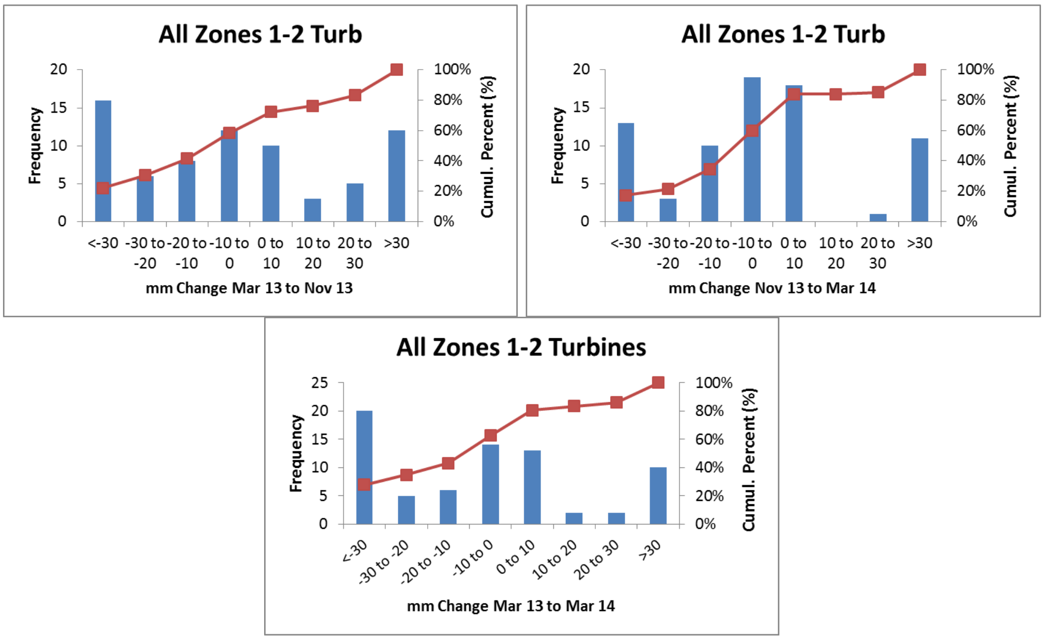

Figure 3-46: Distribution of erosion pin results from all zones in the 1-2 turbine bank level.

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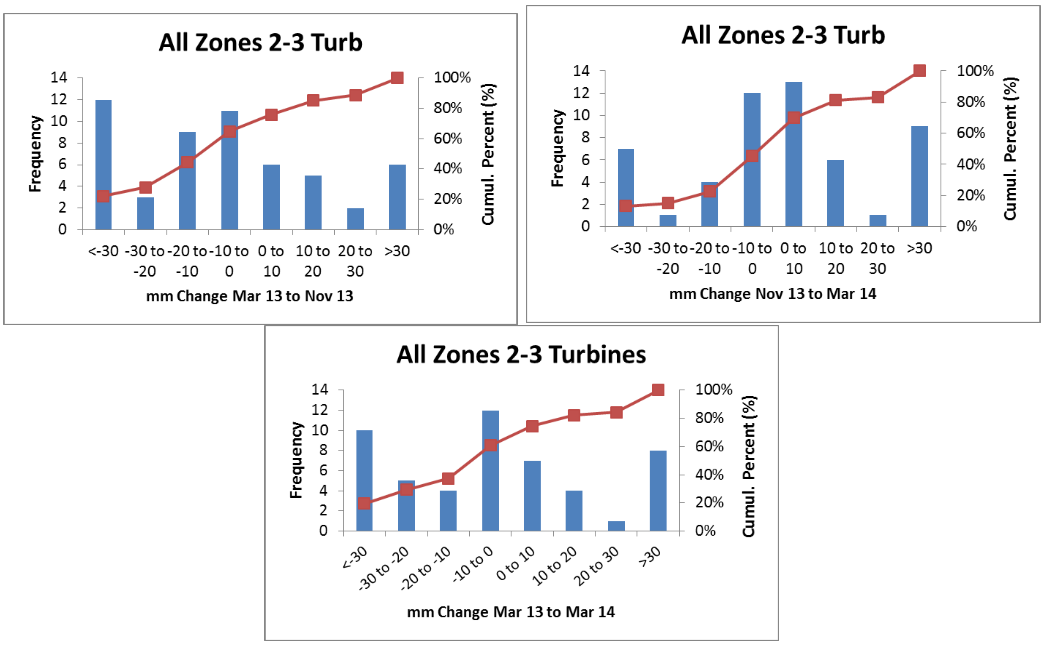

Figure 3-47: Distribution of erosion pin results from all zones in the 2-3 turbine bank level.

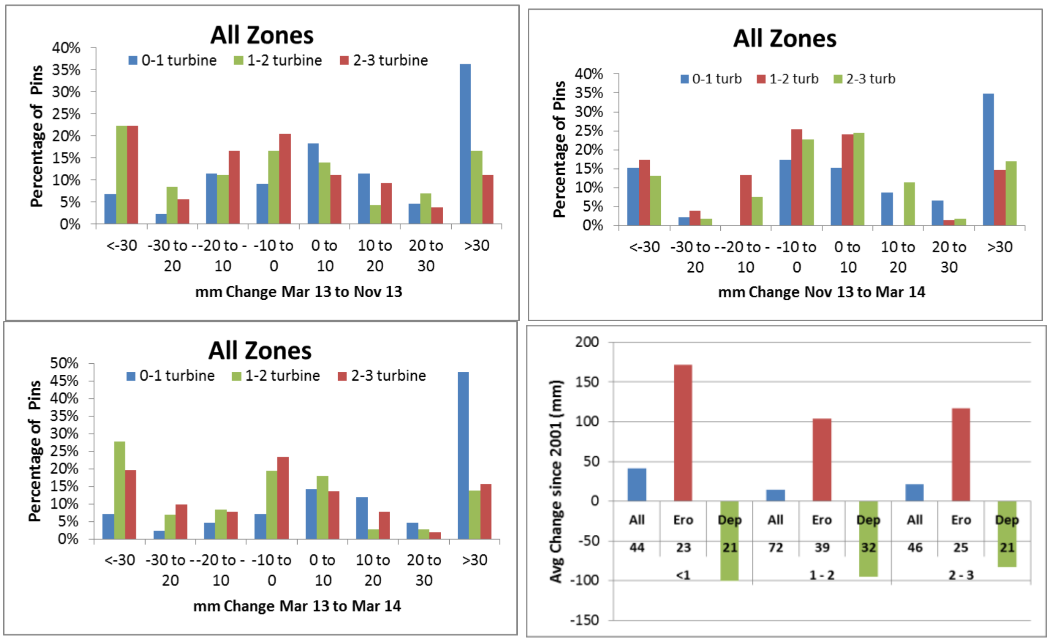

Figure 3-48: Comparison or erosion pin results between turbine levels. Results presented as percentage of total pins in each turbine level for comparison for the first three graphs. Lower right graph shows change of all pins recording net erosion and net deposition over the 2001 to 2014 monitoring period. The numbers indicate the number of pins in each grouping. The <1 and 1-2 turbine levels each had a pin with no net change over the period, accounting for the discrepancy between the ‘all pins ’ and the pins showing erosion or deposition.

3.5.4.4 Comparison of zones and turbine levels

Grouping erosion pin results by zones and turbine levels (Figure 3-49 and Figure 3-50) provides additional insights into the distribution of geomorphic processes in the river. In zones 2 and 3 (Figure 3-49), during the autumn 2013 to spring 2013 monitoring period there was a clear trend of decreasing erosion and increasing deposition with distance up the bank face. During spring 2013 to autumn 2014, scour of the bank toe continued, but deposition decreased, with no pins recording deposition in excess of 30 mm in the 2-3 turbine bank level. The other turbine levels also recorded a shift towards no change or higher erosion, suggesting the extended high discharge from the power station resulted in scour greater than any subsequent deposition associated with seepage processes (which were observed in zones 2 and 3).

In contrast, in zones 4 and 5 (Figure 3-50), erosion of the bank toe was recorded in both monitoring periods, but there was a shift towards deposition in spring 2013 to autumn 2014 in the upper bank levels. This is consistent with the field observations and suggests that the high flow events which occurred during the summer months, combined with seepage processes were responsible for the increased deposition on the upper banks later in the year.

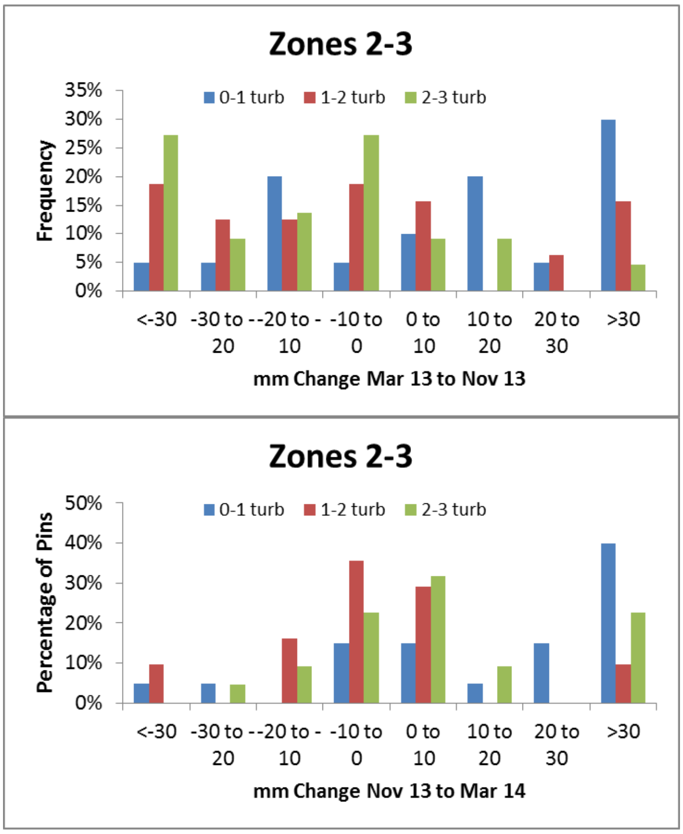

Figure 3-49: Erosion pin results grouped by turbine levels for zones 2 & 3.

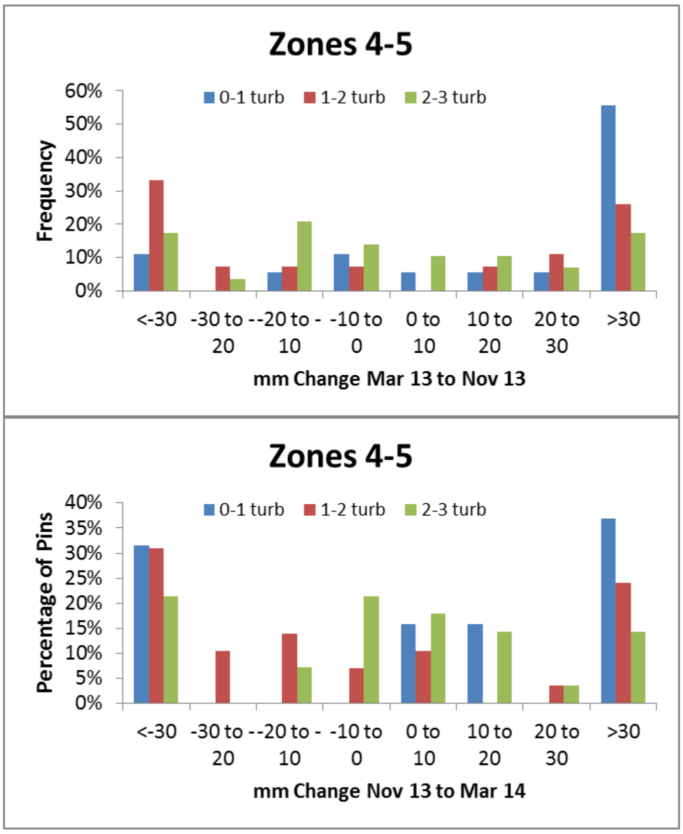

Figure 3-50: Erosion pin results grouped by turbine levels for zones 4 & 5.

3.5.5 Photo-monitoring results

Photos were obtained at 55 of the photo monitoring sites in March 2014. The most recent photos and all previous photos are contained in Appendix D, along with a table summarizing the observed changes for each year. The results are summarized in Figure 3-51 and Figure 3-52 which also contains results from previous monitoring years for comparison. High water levels, poor visibility and poor light at the end of the day, combined with several of the sites being difficult to identify due to increased vegetation or other changes over the years, resulted in five sites not being photographed in March 2014.

Fewer sites showed ‘no change’ than during any previous pre- or post-Basslink monitoring. Zone 2 contained the fewest sites that did not show any change (three out of 16 sites). Most of the observed changes were associated with the loss of vegetation from the bank face in the power station controlled operating zone. This vegetation had established during the preceding years when power station operation was low.

The dieback of vegetation, including Huon pine trees, was observed at four sites, which accounts for about one-third of the sites showing loss of vegetation below the power station controlled high water level. The loss of *Restio*, ferns and other vegetation accounts for most of the remaining vegetation changes. One large, very recent (leaves still intact) tree-fall at the downstream end of the Albert ‘pool’ was captured at photo monitoring site 2-1a (Figure 3-53). This large tree had been observed leaning towards the river since 2000 and was a prominent feature of the bank at the top of the rapids.

Zone 5, showed few changes, which is likely attributable to the zone being continually subjected to variable flows. The upstream zones (1-3) where the power station discharge dominates the flow regime, appear to respond rapidly to changes in the operation of the station.

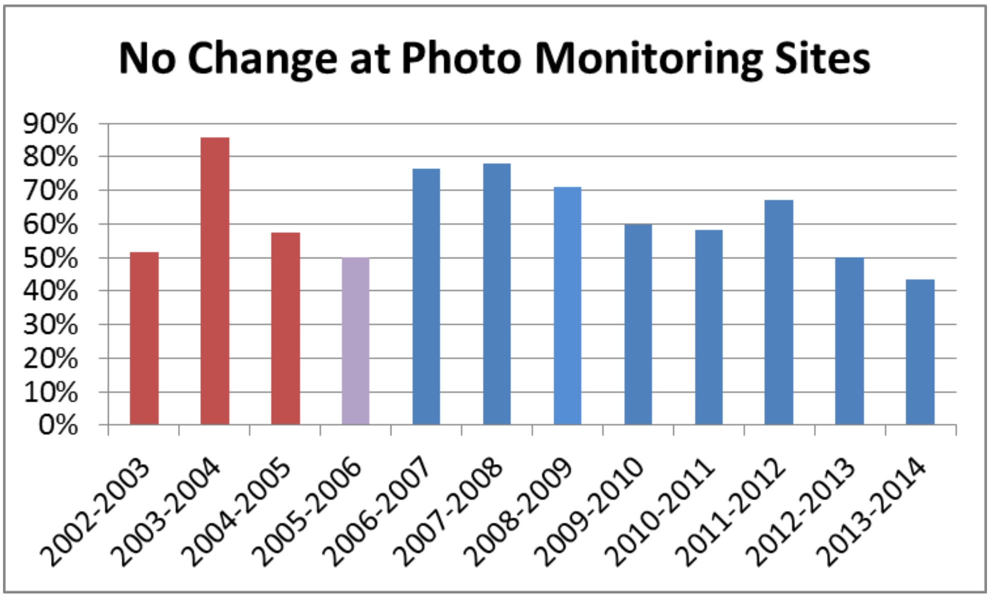

Figure 3-51: Summary of photo-monitoring results for 2013–2014. Comparison of percentage of photo monitoring sites showing no change compared with previous years, with pre-Basslink results shown in red, and post-Basslink in blue (2005 – 2006 was a transitional year).

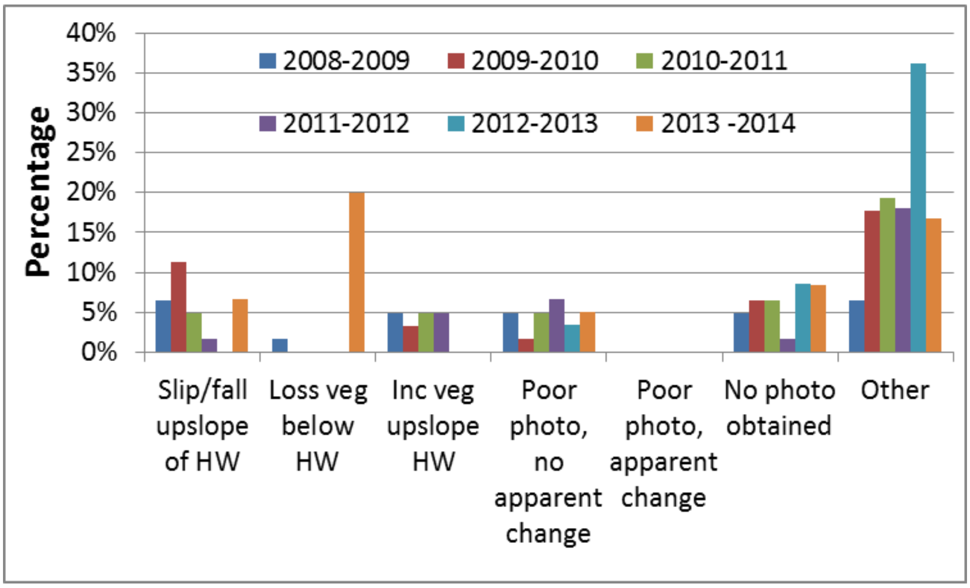

Figure 3-52: Summary of photo-monitoring results for 2013–2014. Distribution of changes by category.

Figure 3-53: Tree fall at upstream end of zone 2, near the Albert 'pool'.

3.6 Conclusion

Overall the results are consistent with the present understanding of the relationship between power station operations and geomorphic processes in the middle Gordon River. The observation that increases in either duration or discharge volume from the power station affect the riparian vegetation and lead to possible additional tree fall and bank adjustment is similar to the previous observations of the effects on bank processes in 1999-2000 when extended 3 turbine power station operation. The lack of large-scale 'new' sediment flows associated with the recent power station suggests that the ramp-down rule is modulating the impacts to some degree, even if it has not prevented seepage processes under all operating flow patterns.

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4 Macroinvertebrates

4.1 Introduction

Macroinvertebrate sampling was conducted in spring (8-9 November) 2013 and autumn (29-30 March) 2014 consistent with the requirements of the Gordon River Interim Monitoring Program. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at nine 'monitoring' sites in the Gordon River between the power station and the Franklin River junction. This sampling was also conducted at six 'reference' sites located in rivers within the Gordon River catchment.

This sampling completes 13 years of macroinvertebrate monitoring being conducted in the Gordon River catchment (five years pre-Basslink and eight years post-Basslink commissioning).

This document reports on the results of field sampling for macroinvertebrates in spring and autumn 2013-14, provides a comparison of these results with those for the pre-Basslink period (2001-2005) and describes trends over the entire monitoring program to date.

Results were also compared with triggers derived from pre-Basslink period data, as detailed in the Basslink baseline report.

4.2 Methods

4.2.1 Sample sites

The locations of the monitoring and reference sites are shown in Figure 4-1. All sites sampled in 2013-14 are listed in Table 4-1.

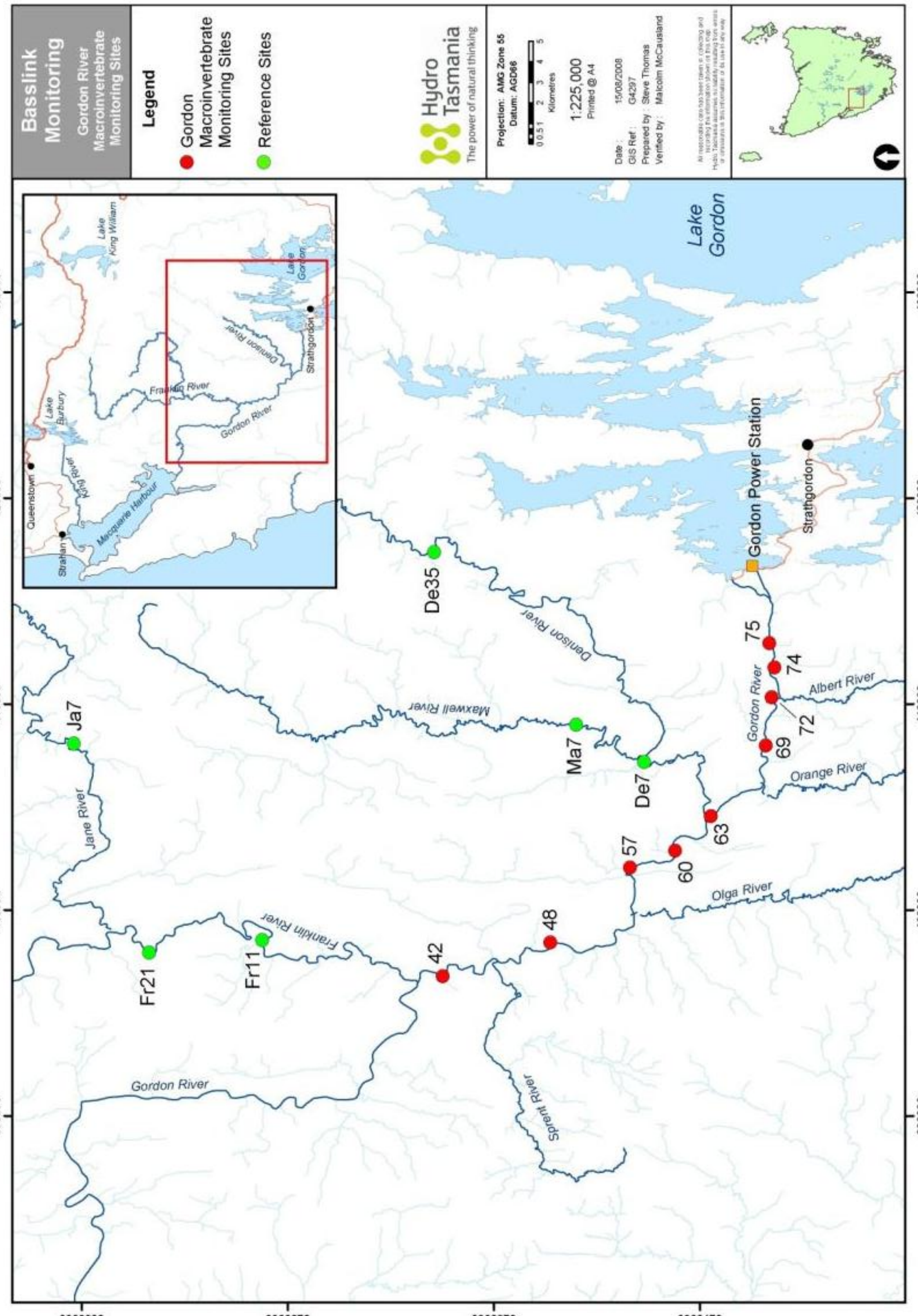


Figure 4-1: Map of locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin rivers.

Table 4-1: Sites sampled in 2013–14 for macroinvertebrates.

River	Site Name	Site code	Zone	Distance from power station (km)	Sampled	Easting	Northing
Gordon	Gordon R ds Albert Gorge (G4)	75	1	2	spring autumn	412980	5266630
	Gordon R ds Piguenit R (G4A)	74	1	3	spring autumn	412311	5266383
	Gordon R in Albert Gorge (G5)	72	1	5	spring autumn	410355	5266524
	Gordon R us Second Split (G6)	69	1	8	spring autumn	408005	5266815
	Gordon R us Denison R (G7)	63	-	14	no longer sampled	404584	5269469
	Gordon R ds Denison R (G9)	60	2	17	spring autumn	402896	5271211
	Gordon R us Smith R (G10)	57	2	20	spring autumn	402083	5273405
	Gordon R ds Olga R (G11A)	48	2	29	spring autumn	398178	5278476
	Gordon R @ Devil's Teapot (G15)	42	2	35	spring autumn	396804	5282486
Franklin	Franklin R ds Blackman's bend (G19)	Fr11	-	-	spring autumn	398562	5291239
Franklin	Franklin R @ Flat Is (G20)	Fr21	-	-	spring autumn	397939	5296733
Denison	Denison ds Maxwell R (G21)	De7	-	-	spring autumn	407206	5272718
Denison	Denison R us Truchanas Reserve (D1)	De35	-	-	autumn	417400	5282900
Jane	Jane R (J1)	Ja7	-	-	autumn	408100	5300400
Maxwell	Maxwell R (M1)	Ma7	-	-	autumn	409011	5276009

4.2.2 Macroinvertebrate sampling

One Gordon River site, site G15 (42) could not be reliably quantitatively sampled in riffle habitat due to high flows during sampling on 9 November 2013. On inspection of the data from that sample, this exception was judged as adversely affecting the ability to generate several of the required macroinvertebrate metrics for that site. The qualitative (RAP) samples from this site in spring were deemed reliable (as they were able to be taken from deeper water), allowing the O/Epa and O/Erk metrics to be reliably derived.

In autumn, sampling could only be conducted at three reference sites - Fr11, Fr21 and De7 due to high river levels prevented helicopter access at some sites. Data from these three 'core' reference sites is the minimum set required to derive the Bray Curtis metrics, and to assist in interpretation of

Gordon River results. The collection of data at these three sites also satisfies minimum sampling requirements at reference sites as prescribed in Hydro Tasmania's Water Licence Agreement.

Quantitative sampling (surber sampling) and rapid bioassessment kick sampling (RBA) methods were conducted at all sites. Thus, at each site at 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 quadrate by hand to a depth of 10 cm 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 10 m (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% using a Marchant box subsampler, and random cell selection. 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% (0.18 m^2) sub-sample data.

Two RBA samples were collected at each site. All RBA samples were live-picked on site for 30 minutes, with pickers attempting to maximise the number of taxa recovered. 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 are:

- 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, bank-full 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, representing the condition where no expected taxa are found in the sample, to 1, 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), and subsequently expanded to include the full six year post-Basslink program (McPherson unpub. data). Mean values of each indicator derived from the 2013-14 data were compared against the relevant one-year trigger values (shown graphically in this report).

Plots of trends in indicator values and abundances of selected families are presented, along with relationships between indicators and key flow variables (derived for the 2013-14 year, as described in the final six year Basslink report (Hydro Tasmania 2013)).

4.3 Results

4.3.1 Spring 2013

4.3.1.1 Quantitative data

Data from spring 2013 season quantitative surber samples are shown in Appendix E at the family level of identification and for EPT species. Data from site 42 in spring 2013 was not included in analyses as sampling conditions were sub-optimal due to high flows during sampling - resulting in anomalously low diversities and abundances in the quantitative sample.

Diversity and total abundance in the Gordon River at both family and species level was within or close to the range observed in previous years across most sites (Figure 4-2). High abundances and diversities were observed for the three reference sites in the lower Franklin and Denison rivers.

The absolute and relative (proportional) abundance of EPT species, as well as the richness of EPT species, was generally lower than the pre-Basslink means across both zones 1 and 2 (Figure 4-3 and Figure 4-4) in spring 2013. This was not the case for reference sites.

The community compositional similarity of all zone 1 Gordon River sites relative to the reference sites was similar to the pre-Basslink means, as measured by the mean Bray Curtis Similarity measure based on either abundance or presence/absence data (Figure 4-5). Bray Curtis values in zone 2 were higher than pre-Basslink.

4.3.1.2 RBA data

Spring season RBA data is shown in Appendix E. O/Epa and O/Erk values and their impairment bands are shown in Figure 4-6.

O/Epa values in spring 2013 fell generally close to pre-Basslink means for six of the eight Gordon River sites, in contrast to four of the five reference sites sampled which were below pre-Basslink means (Figure 4-6). Gordon River site 69 showed reduced O/Epa values relative to pre-Basslink means and ranges, indicating a lower number of expected families (Figure 4-6). Values for 2013 were not significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2013 values, $p > 0.3$).

O/Erk values in spring 2013 showed a similar pattern to O/Epa values (Figure 4-6) and were also not significantly different (by paired t-test of spring pre-Basslink means with 2013 values, $p > 0.2$). Reference site O/Epa and O/Erk values were marginally statistically lower than pre-Basslink means (by paired t-test of spring pre-Basslink means with 2013 values, $p < 0.025$ and < 0.05 respectively).

4.3.1.3 Summary

Overall, the diversity at family level and the relative abundance and diversity of EPT species, as well as the number and rank abundance of expected families, were similar to or greater than pre-Basslink values for Gordon River sites in spring 2013. This was also observed for reference sites, with the exception of O/E measures whose values fell below pre-Basslink means due to reactively poorer representation of expected taxa outside the EPT group.

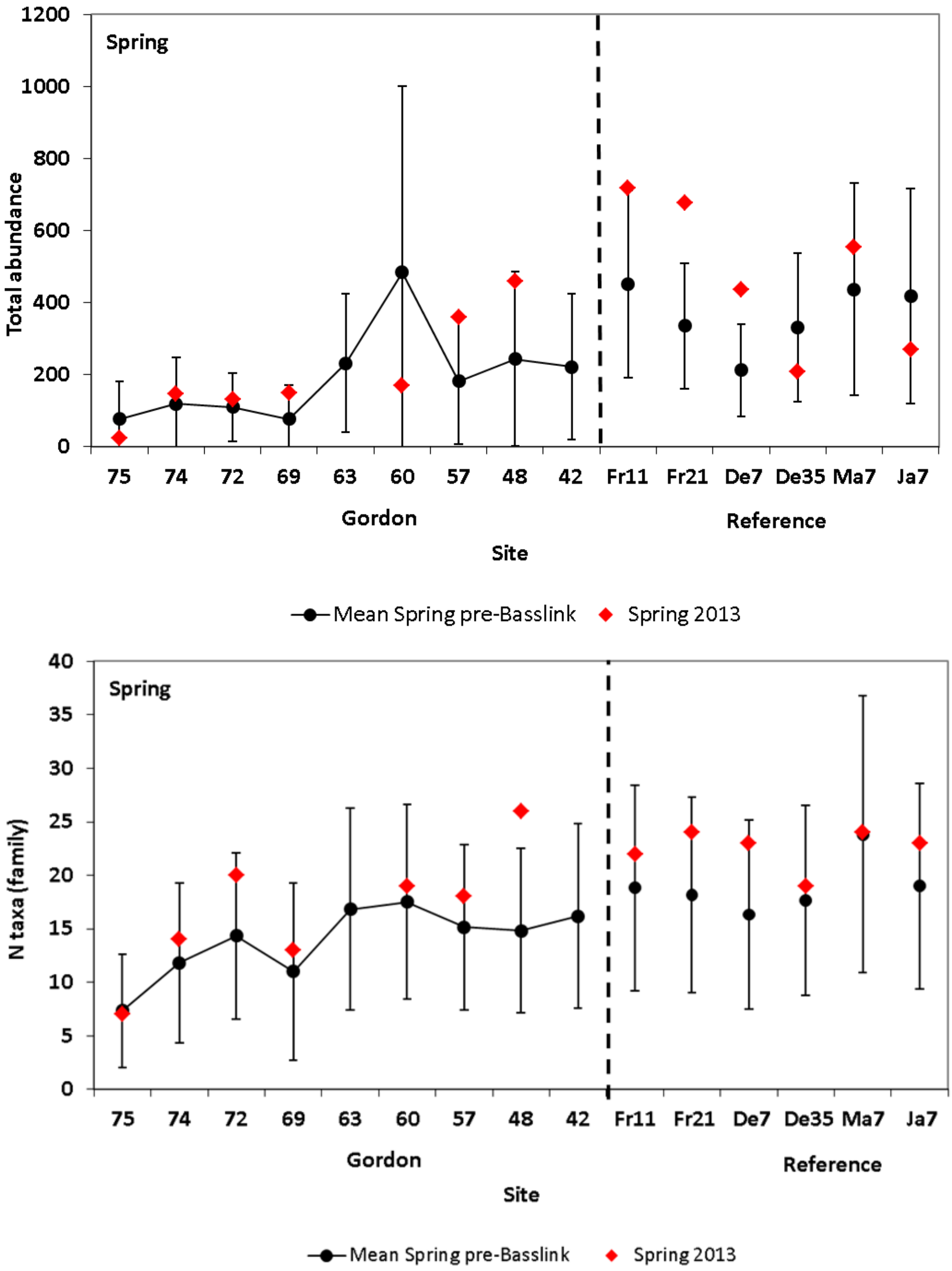
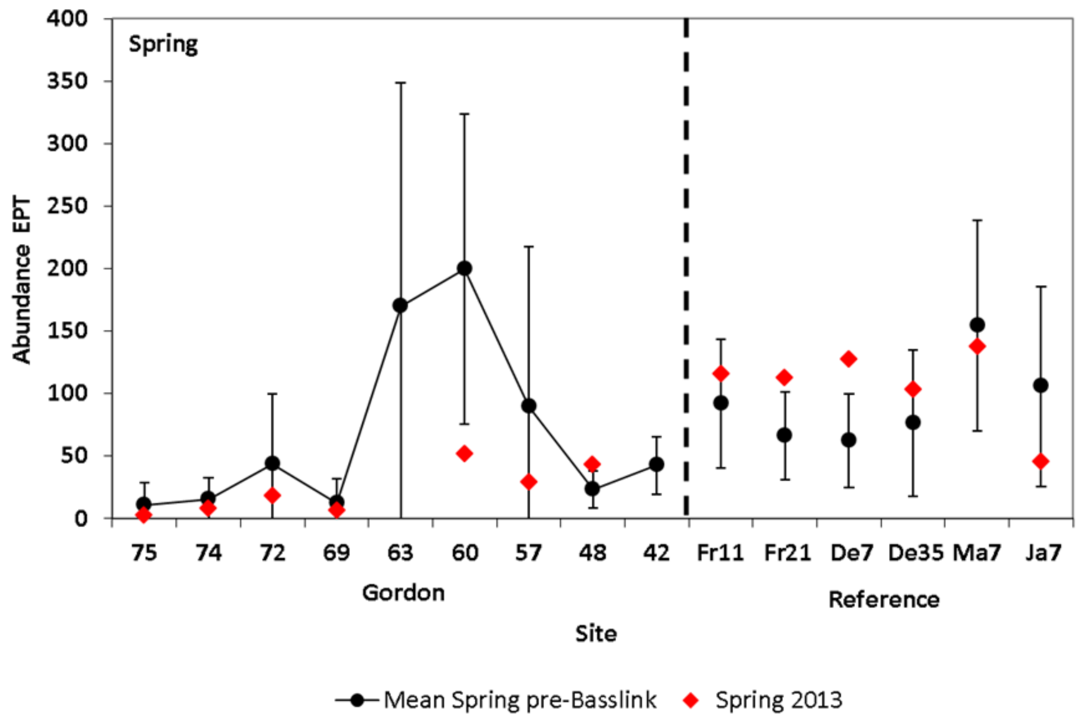


Figure 4-2: Comparison of total abundance of all benthic macroinvertebrates and diversity (number of taxa at family level) for spring 2013 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



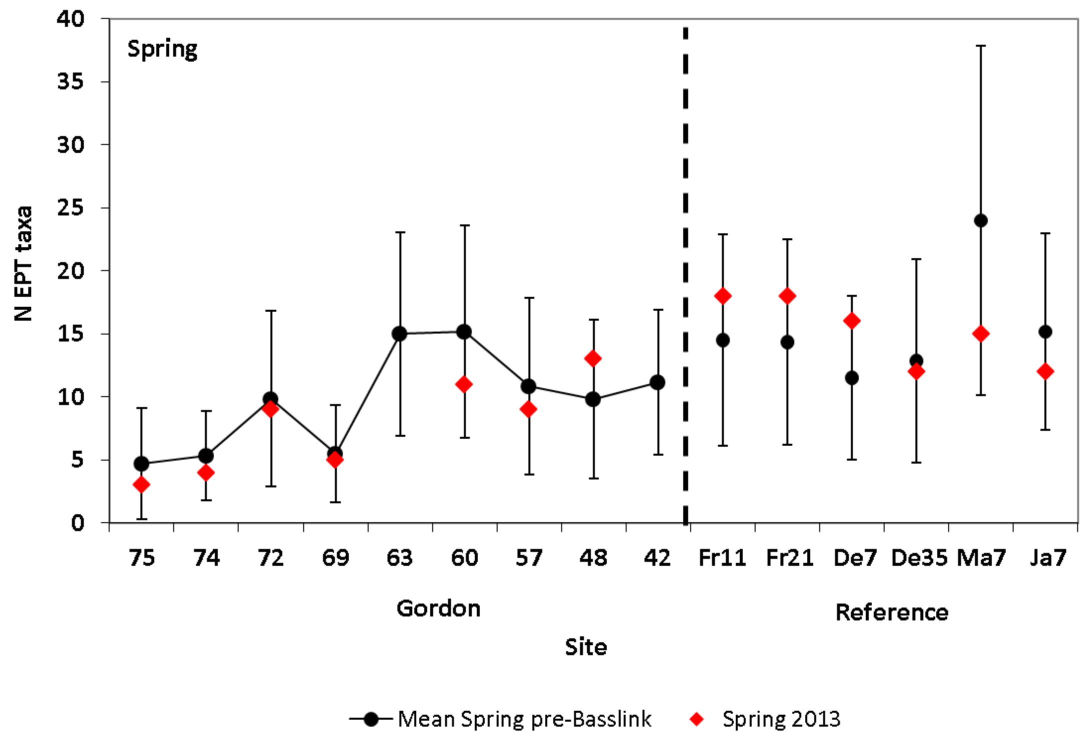


Figure 4-3: Comparison of total abundance and number of benthic EPT taxa (genus and species) for spring 2013 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.

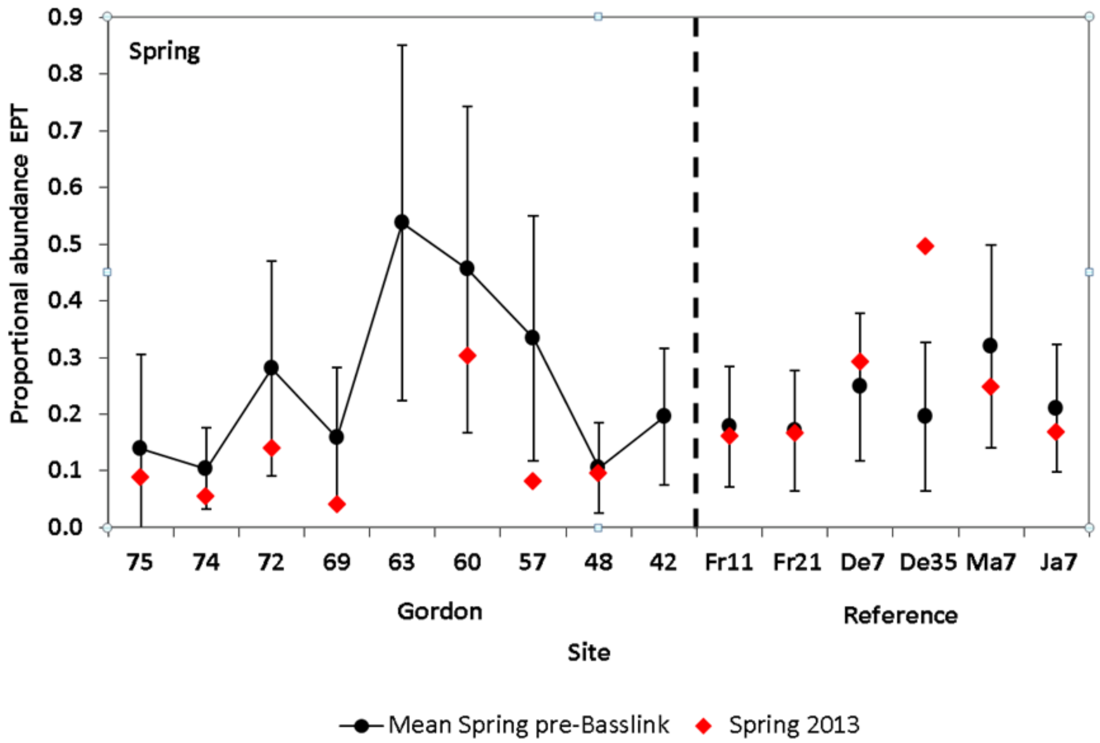
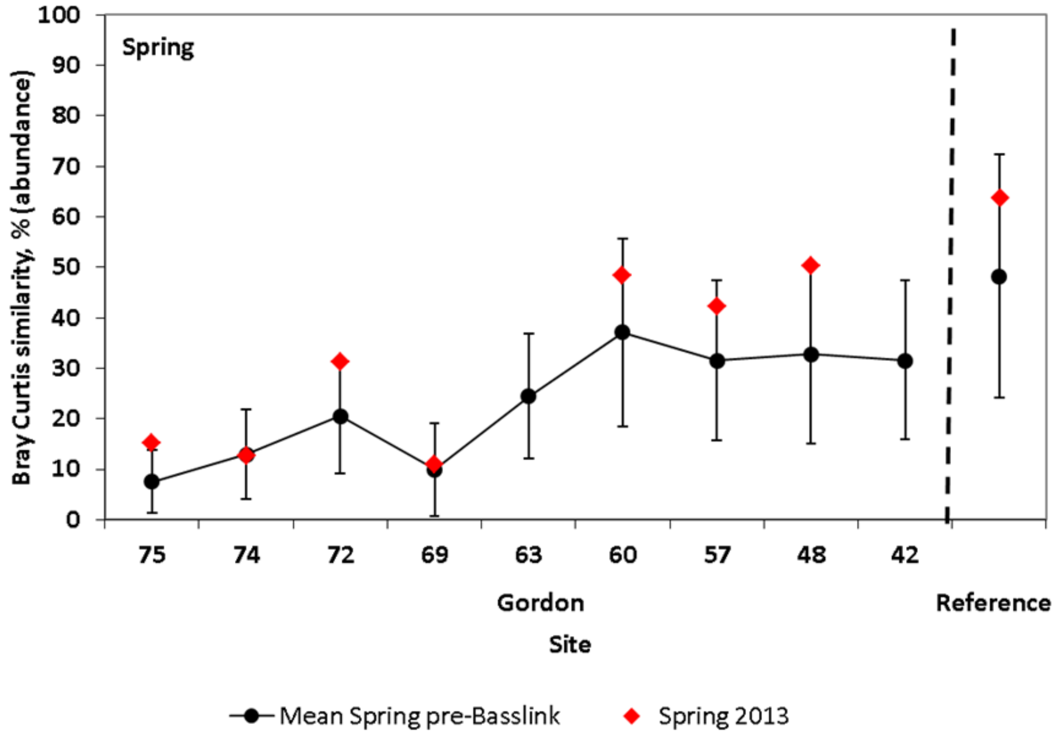


Figure 4-4: Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for spring 2013 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



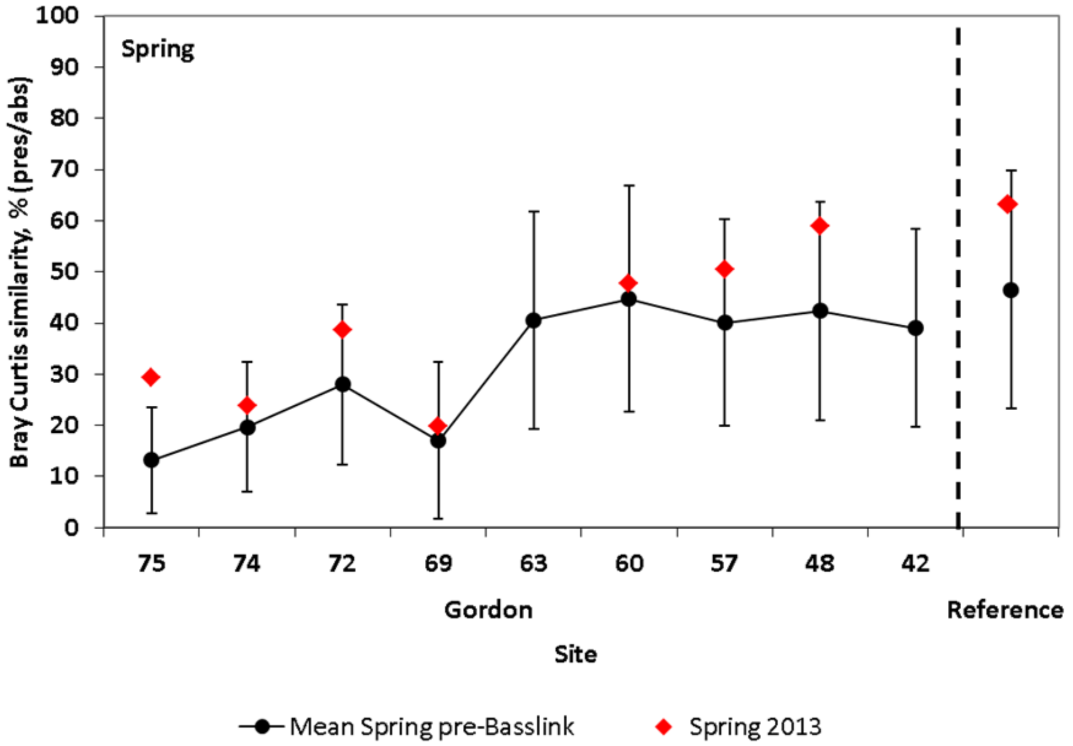
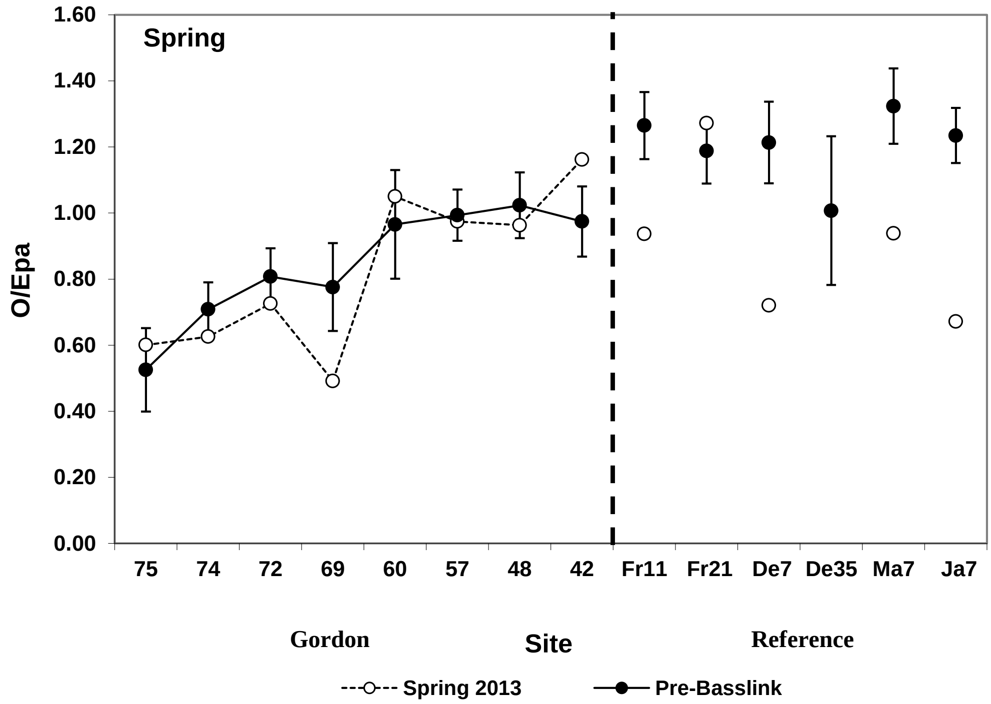


Figure 4-5: Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for spring 2013 with spring values from previous years. Similarities are calculated with either abundance data (square root transformed) or presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. 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. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



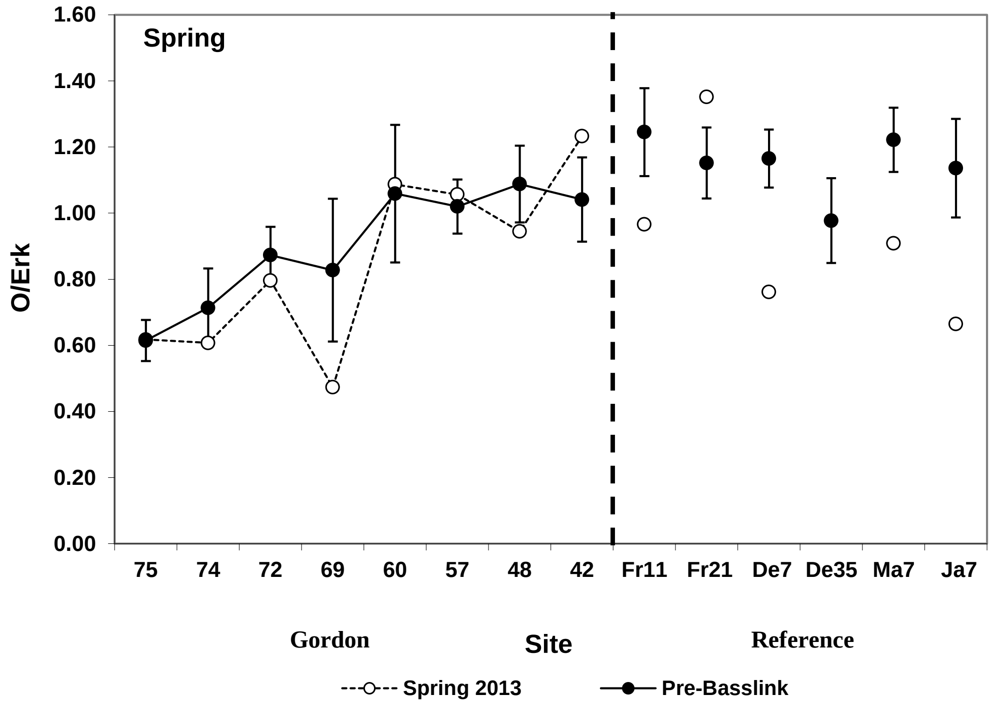


Figure 4-6: Comparison of O/Epa and O/Erk values for spring 2013 with values from previous years. Note high O/Epa values at sites 48 and 69 – 74 upstream of Denison River. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

4.3.2 Autumn 2014

4.3.2.1 Quantitative data

Data from the autumn 2014 season quantitative surber samples are shown in Appendix E at family level and for EPT species.

In zone 1, total abundance and number of taxa at both family and species level for the Gordon River sites fell below pre-Basslink means for sites 72 to 75 (Figure 4-7). Total abundances in zone 2 fell at or above pre-Basslink means (sites 42 to 60, Figure 4-7). Total abundance and number of taxa were low relative to pre-Basslink mean values for two of the three reference sites sampled (Figure 4-7).

The abundance of EPT species was generally low among Gordon River sites, with six of the eight sites falling below their pre-Basslink means (Figure 4-8). Two of the three reference sites also had abundances of EPT species below the pre-Basslink means (Figure 4-8). The number of EPT species was generally well below pre-Basslink mean values for both Gordon River and reference sites (Figure 4-8).

The proportional abundance of EPT species was generally lower than pre-Basslink means in both Gordon River and in reference sites in autumn 2014 (Figure 4-9). This reduced representation of EPT species was primarily due to the presence of high abundances of blackfly (Simuliidae) larvae at most sites (Appendix E). This family therefore contributes to total abundance but is not part of the EPT taxonomic grouping.

The autumn 2014 community compositional similarity of the Gordon River sites relative to reference sites was lower than pre-Basslink means for three of the four zone 1 sites and site 57 in zone 2, for both similarity measures (Figure 4-10). All remaining Gordon River sites had similar or higher Bray Curtis indicator values to pre-Basslink means, with site 74 (zone 1) and site 48 (zone 2) having the highest relative values.

4.3.2.2 RBA data

Autumn season RBA data is shown in Appendix E. O/Epa and O/Erk values and their impairment bands are shown in Table 4-2 and are plotted alongside pre-Basslink values in Figure 4-11.

O/Epa and O/Erk values in autumn 2014 were reduced overall relative to their pre-Basslink means for most of the eight Gordon River sites, with especially low values for both indicators at the four zone 1 sites and in zone 2 sites 42 and 48 (Figure 4-11). There was also a reduction across the three reference sites sampled. The autumn 2014 values for zone 1 were statistically significantly lower than their pre-Basslink mean values (by paired t-test, all $p = 0.016$, and 0.003 for O/Epa and O/Erk respectively). This indicates that both the number of expected families was significantly reduced, and also the rank abundance of those expected families remaining at the site.

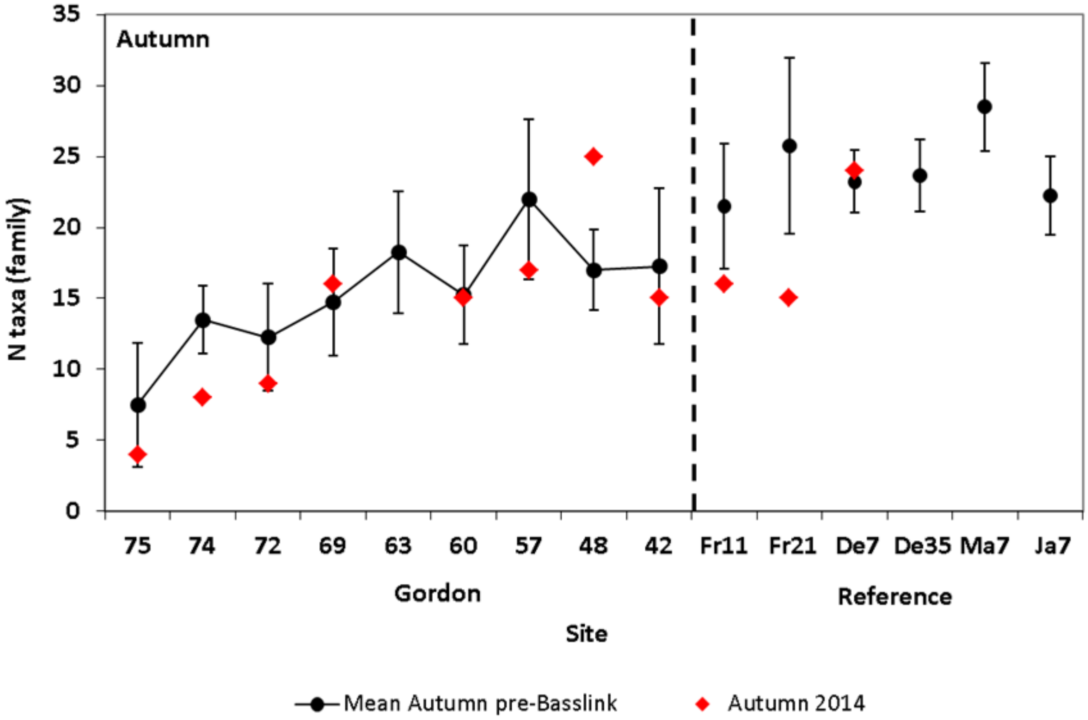
Values of O/Erk in zone 2 were also statistically significantly lower than pre-Basslink values across all sites (by paired t-test, $p = 0.012$), reduction in rank abundance of a number of expected taxa.

4.3.2.3 Summary

In autumn 2014, diversity at family level and total abundance, were reduced in zone 1 while diversity and proportional abundance of EPT species were reduced across both zones 1 and 2 along with values of O/Epa and O/Erk. While this pattern was observed at reference sites, the magnitude of differences was smaller and the causes differed. High flow levels in reference rivers during (and immediately prior to) sampling are deemed responsible for the reduced values observed at reference sites. The high flows in reference rivers required samples to be collected from areas less often inundated, at locations higher up the bank, on suboptimal substrate. In comparison, sampling in the Gordon River occurred at low flow levels on similar substrate to previous sampling occasions, such that the differences in the Gordon River were not influenced by the same factor. The differences in the Gordon River were most likely driven by the long period of sustained high flows prior to sampling which did not affect sampling locations but drove changes in the macroinvertebrate community.

Table 4-2: O/Epa and O/Erk values for all sites sampled in spring and autumn 2013–14, for individual replicate samples, and averages. Impairment bands also indicated.

River	Site	Replicate	Spring 2013				Autumn 2014			
			O/Epa	Band	O/Erk	Band	O/Epa	Band	O/Erk	Band
Gordon R	75	1	0.53	B	0.59	B	0.59	B	0.40	C
		2	0.68	B	0.65	B	0.39	C	0.35	C
		Mean	**0.60**	**B**	**0.62**	**B**	**0.49**	**B**	**0.38**	**C**
	74	1	0.44	B	0.46	B	0.59	B	0.50	B
		2	0.81	A	0.75	B	0.49	C	0.50	B
		Mean	**0.63**	**A**	**0.61**	**B**	**0.54**	**B**	**0.50**	**B**
	72	1	0.65	B	0.74	B	0.59	B	0.45	B
		2	0.80	A	0.85	A	0.68	B	0.50	B
		Mean	**0.73**	**B**	**0.80**	**A**	**0.64**	**A**	**0.48**	**B**
	69	1	0.61	B	0.59	B	0.68	B	0.52	B
		2	0.38	B	0.36	B	0.49	C	0.47	B
		Mean	**0.49**	**B**	**0.47**	**B**	**0.59**	**C**	**0.49**	**B**
	60	1	1.12	A	1.18	A	1.17	A	0.86	A
		2	0.97	A	1.00	A	1.17	A	0.76	B
		Mean	**1.05**	**A**	**1.09**	**A**	**1.17**	**A**	**0.81**	**A**
	57	1	1.12	A	1.17	A	1.27	X	0.81	B
		2	0.82	A	0.94	A	1.27	X	0.81	B
		Mean	**0.97**	**A**	**1.06**	**A**	**1.27**	**X**	**0.81**	**B**
	48	1	1.04	A	0.98	A	1.08	A	0.79	B
		2	0.88	A	0.91	A	0.98	A	0.74	B
		Mean	**0.96**	**A**	**0.94**	**A**	**1.03**	**A**	**0.77**	**B**
	42	1	0.97	A	1.12	A	0.98	A	0.65	B
		2	1.35	X	1.35	X	1.08	A	0.71	B
		Mean	**1.16**	**X**	**1.23**	**X**	**1.03**	**A**	**0.68**	**B**
Franklin R	Fr11	1	0.90	A	0.88	A	0.98	A	0.96	A
		2	0.97	A	1.05	A	1.37	X	0.96	A
		Mean	**0.94**	**A**	**0.97**	**A**	**1.17**	**A**	**0.96**	**A**
	Fr21	1	1.27	X	1.41	X	1.27	X	1.06	A
		2	1.27	X	1.29	X	1.37	X	1.01	A
		Mean	**1.27**	**X**	**1.35**	**X**	**1.32**	**X**	**1.03**	**A**
Denison R	De7	1	0.76	A	0.82	A	1.27	X	0.96	A
		2	0.68	B	0.70	B	1.37	X	1.11	A
		Mean	**0.72**	**B**	**0.76**	**B**	**1.32**	**X**	**1.03**	**A**
	De35	1	0.87	A	0.79	A				
		2	1.11	A	0.97	A				
		Mean	**0.99**	**A**	**0.88**	**A**	**NA**	**NA**	**NA**	**NA**
Maxwell R	Ma7	1	0.90	A	0.94	A				
		2	0.98	A	0.88	A				
		Mean	**0.94**	**A**	**0.91**	**A**	**NA**	**NA**	**NA**	**NA**
Jane R	Ja7	1	0.71	B	0.66	B				
		2	0.63	B	0.66	B				
		Mean	**0.67**	**B**	**0.66**	**B**	**NA**	**NA**	**NA**	**NA**



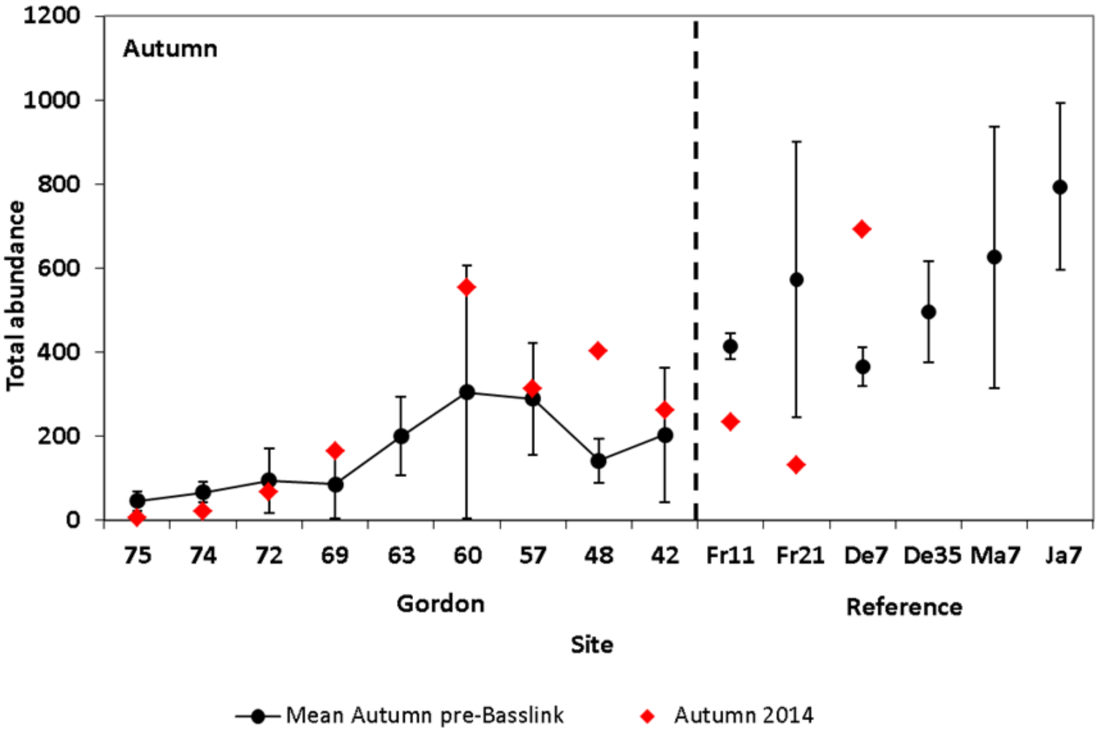
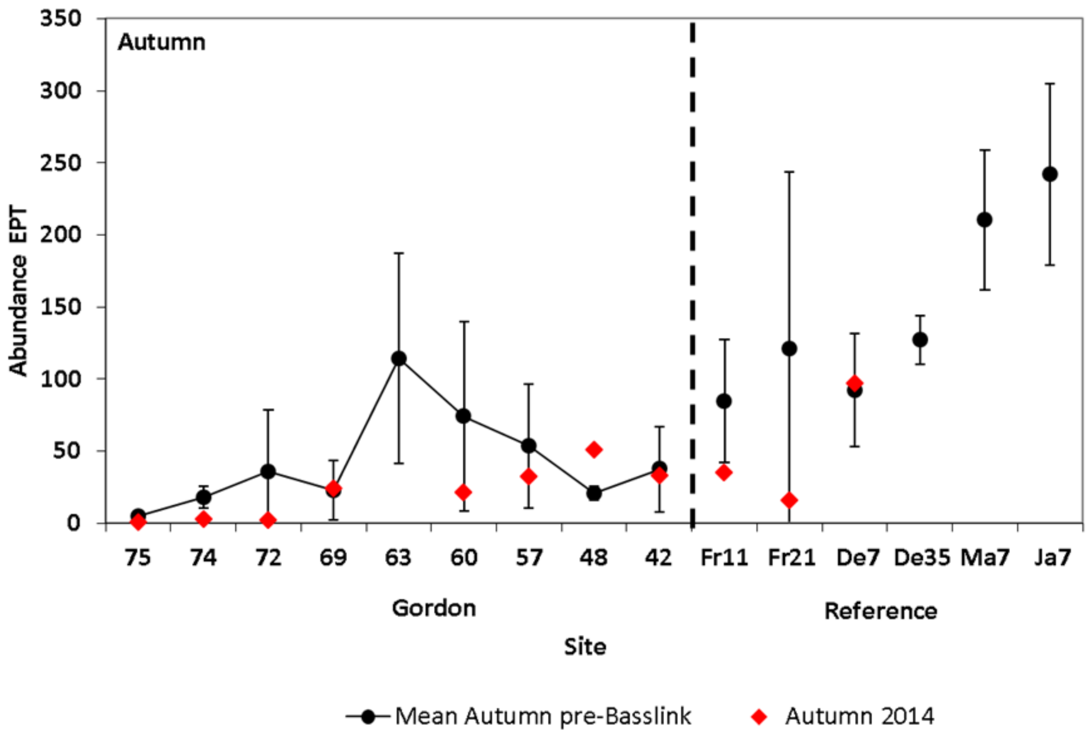


Figure 4-7: Comparison of total abundance and diversity (number of taxa at family level) for autumn 2014 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



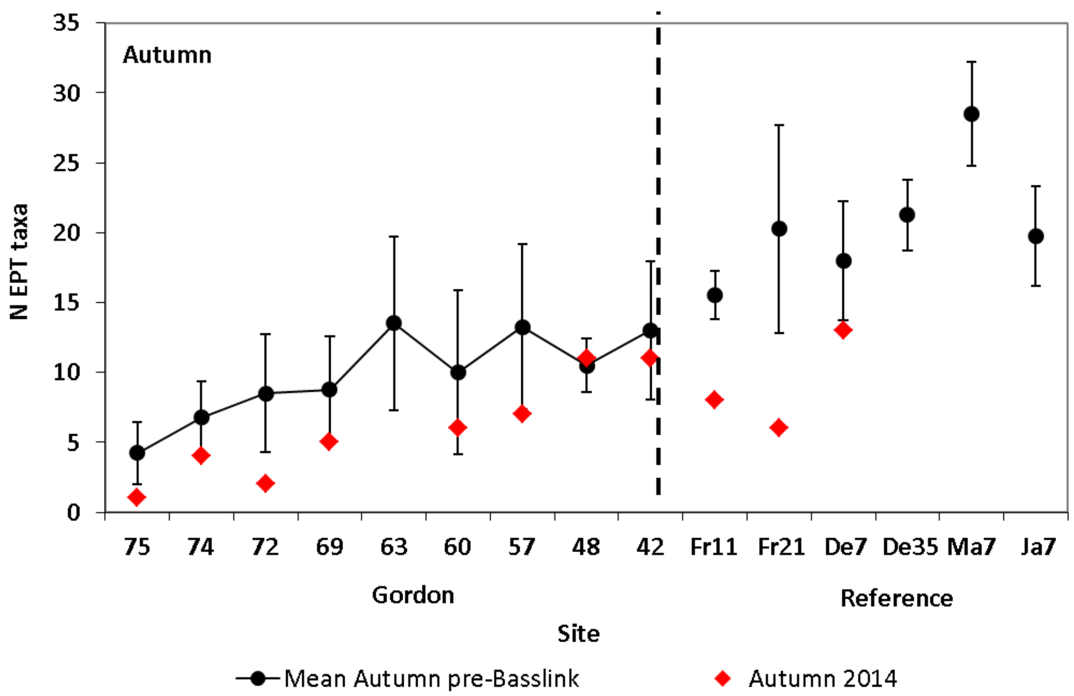


Figure 4-8: Comparison of total abundance and number of benthic EPT species for autumn 2014 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.

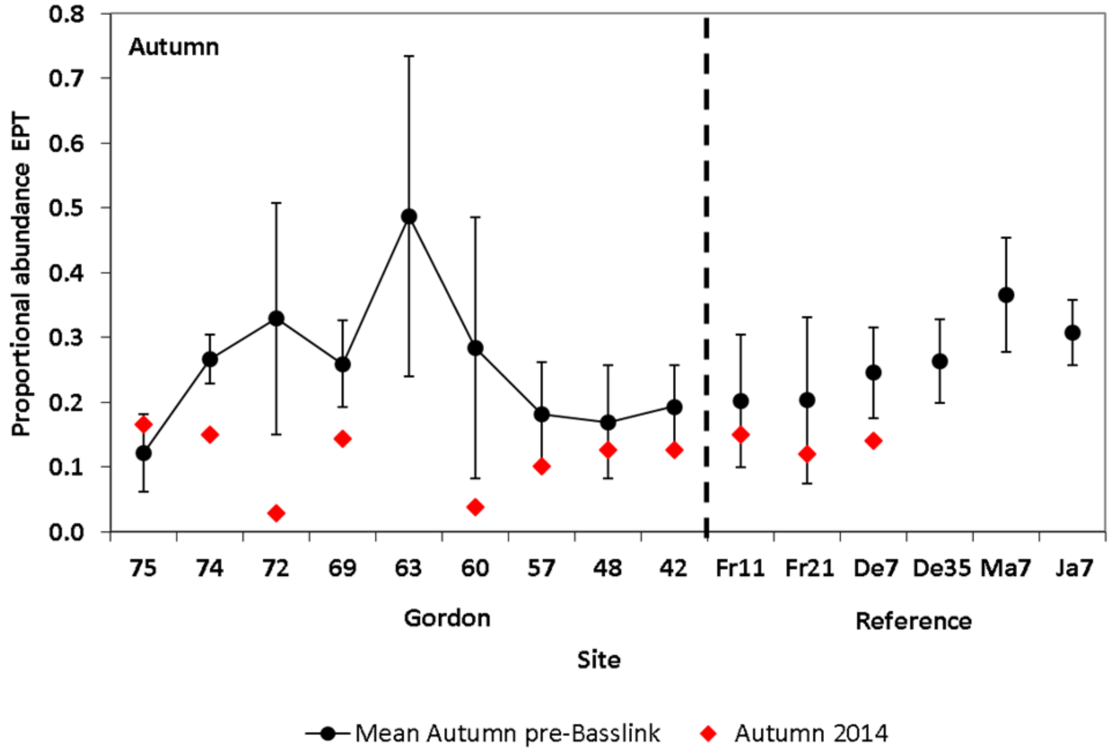
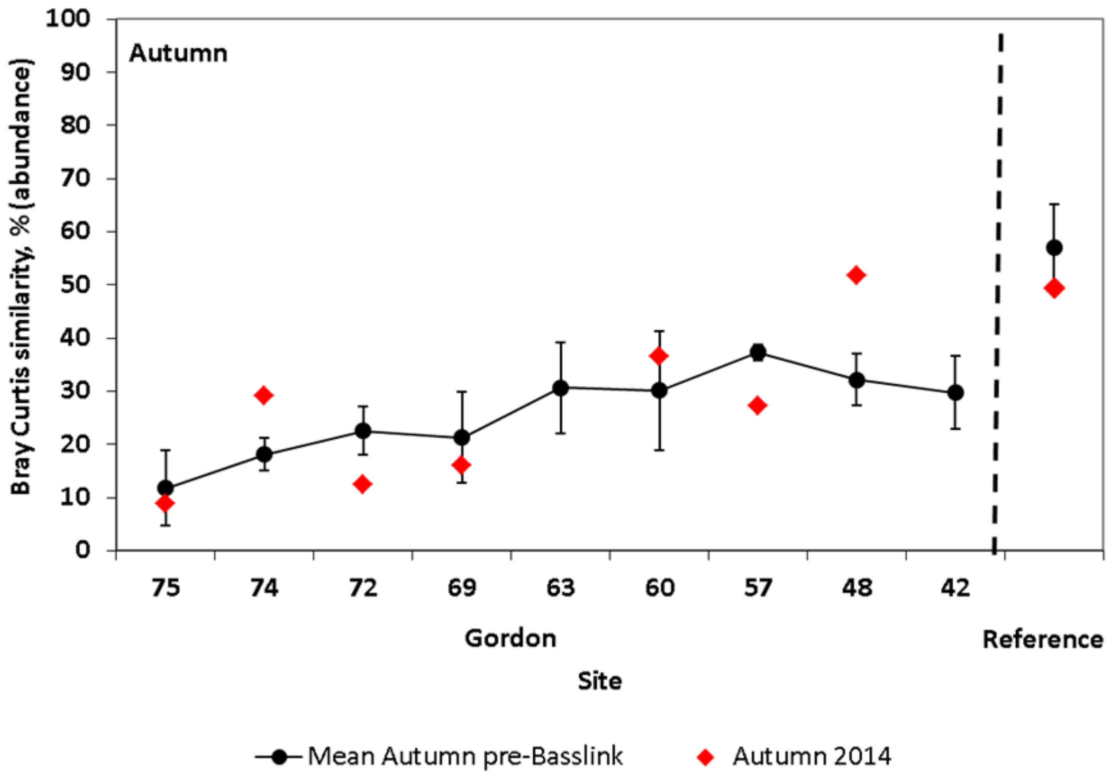


Figure 4-9: Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for autumn 2014 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



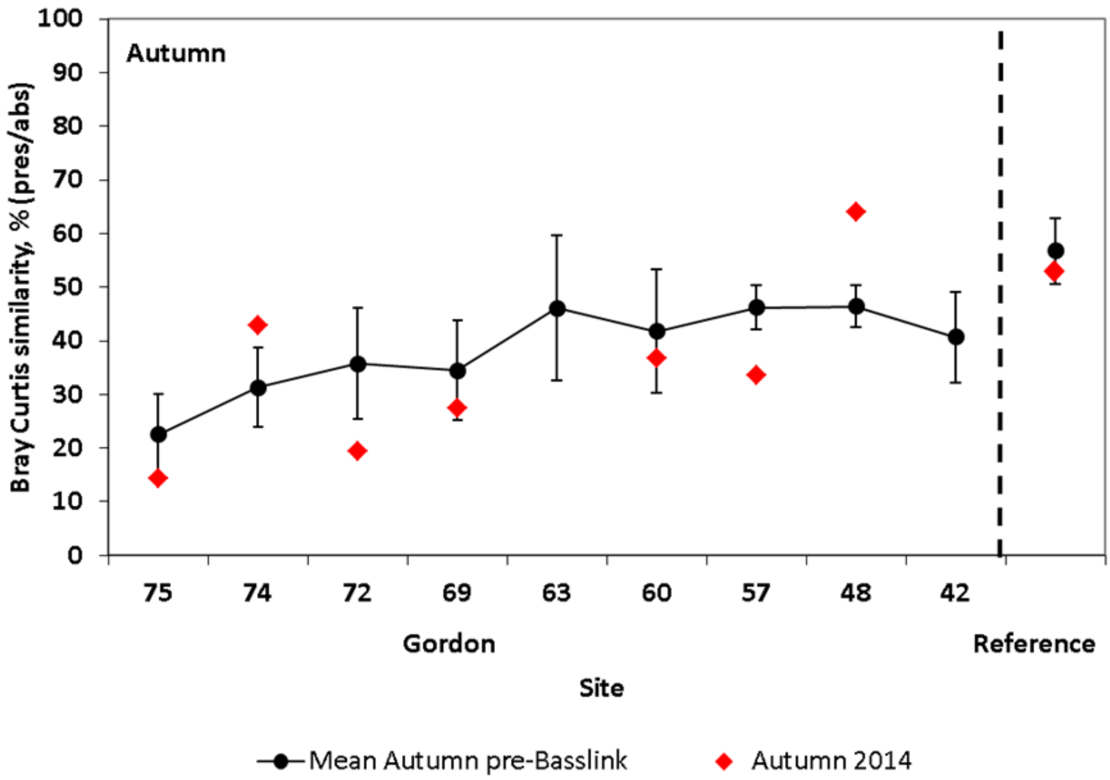
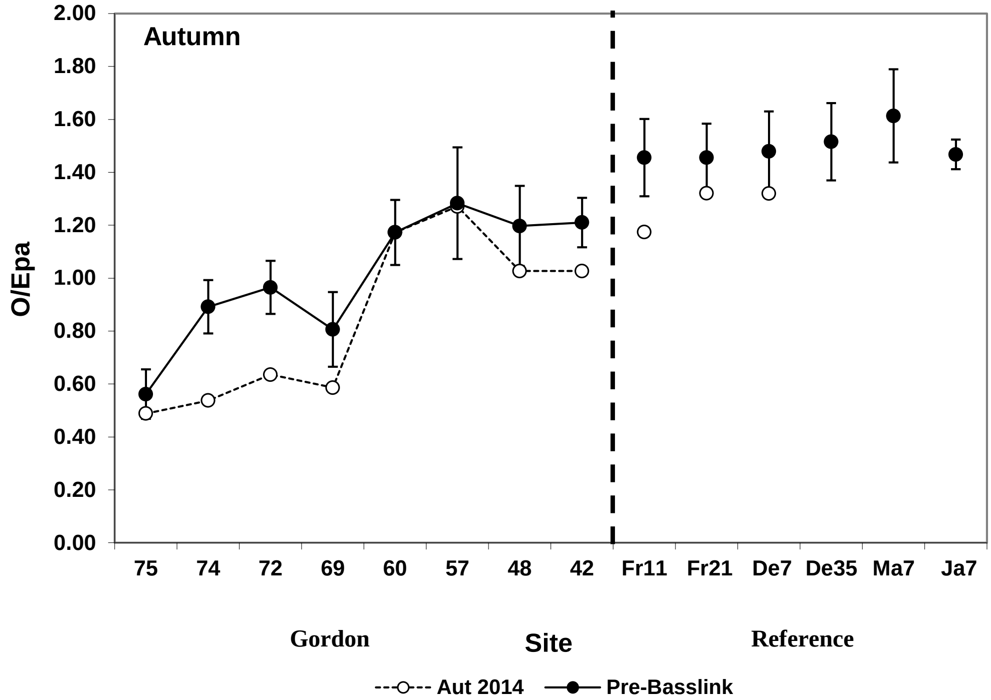


Figure 4-10: Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2014 with autumn values from previous years. Similarities are calculated with either abundance data (square root transformed) or with presence/absence data. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean. 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. Note that the pre-Basslink values for site 63 are shown for interest, though sampling at this site was discontinued in 2012.



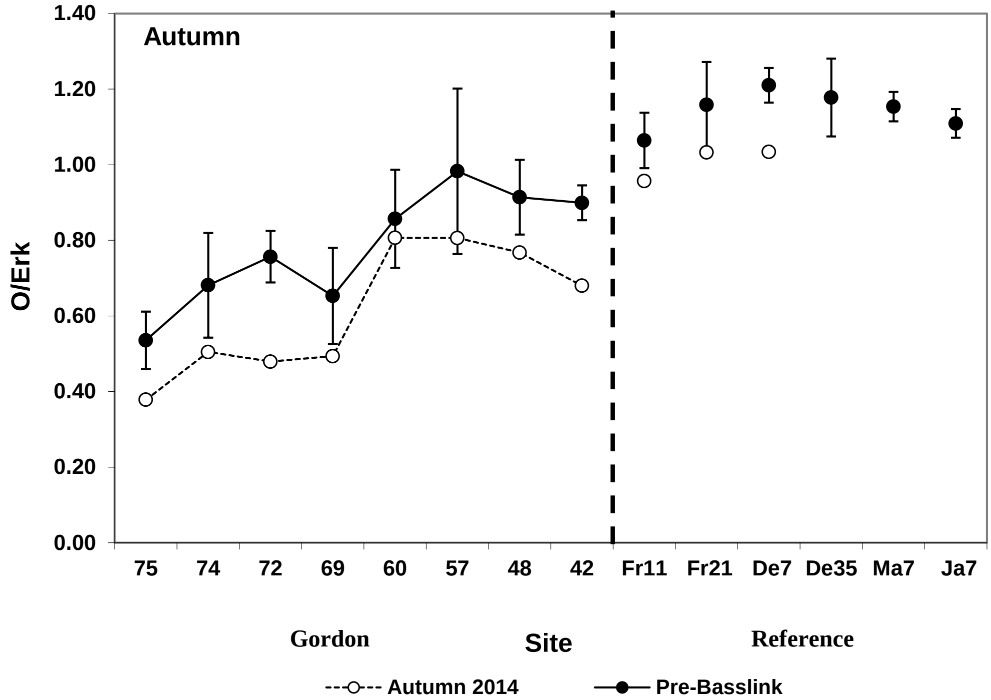


Figure 4-11: Comparison of O/Epa and O/Erk values for autumn 2014 with values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002-05 mean.

4.4 Comparisons with triggers

4.4.1 Results

Nine metrics have been identified 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 metrics have been 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 have been 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. Seasonal differences are also taken into account for the WOR case. 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 2013-14 are shown in Appendix E. It was not possible to use some metric values for site 42 in spring 2013 in calculating means for zones in evaluating trigger compliance, due to the poor quality of the quantitative data. Values for O/Epa and O/Erk, derived from RAP sampling, were however reliable for this site and were used in trigger compliance assessment.

Plots of the trigger levels for each metric are shown below along with the value for the metric recorded in 2013-14 at whole of river (WOR) and zone levels (Figure 4-12 to Figure 4-16).

4.4.2 Trigger status

The following section summarises and comments on the observations for 2013–14 in comparison with the trigger values.

4.4.2.1 Community Structure

Bray Curtis (abundance): All values fall within trigger bounds (Figure 4-12).

Comment – Overall falls within trigger bounds.

O/Erk: Within trigger bounds at Whole of River (WOR) and zone levels for the all year cases (Figure 4-12). A low WOR value in spring that falls within trigger bounds.

A WOR value falling just below the lower trigger bound for autumn 2014. This is the first such trigger exceedance for this indicator. Reduced relative abundance of several expected families, as well as loss of several families. This is a characteristic response to sustained high flows in the Gordon River preceding sampling.

Comment – Below lower trigger bound in autumn, due to the impact of sustained high power station release flows prior to sampling.

4.4.2.2 Community Composition

Bray Curtis (pres/abs data): All values fall within trigger bounds (Figure 4-13). Zone 2 values falling at upper trigger bound.

Comment – Overall within trigger bounds.

O/Epa: Within trigger bounds at WOR level and for zone 2 for the all year cases and for WOR in spring (Figure 4-13). A low value, within trigger bounds in zone 1.

A WOR value falling below the lower trigger bound for autumn 2014. This is the first such trigger exceedance for this indicator resulting from loss of several expected families. This is a response to sustained high flows in the Gordon River preceding sampling.

Comment – Below lower trigger bound in autumn, due to the impact of sustained high power station release flows prior to sampling.

4.4.2.3 Taxonomic richness

N Taxa (fam): All values fall within trigger bounds (Figure 4-14).

Comment – Overall within trigger bounds.

N EPT Species: All values fall within trigger bounds (Figure 4-14). WOR Autumn season and zone 2 all year values falling at close to lower trigger bound.

Comment – Overall within trigger bounds.

4.4.2.4 Ecologically significant species

Proportion of total abundance as EPT: Within trigger bounds for WOR in autumn and zone 2 (all year) (Figure 4-15).

Outside trigger bounds for WOR all year and in spring and in zone 1 (all year). This response was likely driven by sustained high Gordon River flows prior to sampling.

Comment – Below minimum trigger values due to sustained high flows.

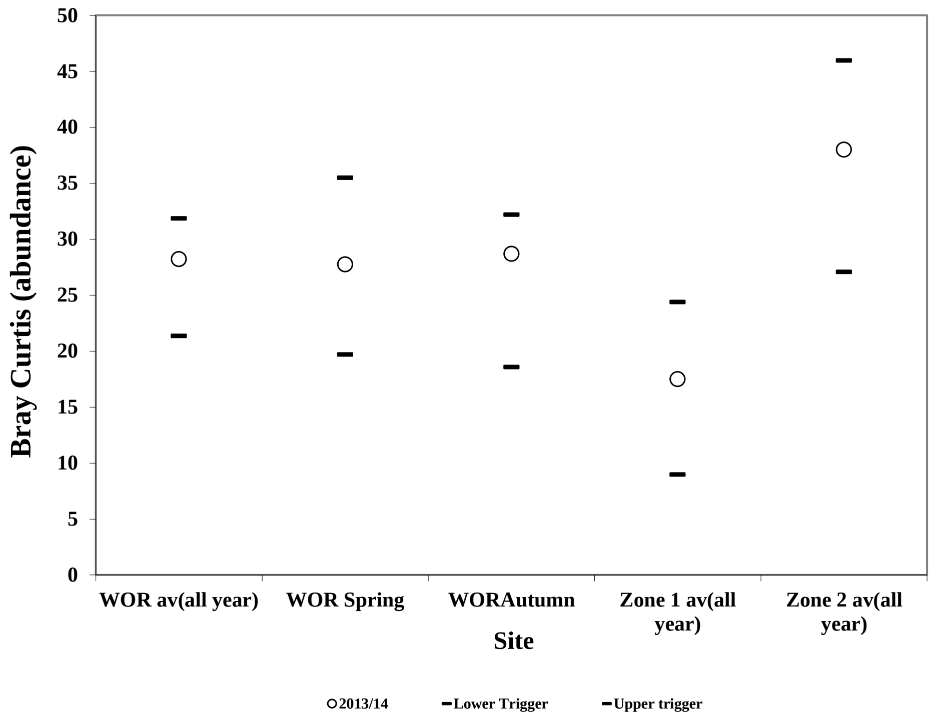
Abundance EPT: Exceeds upper trigger value for WOR (all year and in spring) and in zone 1 (Figure 4-15). Within trigger bounds in autumn and for zone 2 all year

Comment – Upper exceedances not of environmental concern.

4.4.2.5 Biomass/productivity

Total abundance: Values above upper bound for WOR (all year and in autumn) and within trigger bounds in spring and at zone scale (Figure 4-16).

Comment – Within trigger bounds or slightly improved at whole of river scale.



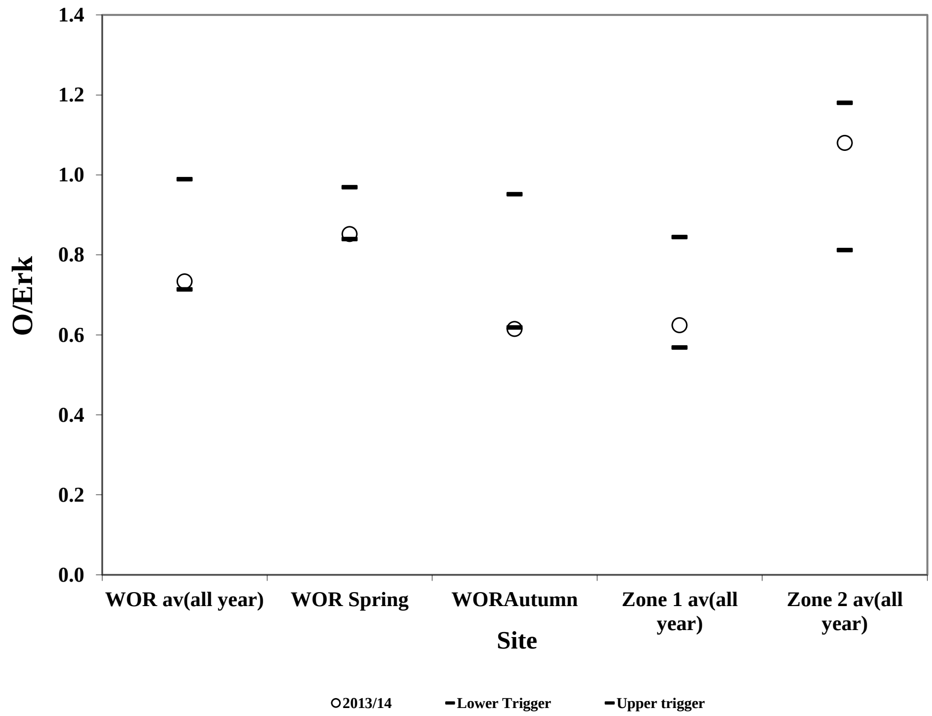


Figure 4-12: Community structure metric values for 2013-14 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: WOR = Whole of River (by year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95 percentile of pre-Basslink data.

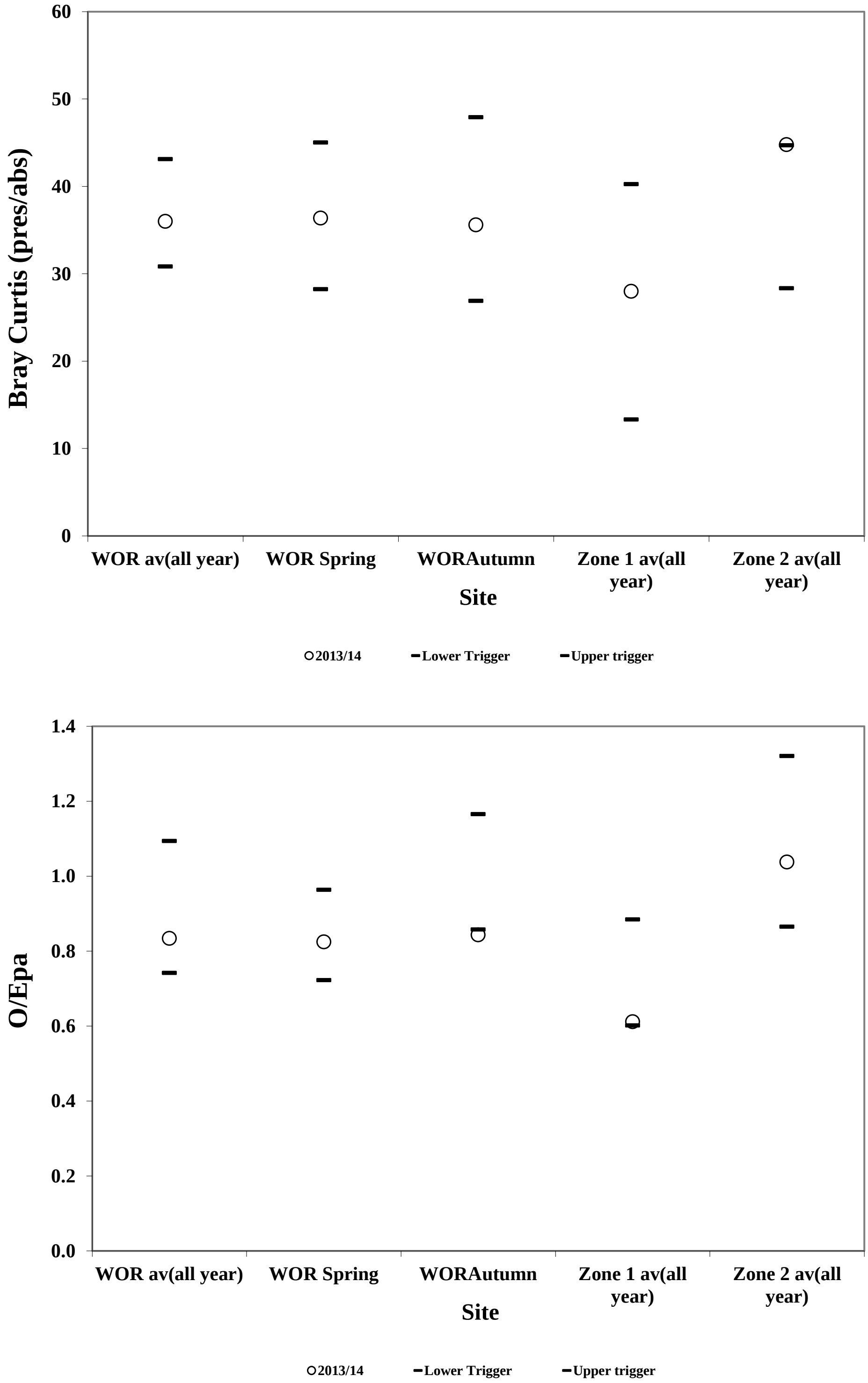
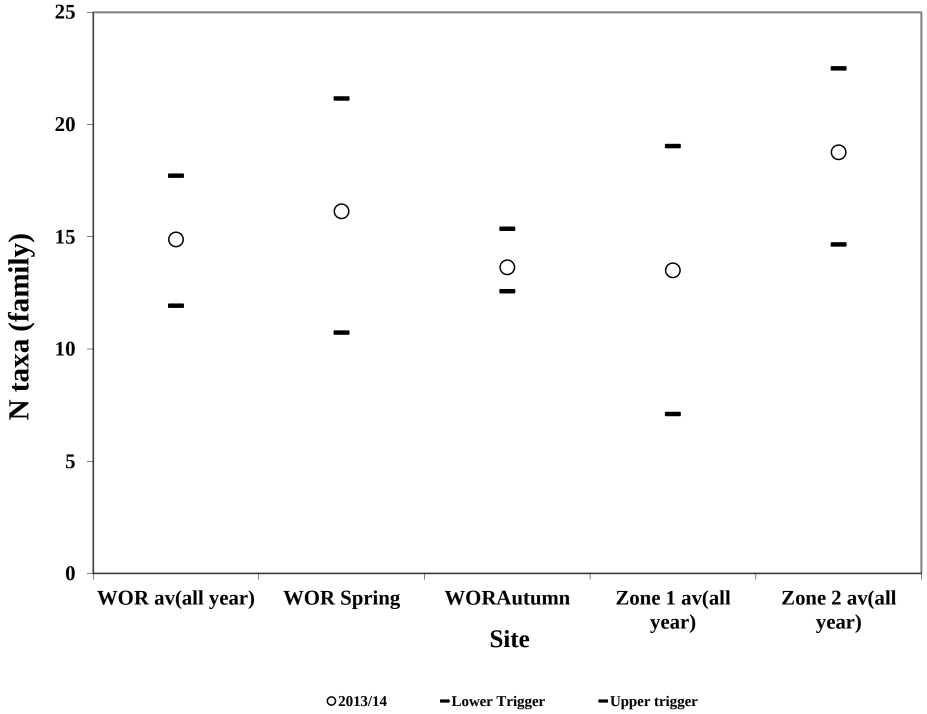


Figure 4-13: Community Composition metric values for 2013-14 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95 percentile of pre-Basslink data.



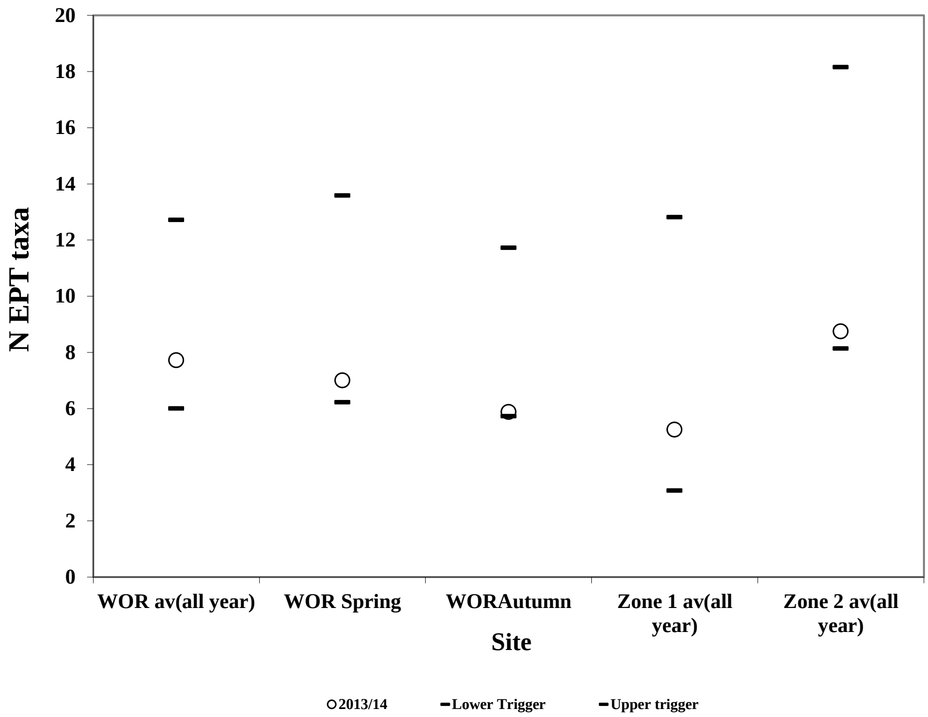
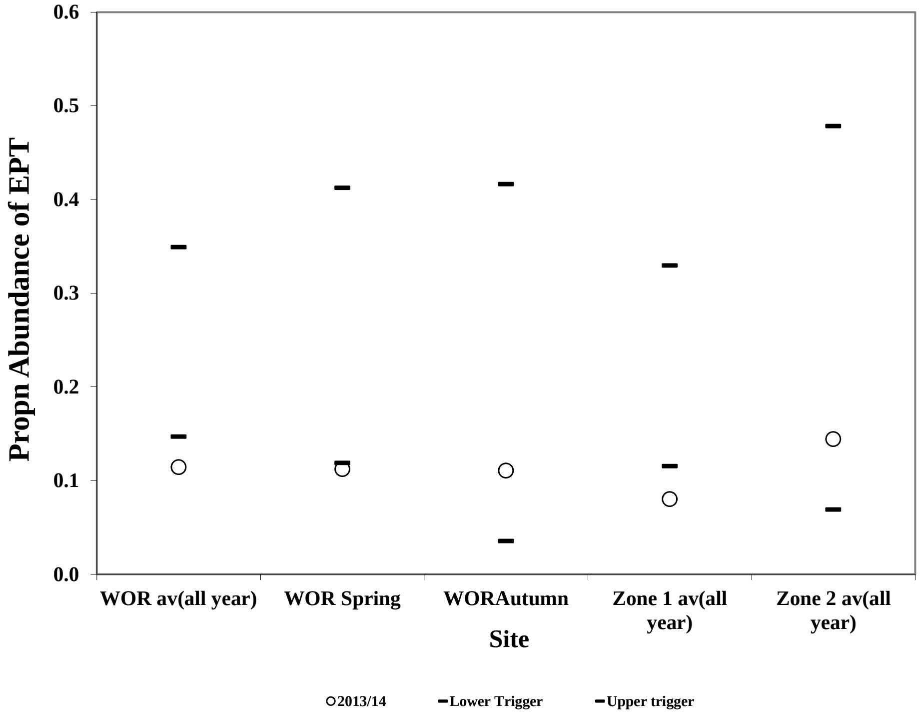


Figure 4-14: Taxonomic Richness metric values for 2013-14 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95 percentile of pre-Basslink data.



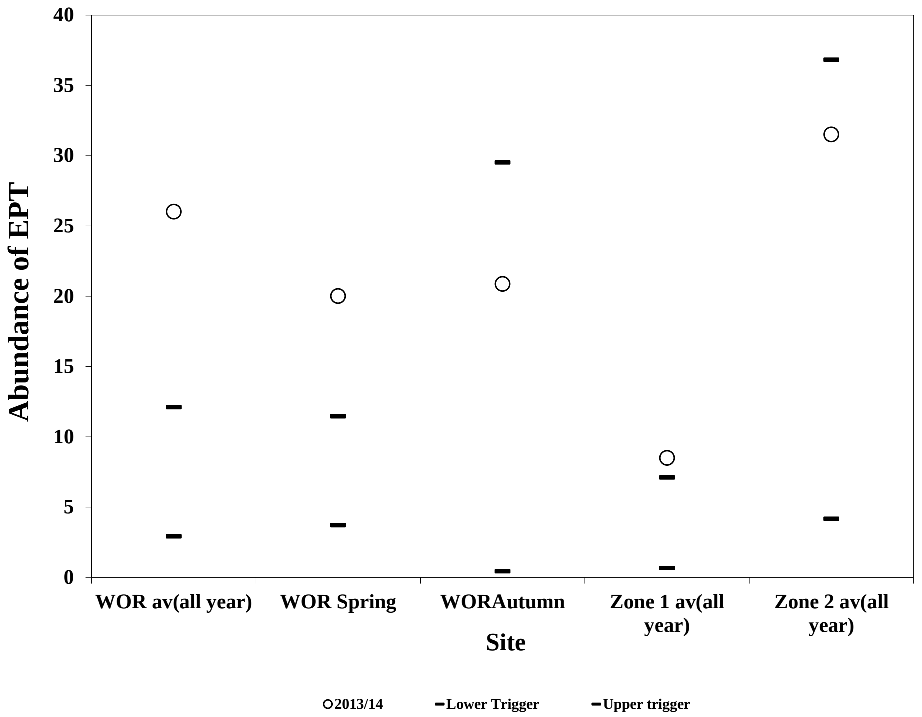


Figure 4-15: Ecologically Significant Species metric values for 2013-14 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95 percentile of pre-Basslink data.

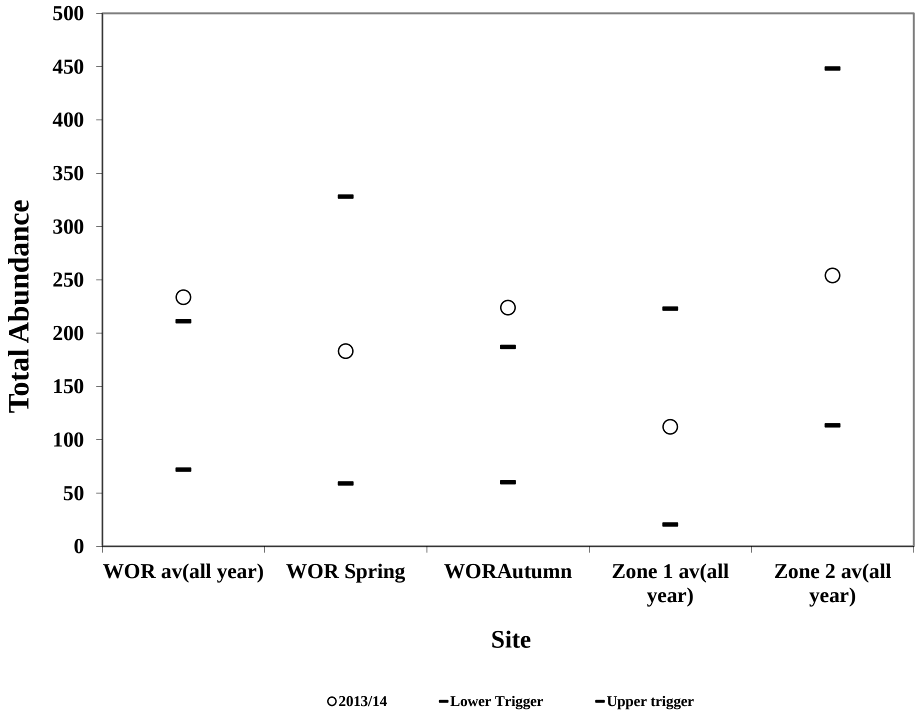


Figure 4-16: Biomass/Productivity metric values for 2013-14 compared with upper and lower LOAC Trigger values in the Gordon River for the following cases: Whole of River (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95 percentile of pre-Basslink data.

4.5 Long-term trends

4.5.1 Univariate indicators

Trends in all metrics are shown in Figure 4-17 to Figure 4-21. As in previous years, the value of all metrics is predominantly highest in reference sites, lowest in zone 1 and intermediate in zone 2. Most metrics show no monotonic trend over the entire sampling period in the Gordon River, and are broadly consistent in values with time (with zone 1 being a recent exception).

Some post-Basslink trends are apparent. Some metrics experienced post-Basslink rises in value for zone 1 over the period 2007-08 to 2011-12. These included O/Epa, the proportional and total abundance of EPT species, the number of EPT species, the number of macroinvertebrate families and the Bray Curtis similarity to reference (based on both abundance and presence/absence data) (Figure 4-17 to Figure 4-19).

In all cases, however, these metrics have subsequently declined in zone 1 during the period 2012-13 to 2013-14. The values of O/Epa, O/Erk and the number of EPT species and their proportional abundance fell in 2013-14 to levels not experienced previously (Figure 4-17). This is the first time that monitoring has detected a declining trend in macroinvertebrate condition.

No substantive overall post-Basslink changes in metric values have been observed in zone 2, with the exception of O/Erk which declined in autumn 2014 to the lowest value observed to date (Figure 4-17). 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 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 4-18). It is also worth noting that the abundance-based value of this metric sustained higher values than for the pre-Basslink period between autumn 2009 and autumn 2012 (Figure 4-18) and, after a substantial decline 2012-13, again in spring 2013.

Indicator values for reference rivers have generally been more stable over the entire monitoring period than those for the Gordon River. However, reference rivers experienced a decline over the monitoring period between 2001 and 2012 in the number of EPT species and to a lesser extent in total macroinvertebrate abundance (Figure 4-19 to Figure 4-21). Several metrics rose substantially in spring 2011-12, and a subsequent rise in the number of EPT species and the absolute and proportional abundance of EPT species was observed in 2012-13 (Figure 4-19 and Figure 4-20). A fall in the number of EPT species and their abundance in 2013-14 at reference sites may have been influenced by high flow conditions immediately preceding sampling causing samples to be transiently more depauperate than normal.

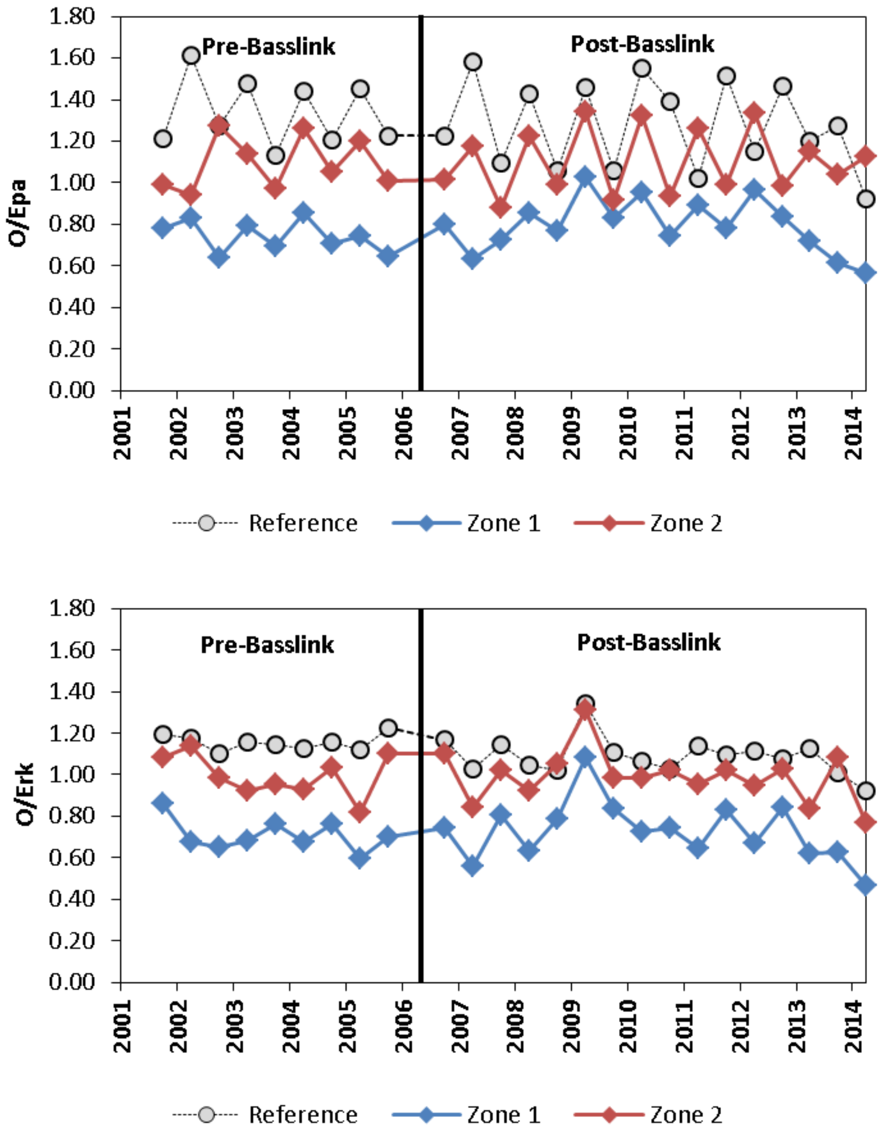
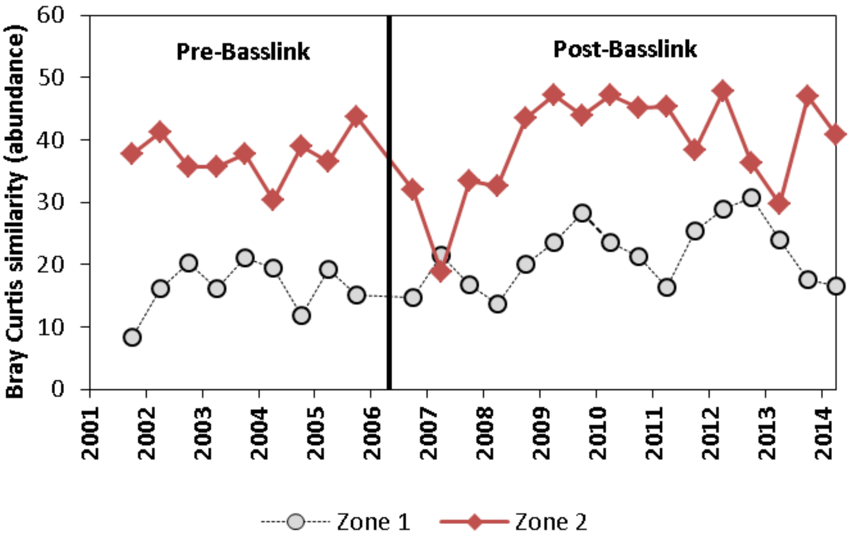


Figure 4-17: Mean O/Epa and O/Erk indicator values for each zone in the Gordon river and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations.



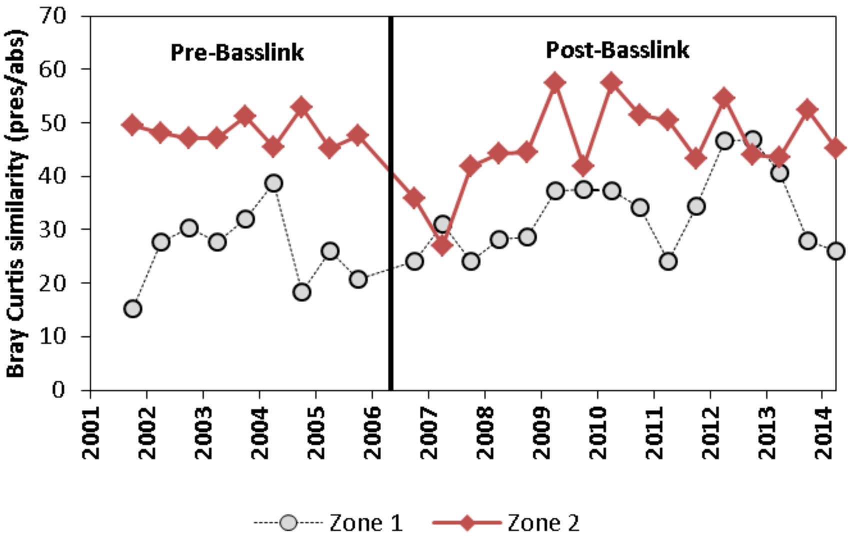


Figure 4-18: Mean Bray Curtis Similarity indicator values between each zone in the Gordon River and the reference rivers on each sampling occasion.

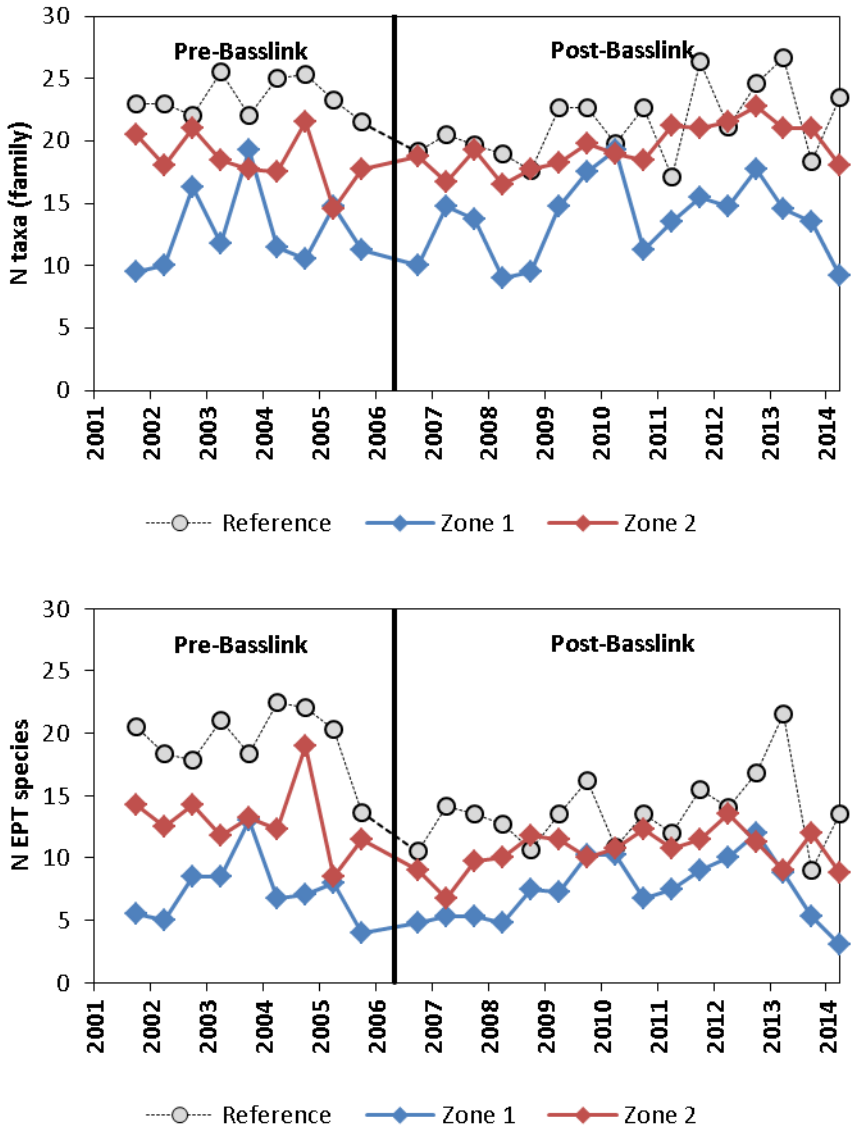


Figure 4-19: Mean N taxa (family) and N EPT species indicator values for each zone in the Gordon River and reference rivers on each sampling occasion.

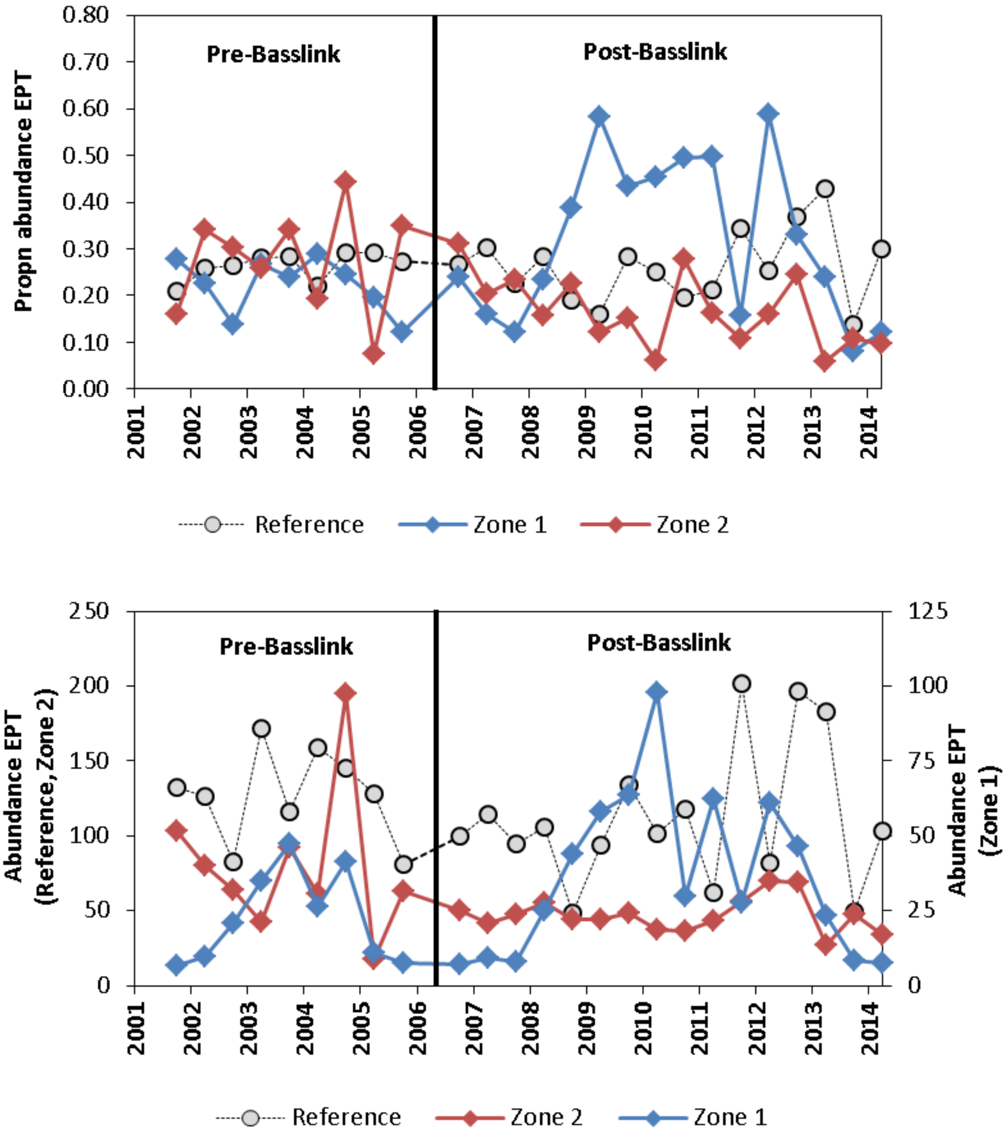


Figure 4-20: Mean proportional abundance and absolute abundance of EPT taxa indicator values for each zone in the Gordon River and reference rivers on each sampling occasion.

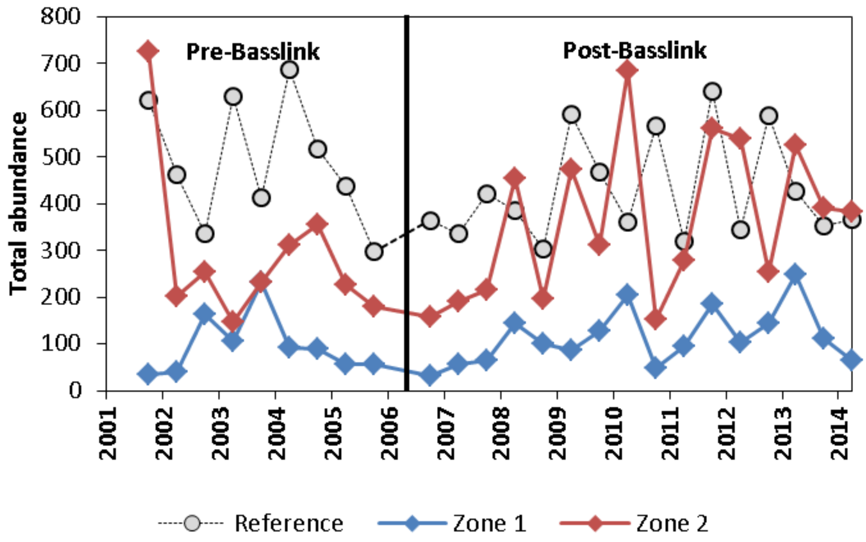


Figure 4-21: Mean total benthic macroinvertebrate abundance indicator values for each zone in the Gordon River and reference rivers on each sampling occasion.

4.5.2 Individual taxon abundances

Both marked variation and long term trends have been evident over the monitoring period in several of the numerically dominant macroinvertebrate taxa in the Gordon River (Figure 4-22 to Figure 4-24).

The taxon primarily responsible for the change in the absolute and proportional abundance of EPT taxa indicators in zone 1 until 2012 was the caddis family Hydropsychidae (especially *Asmicridea*, the snowflake caddis), for which an increased abundance was observed between spring 2008 and autumn 2011 in zone 1 (Figure 4-22). Numbers have reduced since 2010-11 but are still higher than observed during the pre-Basslink period.

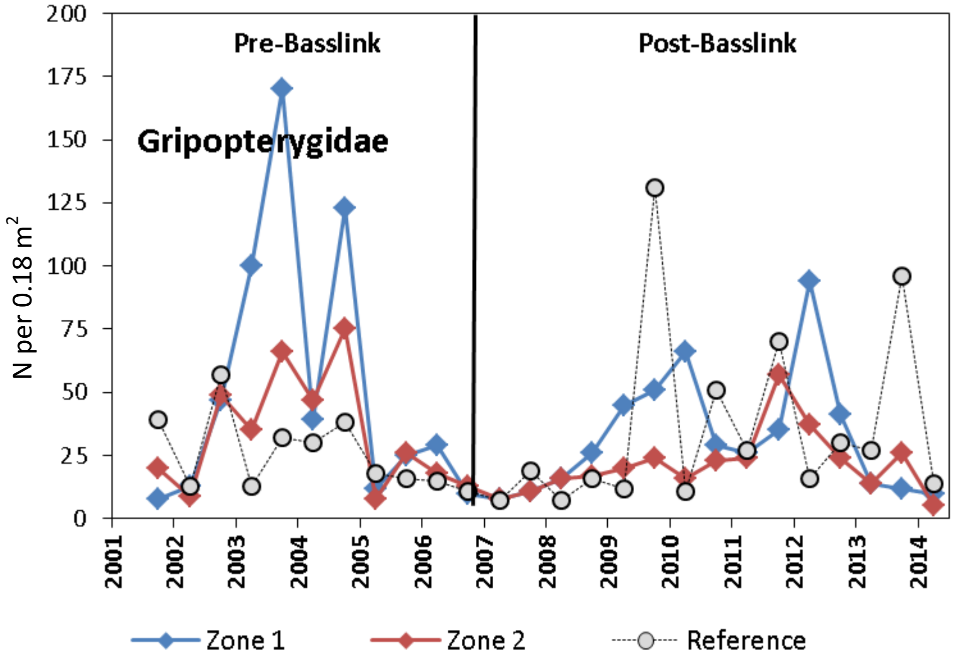
Gripopterygidae and Hydrobiosidae also increased post-Basslink in abundance in zone 1 (though with considerable inter-annual variation) and have contributed to the observed increase in proportional EPT representation and to community compositional similarity to reference sites (Figure 4-22 and Figure 4-23). These taxa are favoured by uninterrupted, steady flow conditions combined with abundant food resources in the form of particulate organic material - especially the net-building filter feeder *Asmicridea*. Post-Basslink, these conditions were increasingly being met upstream of the Denison River junction in zone 1 due to the presence of the environmental flow, especially between sites 63 and 74 downstream of the tributaries of the Orange, Albert and Piguenit rivers. The timing and rate of these abundance increases were consistent with a lagged response to post-Basslink environmental flows controlled by recruitment and responses to food availability.

Abundances of Gripopterygidae and Hydrobiosidae declined in 2010-11 in zone 1, particularly for Hydrobiosidae (Figure 4-22 and Figure 4-23). Abundances recovered in 2011-12 but then decreased in 2012-13 and again in 2013-14. This decrease is likely due to the relatively constant high flows experienced in 2013-14 caused by sustained high volume power station releases. A similar decline during 2012-13 to 2013-14 periods was observed in zone 2.

A seasonal (generally autumn) increase in simuliid (blackfly) larval densities post-Basslink has been evident for zone 2 from spring 2007 to 2013 (Figure 4-23). A decline in 2010-11 reversed in 2011-12 to 2012-13. The density of simuliids were slightly raised in zone 1 2013-14 but declined in zone 2.

It is also noteworthy that Hydrobiid snails (which generally consist of the species *Beddomeia franklinensis*) increased in abundance in zone 1 during the post-Basslink period, with a slight decline noted in 2013-14 (Figure 4-24). A substantial spike in abundance of Hydrobiid snails was also observed in zone 2 and in reference rivers in autumn 2013 which has been followed by a sharp decline through 2013-14.

Until 2013-14 there has been an overall post-Basslink increase in the abundance of the aquatic insect families Hydropsychidae, Gripopterygidae and Hydrobiosidae in zone 1, with indications of other longer generation taxa (e.g. Hydrobiid snails) showing a lagged increase in both zones. General declines observed for flow-sensitive taxa in 2010-11, due to changes in power station operations, were partially reversed in 2011-12, and then repeated in 2012-13. Further declines were observed in 2013-14, consistent with the effects of sustained high level flow releases from the Gordon Power Station.



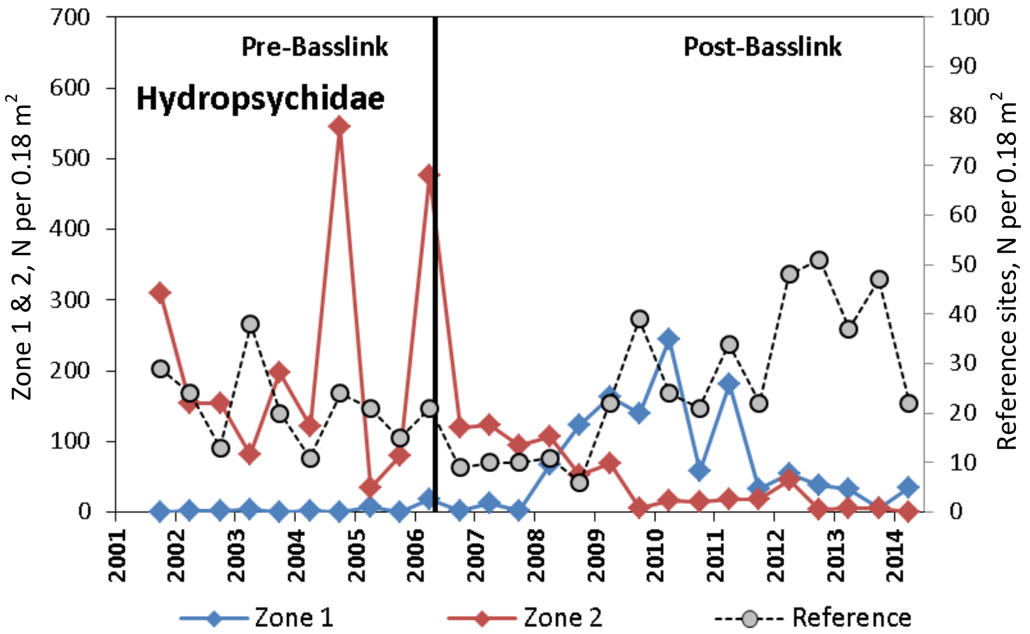
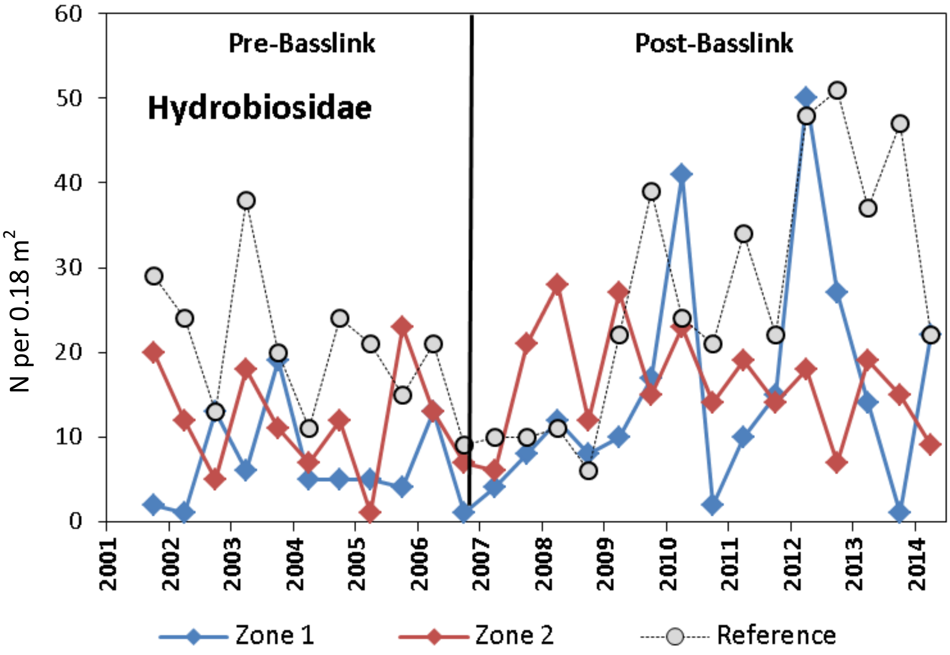


Figure 4-22: Mean abundance (n per 0.18 m^2) of two key taxa for zones 1 and 2 in the Gordon River and for the Reference river sites against time.



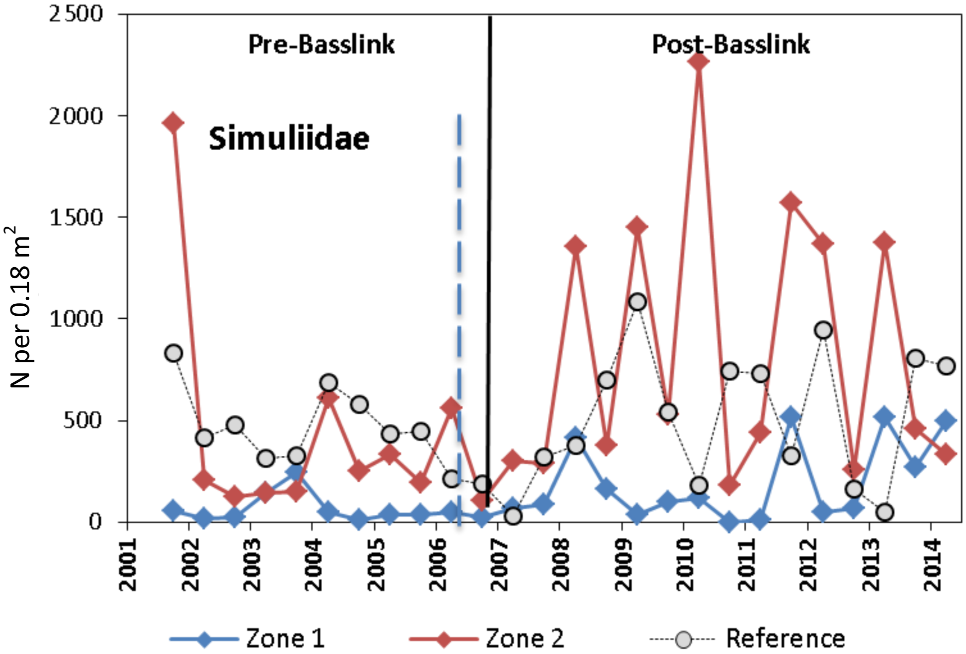


Figure 4-23: Mean abundance (n per 0.18 m^2) of two key taxa for zones 1 and 2 in the Gordon River and for the Reference river sites against time.

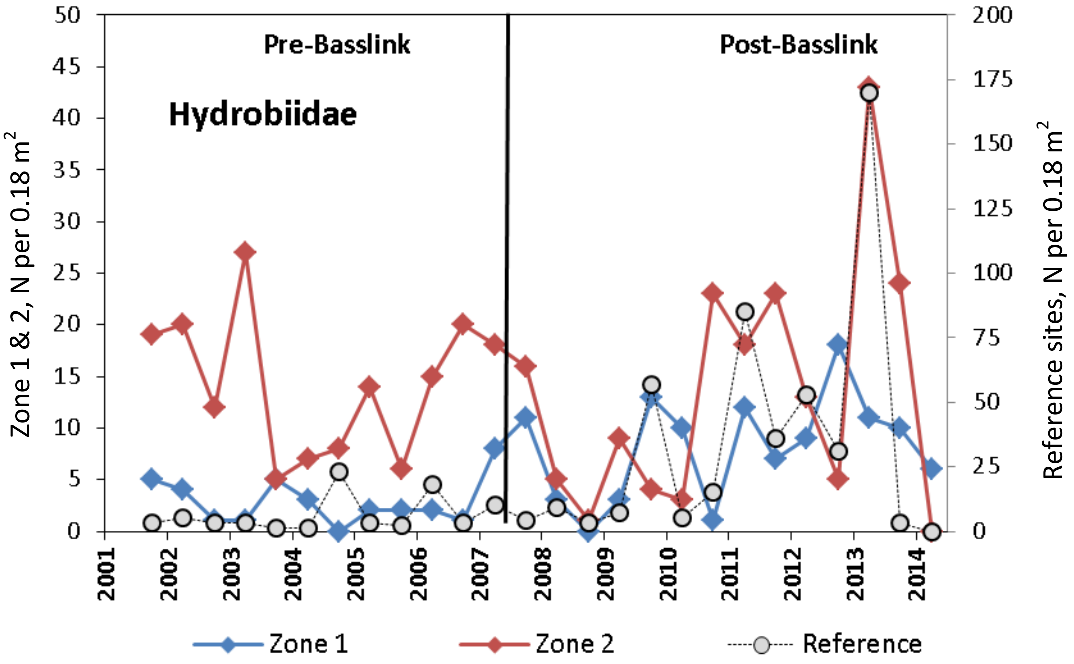


Figure 4-24: Mean abundance (n per 0.18 m^2) of Hydrobiid snails for zones 1 and 2 in the Gordon River and for the Reference river sites against time.

4.6 Conclusions

Sampling was conducted consistent with the requirements of the Interim Gordon River Basslink monitoring program for all sites, with the exception of Gordon River site 42 in spring 2013 (when high flows led to poor quality quantitative samples) and reference sites De35, Ma7 and Ja7 (when high flows in autumn 2014 precluded sampling).

Trigger compliance was observed for six of the nine macroinvertebrate indicators. Sustained high flow releases in 2013-14 appear to have resulted in reductions to levels below the minimum trigger values for the indicators O/Epa, O/Erk and the proportion of total abundance as EPT species. Each of these indicators fell to levels not previously observed and below their respective lower trigger bound.

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

- lower trigger exceedances for the O/Epa, O/Erk and the proportion of total abundance as EPT species, with values falling below the lowest trigger bound;
- general agreement with trigger bounds (or upper trigger bound exceedances) for all other metrics.

The reduction below lower trigger bounds for O/Epa, O/Erk and the proportion of total abundance as EPT species represent the first time that the overall condition of the macroinvertebrate community has declined below pre-Basslink levels since the Basslink monitoring program began.

The upper level exceedances representing improvement in biological condition relative to pre-Basslink conditions have declined in number and magnitude in 2013-14. Most of the observed improvements in macroinvertebrate condition occurred prior to 2010-11, followed by large, short-term swings and decline since then. The environmental flow has been observed to mitigate post-Basslink operation effects on instream biota in the Gordon River, though interannual variations in power station release patterns drive large swings in indicator values. The latter appear to have caused a general decline in macroinvertebrate indicators 2013-14.

5 References

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A Appendix A: Power station discharges graphed per month

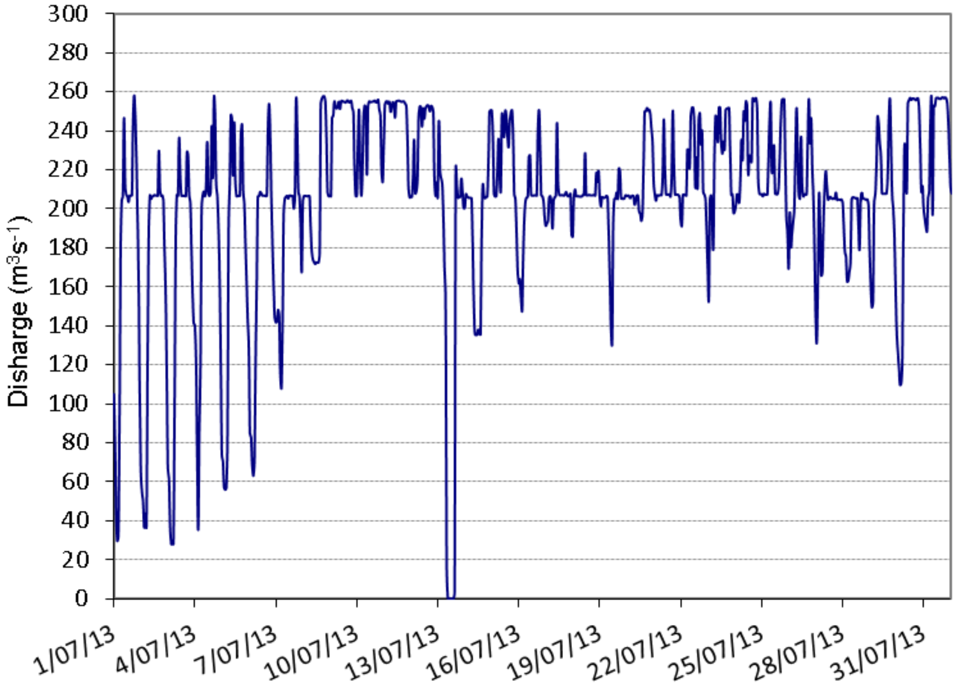

Figure A.1: Gordon Power Station discharge (hourly data) for July 2013.

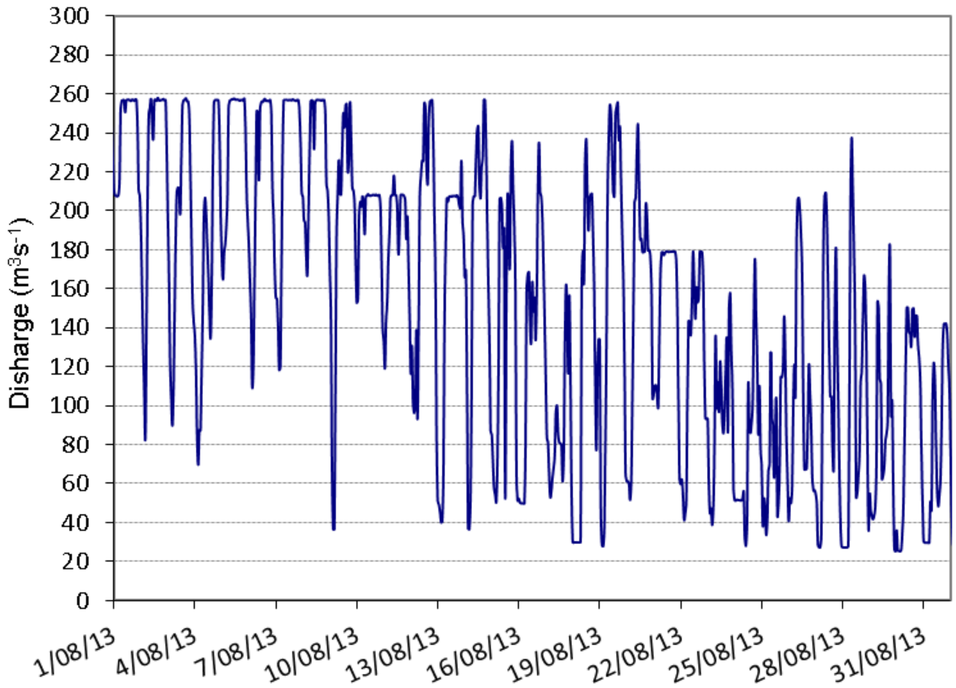

Figure A.2: Gordon Power Station discharge (hourly data) for August 2013.

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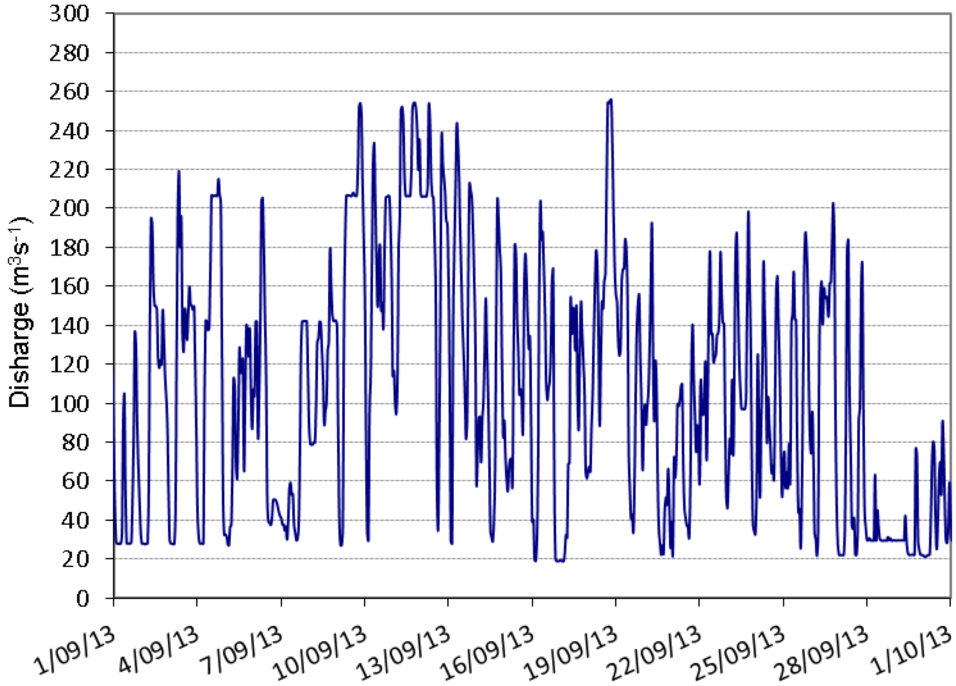

Figure A.3: Gordon Power Station discharge (hourly data) for September 2013.

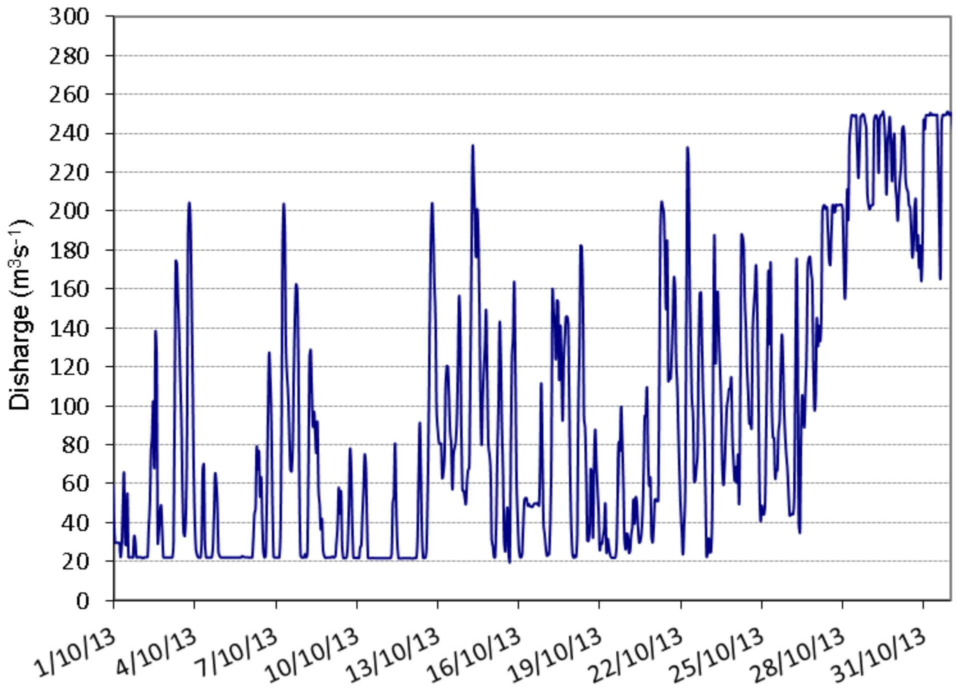

Figure A.4: Gordon Power Station discharge (hourly data) for October 2013.

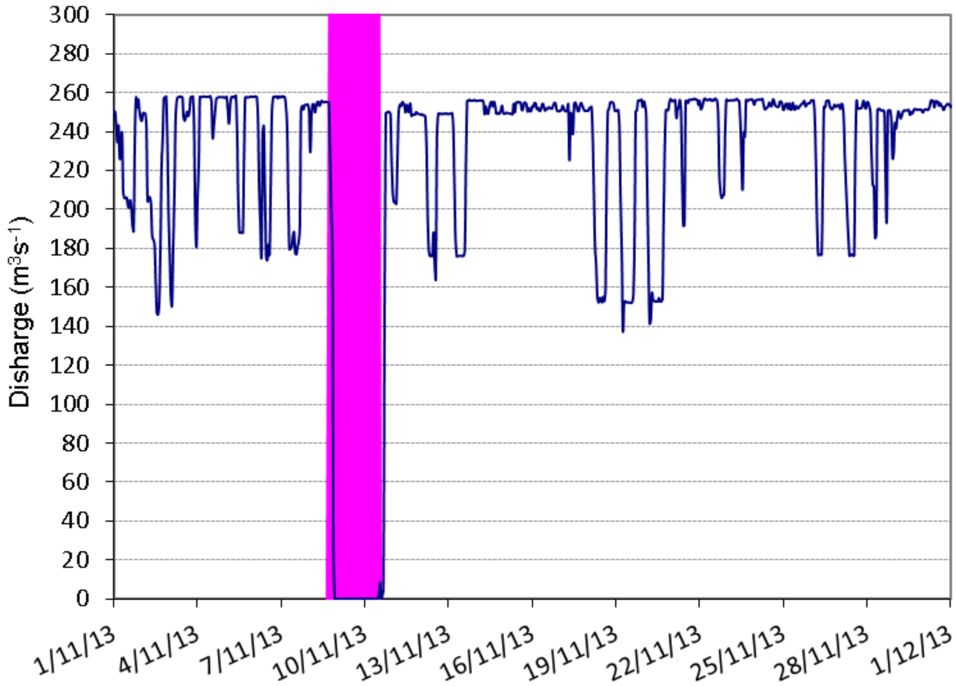

Figure A.5: Gordon Power Station discharge (hourly data) for November 2013. Pink block indicates a monitoring shutdown.

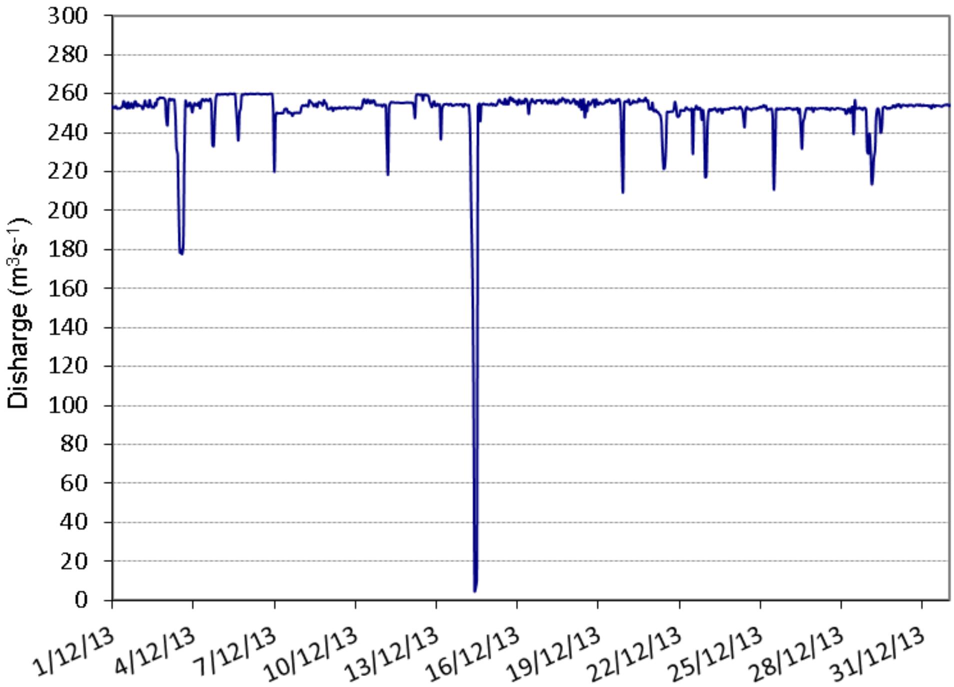

Figure A.6: Gordon Power Station discharge (hourly data) for December 2013.

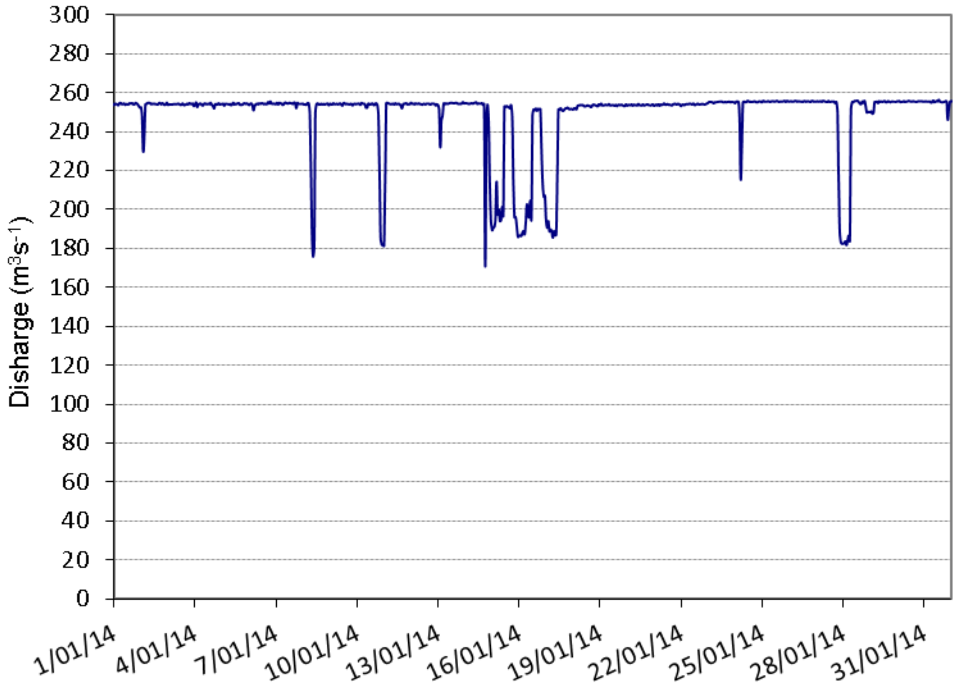

Figure A.7: Gordon Power Station discharge (hourly data) for January 2014.

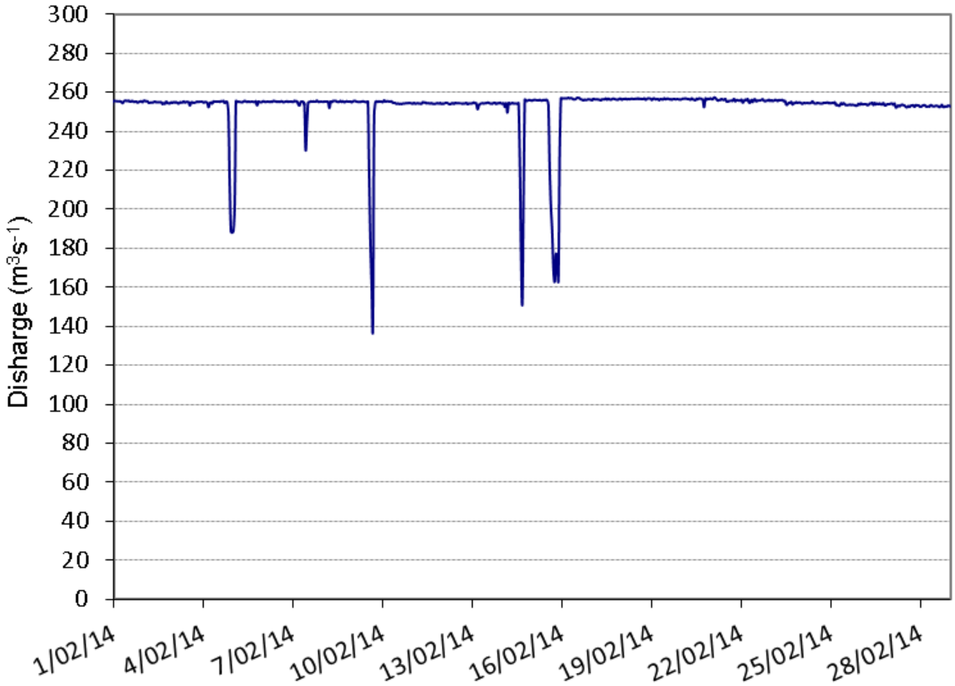

Figure A.8: Gordon Power Station discharge (hourly data) for February 2014.

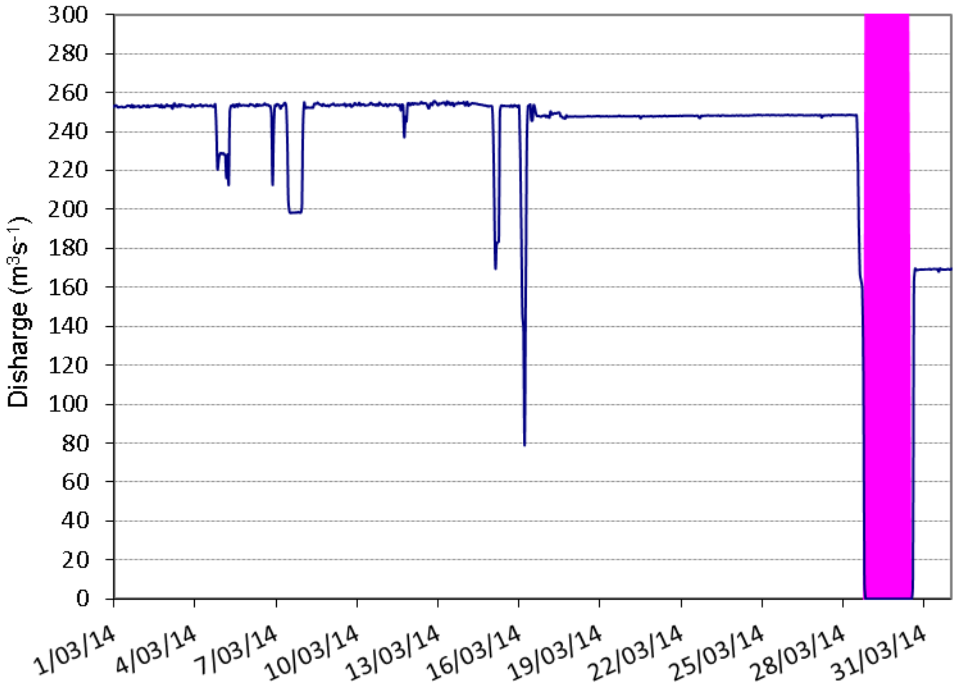

Figure A.9: Gordon Power Station discharge (hourly data) for March 2014. Pink block indicates a monitoring shutdown.

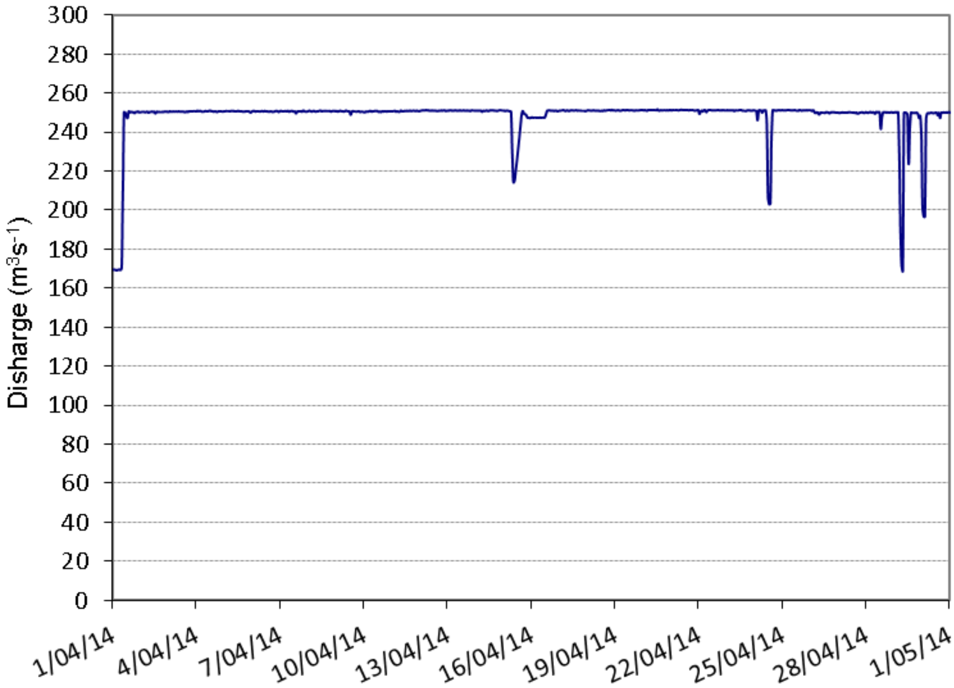

Figure A.10: Gordon Power Station discharge (hourly data) for April 2014.

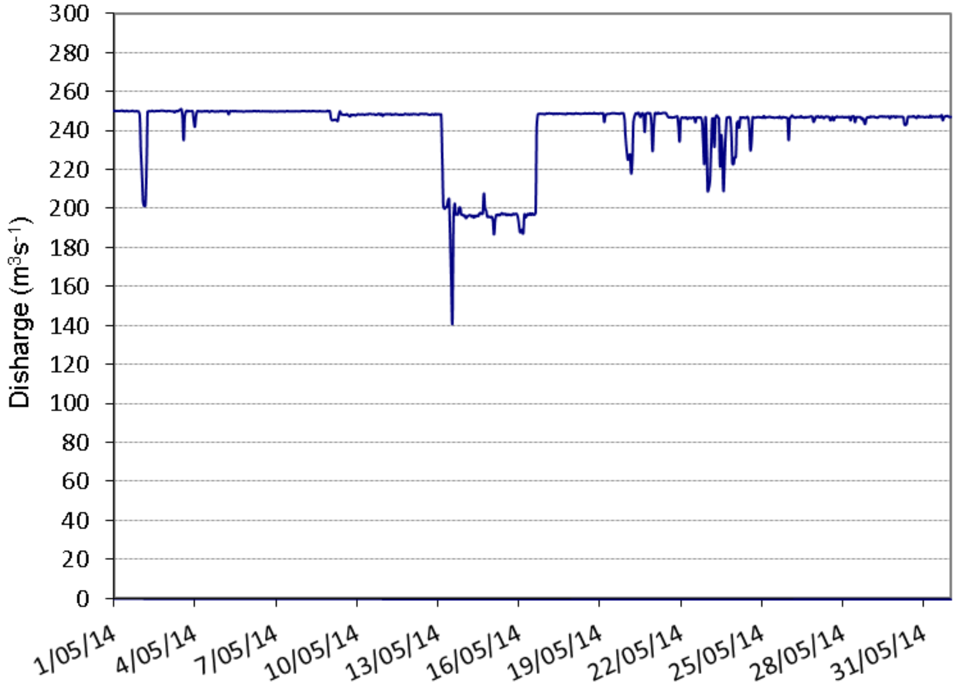

Figure A.11: Gordon Power Station discharge (hourly data) for May 2014.

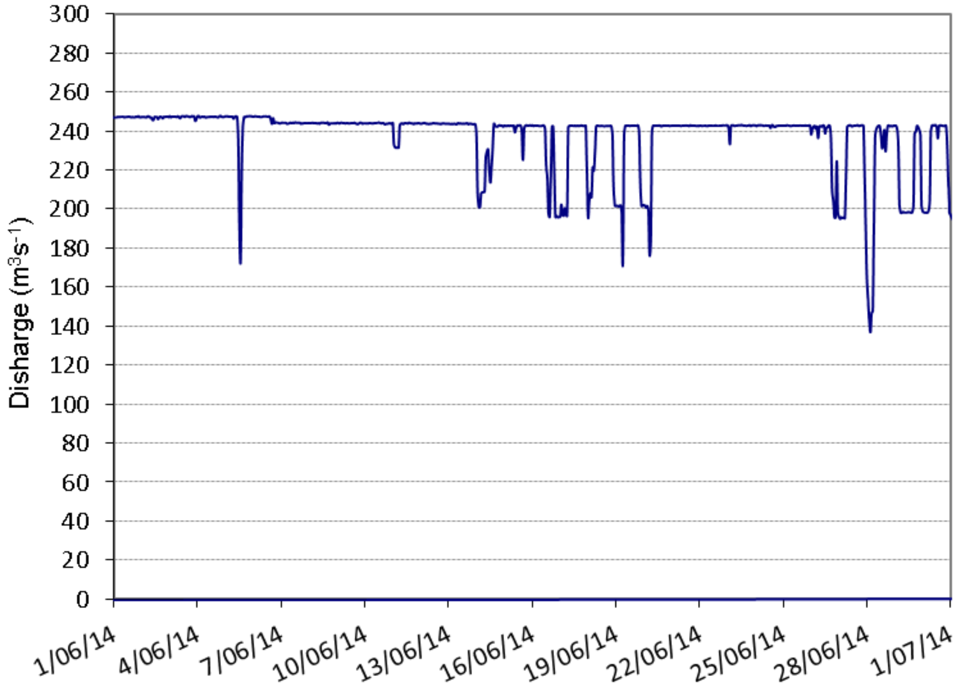

Figure A.12: Gordon Power Station discharge (hourly data) for June 2014.

B Appendix B: Ramp-down rule exceedence events

Figure B.1: Ramping events that exceeded 1 MW per minute between 1 April 2012 and 30 June 2013. The longest events are indicated in bold.

Event no.	Date	Duration (minutes)	Average Generation reduction rate (MW/min)	Maximum Generation reduction rate (MW/min)	Starting level of piezometer (m)
1	1 Jul 2013	10	-1.02	-1.05	3.59
2	1 Jul 2013	55	-1.07	-1.17	3.83
4	2 Jul 2013	5	-1.01	-1.01	3.64
6	3 Jul 2013	10	-1.00	-1.00	3.57
7	4 Jul 2013	10	-1.04	-1.05	3.64
8	13 Jul 2013	5	-1.01	-1.01	3.78
9	14 Jul 2013	15	-1.09	-1.12	3.42
10	19 Jul 2013	5	-1.07	-1.07	3.69
11	19 Jul 2013	10	-1.06	-1.07	3.70
12	24 Jul 2013	5	-1.06	-1.06	3.93
13	25 Jul 2013	10	-1.04	-1.04	3.89
14	26 Jul 2013	10	-1.02	-1.04	3.87
16	27 Jul 2013	15	-1.03	-1.05	3.54
17	**31 Jul 2013**	**25**	**-3.06**	**-4.44**	**3.77**
19	3 Aug 2013	20	-1.05	-1.09	3.97
23	4 Aug 2013	20	-1.02	-1.03	3.76
24	6 Aug 2013	10	-1.04	-1.08	3.91
25	9 Aug 2013	10	-1.02	-1.03	3.88
27	9 Aug 2013	5	-1.03	-1.03	3.77
28	9 Aug 2013	10	-1.01	-1.01	3.76
29	10 Aug 2013	10	-1.07	-1.11	3.75
30	10 Aug 2013	20	-1.06	-1.09	3.73
31	12 Aug 2013	5	-1.02	-1.02	3.77
32	12 Aug 2013	20	-1.09	-1.13	3.78
34	14 Aug 2013	20	-1.03	-1.06	3.69
36	15 Aug 2013	15	-1.07	-1.09	3.48
46	18 Sep 2013	5	-1.00	-1.00	2.96
48	30 Oct 2013	5	-1.02	-1.02	3.22

Event no.	Date	Duration (minutes)	Average Generation reduction rate (MW/min)	Maximum Generation reduction rate (MW/min)	Starting level of piezometer (m)
49	30 Oct 2013	5	-1.01	-1.01	3.07
50	31 Oct 2013	5	-1.00	-1.00	3.31
51	1 Nov 2013	10	-1.04	-1.07	3.39
52	2 Nov 2013	10	-1.06	-1.06	3.46
53	2 Nov 2013	10	-1.03	-1.05	3.49
54	3 Nov 2013	20	-1.08	-1.14	3.64
55	3 Nov 2013	40	-1.04	-1.08	3.64
56	6 Nov 2013	5	-1.02	-1.02	3.85
57	6 Nov 2013	5	-1.01	-1.01	3.68
58	6 Nov 2013	5	-1.00	-1.00	3.70
59	6 Nov 2013	5	-1.22	-1.22	3.75
60	7 Nov 2013	5	-1.06	-1.06	3.90
61	7 Nov 2013	10	-1.00	-1.00	3.90
62	7 Nov 2013	5	-1.03	-1.03	3.90
63	8 Nov 2013	5	-1.01	-1.01	4.02
64	8 Nov 2013	5	-1.01	-1.01	4.02
65	12 Nov 2013	10	-1.08	-1.09	3.74
66	13 Nov 2013	10	-1.02	-1.03	3.79
67	13 Nov 2013	10	-1.02	-1.02	3.79
68	19 Nov 2013	20	-1.10	-1.14	3.86
69	19 Nov 2013	15	-1.26	-1.31	3.85
70	20 Nov 2013	65	-1.05	-1.09	3.81
71	20 Nov 2013	25	-1.04	-1.07	3.81
73	22 Nov 2013	5	-1.05	-1.05	3.94
74	26 Nov 2013	10	-1.03	-1.04	4.21
75	28 Nov 2013	10	-1.03	-1.03	4.13
76	28 Nov 2013	10	-1.06	-1.12	4.15
77	3 Dec 2013	20	-1.05	-1.08	4.24
78	14 Dec 2013	5	-1.02	-1.02	4.32
79	14 Dec 2013	5	-1.01	-1.01	4.32
81	25 Dec 2013	5	-1.01	-1.01	4.29
82	8 Jan 2014	15	-1.04	-1.05	4.32
83	10 Jan 2014	10	-1.03	-1.03	4.31

Event no.	Date	Duration (minutes)	Average Generation reduction rate (MW/min)	Maximum Generation reduction rate (MW/min)	Starting level of piezometer (m)
84	**14 Jan 2014**	**35**	**-3.24**	**-4.46**	**4.32**
85	15 Jan 2014	10	-1.02	-1.04	4.20
86	15 Jan 2014	15	-1.02	-1.03	4.20
87	16 Jan 2014	15	-1.05	-1.06	4.02
88	7 Feb 2014	10	-1.03	-1.03	4.32
89	9 Feb 2014	35	-1.19	-1.30	4.32
90	14 Feb 2014	75	-1.15	-1.24	4.32
91	7 Mar 2014	10	-1.11	-1.11	4.31
92	15 Mar 2014	15	-1.04	-1.05	4.30
93	16 Mar 2014	5	-1.04	-1.04	4.25
95	28 Mar 2014	10	-1.07	-1.07	4.24
96	28 Mar 2014	20	-1.04	-1.08	4.24
97	28 Mar 2014	5	-1.01	-1.01	4.24
98	29 Apr 2014	5	-1.07	-1.07	4.27
99	5 Jun 2014	45	-1.28	-1.45	4.22

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C Appendix C: Erosion pin descriptions and graphs

Abbreviations used in graphs

b/slope – back slope; slope behind crest of bank
b/water – back water
cave – bank cavity
cob – vertical cobble bank
col – vertical colluvial bank
crest – crest of bank
flow – sediment flow
HW – power station controlled high water marker
pipe – casing for piezometer measured as erosion pin
slope – sandy bank slope
toe – sandy bank toe
top – top of bank

Appendix C.1. Description of erosion pin monitoring sites

Zone	Turbine Level	Bank Material-Colluvial	Bank Material - Alluvial	Bank Material – Alluvial over cobbles or bedrock	Location - Inside bend	Location-Outside bend	Location-Straight reach	Turbine level Totals
Zone 1	<1		1C/1-4, 1E/4, 1E/5		1C/1-4, 1E/4, 1E/5			6
	1-2	1A/1-7,1A/9	1E/2, 1E/3	1B/1, 1B/3, 1B/4, 1D/2, 1D/3	1B/1, 1B/3, 1B/4,	1D/2, 1D/3, 1E/2, 1E/3	1A/1-7,1A/9	15
	2-3	1A/8C	1E/1, 1E/6, 1E/7	1B/2, 1B/5, 1D/1, 1D/4	1B/2, 1B/5,	1D/1, 1D/4, 1E/1, 1E/6, 1E/7	1A/8C	8
	>3	1A/8a, 1A/8b		1F/1-4			1A/8a, 1A/8b, 1F/1-4	6
Bank type, location totals		11	11	13	9	9	15	
Zone 2	<1		2B/8, 2C/4, 2D/4, 2E/5, 2H/3, 2H/6, 2J/3, 2K/5, 2L/4	2G/6	2D/4, 2J/3, 2K/5	2C/4, 2E/5	2B/8, 2G/6, 2H/3, 2H/6, 2L/4	10
	1-2		2B/1, 2B,3, 2B/5, 2B/7, 2C/3, 2D/3, 2E/3, 2E/4, 2H/2, 2H/5, 2I/1, 2I/2, 2J/2, 2K/4, 2K/3, 2L/2, 2L/3	2A/1, 2A/2, 2G/2	2D/3, 2E/3, 2I/1, 2I/2, 2J/2, 2K/4, 2K/3	2C/3, 2E/4	2A/1, 2A/2, 2B/1, 2B,3, 2B/5, 2B/7, 2G/2, 2H/2, 2H/5, 2L/2, 2L/3	20
	2-3		2B/2, 2B/4, 2B/6, 2C/1, 2C/2, 2D/1, 2D/2, 2E/1, 2E/2, 2H/1, 2H/4, 2J/1, 2K/1, 2K/2, 2L/1, 2L/5, 2L/6	2A/3, 2A/5, 2A/6, 2A/7, 2G/1, 2G/3, 2G/4, 2G/5	2D/1, 2D/2, 2J/1, 2K/1, 2K/2	2C/1, 2C/2, 2E/1, 2E/2	2A/3, 2A/5, 2A/6, 2A/7, 2B/2, 2B/4, 2B/6, 2G/1, 2G/3, 2G/4, 2G/5, 2H/1, 2H/4, 2L/1, 2L/5, 2L/6	25
	>3			2A/4			2A/4	1
Bank type, location totals		0	43	13	15	8	33	
Zone 3	<1		32A/1, 3A/4, 3A/5, 3C/5, 3D/3, 3Ea/3, 3Eb/5, 3F/4, 3G/5	3B/5	3C/5	3D/3	32A/1, 3A/4, 3A/5, 3B/5, 3Ea/3, 3Eb/5, 3F/4, 3G/5	10
	1-2		3A/2, 3A/3, 3C/2, 3C/3, 3C/4, 3D/2, 3Ea/4, 3Eb/3, 3Eb/4, 3G/2, 3G/3, 3G/4	3B/1, 3B/4, 3F/2, 3F/3,	3C/2, 3C/3, 3C/4	3D/2	3A/2, 3A/3, 3B/1, 3B/4, 3Ea/4, 3Eb/3, 3Eb/4, 3F/2, 3F/3, 3G/2, 3G/3, 3G/4	16
	2-3		3A/5, 3A/6, 3C/1, 3D/1, 3D/4, 3Ea/2, 3Ea/5, 3Eb/2, 3Eb/6, 3G/1	3B/2, 3B/3, 3F/1	3C/1	3D/1, 3D/4	3A/5, 3A/6, 3B/2, 3B/3, 3Ea/2 3Ea/5, 3Eb/2,	13

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Zone	Turbine Level	Bank Material-Colluvial	Bank Material - Alluvial	Bank Material – Alluvial over cobbles or bedrock	Location - Inside bend	Location-Outside bend	Location-Straight reach	Turbine level Totals
							3Eb/6, 3F/1, 3G/1	
	>3		3Ea/1, 3Ea/6, 3Eb/1				3Ea/1, 3Ea/6, 3Eb/1	3
Bank type, location totals			34	8	5	4	33	
Zone 4	<1		4A/3, 4B/3, 4E/4, 4Ga/3, 4Ga/4, 4Gb/3, 4Gb/4, 4Gb/5, 4H/4, 4H/5		4E/4	4H/4, 4H/5	4A/3, 4B/3, 4Ga/3, 4Ga/4, 4Gb/3, 4Gb/4, 4Gb/5	10
	1-2		4A/2, 4B/2, 4E/3, 4Ga/2, 4Gb/2, 4H/3	4D/2, 4D/3, 4F/3, 4F/4, 4F/5	4E/3, 4F/3, 4F/4, 4F/5	4D/2, 4D/3, 4H/3	4A/2, 4B/2, 4Ga/2, 4Gb/2	11
	2-3		4A/1, 4A/4, 4B/1, 4/B/4, 4E/1, 4E/2, 4Ga/1, 4Gb/1, 4H/1, 4H/2	4D/1, 4D/4, 4F/1, 4F/2,	4E/1, 4E/2, 4F/1, 4F/2,	4D/1, 4D/4, 4H/1, 4H/2	4A/1, 4A/4, 4B/1, 4/B/4, 4Ga/1, 4Gb/1	14
	>3			4F/HW	4F/HW			1
Bank type, location totals			26	10	10	9	17	
Zone 5	<1		5A/4, 5B/4, 5C/3, 5D/3, 5E/3, 5E/4, 5F/3, 5G/6, 5H/4, 5I/4, 5J/4, 5K/3, 5L/4, 5M/3		5B/4, 5C/3, 5F/3, 5J/4, 5K/3	5H/4, 5I/4, 5M/3	5A/4, 5D/3, 5E/3, 5E/4, 5G/6, 5L/4	14
	1-2		5A/3, 5B/2, 5B/3, 5B/5, 5B/6, 5C/2, 5D/2, 5E/2, 5F/2, 5G/2, 5G/3, 5G/4, 5G/5, 5H/2, 5H/3, 5I/2, 5I/3, 5I/6, 5J/3, 5J/2, 5K/2, 5L/2, 5L/3, 5M/2		5B/2, 5B/3, 5B/5, 5B/6, 5C/2, 5F/, 5J/3, 5J/2, 5K/2	5H/2, 5H/3, 5I/2, 5I/3, 5I/6	5A/3, 5D/2, 5E/2, 5G/2, 5G/3, 5G/4, 5G/5, 5L/2, 5L/3, 5M/2	24
	2-3		5A/1, 5A/2, 5B/1, 5C/1, 5C/4, 5D/1, 5E/1, 5F/1, 5G/1, 5H/1, 5I/1, 5I/5, 5J/1, 5J/5, 5J/6, 5K/0, 5K/1, 5L/1, 5M/1		5B/1, 5C/1, 5C/4, 5F/1, 5J/1, 5J/5, 5J/6, 5K/0, 5K/1	5H/1, 5I/1, 5I/5	5A/1, 5A/2, 5D/1, 5E/1, 5G/1, 5L/1, 5M/1	19
	>3							
Bank type, location totals			57	0	23	11	23	

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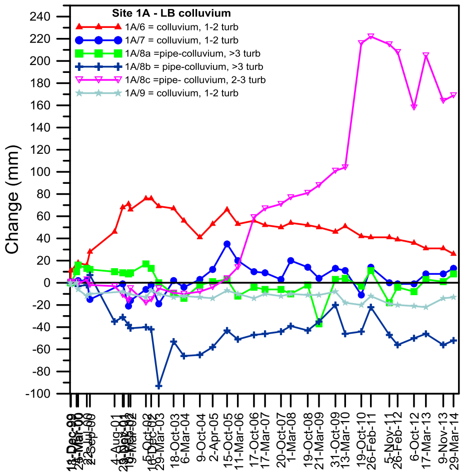
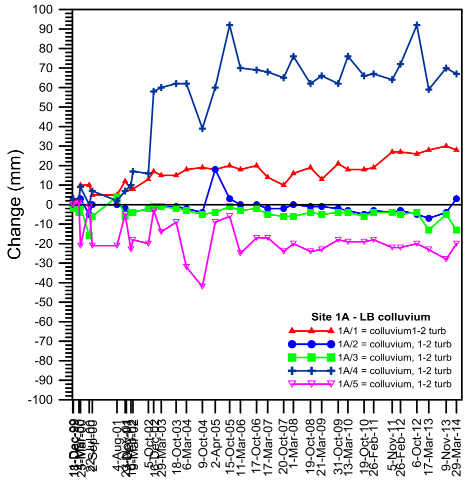
Appendix C.2. Graphs of erosion pin results at each site

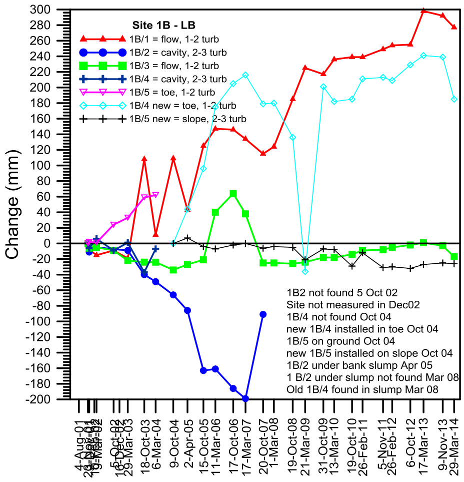
Zone 1



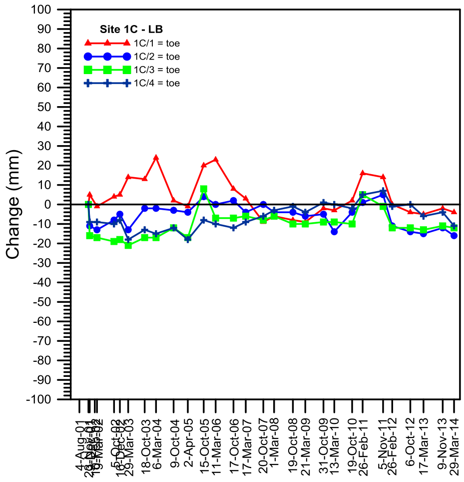
Site 1A



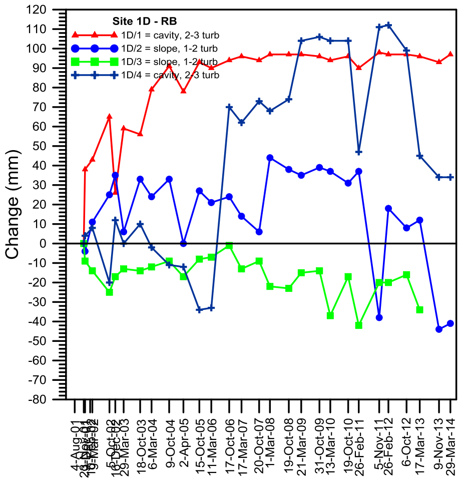
Site 1/A (continued)



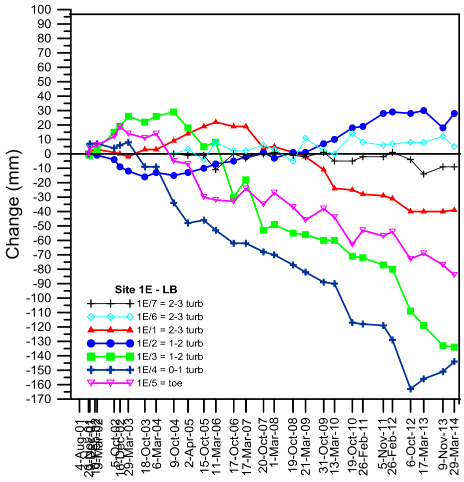
Site 1/B



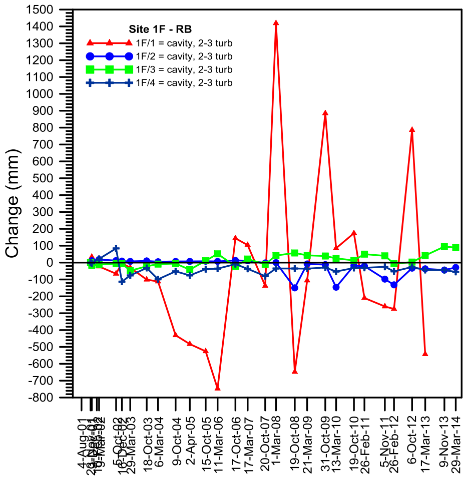
Site 1/C



Site 1/D

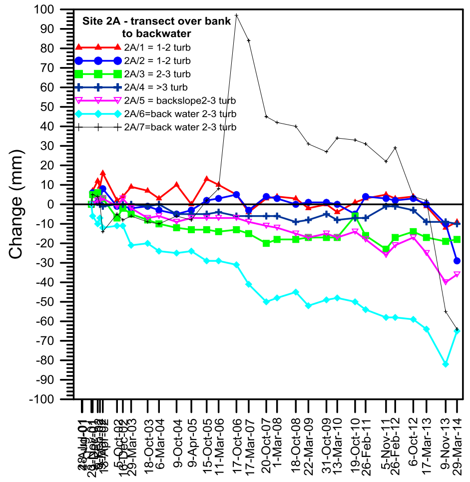


Site 1/E

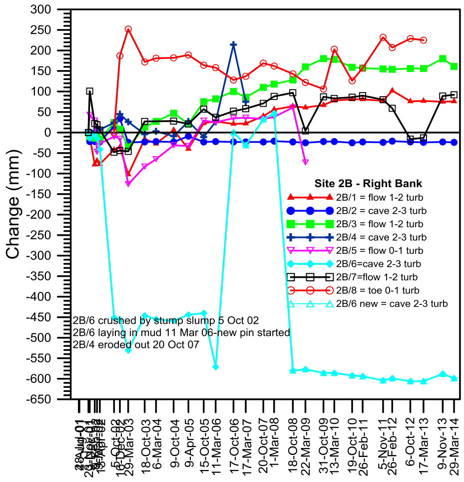

Site 1F - RB
1F/1 = cavity, 2-3 turb
1F/2 = cavity, 2-3 turb
1F/3 = cavity, 2-3 turb
1F/4 = cavity, 2-3 turb
Change (mm)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05
15-Oct-05
11-Mar-06
17-Oct-06
17-Mar-07
20-Oct-07
1-Mar-08
19-Oct-08
21-Mar-09
31-Oct-09
13-Mar-10
19-Oct-10
26-Feb-11
5-Nov-11
26-Feb-12
6-Oct-12
17-Mar-13
9-Nov-13
29-Mar-14

Site 1/F

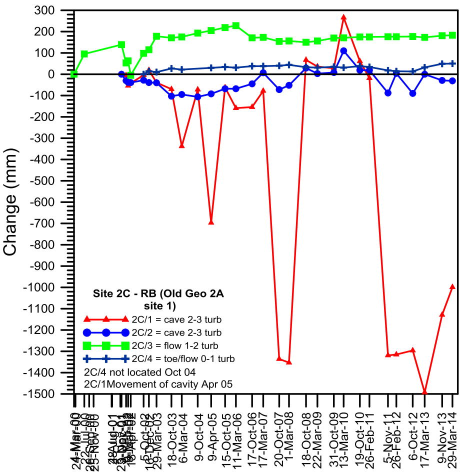
Zone 2



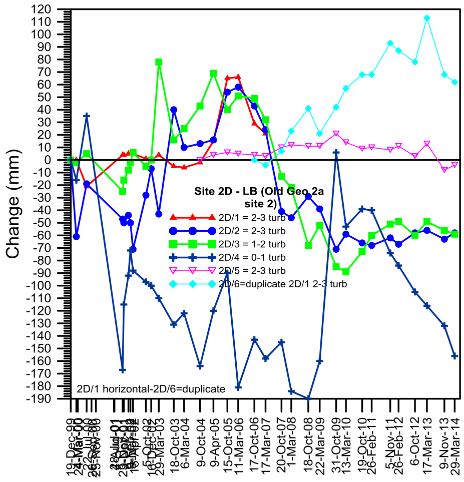
Site 2A



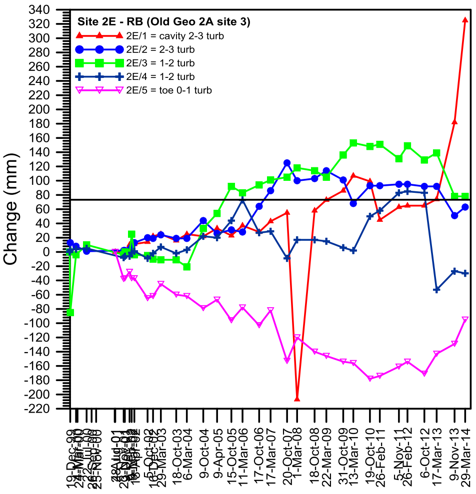
Site 2/B



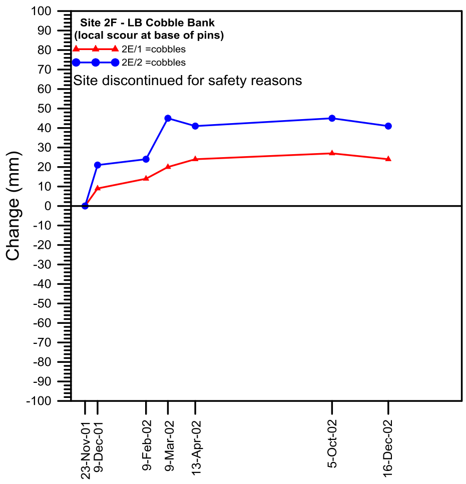
Site 2C



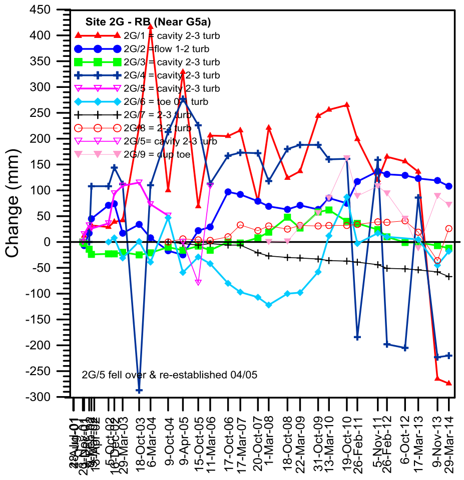
Site 2D



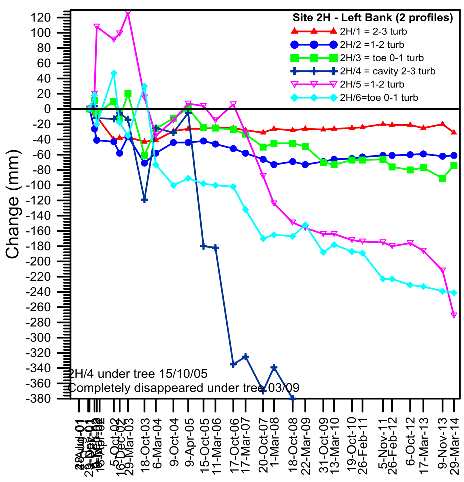
Site 2E



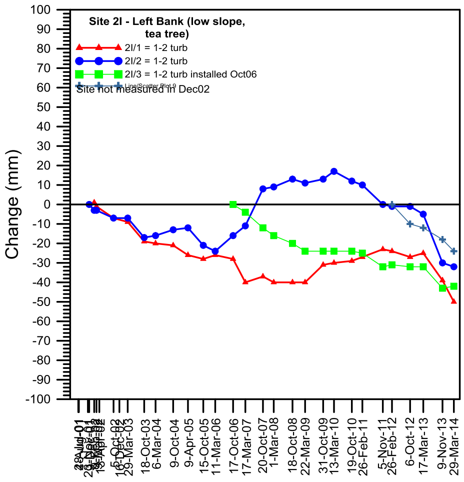
Site 2F



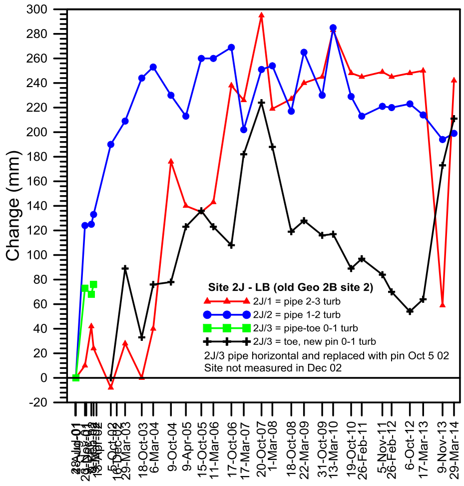
Site 2G



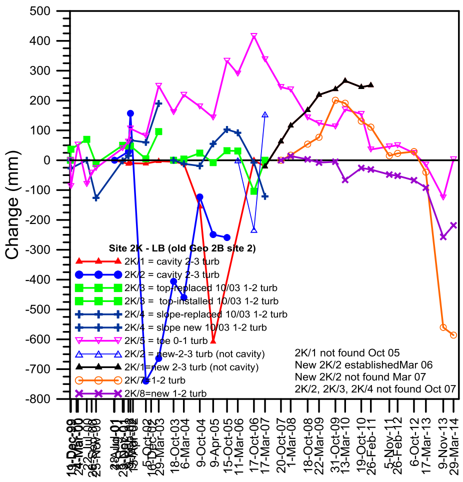
Site 2H



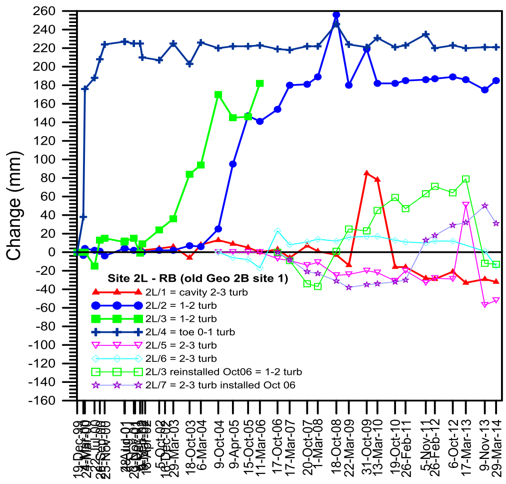
Site 2I



Site 2J

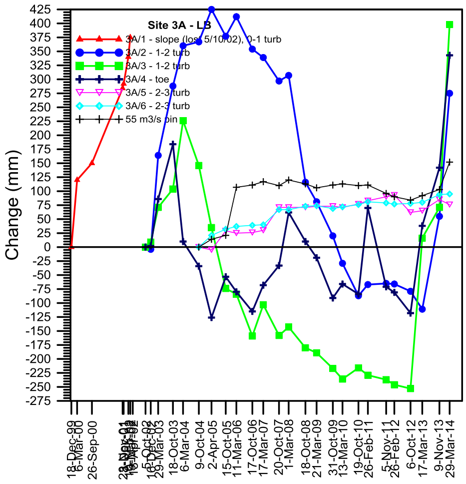


Site 2K

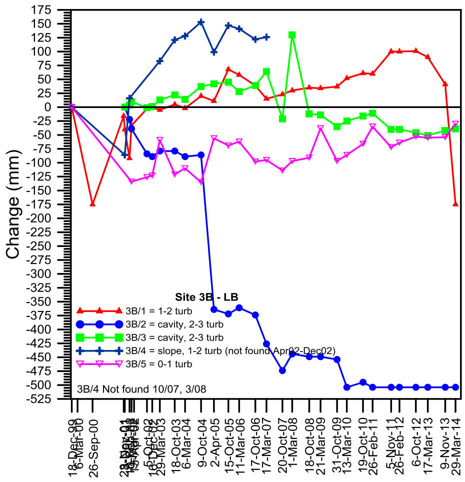


Site 2L

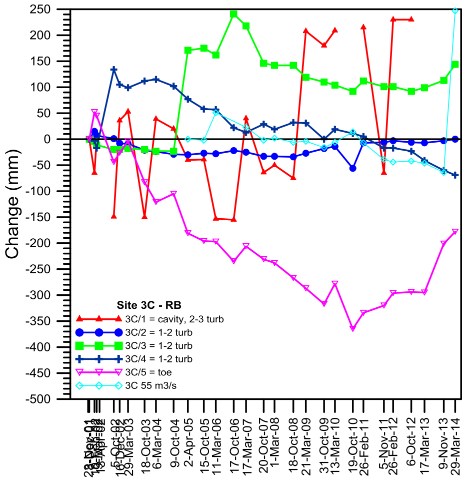
Zone 3



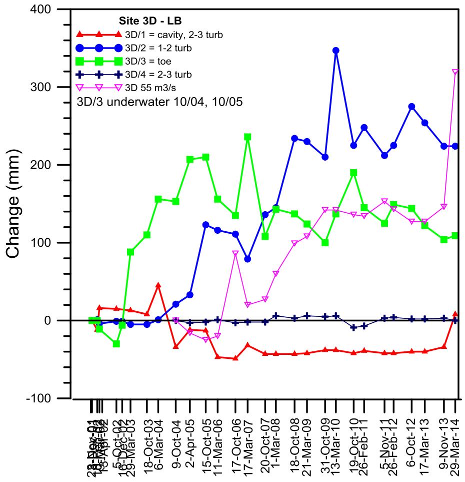
Site 3A



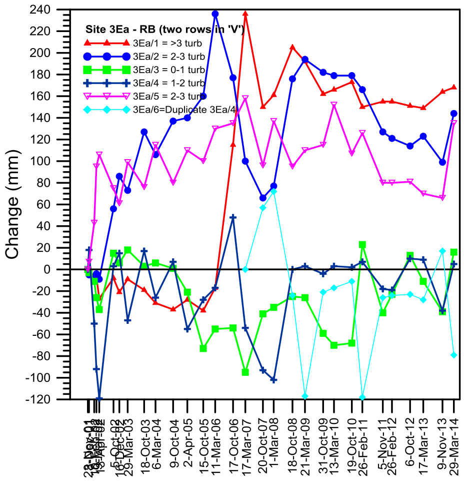
Site 3B



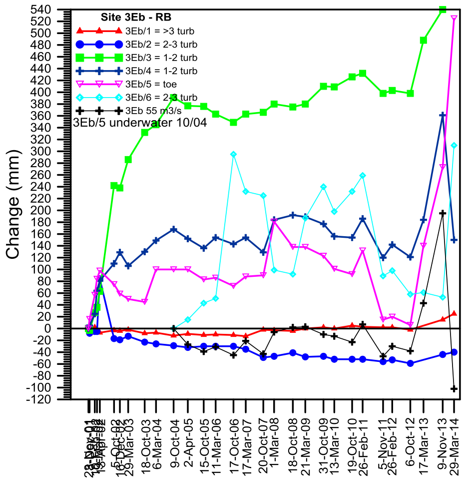
Site 3C



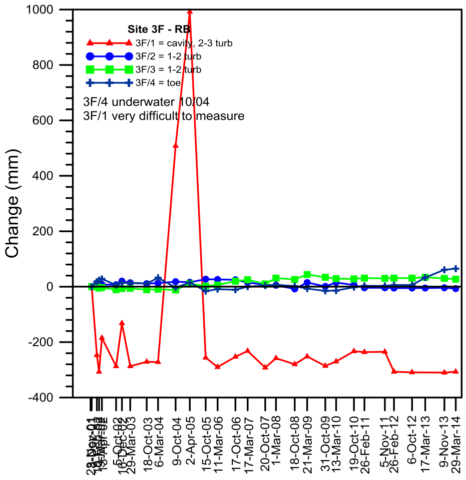
Site 3D



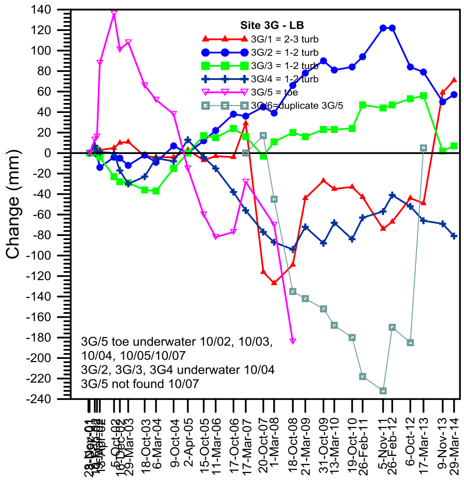
Site 3Ea



Site 3Eb

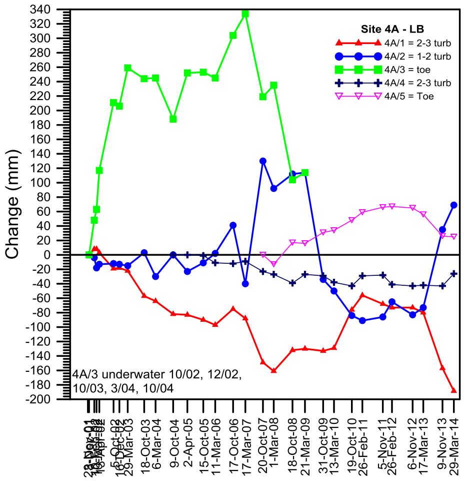


Site 3F

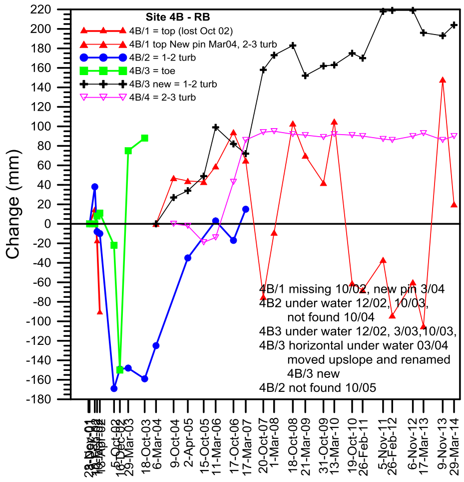


Site 3G

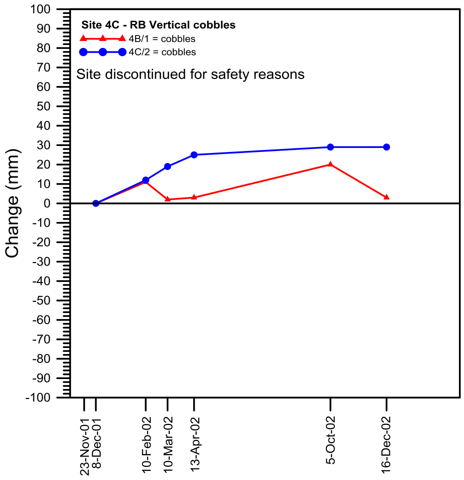
Zone 4



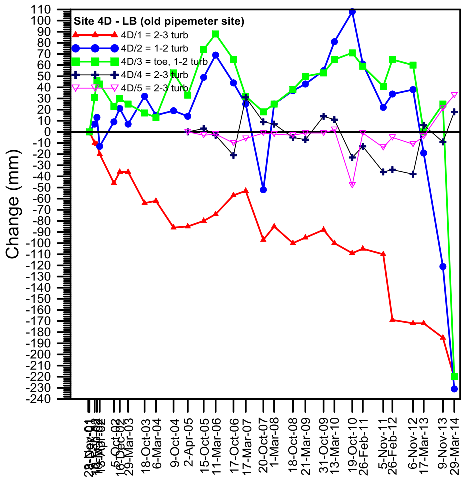
Site 4A



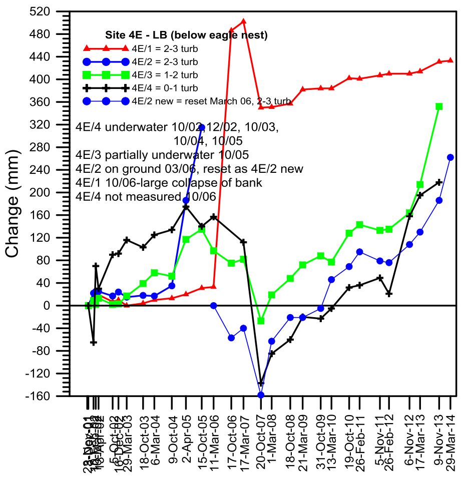
Site 4B



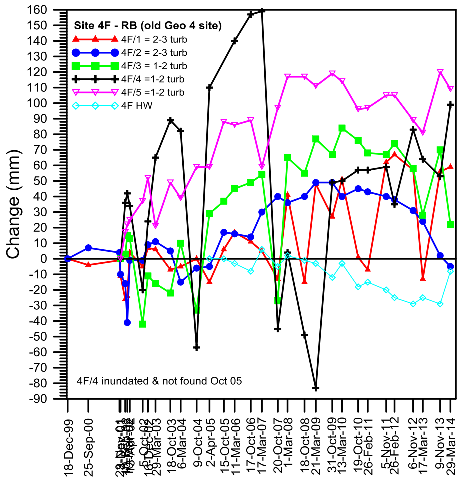
Site 4C



Site 4D



Site 4E



Site 4F

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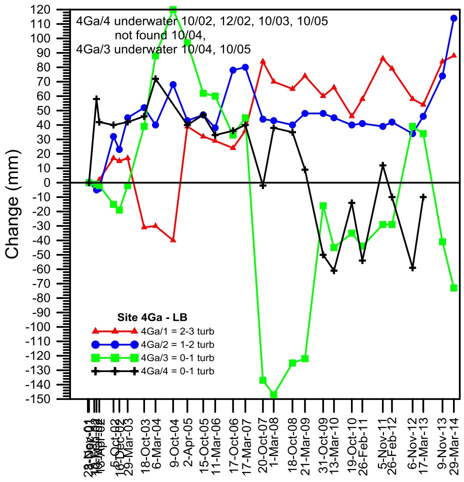
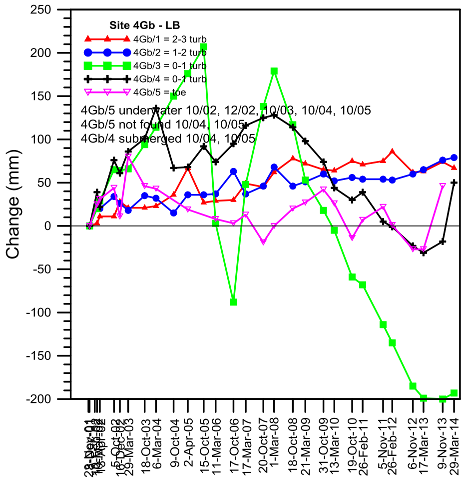
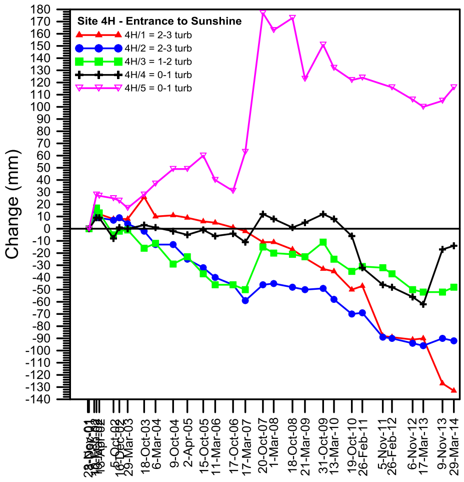


Site 4Ga

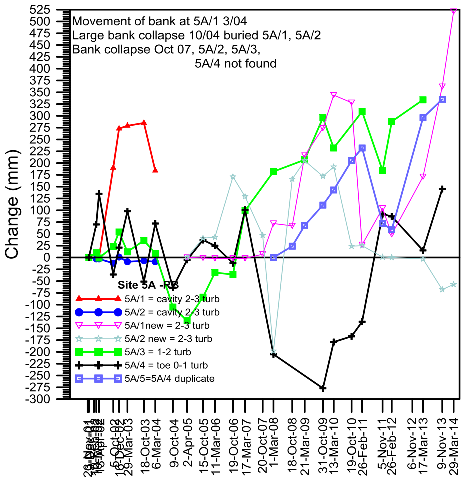


Site 4Gb

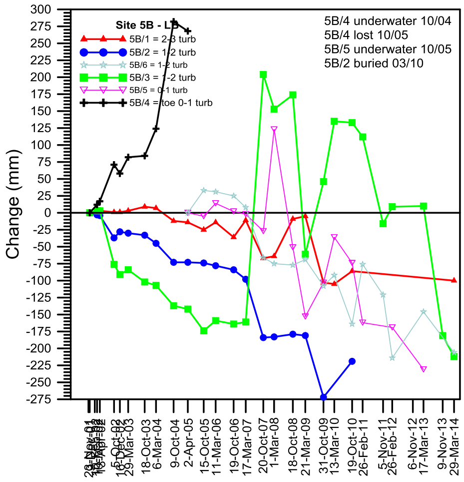


Site 4H

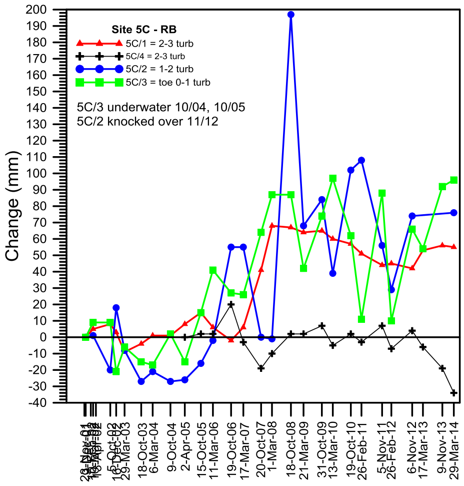
Zone 5



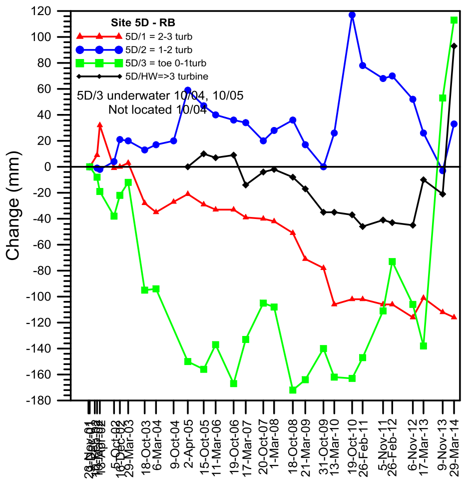
Site 5A



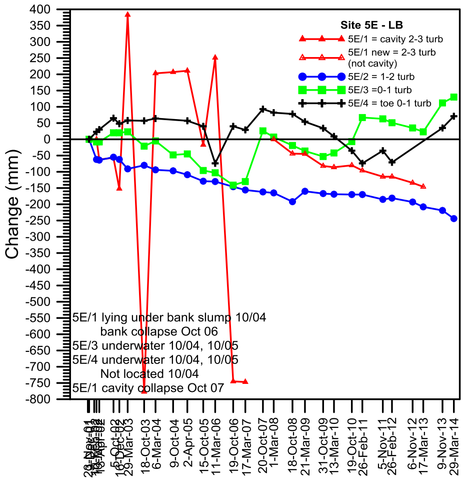
Site 5B



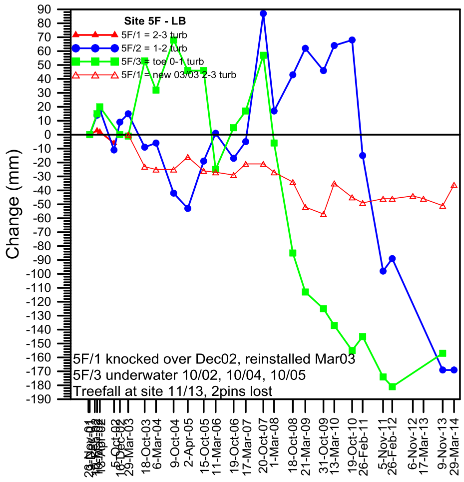
Site 5C



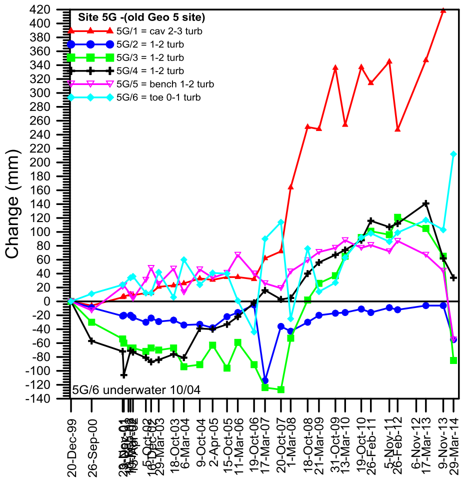
Site 5D



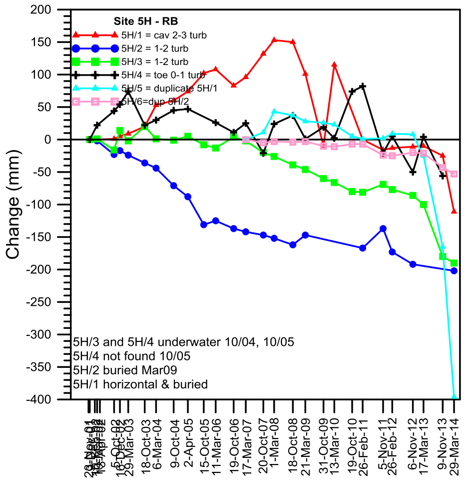
Site 5E



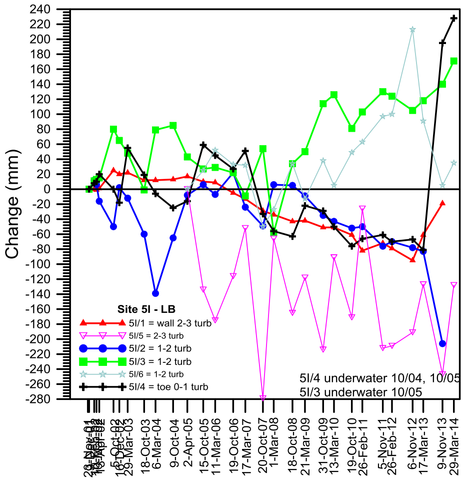
Site 5F



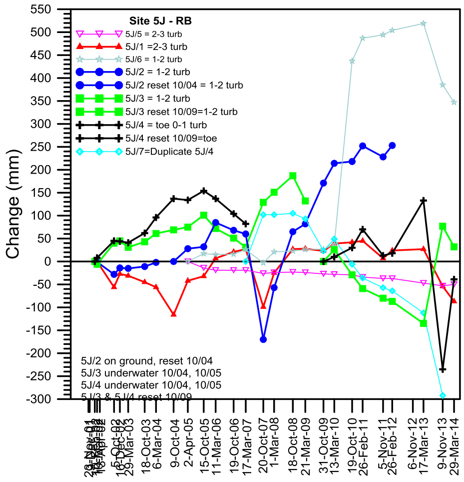
Site 5G



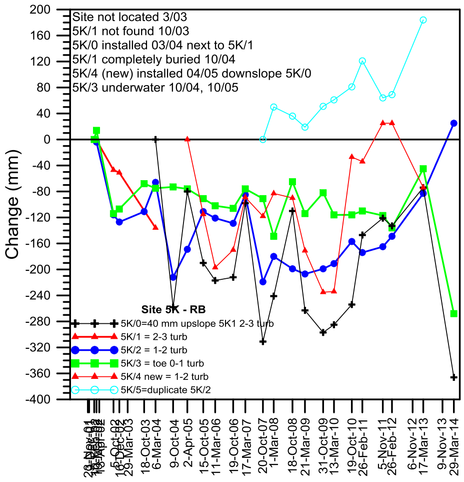
Site 5H



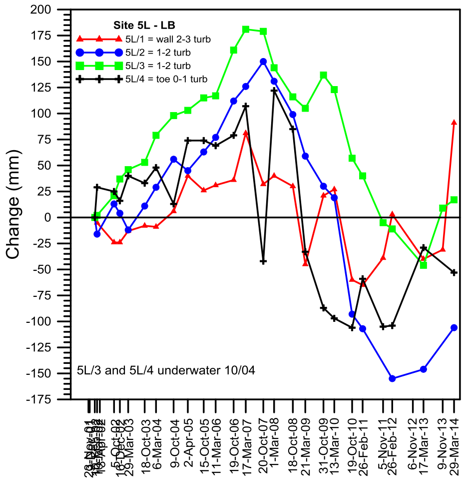
Site 5I



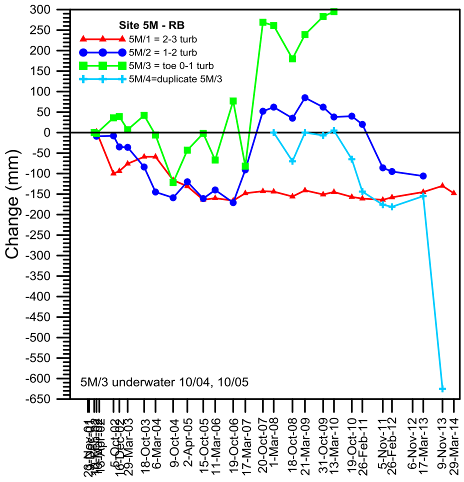
Site 5J



Site 5K



Site 5L


Site 5M - RB
5M/1 = 2-3 turb
5M/2 = 1-2 turb
5M/3 = toe 0-1 turb
5M/4=duplicate 5M/3
Change (mm)
5M/3 underwater 10/04, 10/05

Site 5M

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D Appendix D: Fluvial geomorphology photo-monitoring and site descriptions

Appendix D.1. Summary of photo-monitoring, March 2014

Table D.1: Evaluation of changes based on comparison of photos taken up to March 2014. P = zone, FI = Flood impact, Mvmt = movement, WD = woody debris, WL = water level, Turb = turbine level.

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P1-1	03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14							
P1-2	03, 04, 06, 07, 08, 09, 10, 11, 12, 13, 14				05			
P1-3	03, 04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14							
P1-4a	03, 04, 05, 07, 08, 10, 11, 12, 13		06				09	14 – scour of cobble toe
P1-4b	0, 05, 07, 08, 09, 10, 11, 12, 13	03, 14	03, 06					
P1-5	03, 04, 06, 07, 08, 09, 10, 11, 13		14 dieback		05			12 (new log in river)
P2-1a	03, 04, 05, 07, 08, 09, 10, 11, 12, 13	14						06 Inc in veg bel HW level
P2-1b	03, 04, 05, 09, 12		14				08	06 Inc in veg bel HW level, 07 less sand on bank toe, 11 sand dep on toe, 13 sand dep on toe
P2-2 new1	08	09, 14						10 eros. Of slumped root mat, 11 Inc veg, mvmt of WD on toe, 12 mvmt WD on toe & sed flows, 13 additional slumping, mvmt WD on toe
P2-2 new2	06, 07, 08, 10, 12	09	05, 14					11 mvmt of WD on toe, 13 mvmt WD on toe
P2-2a	07, 09, 10	04, 08	14	03, 05	06, 12			13 mvmt WD on toe
P2-2b	03, 04, 07, 13	08, 10, 11	14	06, 09, 11, 12			05	06, Inc in veg bel HW level,

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P2-3	07, 11, 13, 14	04, 08	05	03	06, 10			12 Inc WD on toe
P2-4	11, 12, 13, 14	03		03, 04, 05, 06, 08, 09, 10				07 loss of leaves from tree fall on bank crest; 09 shifting of wd on toe
P2-5	04, 07, 08, 12	03, 11	06, 14			03, 04		04 inc tree fall?, 05 small tree fall or accum of debris on toe; 07 inc sand dep on bank?, 09 mvmt of wd on toe, 10 mvmt of wd on toe, 13 slumping, mvmt WD on toe
P2-6	04, 05, 08							03 inc. coating on cobbles; 06 loss of cobbles, 09 loss of cobbles, 10 scour of cobbles, 11 scour of cobbles, 12 loss of tea tree, 13 mvmt cobble blocks on toe, 14 sed flow
P2-new3	07, 08, 09, 10, 11, 12		14					13 mvmt small WD on toe
P2-7	03, 04, 05, 06, 07, 08, 09, 10, 11, 12		14					13 dep of sands on bank and debris in tea tree, collapse of tea tree
P2-8	03, 04, 05, 06, 07, 08, 09, 10, 11, 12							13 dep sands, collapse of tea tree, 14 mvmt wd
P2-9	04, 05, 08, 09,		14	03, 06, 07, 10, 11, 12		03		07 maybe inc erosion on face, 10 & 11 mvmt wd on toe, 13 mvmt WE on toe
P2-10	03, 04, 05, 06, 07, 08, 09, 11, 12, 14					13		
P2-11	04, 05, 06, 07, 08				09, 11		03, 10 poor light	Discontinued 2011
P3-1	04, 05, 06, 07, 08, 09, 10, 12, 13, 14		03					11 change to WD on toe
P3-2	03, 04, 05, 07, 08, 09, 11, 12, 13, 14						06	10 mvmt wd on toe

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P3-3	03, 04, 05, 09, 11			07			14	06 flood debris 08 loss of small veg in 2-3 turb, 10 mvmt wd on toe, 12 mvmt to WD on toe, 13 mvmt WE on toe
P3-4	04, 05, 06, 07, 08, 09	10, 11				03	13, 14	03 may not be same site, 12 mvmt to WD on toe
P3-5	03, 04, 05, 06, 07, 10, 11, 12, 13	09	14					08 removal of WD & veg (FI)
P4-new1	07, 11, 12	09, 10			14			08 new wd on toe (FI), 13 mvmt WD on toe, new slump
P4-new2	07				09, 12		14	08 new wd on toe (FI);09 poor light conditions, 10, 11 mvmt wd on toe
P4-1	03, 04, 05, 06, 07, 08, 09, 10, 12, 13						11, 14	
P4-new3	07, 09, 10, 11, 12						13	08 loss of WD from toe (FI), 14 mvmt WD
P4-2	04, 08, 09, 11, 12	07			03, 14			06 inc veg 2-3 turb level, 10 mvmt WD on toe, 13 mvmt WD and slumping
P4-3	05, 06, 12, 14	10	03, 04, 09					07 overhanging veg may be lower 08 inc WD on toe (FI); 09 loss of fine branches on toe wd, 11 mvmt of WD on toe, 13 mvmt WE and pebbles/cobbles on toe
P4-4a	03, 04, 05, 07, 08, 09, 10, 11, 12, 14		06				13	
P4-4b	03, 04, 05, 09, 10, 11, 12, 14		06					07 movmt of WD 08change to WD (FI)
P4-4c	07, 08, 09, 10, 11, 12							04, change to dist'n of sand on cobble bar; 06 loss of flood debris
P4-5	03, 04, 05, 06, 07, 08, 09, 10,11, 12, 14				13			

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P4-6	03, 04, 07, 08, 09, 11, 12, 13, 14				05, 06		10	
P4-7	04, 06, 08, 09			05	03	14	10 (bad light), 11, 13	07 movmt of submerged wd, 12 mvmt of WD
P4-8	04, 05, 06, 07, 09, 10, 13				03			08 movmt of WD (FI), 11 mvmt of WD on toe, 12 mvmt of WD on toe, 14 mvmt wd and dieback
P5-1	04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14					03		03 extra slip?
P5-2	03, 04, 06, 07, 08, 09, 10, 11, 12, 14		05					13 mvmt WE on toe
P5-3	04, 06, 08, 09, 11, 12, 13, 14			05	03, 07		10	
P5-4	03, 04, 05, 06, 07, 09, 10, 11, 13, 14	12					08	
P5-5	05, 08, 09, 12, 14					04	11	04, additional small tree fell, 06 movement of veg d/slope, 07 loss of branches, 10 mvmt wd on toe, 13 mvmt WD on oe
P5-6	04, 07, 09, 10, 11, 12, 13			05, 06	03,			06 inc veg 2-3 turb 08 movmt of WD on toe (FI), 14 loss WD
P5-7	04, 07, 08, 09, 10, 14		05	06	03			06 inc veg 2-3 turb, 11 mvmt WD on toe, 12 mvmt WD on toe, 13, mvmt WD on toe
P5-8	04, 06, 07, 08, 09, 10, 11, 12, 13			05	03			14 mvmt WD
P5-9	03, 04, 05, 06, 07		14 dieback				11	08 inc WD on toe (FI), 09 mvmt wd on toe, 12 mvmt WD on toe, mvmt WD on toe
P5-10	04, 05, 07, 08, 09, 10, 11, 12, 13, 14		03					06 inc WD at base
P5-11	03, 04, 07, 08, 09, 10, 11, 12, 13, 14		06	05				05 inc veg below high WL

Site	No apparent change	Slip/ tree fall upslope of HW level	Removal of veg at base of slip	Increased veg on slip upslope of HW level	Poor photo-no apparent change	Poor photo-apparent change	No photo obtained	Other
P5-12	04, 05, 07, 09, 10, 11, 12, 13, 14		03					06 inc WD at base 08inc SWD on toe
P5-13	03, 04, 05, 06, 07, 08, 11, 12, 13	10, 14					09	
P5-14	03, 04, 07	10	14 dieback	06	11		09	08 inc WD on toe (FI), 12 mvmt WD on toe (dif angle), 13 mvmt WD on toe
P5-15	04, 05, 06, 07, 08, 09, 10, 11, 12, 13, 14			03 inc. in veg on bar		03		
P5-16	06, 07, 08, 09, 10, 11, 12, 13, 14		03	04, 05				03 movement of branch downslope
P5-17	03, 04, 06, 08, 09		05	07	12			06 maybe inc veg in 2-3 turb, 10&11 mvmt wd on bank, 14 slump on toe
P5-18	04, 05, 06, 08, 09, 10, 12							03 may not be same site;07 new dead tree fall, 11 mvmt WD on toe, 13 bank slump
P5-19	06, 07, 09, 13, 14			04, 05, 10, 11, 12	03			08 Erosion of slip face-major change
P5-20	04, 05, 06, 07, 08, 09, 10, 11, 13		14		03, 12			
P5-21	04, 07, 10, 12			09	11		03, 05, 14	06 inc veg 2-3 turb 08 loss of veg 2-3 turb (may not be same site), 13 mbmt to WD
2014 Total	26	4	12	0	3	0	5	10

Appendix D.2. Photo monitoring photos

Zone 1

Zone 1, site 1

(L-R) 9 March 2002, 29 March 2003

No data available for 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 1, site 2

(L-R) 9 March 2002, 29 March 2003

(L-R) 6 March 2004, 3 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

(L-R) 17 March 2013, 29 March 2014

Zone 1, site 3

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 3 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone1 site 4

(L-R) 9 March 2002, 29 March 2003

(L-R) 6 March 2004, 3 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009 (wrong site, slightly upstream)

(L-R) 13 March 2010, 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 1 site 4b

(L-R) 9 March 2002, October 2002, 29 March 2003.

Note vegetation at base in 2002 which is absent in 2003

(L-R) 6 March 2004, 3 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

(L-R) 17 March 2013, 29 March 2014

Zone 1, site 5

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 3 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2

Zone 2 site 1a



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 3 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site 1b

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 3 April 2005, 11 March 2006, 17 March 2007

Not photographed on 1 March 2008 (field error)—no changes noted in field notes.

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 2, site new 1

(L-R) 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site new 2



(L-R) 6 March 2004, 9 April 2005, 11 March 2006



(L-R) 17 March 2007, 1 March 2008, 21 March 2009



(L-R) 13 March 2010, 26 February 2011, 25 February 2012


(L-R) 17 March 2013, 29 March 2014

Zone 2, site 2a

(L-R) 9 March 2002, 29 March 2003, 6 March 2004 (d/s end)

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Not photographed in 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 2, site 2b

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

Not photographed in April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 2, site 3

(L-R) 9 March 2002, 29 March 2003, 11 March 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

(L-R) 17 March 2013, 29 March 2014

Zone 2, site 4

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site 5

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site 6

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 25 February 2012 (loss of tea tree)

(L-R) 17 March 2013, 29 March 2014

Zone 2, site new 3


(L-R) 17 October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site 7

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site 8



(L-R) 9 March 2002, 29 March 2003, 6 March 2004



(L-R) 9 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2 site 9

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 9 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 2, site 10



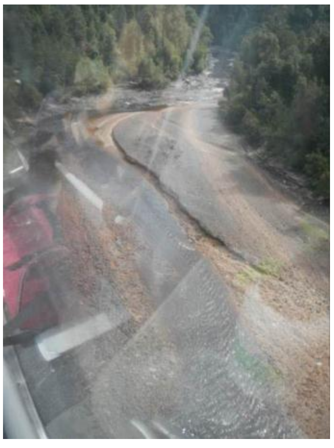
(L-R) 9 March 2002, 29 March 2003, 9 April 2005

Not photographed in March 2004


(L-R) 11 March 2006, 17 March 2007, 1 March 2008



(L-R) 21 March 2009, 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 2, site 11


(L-R) 9 March 2002, 9 April 2005

No suitable photo obtained March 2003 or March 2004



(L-R) 11 March 2006, 17 March 2007, 1 March 2008


(L-R) 21 March 2009, 26 February 2011

Not photographed in March 2010
Site discontinued in 2012 as difficult to obtain similar photos from helicopter

Zone 3

Zone 3, site 1

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 3 site 2


(L-R) 9 March 2002, 29 March 2003


(L-R) 6 March 2004, 2 April 2005

Photo not taken 11 March 2006


(L-R) 17 March 2007, 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011, 25 February 2012


(L-R) 17 March 2013, 29 March 2014

Zone 3, site 3

(L-R) 9 March 2002, 29 March 2003

(L-R) 6 March 2004, 2 April 2005

Wrong site photographed in 2006

(L-R) 17 March 2007, 1 March 2008, 21 March 2009

(L-R) 13 March 2010, 26 February 2011, 25 February 2012

17 March 2013,

No Photo taken on 29 March 2014 (high water level)

Zone 3 site 4

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012

Not photographed in 2013 or 2014

Zone 3 site 5

(L-R) 9 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009 (different site), 13 March 2010 (different site)

(L-R) 26 February 201, 25 February 2012, 17 March 2013 –correct site

29 March 2014

Zone 4

Zone 4, site new 1


(L-R) October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011



(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 4, site new 2


(L-R) October 2006, 17 March 2007

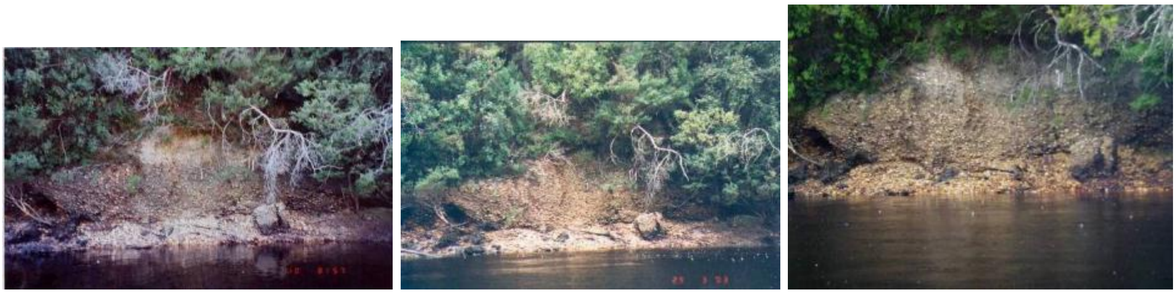

(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011

25 February 2012 (taken from different angle)

Not photographed in 2013 and 2014

Zone 4, site 1



(L-R) 10 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Not photographed in February 2011

(L-R) 25 February 2012, 17 March 2013

Not photographed in 2014

Zone 4, site new 3


(L-R) October 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009


(L-R) 13 March 2010, 26 February 2011


(L-R) 25 February 2012, 29 March 2014

Not photographed in March 2013

Zone 4, site 2



(L-R) 10 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 4, site 3



(L-R) 10 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 4, site 4a



(L-R) 10 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012

Not photographed in 2013 March

29 March 2014

The power of natural thinking

Zone 4, site 4b

(L-R) 10 March 2002, 29 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

No photo taken in 2014

Zone 4, site 4c

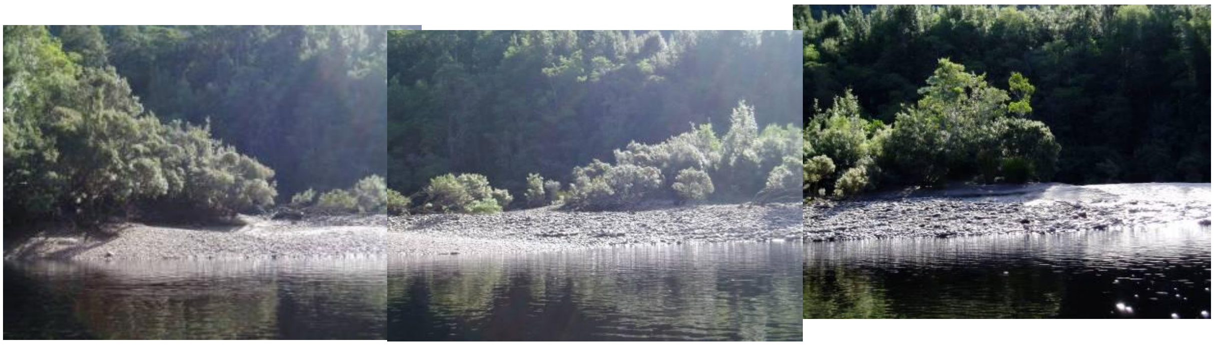
10 March 2002

29 March 2003

6 March 2004

2 April 2005

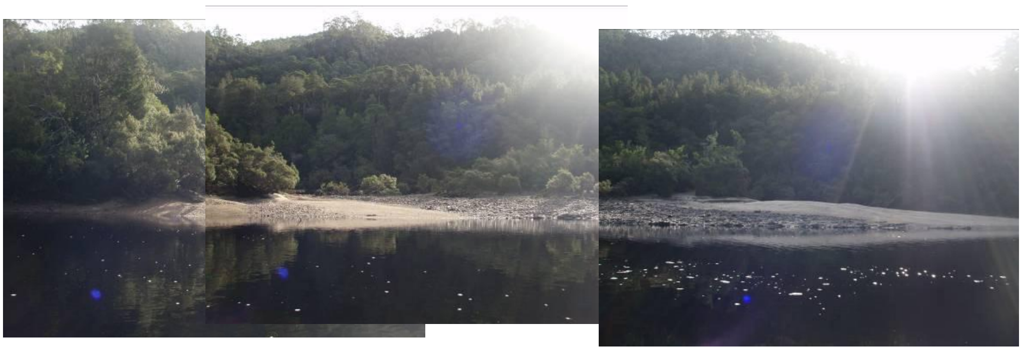
Zone 4, site 4c continued



11 March 2006

17 March 2007

1 March 2008



21 March 2009

Zone 4, site 4c continued

13 March 2010

26 February 2011

26 February 2012

Not photographed in March 2013

29 March 2014

Zone 4, site 5

(L-R) 10 March 2002, 29 March 2003

(L-R) 29 6 March 2004, 2 April 2005, 11 March 2006

(L-R) 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013 (upstream end), 29 March 2014

Zone 4, site 6

(L-R) 10 March 2002, 29 March 2003, 6 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008, 21 March 2009

Not photographed in March 2010




(L-R) 26 February 2011, 25 February 2012, 17 March 2013, 29 March 2014

Hydro Tasmania
The power of natural thinking

Zone 4, site 7



(L-R) 10 March 2002, 29 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007


(L-R) 1 March 2008, 21 March 2009

Not photographed in March 2010 or February 2011

25 February 2012

Not photographed in March 2013 and March 2014 (incorrect site)

Hydro Tasmania
The power of natural thinking

Zone 4, site 8

(L-R) 10 March 2002, 29 March 2003, 6 March 2004, 2 April 2005

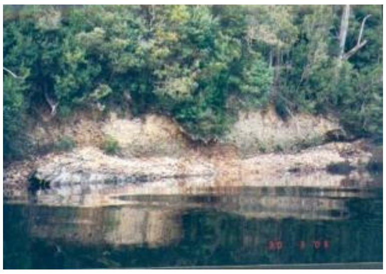
(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 5

Zone 5, site 1


(L-R) 10 March 2002, 30 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



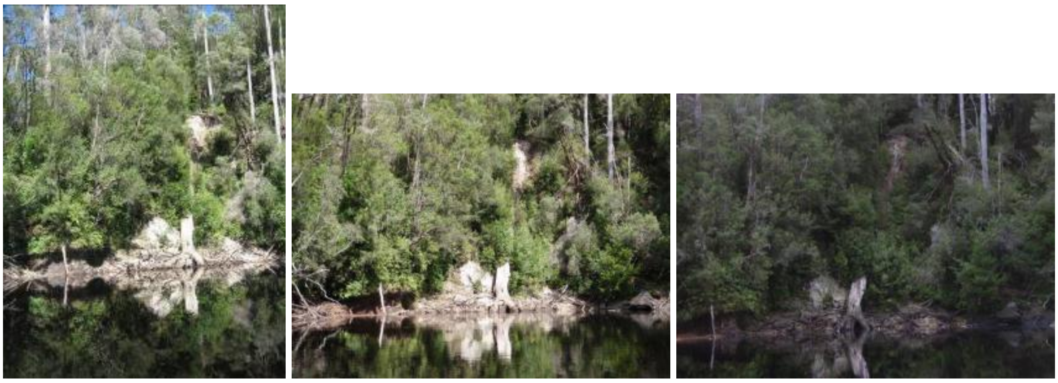
(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 2

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007, 1 March 2008



(L-R) 21 March 2009, 13 March 2010, 26 February 2011

Photo not obtained February 2012

(L-R) 17 March 2013, 29 March 2014

Zone 5, site3

(L-R) 10 March 2002, 30 March 2003, 6 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008, 21 March 2009

Photo not obtained March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 4

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

Photo not taken in March 2008

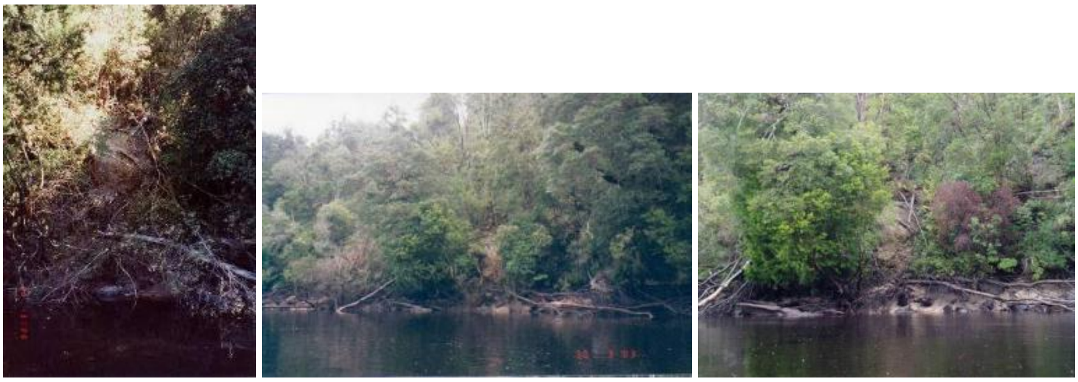
(L-R) 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 5



(L-R) 10 March 2002, 30 March 2003, 6 March 2004

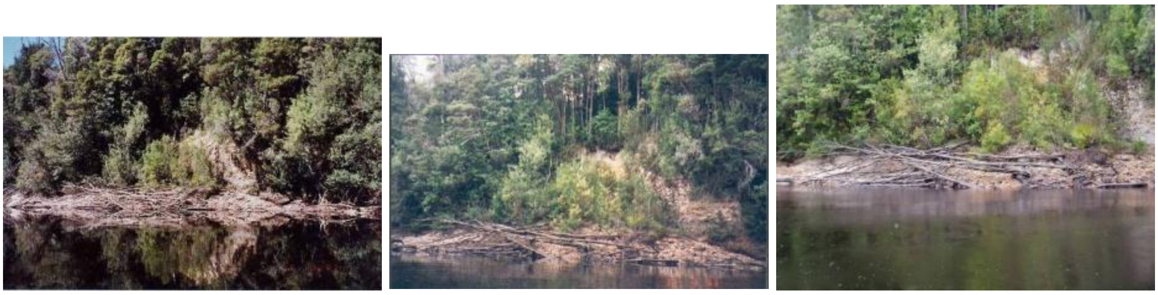
(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Not photographed in February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 5, site 6



(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 7

(L-R) 10 March 2002, 30 March 2003, 10 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 5, site 8

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 9

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

Not photographed in February 2011

(L-R) 25 February 2012, 17 March 2013

Not photographed in March 2014

Zone 5, site 10

(L-R) 10 March 2002, 30 March 2003, 6 March 2004, 2 April 2005

(L-R) 11 March 2006, 17 March 2007, 1 March 2008

(L-R) 21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 5, site 11

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 12

(L-R) 10 March 2002, 30 March 2003, 6 March 2004, 2 April 2005

(L-R) 11March 2006, 17 March 2007, 1 March 2008

21 March 2009, 13 March 2010, 26 February 2011

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 5, site 13

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 13 March 2010 (wrong site), 26 February 2011

Photo not taken March 2009

(L-R) 25 February 2012, 17 March 2013, 29 March 2014

Zone 5, site 14


(L-R) 10 March 2002, and March 2003

Photo not taken in 2004 and 2005.



(L-R) 11 March 2006, 17 March 2007, 1 March 2008

Photo not taken in March 2009



(L-R) 13 March 2010, 26 February 2011, 25 February 2012


(L-R) 17 March 2013, 29 March 2014

Zone 5, site 15

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 11 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 16

(L-R) 10 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 17

(L-R) 9 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012 (taken on different angle), 17 March 2013

29 March 2014

Zone 5, site 18



(L-R) 9 March 2002, 30 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 19



(L-R) 9 March 2002, 30 March 2003, 6 March 2004



(L-R) 2 April 2005, 11 March 2006, 17 March 2007



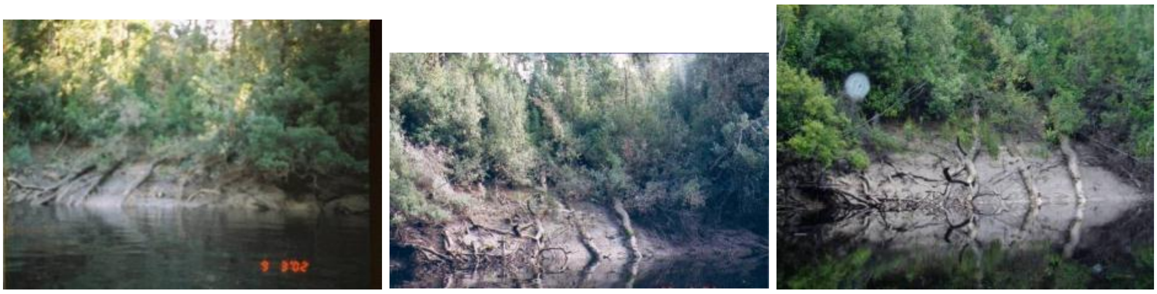
(L-R) 1 March 2008, 21 March 2009, 13 March 2010



(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

Zone 5, site 20



L-R) 9 March 2002, 30 March 2003, 6 March 2004

(L-R) 2 April 2005, 11 March 2006, 17 March 2007

(L-R) 1 March 2008, 21 March 2009, 13 March 2010

(L-R) 26 February 2011, 25 February 2012, 17 March 2013

29 March 2014

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Zone 5, site 21

   

(L-R) 30 March 2003, 6 March 2004, 11 March 2006, 17 March 2007

Photo not obtained in March 2002, or in April 2005

  

(L-R) 1 March 2008 (may not be same site), 21 March 2009 (correct site), 21 March 2009

  

(L-R) 13 March 2010, 26 February 2011, 25 February 2012, 13 March 2013

Not photographed in March 2014

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E Appendix E: Macroinvertebrate data

Appendix E.1. Quantitative macroinvertebrate ‘family level’ data – spring 2013

Table E.1: Abundances as n per 0.18 m^2 for middle Gordon River and reference sites sampled in spring 2013.

			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														
Cnidaria	Hydrozoa					1											
Platyhelminthes	Turbellaria					1			1	1		2			2	4	3
Nematoda					3		1	1	6	12	4	1	4			6	6
Mollusca	Bivalvia	Sphaeriidae								1							
	Gastropoda	Hydrobiidae			4	2	4	8	3	12	1					3	
		Glacidorbidae			1		1										
Annelida	Oligochaeta			1	24	28	30	19	50	202	12	101	191	122	8	178	92
Arachnida	Acarina												1				
Crustacea	Amphipoda	Paramelitidae								6		1		1			
		Neoniphargidae		1	3	1				1							
	Isopoda	Janiridae		10	6	7	1	2	2	1			1	1			1
		Phreatoicidea					1	2									
Insecta	Plecoptera	Eustheniidae				1	1	5		3	1	2	2	3	5	1	
		Gripopterygidae			1	8	3	16	1	8	1	13	9	9	31	27	7
		Notonemouridae				1			1	1		2	3				
	Ephemeroptera	Leptophlebiidae		1	1	5		26	16	13		67	58	87	50	75	25
		Baetidae										5	11	5	6	14	8
	Collembola												1				
	Diptera	Chironomidae:	Chironominae					5	2	3			6	3	6		3
		Chironomidae:	Orthocladiinae			1				2	1	2		1	8	5	3
		Chironomidae:	Podonominae	1				1		4		56	26	26	8	9	2
		Chironomidae:	Tanypodinae										2	1			
		Chironomidae:	Aphroteniinae							1				1		6	1
		Simuliidae		8	96	63	102	58	252	147	4	351	283	70	47	28	26
		Tipulidae				2	1				1						1
		Blephariceridae				1		10	6	16		24	19	8	2	3	4
		Ceratopogonidae										3	1	1	1	2	1
		Chaoboridae				1											
		Empididae							1								
		Tanyderidae										1					
		Dip. Unid. Pup.			1	1		4		1	2	7	5				1
	Trichoptera	Conoesucidae			1	2				3				1	1		
		Glossosomatidae												1		6	1
		Hydrobiosidae		1				2	5	8		13	11	9	7	5	2
		Hydropsychidae			4	1	1	1	3	2						1	
		Leptoceridae							2	4		12	17	11	3	6	2
		Philorheithridae										1	1	1		1	
		Trich. Unid. Pup.			1		1	1	1	1	1					1	

* Data for site 42 is of poor quality and has not been included in the analyses

			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**														
	Coleoptera	ElmidaeA				2		2	1		1	7	4	17	8	44	14
		ElmidaeL			1		1	4	6	4		23	13	33	10	101	62
		ScirtidaeL								1	1	24	6	23	4	11	3
		PsepheniidaeL				1		2					1		1	16	1
			Total abundance	**23**	**147**	**130**	**148**	**169**	**359**	**458**	**30**	**718**	**676**	**435**	**208**	**553**	**269**
			N Taxa (families)	**7**	**14**	**20**	**13**	**19**	**18**	**26**	**12**	**22**	**24**	**23**	**19**	**24**	**23**

* Data for site 42 is of poor quality and has not been included in the analyses

Appendix E.1 continued

Appendix E.2. Quantitative ‘species level’ data for EPT taxa – spring 2013

Table E.2: Ephemeroptera, Plecoptera and Trichoptera for middle Gordon River and reference sites sampled in spring 2013 (abundances as 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
x = formerly Baetid Genus 2 MV sp3		Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21	D1	M1	J1
Order	Family	Genus/Species														
Ephemeroptera	Baetidae	x *Offadens hickmani*									5	11	5	6	14	8
	Leptophlebiidae	*Austrophlebioides* sp. AV7									1			1		1
		Nousia sp. AV5/6	1	1	4		14	13	10		63	53	82	37	74	24
		Nousia sp. AV7			1		6	1	2		2	3	3	6	1	
		Tillyardophlebia sp AV2					6	2	1		1	2	2	6		
Plecoptera	Eustheniidae	*Eusthenia costalis*					1									
		Eusthenia spectabilis	1		1	1	4		3	1	2	2	3	5	1	
	Gripopterygidae	*Cardioperla incerta*				1			2		2	1			3	1
		Cardioperla media/lobata			5				2		2		2		4	1
		Dinotoperla serricauda					1				2	1	1			1
		Leptoperla varia				1	2									
		Trinotoperla tasmanica				1	1					1			1	
		Trinotoperla zwicki		1	3		12	1	4	1	7	6	6	31	19	5
Trichoptera	Notonemouridae	*Austrocercoides sp*			1			1				3				
	Conoesucidae	*Conoesucus digitiferus*		1												
		Conoesucus fromus			1											
		Conoesucus nepotulus											1	1		
		Conoesucus norelus							3							
		Conoesucus ramosa/krene			1											
	Glossosomatidae	*Agapetus* sp. AV1											1		6	1
	Hydrobiosidae	*Apsilochorema obliquum*									1	1		2	1	1
		Koetonga clivicola												1		
		Moruya opora						3	5		2	1	1			1
		# *Taschorema apobamum*						2	2		2	1			2	1
		# *Taschorema asmanum*							1			2	2			
		# *Taschorema ferulum*											1			
	Includes all#	*Taschorema ferulum* grp	1				2				6	6	5	4	2	
		Taschorema evansi									1					
		Ulmerochorema rubiconum									1					
	Hydropsychidae	*Asmicridea* sp. AV1		4	1	1	1	3	2						1	
	Leptoceridae	*Notalina* sp.AV1										2				
		Notalina sp.						2	4		12	15	11	3	6	2
	Philorheithridae	*Tasmanthrus* sp.									1	1	1		1	
		Abundance EPT	**3**	**7**	**18**	**5**	**50**	**28**	**41**	**2**	**113**	**112**	**127**	**103**	**136**	**47**
		N EPT Taxa	**3**	**4**	**9**	**5**	**11**	**9**	**13**	**2**	**18**	**18**	**16**	**12**	**15**	**12**

Appendix E.3. RBA macroinvertebrate data – spring 2013

Table E.3: Abundances per live picked sample for middle Gordon River and reference sites sampled in spring 2013.

			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	
			Old site code:	G4		G4a		G5		G6		G9		G10		G11B		G15		G19		G20		G21		D1		M1		J1	
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				2																										
Nematoda						1												5	1												
Mollusca	Gastropoda	Hydrobiidae								1				1			2								1						
Annelida	Oligochaeta				1	17	8	3	13	3		6	8	10	18	50	35	9	8	7	24	8	22		7	10	14	14	15	8	4
Arachnida	Acarina																						1				1			2	3
Crustacea	Amphipoda	Paramelitidae										9	5	3	6	3	5		1												
		Neoniphargidae		1	12			1	2		2		1	1		1	1								1			2			
		Paracalliopiidae											2					4	2												
	Isopoda	Janiridae		14	11																										
		Phreatoicidea																	1												
Insecta	Plecoptera	Eustheniidae		3	2		1	2		3	1	9	3			6	5	1	2	1	1	4	2			2	5			1	
		Austroperlidae					1								2																
		Gripopterygidae		4		2	5	20	18			15	10	4		5	8	3	2	3	4	10	10	1		4	9	2	3	12	13
		Notonemouridae			2		1		2	1						1		2	3				1								
	Ephemeroptera	Leptophlebiidae		11	2		1	38	36	6	9	55	56	43	32	24	31	10	19	86	94	64	99	68	21	156	151	58	57	61	71
		Baetidae															1	3	4	7	3	16	8	1		20	10	11	11	17	14
	Diptera	Chironomidae:	Chironominae										2		1		1	1					1		1	2		1			
		Chironomidae:	Orthocladiinae	3	1													1	2								1			1	1
		Chironomidae:	Podonominae				1		2			1			2	1	1	6	10	16	20	21	12	28	34	6	2	8	3	14	1
		Chironomidae:	Tanypodinae							1			1						2					1							
		Chironomidae:	Aphroteniinae	1																											
		Simuliidae		71	50	44	73	60	65	18	41	33	33	55	44	39	25	5	9	7	27	56	32	7	37	10	4	2	5	3	3
		Tipulidae							3	1			1	1		1	1	1	2			1				1	3	1			
		Athericidae																													1
		Blephariceridae										1	3	1		5		1	2	5	4	28	30								
		Ceratopogonidae				1											4		2			7	5			1	1				
		Empididae																	1												
		Dolichopodidae													1																
	Trichoptera	Conoesucidae					1	2	3			1	1	1			2	2	1			2	1			1				1	1
		Glossosomatidae																			1										2
		Hydrobiosidae		21	6	4	8		1	3		15	17	17	16	13	10		4	30	29	29	26	18	14	28	20	11	17	19	5
		Hydropsychidae					3	4	2					1	1							2									
		Leptoceridae									1	2	2	3					2	1		1	1	1	1		3				
		Philorheithridae										1		2	4	1		1				3		2	1						
		Tasimiidae										2																			1
		Trich. Unid. Pup.						2	1					1	3	3	2				3							4		1	
	Coleoptera	ElmidaeA			1			1			1	8	7	3	1	1		1	1	18	20	5	6	39	68	13	9	5	8	27	1
		ElmidaeL			1	1									2	1			2		1		2		1	8	1		1	4	
		ScirtidaeL		1				1	2			2		2						3	1	7	3	1			2				
		PsepheniidaeL										2		2					1								1				1
			N Taxa	**10**	**12**	**7**	**11**	**11**	**13**	**9**	**6**	**16**	**16**	**18**	**14**	**16**	**16**	**17**	**24**	**12**	**14**	**17**	**18**	**11**	**12**	**14**	**17**	**12**	**9**	**14**	**15**

Appendix E.4. Quantitative macroinvertebrate 'family level' data – autumn 2014

Table E.4: Abundances as n per 0.18 m^2 for middle Gordon River and reference sites sampled in autumn 2014.

			River:	Gordon R								Franklin R		Denison R
			Site code:	75	74	72	69	60	57	48	42	Fr11	Fr21	De7
			Old site code:	G4	G4a	G5	G6	G9	G10	G11B	G15	G19	G20	G21
Class	Order	Family	Sub family											
Cnidaria	Hydrozoa					2								
Platyhelminthe	Turbellaria				1			1		5				2
Nematoda									1	20	6		1	2
Mollusca	Bivalvia	Sphaeriidae					1							
	Gastropoda	Hydrobiidae				1	15	2	1	2	3			
		Glacidorbidae			1									
Annelida	Oligochaeta			1	2	7	16	12	5	221	55	110	60	60
Arachnida	Acarina											1	2	
Crustacea	Amphipoda	Paramelitidae								1				
		Neoniphargidae					2			1				
	Isopoda	Janiridae		2	7		1		1	1				3
		Phreatoicidea					2							
Insecta	Plecoptera	Eustheniidae						1						
		Gripopterygidae			2		1	4	3	2	3	2	1	4
		Notonemouridae					1		1	1				1
	Ephemeroptera	Leptophlebiidae				1	1	8	4	23	19	25	10	62
		Baetidae							1	1		5	3	14
	Collembola												1	
	Diptera	Chironomidae:	Chironominae			1	2		2	14	15	1		4
		Chironomidae:	Orthocladiinae		1		3			6		2	1	3
		Chironomidae:	Podonominae							1		2		1
		Chironomidae:	Aphroteniinae											4
		Simuliidae		2	5	52	97	503	257	52	136	52	43	288
		Tipulidae								1	1			2
		Blephariceridae						1		1	3			
		Ceratopogonidae								4		4	2	
		Empididae							1					
		Dip. Unid. Pup.					2	7	11	3	3	2		2
	Trichoptera	Calocidae												1
		Conoesucidae									1			1
		Hydrobiosidae		1	1		2	2	3	12	5	2	2	7
		Hydropsychidae				1	19	5	19	11	4			
		Leptoceridae										1		5
		Philorheithridae									1			1
		Trich. Unid. Pup.						1	1	1				1
	Coleoptera	ElmidaeA					1	1	2	2		1	1	11
		ElmidaeL				1				4		11	3	92
		ScirtidaeL						3	1	14	6	12	1	121
		PsepheniidaeL				1		2					1	
			Total	**6**	**20**	**67**	**166**	**553**	**314**	**404**	**261**	**233**	**132**	**692**
			N Taxa	**4**	**8**	**9**	**16**	**15**	**17**	**25**	**15**	**16**	**15**	**24**

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Appendix E.5. Quantitative ‘species level’ data for EPT taxa – autumn 2014

Table E.5: Ephemeroptera, Plecoptera and Trichoptera for middle Gordon River and reference sites sampled in autumn 2014 (abundances as n per 0.18 m^2).

		River:	**Gordon R**								**Franklin R**		**Denison R**
		Site code:	**75**	**74**	**72**	**69**	**60**	**57**	**48**	**42**	**Fr11**	**Fr21**	**De7**
x = formerly Baetid Genus 2 MV sp3		**Old site code:**	**G4**	**G4a**	**G5**	**G6**	**G9**	**G10**	**G11B**	**G15**	**G19**	**G20**	**G21**
Order	**Family**	**Genus/Species**											
Ephemeroptera	Baetidae	x *Offadens hickmani*						1	1		5	3	14
	Leptophlebiidae	*Nousia* sp. AV5/6			1	1	8	4	17	17	21	5	62
		Nousia sp. AV7		1					5		2	1	
		Tillyardophlebia sp AV2							1	2	2	4	
	Eustheniidae	*Eusthenia costalis*					1						
	Gripopterygidae	*Cardioperla incerta*						1					
		Cardioperla media/lobata							1				1
		Leptoperla varia				1				1			
		Trinotoperla tasmanica						2					
		Trinotoperla zwicki		1			4		1	2	2	1	3
	Notonemouridae	*Austrocercoides* sp				1			1				1
Trichoptera	Calocidae	*Tamasia variegata*											1
	Conoesucidae	*Conoesucus nepotulus*		1						1			1
	Hydrobiosidae	*Apsilochorema gisbum*									1		1
		Ethochorema nesydrion											1
		Moruya opora					1			1			
		# *Taschorema apobamum*						1	1	2			
		# *Taschorema asmanum*	1	1			1		4	1		2	1
	(Includes all #)	*Taschorema ferulum* grp				2		2	7	1	1		4
	Hydropsychidae	*Asmicridea* sp. AV1			1	19	5	19	11	4			
	Leptoceridae	*Notalina* sp.AV1											5
		Notalina sp.									1		
	Philorheithridae	*Tasmanthrus* sp.								1			1
		Abundance EPT	**1**	**4**	**2**	**24**	**20**	**30**	**50**	**33**	**35**	**16**	**96**
		N EPT Taxa	**1**	**4**	**2**	**5**	**6**	**7**	**11**	**11**	**8**	**6**	**13**

Appendix E.6. RBA macroinvertebrate data – autumn 2014

Table E.6: Abundances per live picked sample for middle Gordon River and reference sites sampled in autumn 2014.

			River :	**Gordon R**																**Franklin R**				**Denison R**	
			Site :	**75**		**74**		**72**		**69**		**60**		**57**		**48**		**42**		**Fr11**		**Fr21**		**De7**	
			Old site code:	**G4**		**G4a**		**G5**		**G6**		**G9**		**G10**		**G11B**		**G15**		**G19**		**G20**		**G21**	
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**
Platyhelminthes	Turbellaria										2	3			2			1						3	4
Nematoda						1												1							
Mollusca	Gastropoda	Hydrobiidae					1												1						
Annelida	Oligochaeta			1		5	17	10	13	4		25	9	13	3	16	21	2	2	21	4	34	7	15	9
Arachnida	Acarina												1										1		
Crustacea	Amphipoda	Paramelitidae										2	2		1	2			1					1	1
		Neoniphargidae		3						1	1	1													
	Isopoda	Janiridae		16		1	11	1																1	
Insecta	Plecoptera	Eustheniidae		1					1	5		2	1	1	2		1				1	1	2	1	1
		Gripopterygidae		1	2	2			2	1	2	9	8	4	5	13	6	5	8	4	3	2	2		1
		Notonemouridae				1	1	1			1	1													
	Ephemeroptera	Leptophlebiidae				1		5	3	22	23	28	10	9	16	22	18	18	17	47	86	23	46	57	35
		Baetidae										1	1				1		1	13	12	11	22	4	
	Diptera	Chironomidae:																							
			Chironominae					1	1							1	1								
			Orthocladiinae	1	1				1			1		1	1	1	1			7	2		1		
			Podonominae										1	1			1	1		9	8	5	7	1	1
		Simuliidae		11	10	66	24	78	59	76	66	109	181	86	163	68	60	90	63	41	31	31	22	34	34
		Tipulidae												3	1	1		1	1					1	1
		Blephariceridae										1													
		Ceratopogonidae															1			2	4	5	1		1
		Chaoboridae		2	3																				
		Empididae				1																			
		Dip. Unid. Pup.							2					1						1					
	Trichoptera	Conoesucidae																			1				
		Hydrobiosidae		34	7	33	25	4		5	9	12	11	7	21	17	9	7	8	4	17	12	10	2	3
		Hydropsychidae				4	1		2	6	3	7	15	3	7	4	9	3	4						
		Leptoceridae											1							1	1	2	2	6	5
		Philorheithridae												1	1						1	1	1		1
		Polycentropodidae																							1
		Trich. Unid. Pup.										2							1						
	Coleoptera	ElmidaeA					1					5	4	2	2	4	4	2	1	1	5	4	7	11	6
		ElmidaeL													1				1		7	3	1	3	6
		ScirtidaeL						1						2		3		2		5	25	14	8	17	18
		PsepheniidaeL												1									1		
			N Taxa	**9**	**5**	**10**	**8**	**8**	**9**	**8**	**8**	**16**	**13**	**15**	**14**	**12**	**13**	**12**	**13**	**13**	**16**	**14**	**17**	**15**	**17**

Appendix E.7. Trigger value metrics

Table E.7: Values of all metrics for each site sampled in spring 2013 and autumn 2014. (Note: figures shown in red for site 42 in spring 2013 are deemed unreliable due to poor sampling conditions).

			Spring 2013									Autumn 2014								
			Community Structure		Community Composition		Taxonomic richness		Ecologically significant species		Biomass / productivity	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	Bray Curtis (abundance)	O/Erk	Bray Curtis (pres/abs data)	O/Epa	N Taxa (fam)	N EPT species	Propn abundance EPT	Abundance EPT	Density (total abundance)
Gordon																				
	75	G4	15.17	0.62	29.36	0.60	7	3	0.087	2	23	8.93	0.38	14.29	0.49	4	1	0.167	1	6
	74	G4a	12.75	0.61	23.95	0.63	14	4	0.054	8	147	29.09	0.50	42.88	0.54	8	4	0.150	3	20
	72	G5	31.19	0.80	38.74	0.73	20	9	0.138	18	130	12.42	0.48	19.44	0.64	9	2	0.030	2	67
	69	G6	10.91	0.47	19.83	0.49	13	5	0.041	6	148	16.14	0.49	27.43	0.59	16	5	0.145	24	166
	60	G9	48.47	1.09	47.83	1.05	19	11	0.302	51	169	36.64	0.81	36.72	1.17	15	6	0.038	21	553
	57	G10	42.19	1.06	50.50	0.97	18	9	0.081	29	359	27.22	0.81	33.59	1.27	17	7	0.102	32	314
	48	G11B	50.28	0.94	58.97	0.96	26	13	0.094	43	458	51.82	0.77	64.03	1.03	25	11	0.126	51	404
	42	G15	11.05	1.23	21.72	1.16	12	2	0.100	3	30	47.21	0.68	46.39	1.03	15	11	0.126	33	261
Reference																				
Franklin	Fr11	G19	71.92	0.97	72.22	0.94	22	18	0.160	115	718	57.30	0.96	59.52	1.17	16	8	0.150	35	233
	Fr21	G20	69.27	1.35	66.78	1.27	24	18	0.166	112	676	48.56	1.03	56.77	1.32	15	6	0.121	16	132
Denison	De7	G21	63.12	0.76	62.52	0.72	23	16	0.292	127	435	42.88	1.03	44.86	1.32	24	13	0.140	97	692
	De35	D1	61.04	0.88	60.04	0.99	19	12	0.495	103	208									
Maxwell	Ma7	M1	65.88	0.91	67.18	0.94	24	15	0.248	137	553									
Jane	Ja7	J1	59.30	0.66	61.43	0.67	23	12	0.167	45	269									