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# Basslink Monitoring Program

## Gordon River Basslink Monitoring Annual Report

## 2011–12

## Volume I: The Report

Prepared by

Hydro Tasmania

September 2012

# Executive summary

The Gordon River Basslink Monitoring Annual Report is the product of Hydro Tasmania's Gordon River Basslink Monitoring Program. This monitoring program is required under Hydro Tasmania's Special Water Licence and seeks to identify and document changes in the Gordon River environment in response to Basslink operation. The program extends the knowledge gained during the 1999–2000 investigative years and the 2001–05 monitoring on the pre-Basslink condition, trends, and spatial and temporal variability of the middle Gordon River environment. The 2011–12 monitoring year was the tenth year of Basslink monitoring, and the sixth year of monitoring completed since the commissioning of Basslink operation in April 2006.

The principal objective of this report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2011–12 reporting year.

Monitoring was completed across the full range of scientific disciplines in 2011–12. This report is the last annual monitoring report required for the current Gordon River Basslink Monitoring Program. A final review report is to be completed in April 2013, summarising all the monitoring conducted as part of this program.

## Hydrology and water management

The 2011–12 power station operating regime was dominated by low discharge as a result of the prevailing market conditions. The outage at Poatina Power Station from April to August 2011 required the use of Gordon Power Station in a daily peaking mode, alternating between high and low discharge in the first two months of the monitoring period (July–August 2011). Despite the use of Gordon Power Station in this manner, the monthly median discharge values were relatively low and similar to the long-term median. The overall discharge in 2011–12 from Gordon Power Station was the lowest on record, with the energy generated at Gordon Power Station being 20% of the long-term average. Under this low discharge operation, Lake Gordon storage water level has continued to increase.

The discharge from Gordon Power Station consisted of periods of regular hydro-peaking in July and August 2011 to levels corresponding to three-turbine operation. The months of April and June 2012 also had some periods of peaking operation that generally corresponded to two-turbine operation. However, most of the year was dominated by low discharge in the vicinity of the environmental flow. Only a moderate number of low to high discharge peaking events were measured at the Gordon above Denison site.

This year, the ramp-down rule has been improved. The original rule was replaced on 1 April 2012 with a new ramp-down rule which is based on bank saturation.

There was only one exceedance of the ramp-down rule outside the tolerances defined in the Special Water Licence recorded for the period July 2011 to March 2012. From 1 April to 30 June 2012, there were no exceedances. There were no periods when ramping was required, due to low saturation level of the banks. The minimum environmental flow requirements were achieved 100% of the time in summer and 99.8% of the time in winter.

Flow patterns at the Gordon above Denison site were reflective of flows from the power station. However, at the more distant Gordon above Franklin site the lower power station discharges were less reflective of the overall flow pattern with significantly greater proportion of flows originating from tributaries.

## Water quality

Lake Gordon and Lake Pedder continued to have good water quality in 2011–12.

The thermal structure of Lakes Gordon and Pedder were similar to previous years. Dissolved oxygen showed declines at depth at all sites in Lake Gordon during summer. Anoxic conditions were recorded for bottom waters at the Knob Basin on all sampling occasions. The power station intake was above the oxycline on three of the sampling occasions and at the oxycline on one occasion in April 2012. The lowest oxygen concentration at the intake was recorded in April 2012 at approximately 5.5 mg $L^{-1}$.

Lower dissolved oxygen was rarely observed in the tailrace, the lowest measured concentration was 6.4 mg/L. Concentrations of dissolved oxygen in the tailrace were highly variable as a result of changes to power station discharge and concomitant changes in aeration inside the turbines.

Dissolved oxygen and water temperatures in the Gordon River displayed broad seasonal patterns related to the thermal pattern of Lake Gordon.

Water temperatures along the river differed between sites and were higher during summer at sites further downstream due to inputs of warmer water from tributaries, as well as from warming in the Gordon River itself. Water temperature in the Gordon River was sensitive to fluctuations in power station discharge. The seasonal temperature variation in the river was accentuated in 2011–12 due to the low power station operation during the summer, with higher water temperatures and obvious diurnal temperature variations.

Dissolved oxygen concentrations at the compliance site were generally high. Changes in dissolved oxygen concentration at the compliance site are influenced by the rate of discharge from the power station. Higher dissolved oxygen coincided with higher discharges, probably due to the significant aeration that the water receives as it travels the 12 km from the tailrace to the compliance site.

## Fluvial geomorphology

Power station peaking patterns in the first part of the monitoring year produced some high risk periods for seepage erosion, and field evidence and time-lapse photos suggest that seepage processes were active in some limited areas of the river during the first half of the monitoring year.

Erosion pin results in November showed some deposition in the 2–3 turbine bank level in the zones upstream of the Denison River, indicative of seepage erosion. Scour was observed in the 1–2 turbine bank level, indicative of peaking operation. In the zones downstream of the Denison River, scour of the bank face, possibly associated with peaking, was accompanied by deposition on bank toes, which is likely related to unregulated inflows.

Piezometer results show that bank saturation was low throughout the second half of the monitoring year, and there was no evidence of seepage processes in field observations or erosion pin results, which recorded very low rates of change throughout the study area. This is consistent with the very low discharge from the power station.

Photo-monitoring results in February 2012 found the majority of the monitoring sites had no change relative to 2011, with the exception of increased vegetation. Where other changes were noted, the movement of woody debris on bank toes was the dominant change.

The modelled sediment transport capacity for the 2011–12 year was similar to the previous year, and continues the trend of very low transport rates compared to the pre-Basslink or historic periods.

The 2011–12 findings are consistent with the understanding of processes in the river and the conceptual model, even though the erosion pin results in zones 2–5 continue to fall outside of the projected ‘envelope’ of change based on pre-Basslink results. Zones 2–4 continue to show substantially reduced rates of erosion compared to the projected trends, presumably due to the much lower river flows post-Basslink as compared to pre-Basslink. Erosion rates in zone 5 continue to be higher than projected (although still the lowest of zones 2–5), which may be related to reduced erosion in the upstream zones reducing sediment available for deposition in zone 5. Alternatively the higher erosion may also be influenced by natural variability not captured in the pre-Basslink period. Zone 1 continues to show net deposition within the predicted range based on pre-Basslink monitoring.

## Karst geomorphology

Minor sediment changes were observed in the caves during 2011–12, closely reflecting the relatively low power station discharge in comparison to the pre-Basslink years.

In Bill Neilson Cave, high flows over winter gave rise to deposition at the higher levels of the wet sediment banks, while the fluctuations between 150 and 250 $m^3 s^{-1}$ resulted in erosion at the mid levels. The cave stream drove sediment erosion at the lower levels when power station discharges were low.

In Kayak Kavern, deposition occurred over winter on the sediment bank due to the period of inundation, in May 2011, which led to periods of stable conditions. Over the summer, there was generally little change in the sediments due to the lack of power station activity.

In GA-X1, the period of power station discharges greater than 150 $m^3 s^{-1}$ over winter resulted in deposition occurring in the cave, particularly at the lower levels, in contrast to the summer months when the flows were low and the sediment changes were very minor.

In Channel Cam, there was minor deposition during the winter months from the limited inundation from the river and the adjacent small tributary. This sediment was removed again over the summer at the pin closest to the river.

In the dolines, consistent with previous trips, there were no significant changes between the pins, indicating that their morphology has remained stable since the program commenced.

None of the informal triggers were exceeded this monitoring period.

The findings from the 2011–12 monitoring year showed no significant impacts to the karst features of the Gordon River during the post-Basslink period.

## Riparian vegetation

The recovery of the vegetation along the Gordon River noted in the previous monitoring periods has continued in the 2011–12 monitoring period. Sites generally had an increase in total vegetation cover and a consequent reduction in bare ground in all quadrat types. Bryophyte and fern cover either increased slightly or remained stable, while shrub cover increased slightly. Associated with the recovery of vegetation was an increase in species richness as additional species have colonised the lower quadrats.

A number of values were recorded outside the triggers for community composition and this has largely been due to small changes in the similarity indices and species richness, and is attributable to the change in the presence and absence of a few species.

Diverging similarity seen in the lower quadrats is due to additional species becoming established in the low flows encountered during the monitoring period. Species evenness was mostly within trigger ranges indicating the proportional representation of species present was generally stable.

The proportional changes in the cover of life form variables (e.g. shrubs, moss, bryophytes) and ground cover between ‘above’ and ‘high’ and ‘above’ and ‘low’ quadrats have resulted in several trigger values being exceeded. In most cases this can be explained by the increased growth of life forms in the lower quadrats resulting from the low frequency and duration of high flow events in 2011–12.

The impact of Basslink on the riparian vegetation is considered to be minimal, with the continued recovery of vegetation in 2011–12 on banks being the result of periods of lower than average flows.

## Macroinvertebrates

Patterns and trends in benthic macroinvertebrate metric values for 2011–12 were similar to those observed in the four years pre-Basslink with the following exceptions:

- community compositional similarity between Gordon and reference sites was again higher than pre-Basslink means;
- the absolute and proportion of abundance of EPT species was substantially raised in zone 1.

Trigger values were generally compliant in 2011–12, with the exception of:

- the total and proportional abundance of EPT species and Bray Curtis similarity to reference sites being raised, especially in zone 1. This is due to high densities of the caddis *Asmicridea* and the insect families Gripopterygidae and Hydrobiosidae and is believed to be driven by the maintenance of the minimum environmental flow in the post-Basslink period; and
- values falling just below the six-year lower trigger bounds for the number of EPT species and O/Epa.

Overall, for benthic macroinvertebrates, there has been general compliance with, or positive exceedance of, established triggers and evidence of lagged improvement in benthic biological condition. The partial decline in biological condition in zone 1 observed in 2010-11 was reversed in 2011–12.

## Algae and moss

As in the pre-Basslink period, overall aquatic plant cover was low in the Gordon River during 2011–12.

Filamentous cover was generally low, peaking in the upper reaches of zone 1, and was very low downstream of the Denison confluence as observed previously. A minor exceedance was noted for whole-of-river and zone 2, but otherwise was consistent in overall magnitudes and trends of cover with pre-Basslink years. The long-term (six-year) post-Basslink mean cover shows that most values fell within trigger level bounds and were consistent with magnitude trends of cover for moss and algae with pre-Basslink years. There were three minor exceedances for algal cover and one minor exceedance for moss cover. The observed algal and moss exceedances do not constitute a substantive ecological change.

## Fish

Spotted galaxias were the most abundant fish in the main river channel over summer, and were second only to brown trout in autumn, reflecting strong recruitment in previous years. Climbing galaxias and jollytails were caught in relatively small numbers, which is consistent with previous years.

Brown trout were the most abundant of all species, native or exotic, captured in the river during the 2011–12 monitoring surveys. Redfin perch were the only other exotic captured, and they were present in small numbers in the upper monitoring zones (1 and 2). No increase in redfin perch distribution was detected. These results are consistent with previous surveys.

Brown trout catches in the upper Gordon zones and its tributaries appear to have increased in the post Basslink period. However, these increases have not resulted in exceedences of the upper exotic trigger which is calculated across all zones.

Pouched lampreys abundances were variable, with summer relative abundances across all zones similar to pre-Basslink levels. Autumn results were variable within both test and reference sites and showed no consistent trends relative to pre-Basslink abundances. Short headed lampreys are uncommon in the region, and the low catches recorded during this year were consistent with the results from previous years.

Short finned eel abundances were generally similar to pre-Basslink means, with elevated catches in autumn probably reflecting strong recruitment in previous years.

Trigger results were above the lower bound for all categories. Out of the 10 triggers for 2011–12, one upper bound exceedence occurred in autumn galaxiid relative abundance (ecologically significant species). Exceedences were driven by elevated spotted galaxias abundance and reflect strong recruitment of this species in the Gordon River over the post Basslink period. There has been no obvious negative impact on Gordon River fish as a result of Basslink.

## Conclusions

Results of the 2011–12 monitoring period continue to be influenced by the flow regime experienced in the Gordon River. Discharge from Gordon Power Station continued to be generally low compared with previous years, with significant periods of operation at levels of the minimum environmental flow. There were some short periods of hydropeaking discharge.

Twenty six per cent of triggers were exceeded in 2011–12. However, many of the exceedences were considered to be positive or neutral changes. In particular, positive exceedences in the macroinvertebrate discipline appear to be related to the environmental flow, while low overall discharge was linked to reduced erosion and good vegetation condition, which can be attributed to the generally low discharge.

Overall, no net negative Basslink impact has been observed in 2011–12.

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# Acronyms and abbreviations

| | |
|---|---|
| AEMO | Australian Energy Market Operator – founded in 2009 with NEMMCO as a founding entity |
| AETV | Aurora Energy Tamar Valley |
| ANOVA | analysis of variance |
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| AUSRIVAS | Australian River Assessment System |
| BBR | Basslink Baseline Report |
| BMP | Basslink Monitoring Program |
| CPUE | catch per unit effort |
| CWD | coarse woody debris |
| DO | dissolved oxygen |
| DPIPWE | Department of Primary Industries, Parks, Water and Environment |
| EC | electrical conductivity |
| EPT | Ephemeroptera (mayflies), Plecoptera (stoneflies), Trichoptera (caddisflies) |
| FLOCAP | Flow calculator application to convert station output to flow |
| FRP | filterable reactive phosphorus |
| GRBMAR | Gordon River Basslink Monitoring Annual Report |
| IIAS | Basslink Integrated Impact Assessment Statement: Potential Effects of Changes to Hydro Power Generation |
| LOAC | Level of acceptable change |
| mASL | metres above sea level |

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|---|---|
| NEMMCO | National Electricity Market Management Company—incorporated into AEMO in 2009 |
| NTU | Nephelometric turbidity units |
| 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 |
| TKN | total Kjeldahl nitrogen |
| WOR | whole-of-river |

# Glossary

| | |
|---|---|
| Ambient | background or baseline conditions |
| Anoxic | absence of oxygen |
| Benthic | the bottom of a lake |
| Bray-Curtis index | a measure of assemblage similarity between sites/samples |
| Catch per unit effort (CPUE) | the catch related to a standardised measure of effort. In this case, the number of fish collected by electrofishing at a site, standardised to a shocking time of 1200 seconds |
| 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. |
| Colluvium | loose bodies of sediment that have been deposited or built up at the bottom of a low-grade slope or against a barrier on that slope, transported by gravity. The deposits that collect at the foot of a steep slope or cliff are also known by the same name. |
| Confluence | the location when two rivers or tributaries flow together |
| Diurnal | relating to or occurring in a 24-hour period |
| Dolines | are karst features which present as depressions or collapses of the land surface. Dolines are formed when a solution cavity in the underlying rock becomes enlarged enough for overlying sediment to collapse into it. |
| Environmental flow | water which has been provided or released for the benefit of the downstream aquatic ecosystem and broader environment |
| Exotic | introduced organisms or species |
| 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 |
| Karst | an area of irregular limestone in which erosion has produced fissures, sinkholes, underground streams and caverns |
| $m^3 s^{-1}$ | cubic metres per second, units for the measure of flow rate |
| mg $L^{-1}$ | milligrams per litre, units for the concentration of a substance dissolved in a solution |
| µg $L^{-1}$ | micrograms per litre |
| µS $cm^{-1}$ | micro Siemens per centimetre, measure of electrical conductivity |
| Morphology | the consideration of the form and structure of organisms |
| MW | megawatts ($10^6$ watts) - a standard measure of power |
| Oxycline | level at which dissolved oxygen decreases rapidly |
| pH | a measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity (scale of 0-14) |
| Piezometer | an instrument for measuring pressure |

| | |
|---|---|
| Pielou’s evenness index | a measurement of diversity in samples using abundance and species richness data developed by Pielou in 1966 |
| 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 |
| Thermal stratification | change in temperature profiles over the depth of a water column |

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# 1 Introduction and background

The purpose of this Gordon River Basslink Monitoring Annual Report (GRBMAR) is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program (BMP) during 2011–12. This is the sixth full year of post-Basslink operation, and the last year of monitoring conducted for all disciplines. The results are assessed against the trigger values set out in the Gordon River Basslink Monitoring Annual Report 2005–06 (Hydro Tasmania, 2006) and other assessment criteria developed for specific disciplines during the course of the monitoring program.

## 1.1 Context

The Gordon River Basslink Monitoring Program (BMP) was an outcome of the Basslink approvals process. The aims of the Gordon River Basslink Monitoring Program are 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 is 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.

The independent investigative studies produced for the Basslink Integrated Impact Assessment Statement (IIAS) (Locher 2001) led to the formulation of the BMP. The BMP was incorporated into the Special Licence held by Hydro Tasmania under the *Water Management Act 1999*.

The post-Basslink monitoring program has a major component that compares post-Basslink data with trigger values derived from pre-Basslink data. Six years of data are now available post-Basslink. In this report both 2011–12 data and combined data from the 2006–12 period are assessed against trigger values. This is the final year of data collection for the current monitoring program. A final review report is to be produced that assesses the full dataset in greater detail than presented here.

## 1.2 Basslink Baseline Report

One of the requirements of Hydro Tasmania's Special Licence was to produce a Basslink Baseline Report (BBR) prior to Basslink commencement. The BBR was submitted to the Minister in December 2005 and provided 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 Basslink Baseline Report is available on Hydro Tasmania's website (www.hydro.com.au/environment/basslink-studies).

## 1.3 Basslink Review Report 2006–12

This has been the final year of data collection for the current monitoring program. A final review report is to be produced by April 2013 that assesses the full dataset in greater detail than presented in this annual report. Its aims are the same as those for the previous Basslink Review Report (above), including the assessment of the effectiveness of mitigation measures, as well as specific adaptive management that have been implemented in the post-Basslink period.

## 1.4 Logistical considerations and monitoring in 2011–12

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 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. Shutdowns are 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 Gordon River Basslink Monitoring Program has a schedule of at least four visits per year, each requiring the power station to be turned off for two to four consecutive days.

The 2011–12 river monitoring surveys were conducted on 3–6 November 2011 and 24–26 February 2012 (macroinvertebrates, algae and moss, geomorphology, karst); and 2–6 December, 7–9 December, 14 December 2011 and on 29 March–1 April 2012 (riparian vegetation, fish).

## 1.5 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.

## 1.6 Document structure

This document is the eleventh of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into ten chapters plus an executive summary.

This first chapter discusses the requirements, context, operational considerations and constraints of the program. Chapters 2–9 report on the monitoring work that was undertaken during 2011–12, and present the consolidated results of each of the individual monitoring elements. These are:

- Hydrology and water management (Chapter 2);
- Water quality (Chapter 3);
- Fluvial geomorphology (Chapter 4);
- Karst geomorphology (Chapter 5);
- Riparian vegetation (Chapter 6);
- Macroinvertebrates (Chapter 7);
- Algae and moss (Chapter 8);
- Fish (Chapter 9); and
- Discussion of trigger results (Chapter 10).

The results from the 2011–12 monitoring are reported in each of these chapters. With the increased understanding of the processes of the Gordon River, it was recognised in the Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) that trigger values are just one important measure in understanding the response of the river to hydrological changes. This is the third report where assessment is provided with a greater emphasis on ‘multiple lines of evidence’ where appropriate. Each discipline chapter also contains a section on comparisons with trigger values. Where available, two comparisons against the trigger values were made; one assessing the 2011–12 results and one comparing the combined results for all the post-Basslink data (2006–12) against the triggers.

When a result fell outside the trigger levels, the terminology ‘a trigger has been exceeded’ has been used in this report. However, it should be noted that an ‘exceedance’ can either be above or below the trigger levels. It should also be noted that a trigger exceedance can be considered an ecological benefit, for example lower levels of exotic fish. Interpretation of the trigger exceedances is discussed in the individual chapters and explored in more detail in chapter 10.

A series of eleven appendices is included in Volume II as follows:

- Power station discharges graphed per month (Appendix 1);
- Gordon bank saturation as a function of flow—Report #1386-09 (Appendix 2)
- Fluvial geomorphology erosion pin descriptions and graphed data (Appendix 3);
- Fluvial geomorphology erosion pin and scour chain data (Appendix 4);
- Fluvial geomorphology photo-monitoring and site descriptions (Appendix 5);
- Karst erosion pin data (Appendix 6);
- Riparian vegetation photo-monitoring (Appendix 7);
- Bank profiles and ground cover variables (Appendix 8);
- Macroinvertebrate data (Appendix 9);
- Fish monitoring data (Appendix 10); and
- Formal trigger levels (Appendix 11).

## 1.7 Authorship of chapters

The information presented in chapters 2–10 was extracted from field reports produced by the various 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, Ray Brereton and Stephen Casey of Entura, with internal review from Will Elvey, Ray Brereton (Entura), Marie Egerrup, Alison Howman, Peter Connolly, Gerard Flack and Greg Carson (Hydro Tasmania), and significant assistance from the researchers. Donna Porter assisted with editing and production.

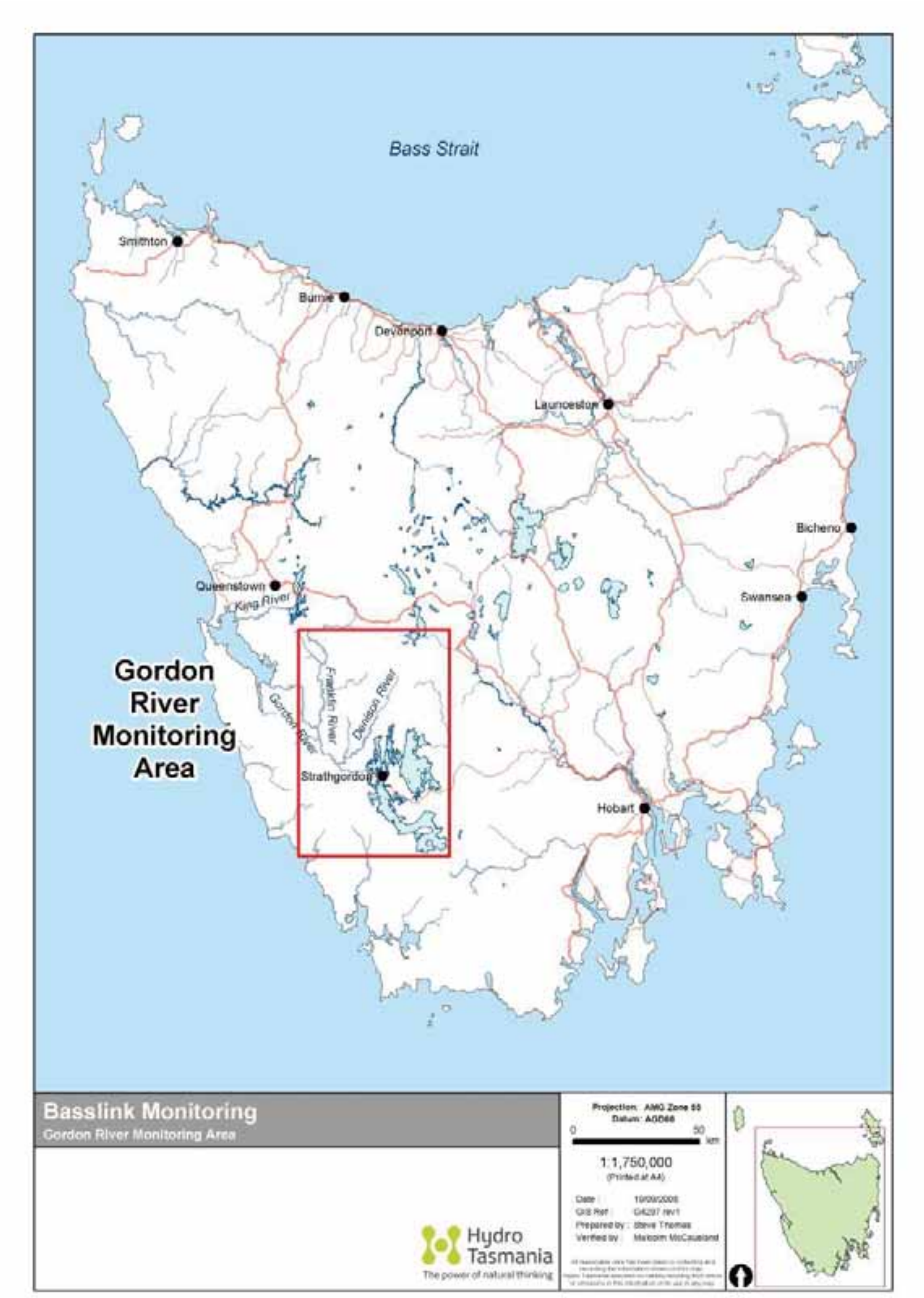
Table 1-1 Chapter numbers, titles and original authors from whose reports the information in chapters 2–10 was extracted

| Chapter | Chapter title | Lead Author(s) |
|---|---|---|
| 2 | Hydrology | Malcolm McCausland and Mark Willis (Entura) |
| 3 | Water quality | Tim Shepherd and Malcolm McCausland (Entura) |
| 4 | Fluvial geomorphology | Lois Koehnken (Technical Advice on Water) |
| 5 | Karst geomorphology | Jenny Deakin (Consultant) |
| 6 | Riparian vegetation | Stephen Casey (Entura) |
| 7 | Macroinvertebrates | Peter Davies and Laurie Cook (Freshwater Systems) |
| 8 | Algae and moss | Peter Davies and Laurie Cook (Freshwater Systems) |
| 9 | Fish | David Ikedife (Entura) |
| 10 | Discussion of trigger value results | Lois Koehnken (Technical Advice on Water), Peter Davies (Freshwater Systems), David Ikedife and Stephen Casey (Entura) |

## 1.8 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 39 (immediately downstream of the Franklin confluence, at the upstream tidal limit) and site 77 (the power station tailrace).

Some disciplines, such as fluvial geomorphology and riparian vegetation, use zones rather than the standard site numbering system. This is because their work is associated with longer reaches of river bank than are suitable for the ‘site’ nomenclature. The fish monitoring uses both systems. Site numbers define the specific monitoring location and fish zones define the river reach to which the sites belong.



Map 1-1 Gordon River Basslink monitoring area

# 2 Hydrology and water management

This section of the Gordon River Basslink Monitoring Annual Report provides an overview of the hydrological data from the Gordon River downstream of the Gordon Power Station for the July 2011 to June 2012 period. Conformance with the two mitigation measures, environmental flow and 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 Table 2-1. The normal factors include:

- inflows to Hydro Tasmania catchments (volume, distribution and sequence);
- 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.

Based on modelling undertaken prior to Basslink commissioning it was expected that the Gordon Power Station running regime would become extremely ‘peaky’, increasing high flow ramping events, as Hydro Tasmania responded to market opportunities. In the first three years post-Basslink, the anticipated degree of increased peaking operation was not observed. A number of factors played differing roles in this operation, and quantification of the individual factors was and continues to be difficult (Hydro Tasmania, 2010b).

In all but four of the last 17 years, Tasmanian electricity demand was higher than the annual yield in the hydro scheme (Table 2-2). The post-Basslink years began with a continuation of a downward trend in overall storage position until 2007–08 (Table 2-3). Implementation of the storage rebuild strategy in June 2008, an opportunity made possible by the commissioning of 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 as a result of an increase in the system-wide hydro generation in response to higher inflows and greater thermal generation from AETV. In 2011–12, hydro generation was reduced from the previous year, while demand was very similar. The difference was met by generation from AETV, wind and a small net import of power.

Gordon Power Station generation (263 GWh) was significantly lower in 2011–12 than any previous year (1996–2011) and was only 20% of the long-term annual generation. A major factor in the lower generation in 2011–12 has been the high run-of-rivers generation elsewhere in the State and increased use of Poatina Power Station following a major outage when Great Lake's level rose. A second major driver was the desire to hold energy in storage until the carbon price was implemented in Australia. Due to the low use of Gordon Power Station in 2011–12, there has been an increasing disparity in storage levels between Lake Gordon and Great Lake (Table 2-3).

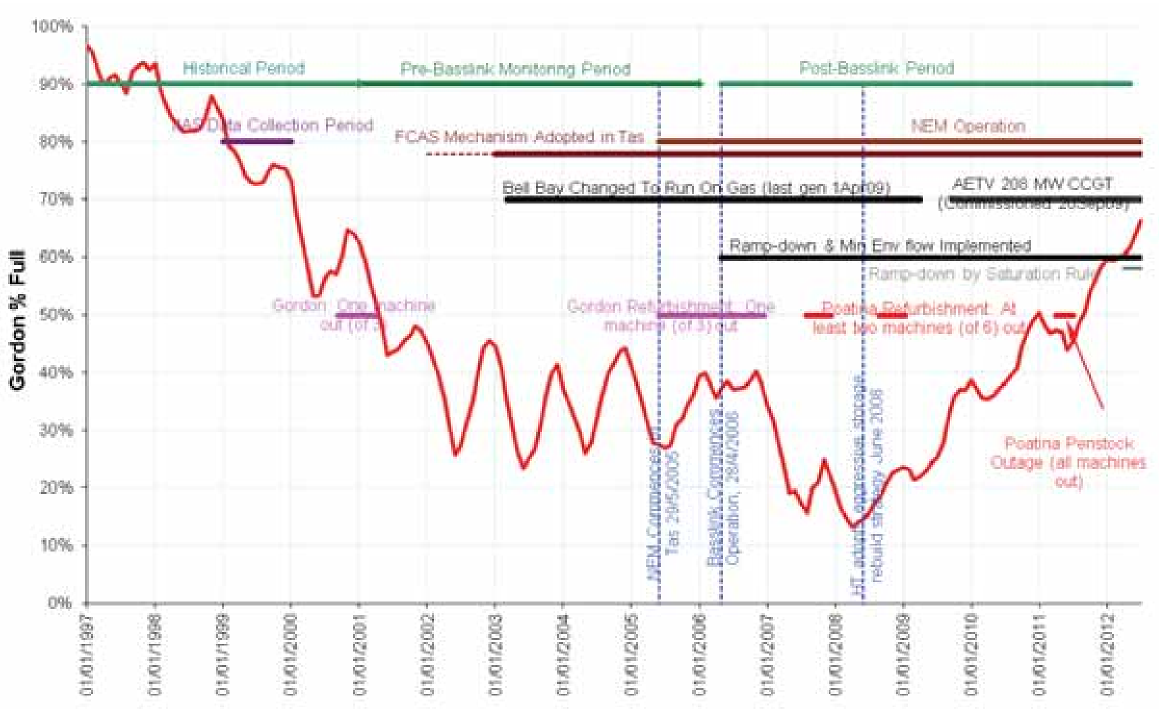


Figure 2-1 Timeline of significant factors affecting Gordon Power Station operation (including storage levels) relative to Basslink monitoring periods

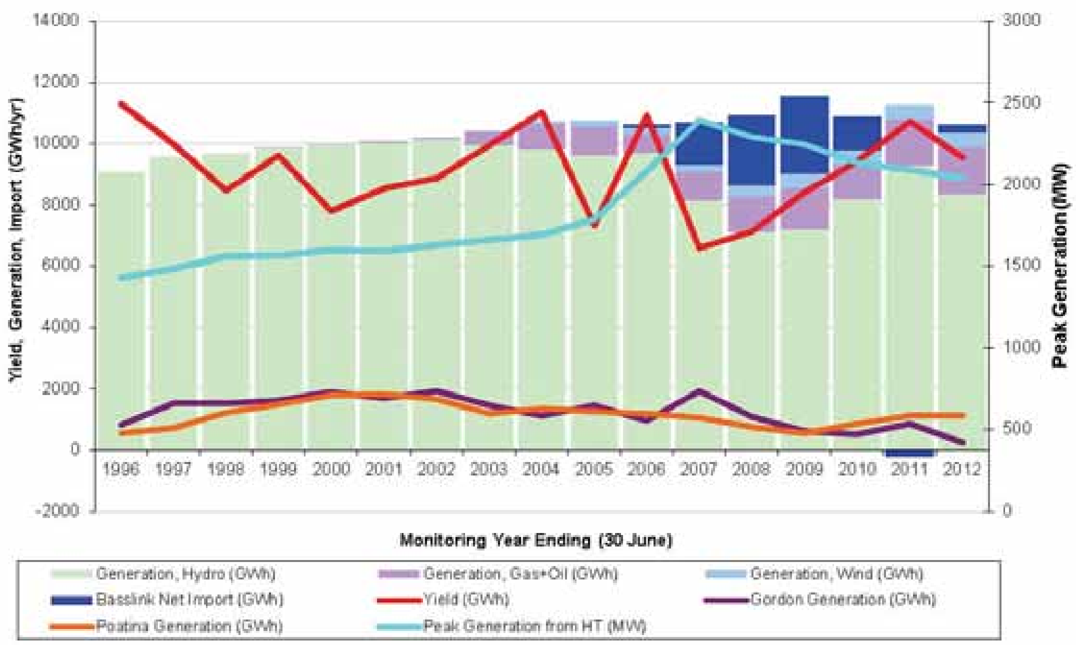


Figure 2-2 Annual hydro generation and yield, Basslink import, wind and gas generation, Gordon and Poatina generation in GWh and peak demand in MW for financial years from 1995–96 to 2011–12. Yield presents system inflows converted to GWh

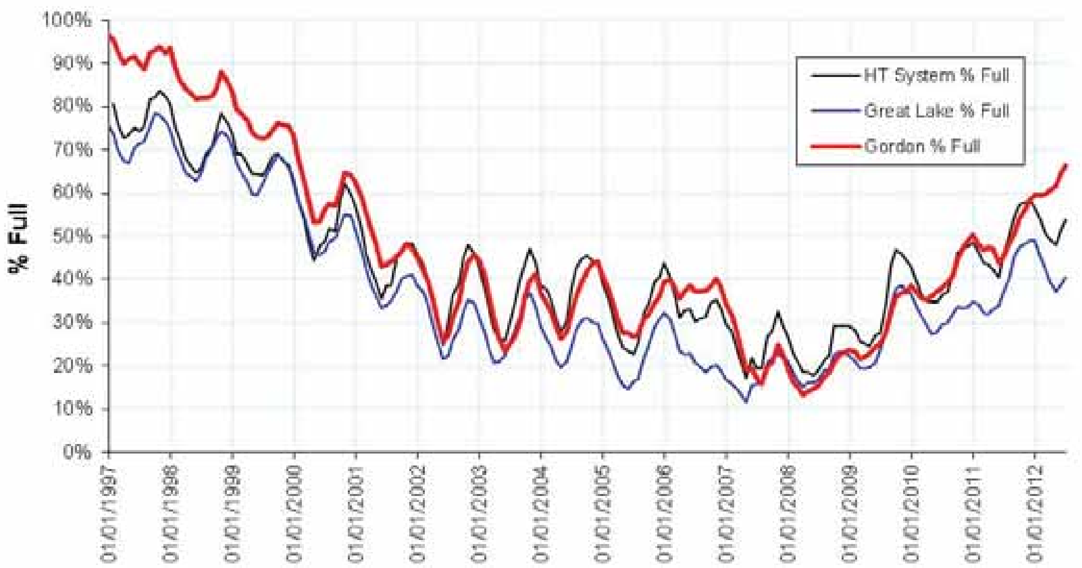


Figure 2-3 System, Lake Gordon and Great Lake water level presented as per cent full for the last 15 years

## 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 determining ramp-down compliance. It is the most accurate method of determining flow from the Gordon Power Station, and is presented in all analyses in this report.

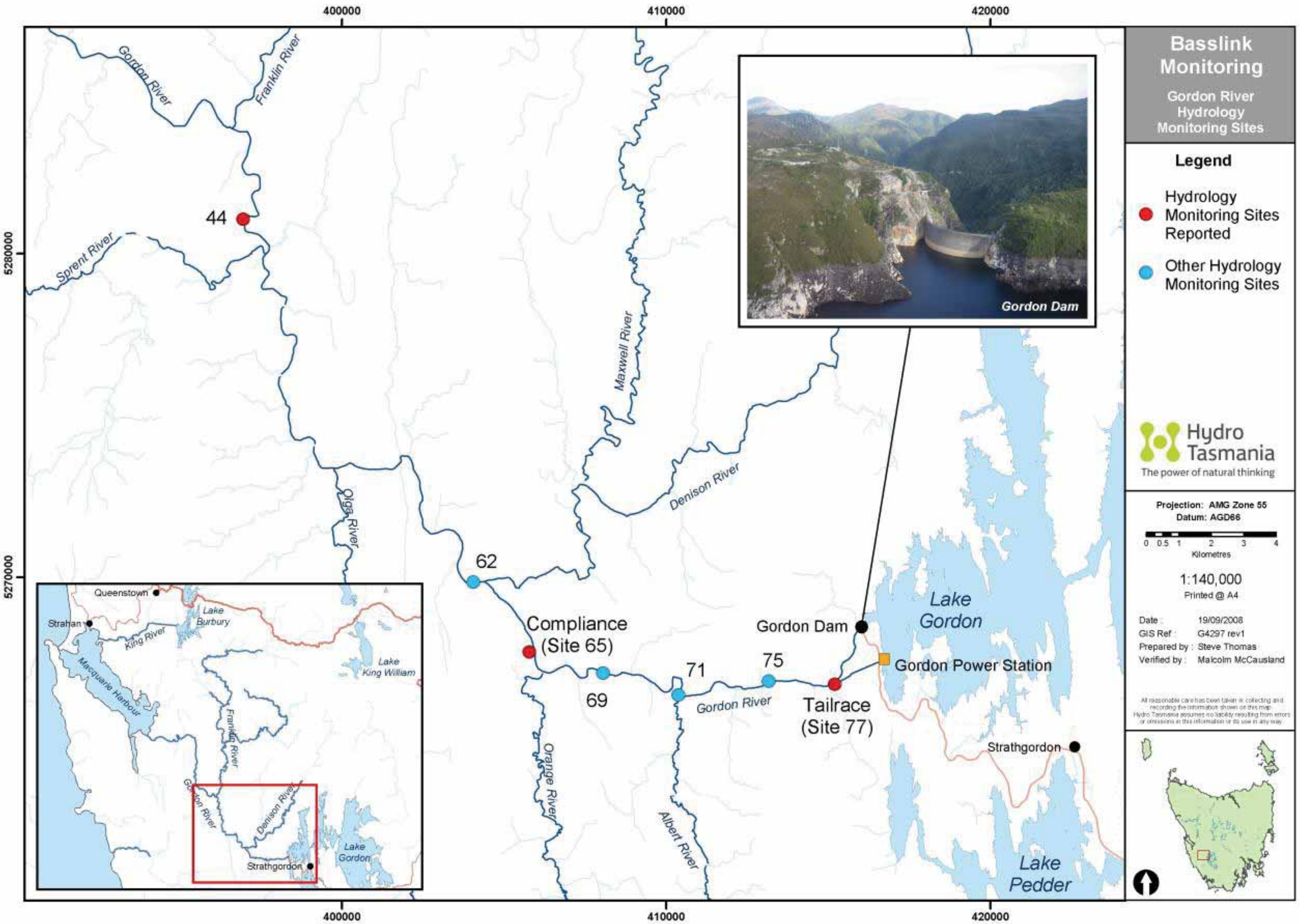
This application utilises the following input data to determine discharge from Gordon Power Station:

- 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 used to record river levels during 2011–12 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 Map 2-1. The 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).



Map 2-1 Gordon River Basslink hydrology monitoring sites

## 2.4 Data analysis

### 2.1.1 General flow analysis

For 2011–12, 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 and are discussed in section 2.5.2. 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. These 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 2011–12 year to the long-term average at that site. It could be argued that only data from the pre-Basslink period (2001–05) should be used to ensure a strict comparison with the baseline period, however longer datasets are considered a more representative comparison. 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.

### 2.1.2 High flow change frequency analysis

Analysis of changes in flow in the 2–3 turbine operation previously presented in the 2010–11 Annual Report (Hydro Tasmania, 2011) have been updated to include the most recent data. 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 4 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.

### 2.1.3 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

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

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 2011–12.

### 2.1.4 Ramp-down rule

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

This work to develop a new rule began in response to the finding that the original ramp-down rule did not achieve its aim of reducing seepage erosion (Koehnken 2008, Rutherfurd 2009). Work was undertaken to investigate the most environmentally and operationally appropriate rule to be implemented. This work included:

- the development of a newly calibrated SEEP-W model, which was used to investigate the possible impacts of varying operations and ramping scenarios on bank stability (Entura 2010)
- the undertaking of field monitoring trials to test selected results of the modelling under a range of operational scenarios including peaking operation, and ramping at different rates. This work also identified the critical bank saturation level of 2.75 m at which seepage erosion would occur (Koehnken 2011); and
- the development of a robust regression model that accurately predicts the saturation level of the banks by utilising available real-time discharge data from Gordon Power Station (Appendix 2).

The rule utilises a Bank Saturation Regression Model to determine when the 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 bank saturation prediction is based on a robust relationship that was established through above modelling work undertaken during 2011–12 (Appendix 2) and the field confirmation that the critical level of bank saturation is 2.75 m (Koehnken 2011). This field work also showed that only minimal seepage erosion was apparent at flow reductions of

45 $m^3 s^{-1}$ per hour. This average flow reduction can be achieved through the reduction in power station generation of 1 MW per minute.

The improved rule were approved by the Minister and implemented from 1 April 2012.

#### *2.1.4.1 Ramp-down rule—July 2011 to March 2012*

The ramp-down rule applicable for 1 July 2011 to 31 March 2012 was as follows:

- if water is discharged from the Gordon Power Station at a rate above 180 cumecs for greater than 65 minutes, then the reduction in that discharge to less than 150 cumecs must:

  (a) occur at a rate of no more than 30 cumecs in any 60 minute period; or

  (b) where that reduction has not commenced from the highest discharge, hold discharges at 150 cumecs until the end of the Ramp Compensation Period (defined below).

There are allowances made within the licence for breaches of the rule as follows:

- allowable tolerances are defined as periods where:

  (a) flow is reduced to 145 $m^3 s^{-1}$ for no longer than 25 minutes;

  (b) flow is reduced to 136 $m^3 s^{-1}$ for no longer than 15 minutes; and

  (c) where the ramping rate is no more than 35 $m^3 s^{-1}$ for one 60-minute period.

- the Ramp Compensation Period is defined as the period ending at the latest point in time calculated by reducing discharges by 30 $m^3 s^{-1}$ in any 60-minute period, for each dispatch interval (five-minute period), in the three hours prior to a reduction.

The analysis of ramp-down rule exceedance events performed for 2010–11 (Hydro Tasmania 2011) was used again for the 2011–12 analysis for the period 1 July 2011 to 31 March 2012. This method analysed data generated by the most accurate flow rating (see section 2.2, the GordonFlowApp).

Results are presented in section 2.1.7.6.

#### *2.1.4.2 Ramp-down rule—April to June 2012*

The improved ramp-down rule, applicable for 1 April to 30 June 2012, 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 $m^3 s^{-1}$.

# 2.5 Results

## 2.1.5 Data availability

Data was collected at all the flow measurement sites. There were some periods of missing data in excess of two days at some sites, which are indicated in Table 2-1. One significant period of data was missing from site 44 (83 days from July–September 2011). This data is missing as a result of instrument error involving the snagging of the float used to measure water level at a height above the water level in the stilling well.

Table 2-1 Data availability for water level sites on the Gordon River 2011–12

| 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 25/02/12 |
| 71 | Gordon River below Albert (G5A) | none | --- | Nil. |
| 69 | Gordon River above 2nd Split (G6) | none | --- | Nil |
| 65 | Gordon above Denison (compliance site) | none | --- | Nil |
| 62 | Gordon River below Denison | none to last download | --- | Data manually downloaded. Currently available to 26/02/12 |
| 44 | Gordon River above Franklin | 1 July –21 September 2011 | Float caught and hanging above true water level | Nil |

## 2.1.6 General analysis

### *2.1.6.1 System yield*

The inflows to Hydro Tasmania’s state-wide system during the 2011–12 was lower than 2010–11. The total system inflows (system yield) of 9538 GWh were equivalent to the long-term mean (1976–2011). The inflows in 2011–12 was greater than the hydro generation which allowed for the continued increase in the system storage and Lake Gordon in particular.

Figure 2-4 shows the total system yield during 2011–12 compared with the long-term (1976–2010) median, 20th and 80th percentile inflows.

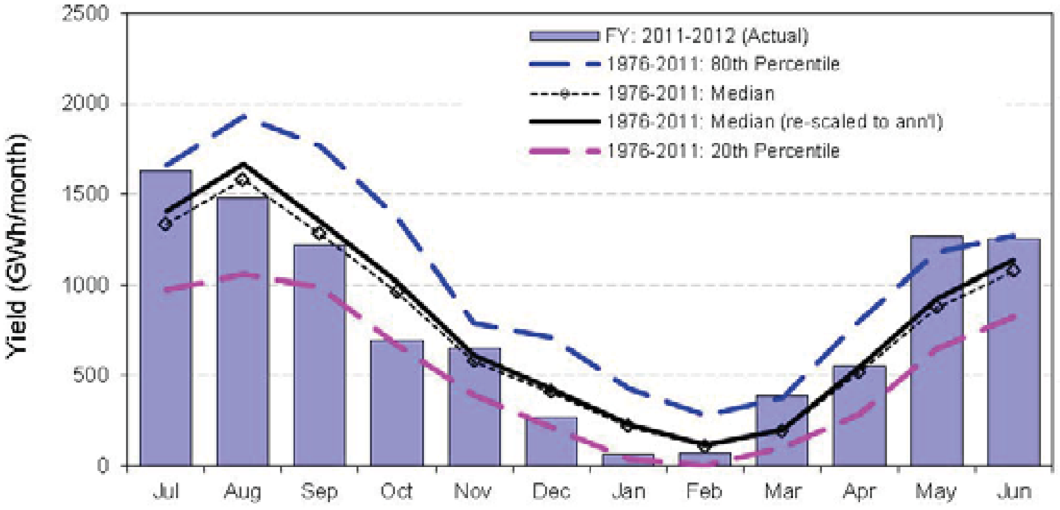


Figure 2-4 Monthly total system yield for 2011–12 compared to the long-term median, 20th and 80th percentiles for 1976–2011

### 2.1.6.2 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 2011–12.

Figure 2-5 shows the total monthly and long-term average rainfall values. In 2011–12, Strathgordon received 2451 mm, which is very similar to the long-term mean (2452 mm) and median (2453 mm). The 2011–12 annual patterns of rainfall in Strathgordon were similar to the patterns of system inflows; most months had rainfalls that fell within the monthly 20th and 80th percentiles and were similar to long-term averages.

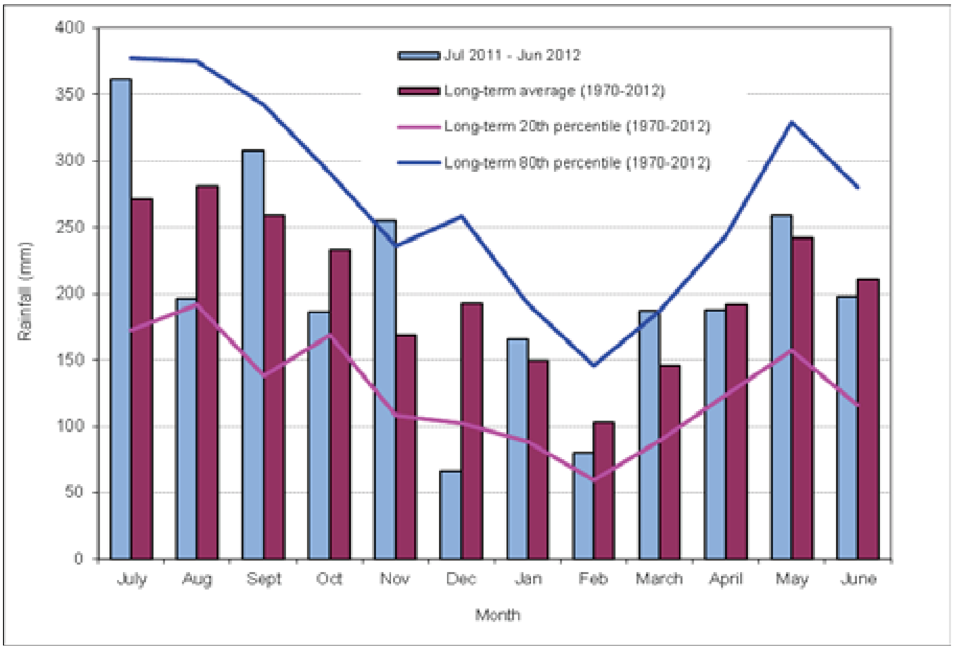


Figure 2-5 Total monthly rainfall values recorded at Strathgordon for 2011–12 compared with the long-term average (1970–2012)

## 2.1.7 Gordon Power Station

### *2.1.7.1 Discharge and power station operation*

As previously discussed, the discharge pattern for the Gordon Power Station is driven by a number of factors, including market price signals as a result of the Tasmanian energy supply/demand and inflows. Figure 2-6 shows the discharge from the power station for 2011–12. For a more detailed view of the graph month by month, please refer to Appendix 1. A summary of significant points of interest in the 2011–12 discharge data is as follows:

- the discharge from Gordon Power Station was very low;
- the net market energy output in 2011–12 from Gordon Power Station was the lowest on record (1996–2011) at 263 GWh. This was only 21% of the average annual generation (1996–2012) of 1253 GWh (Figure 2-2);
- in July and August 2011, the operation was typified by a regular peaking pattern between low (20–30 $m^3 s^{-1}$) and mid-high (150–230 $m^3 s^{-1}$) discharges;
- in the period from September 2011 to March 2012, the discharge pattern was characterised by low flow between 20–50 $m^3 s^{-1}$ with occasional peaks in flow that were mostly less than 150 $m^3 s^{-1}$. There were rare occurrences of short duration flows in excess of 150 $m^3 s^{-1}$ in early August 2011 and early February 2012; and
- there was a period of greater flow variability in April–June 2012, where more regular hydro-peaking to moderate discharges (100–180 $m^3 s^{-1}$) occurred.

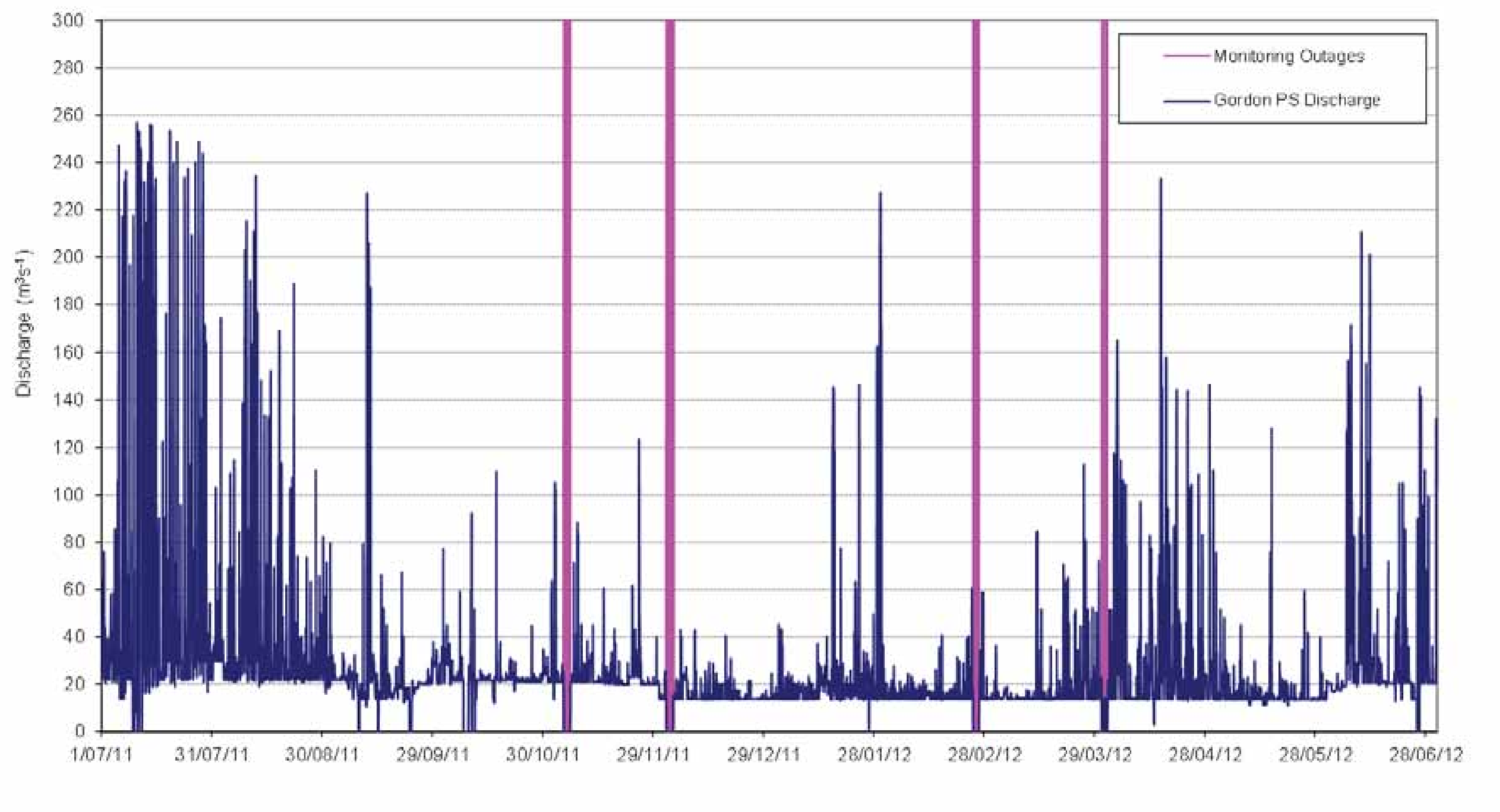


Figure 2-6 Gordon Power Station discharge (hourly data) from July 2011 to June 2012. Vertical lines indicate monitoring events and seepage trial monitoring

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 the third turbine 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. This data indicates that in 2011–12, there was minimal use of the third turbine compared to all previous operations. The use of a single turbine for over 74% of the time in 2011–12 is indicative of the minimal generation at Gordon Power Station, and consequently historically low annual discharge.

Table 2-2 Percentage of time that each configuration of turbines was in operation during 2011–12, in each of the financial years post-Basslink and in all previous records

| **Configuration** | | **Percentage of time operating** | | | | | |
|---|---|---|---|---|---|---|---|
| | **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 11** |
| 0 turbines running | 2.8 | 6.9 | 2.6 | 3.1 | 7.5 | 3.6 | 12.7 |
| 1 turbine running | 74.8 | 42.0 | 33.1 | 34.3 | 22.7 | 9.0 | 25.7 |
| 2 turbines running | 17.3 | 24.5 | 49.9 | 38.1 | 30.8 | 40.1 | 32.4 |
| 3 turbines running | 5.1 | 26.6 | 14.4 | 24.5 | 39.1 | 47.3 | 29.2 |

Table 2-3 Summary information on discharge, weather conditions, market volatility and outages for 2011–12. 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 | Market volatility, inflows and outages | Basslink Net Import (GWh) (negative = export, positive = import) |
|---|---|---|---|---|---|---|---|
| July 2011 | 1.9 | 36.7 | 33.4 | 28.0 | >average | Low market volatility, Poatina station out of service for maintenance and above average yield | -117 |
| August 2011 | 0.0 | 44 | 42.7 | 13.3 | <average | Low market volatility, Poatina station out of service for maintenance and above average yield | -48 |
| September 2011 | 4.0 | 83.2 | 11.4 | 1.4 | >average | Low market volatility, Poatina station return completed by middle of month just under average yield | -62 |
| October 2011 | 5.0 | 78.2 | 16.5 | 0.3 | <average | Low market volatility, below average yield | 121 |
| November 2011 | 5.8 | 75.7 | 16.9 | 1.5 | wet | Low market volatility, above average yield | 86 |
| December 2011 | 5.9 | 86.0 | 8.1 | 0.0 | dry | Low market volatility, below average yield | 136 |
| January 2012 | 0.0 | 88.7 | 7.4 | 3.9 | >average | Low market volatility, below average yield,<br>Derwent scheme outages which results in high Poatina running | 179 |
| February 2012 | 5.9 | 91.9 | 2.2 | 0.0 | <average | Below average yield.<br>Derwent outages continue which results in high Poatina running. Wetter cooler weather on mainland results in low market volatility | 116 |
| March 2012 | 1.8 | 88.3 | 9.8 | 0.1 | wet | Low market volatility, above average yield. John Butters extended outage for maintenance results in high Poatina running | 82 |

Table 2-3 *continued next page*

| Period | 0-turbine operation % time | 1-turbine operation % time | 2-turbine operation % time | 3-turbine operation % time | Strathgordon rainfall | Market volatility, inflows and outages | Basslink Net Import (GWh)<br>(negative = export, positive = import) |
|---|---|---|---|---|---|---|---|
| April 2012 | 2.4 | 64.4 | 29.9 | 3.3 | <average | Above average yield, market a little more active with coal and plant issues in Victoria. John Butters remains out of service which results in high Poatina running. Network Special protection scheme taken out of service due to design issues this restricts generation in West and North West | -94 |
| May 2012 | 0.0 | 93.5 | 6.2 | 0.3 | >average | Above average yield, low market volatility. John Butters remains out of service. West and North West generation still restricted which results in high Poatina running | 26 |
| June 2012 | 1.3 | 68.3 | 22.4 | 8.1 | <average | Above average yield<br>John Butters returned to service. West and North West generation still restricted. Market volatility increased | -148 |

Table 2-3 continued

#### 2.1.7.2 *Power station outages*

There were five power station maintenance outages in 2011–12. Four of these were only a few hours' duration. There was one longer power station maintenance outage, which took place on 8–9 October which lasted 34 hours.

Basslink monitoring power station outages took place on:

- 4–6 November 2011;
- 2–4 December 2011;
- 24–26 February 2012; and
- 31 March–1 April 2012.

#### 2.1.7.3 *Median monthly discharge*

Figure 2-7 shows the median monthly discharge from the power station for 2011–12 compared with long-term values (since January 1997) and the previous five years of the post-Basslink period. This figure illustrates that median discharge was significantly lower than usual for most of the reporting year. The only months when discharge was similar to the long-term median was in July to October 2011. These months correspond to those periods when discharge is usually lower.

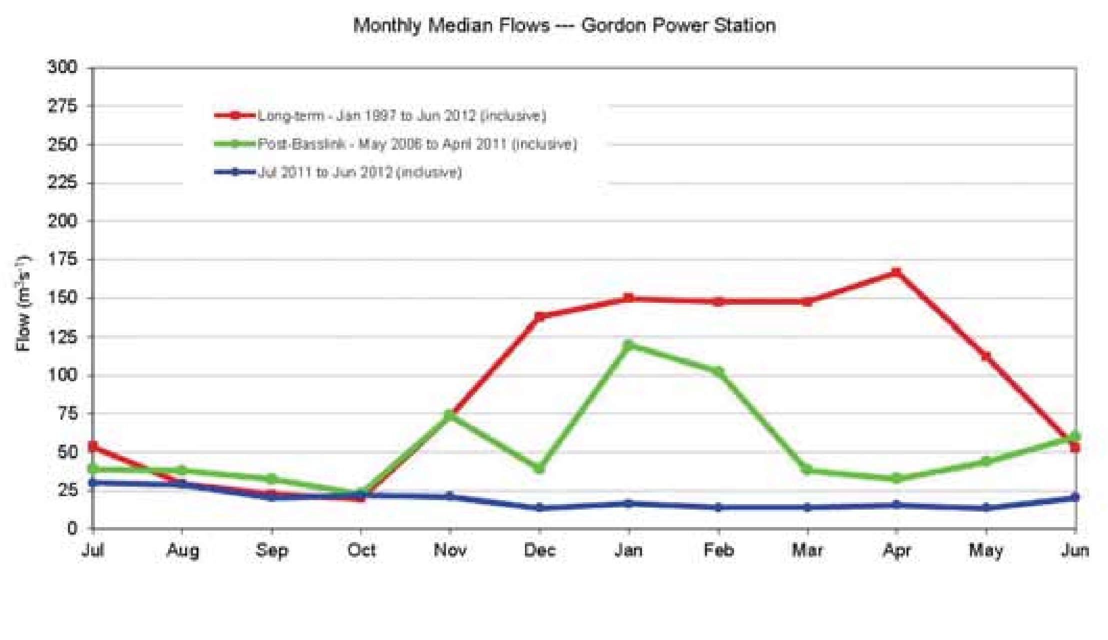


Figure 2-7 Median monthly discharge from the Gordon Power Station (site 77) for 2011–12 compared with long-term median values and previous post-Basslink years

#### 2.1.7.4 *Flow duration curves*

Figure 2-8 to Figure 2-11 show the duration (percentage exceedance) curve for the power station discharge for:

- annual data;
- winter period (May–October);
- summer period (November–April); and
- years one to six of post-Basslink annual data.

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 2012);
- 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 2011) prior to the current year ; and
- 2011–12 financial year (1 July 2011–30 June 2012).

The annual 2011–12 discharge (Figure 2-8) was low for most of the year, relative to long-term, historical and all previous post-Basslink years. In 2011–12 flow discharges less than 30 $m^3 s^{-1}$ were observed for 85% of the time. In comparison, only 35% of discharges over the long-term record are less than 30 $m^3 s^{-1}$. The median discharge in 2011–12 was 20 $m^3 s^{-1}$ compared to the historic, pre-Basslink (2001–05), long-term and post-Basslink median discharges of 120 $m^3 s^{-1}$, 119 $m^3 s^{-1}$, 79 $m^3 s^{-1}$ and 44 $m^3 s^{-1}$, respectively. There were 1% of flows in 2011–12 that exceeded 180 $m^3 s^{-1}$. It was significantly lower than long-term (20%), historical (22%), and pre-Basslink (30%) flow durations >180 $m^3 s^{-1}$.

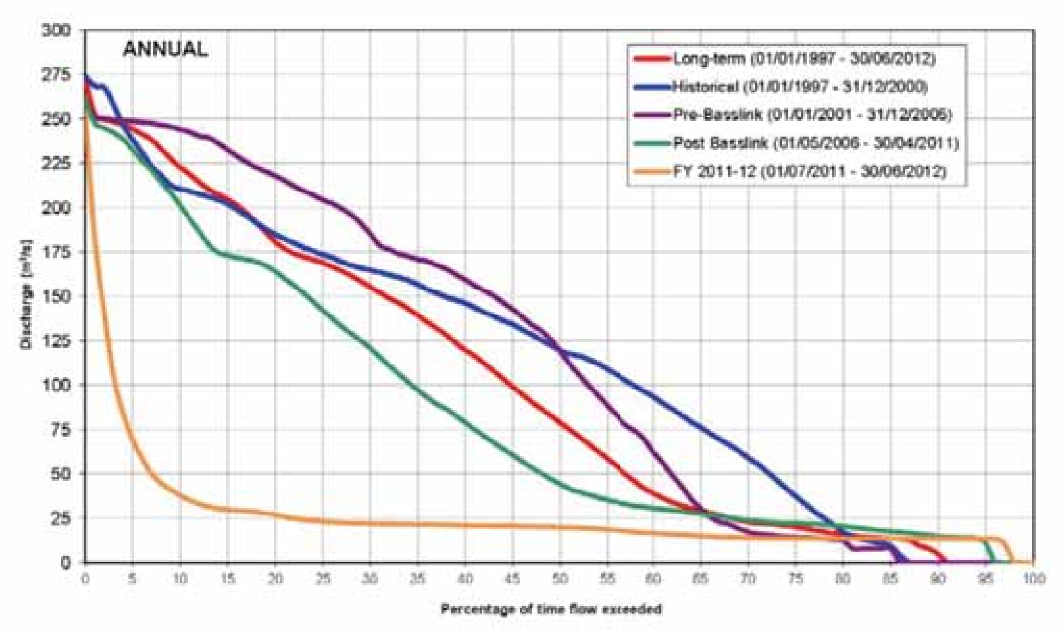


Figure 2-8 Duration curves for discharge from the power station tailrace using annual data for selected periods

The 2011–12 winter duration curve was very different to that of the duration curves for all periods to which it is compared. The majority of flows are lower across all percentiles in 2011–12 in comparison to previous winter duration curves. The median flow value of 22 $m^3 s^{-1}$ was lower compared to a long-term winter median of 35 $m^3 s^{-1}$, but similar to the pre-Basslink winter median of 24 $m^3 s^{-1}$ (Figure 2-9). There was significantly less time where discharges were >180 $m^3 s^{-1}$; 1.8% in 2011–12 compared to 10% for the long-term. This was also lower than the combined post-Basslink years (2006–11), which had 5% of flows >180 $m^3 s^{-1}$.

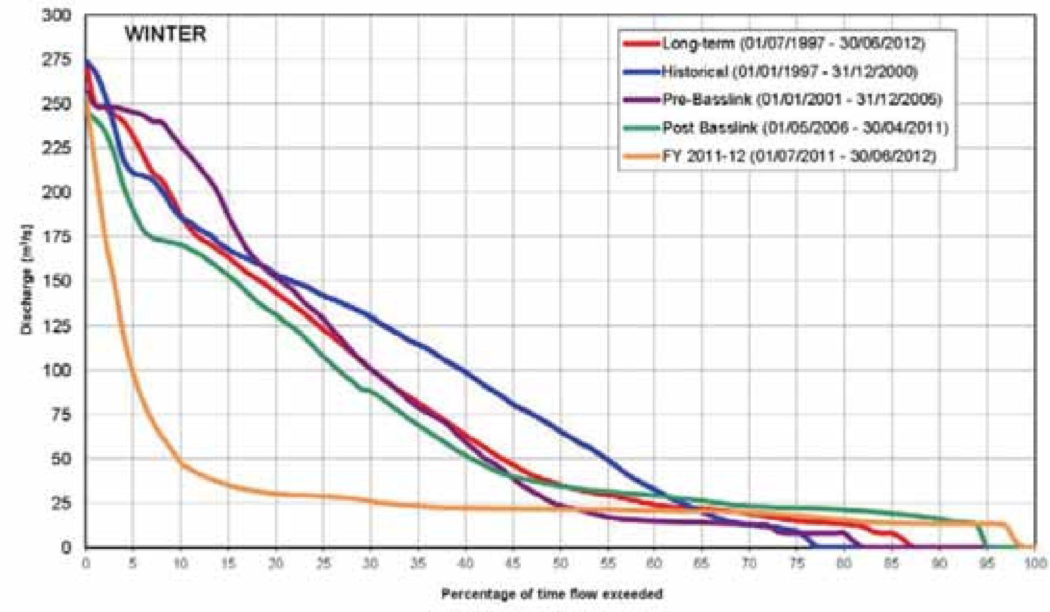


Figure 2-9 Annual duration curves for discharge from the Gordon Power Station using winter data (for the months of May to October inclusive) for selected periods

The 2011–12 summer discharge flow duration curve also differs significantly from curves for other periods (Figure 2-10). The significantly lower discharge over summer 2011–12 relative to the long-term is evident over most flow ranges. Discharges >180 $m^3 s^{-1}$ accounted for <1% of flow, which was significantly lower than the long-term of 29% of flows being >180 $m^3 s^{-1}$. Similarly, median values were lower than other periods, with the 2011–12 and long-term median discharges being 15 $m^3 s^{-1}$ and 135 $m^3 s^{-1}$, respectively.

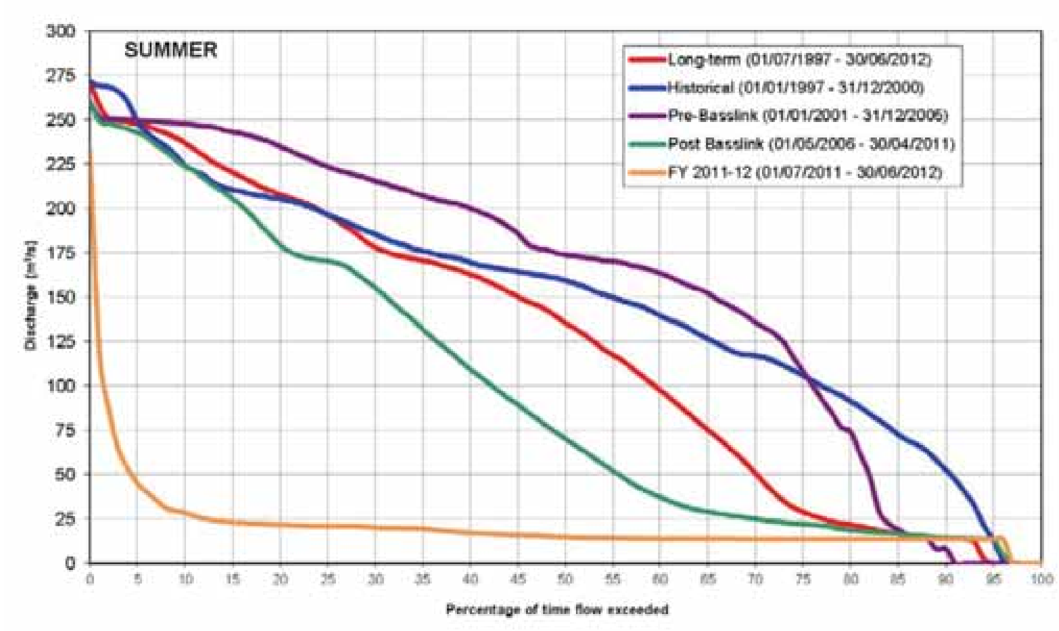


Figure 2-10 Annual duration curves for discharge from the Gordon Power Station using summer data (for the months of November to April inclusive) for selected periods

Each of the post-Basslink monitoring years have their flow duration curves represented in Figure 2-11 to compare the current 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 2011–12 differs from the annual curve in Figure 2-8 as it represents a 12-month period that is offset by two months. In comparison to each of the post-Basslink years, year six (May 2011–April 2012) had a similar flow duration curve to the previous three years (2008–09 to 2010–11). In 2011–12, the proportion of higher discharges were similar to 2010–11 and higher than 2008–09 and 2009–10. The higher proportion of high discharges in both years is related to the April–August 2011 outage at Poatina Power Station outage. The proportion of discharges >150 $m^3 s^{-1}$ were 11% in 2011–12 and 13% in 2010–11, while in 2008–09 and 2009–10 the proportion of these flows were 7% and 5%, respectively.

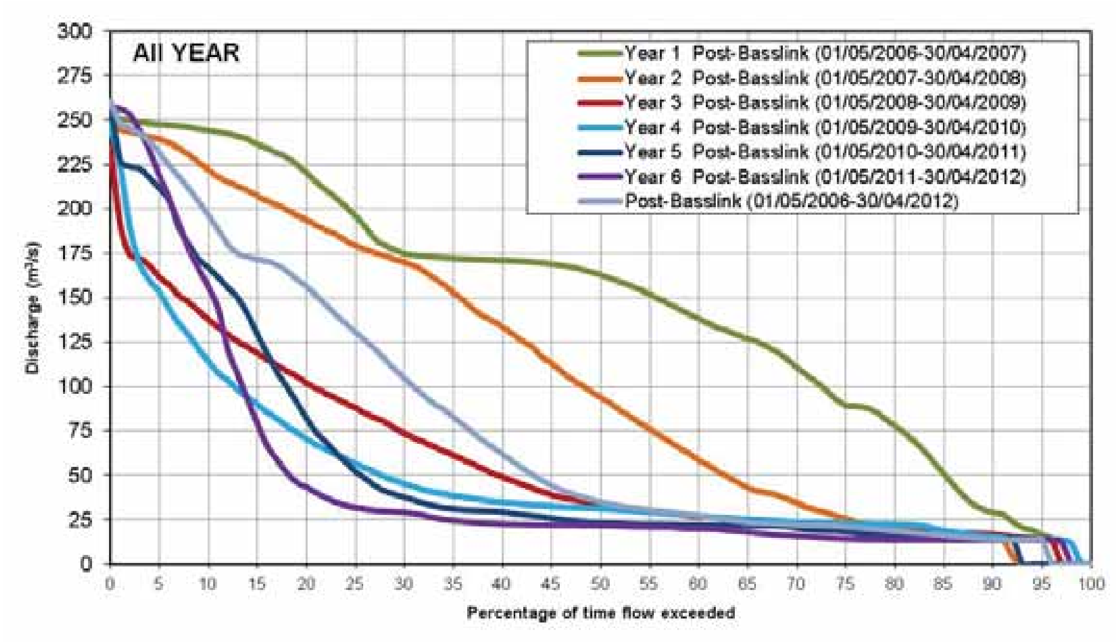


Figure 2-11 Annual duration curves for discharge from the Gordon Power Station for the first six years post-Basslink

#### 2.1.7.5 *Flow change frequency analysis*

The results of the flow change frequency analysis are shown in Figure 2-12 and Figure 2-13. The data for 2011–12 indicates that six months up to October 2011 had greater numbers of hours of rapid flow reduction than the period up to April 2011. The implementation of the ramp-down rule is evident in Figure 2-12 over this period, with the obvious flat spot between 28 and 30 $m^3 s^{-1}$. The six-month periods where flow reductions >30 $m^3 s^{-1}$ in the high discharge range (>180 $m^3 s^{-1}$) indicate that the 1 April to 1 October 2011 period had 100 hours of rapid flow reduction and 1 October 2011 to 1 April 2012 had zero hours. The April–October 2011 period was the second highest six-monthly results recorded due to the high rate of peaking in combination with high discharge. However the six months prior to April 2012 was the lowest on record, and is indicative of the very low power station operation.

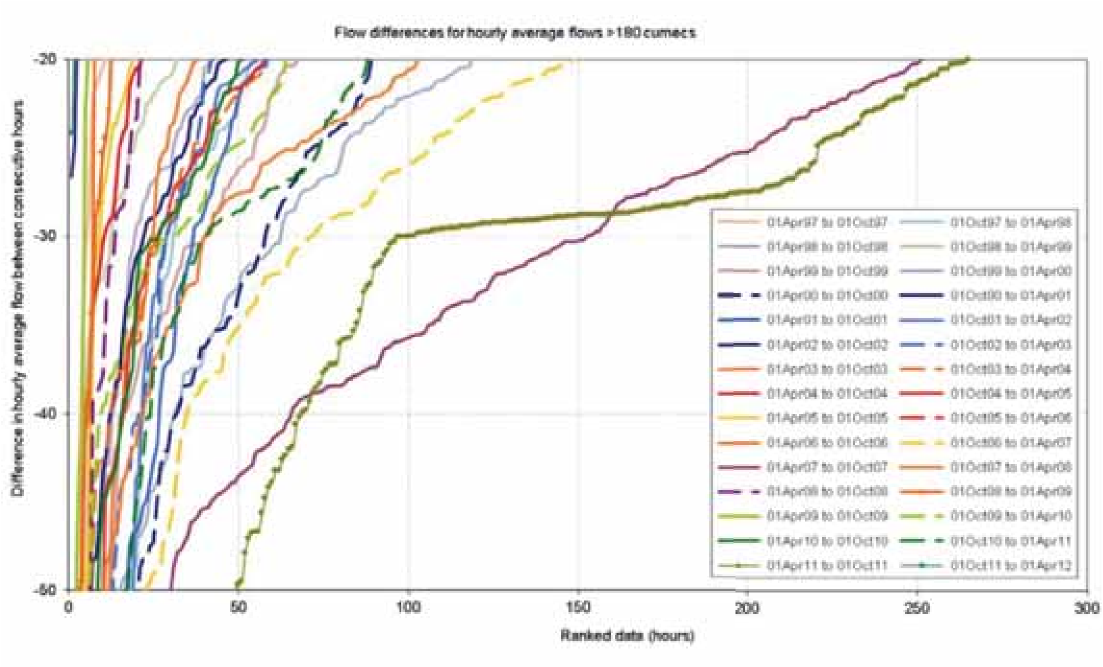


Figure 2-12 Flow change frequency plot showing the ranked rate of flow reductions data for six month periods occurring while power station discharge was greater than 180 m$^3$ s$^{-1}$ for 1997–98 to 2011–12

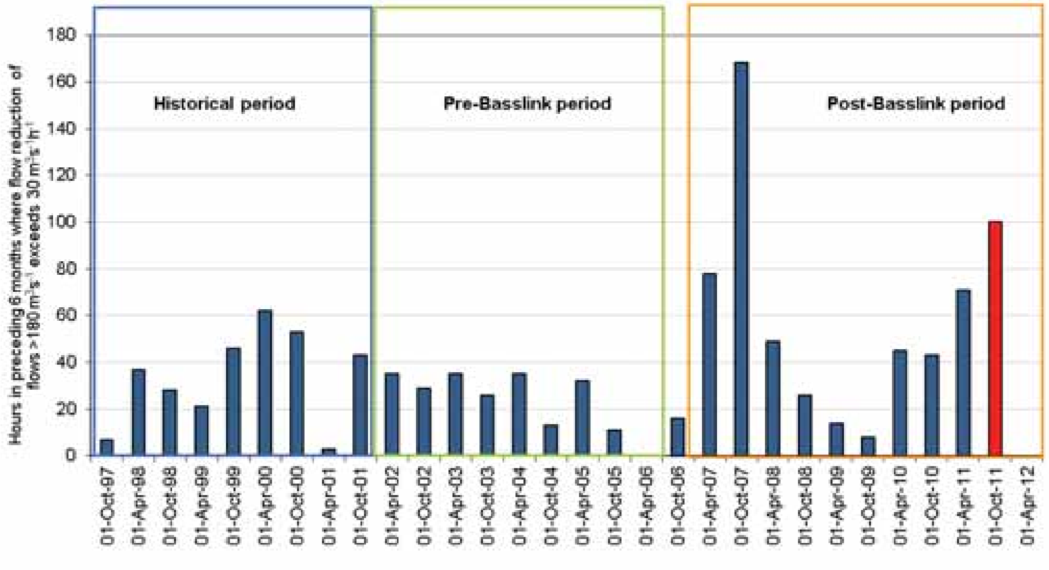


Figure 2-13 Number of hours for each prior six-month period where flow reductions from >180 m$^3$ s$^{-1}$ exceed 30 m$^3$ s$^{-1}$ per hour

### 2.1.7.6 *Flow increase ('peakiness') analysis*

Figure 2-14 presents analysis of flow increase or low flow range 'peakiness'. 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$^{-1}$. In all years for which hourly data are available, 2011–12 had a similar number of events where rapid increases following low discharge occurred (54 instances) to many previous pre- and post-Basslink years. This was significantly lower than the previous year (2010–11) which had the highest number of such rapid increases in flow (100 instances).

Rapid flow increases were most common from July and August 2011, and April and June 2012 (Figure 2-14 and Figure 2-15), and coincided with the greater flow peakiness seen in the hydrograph (Figure 2-16).

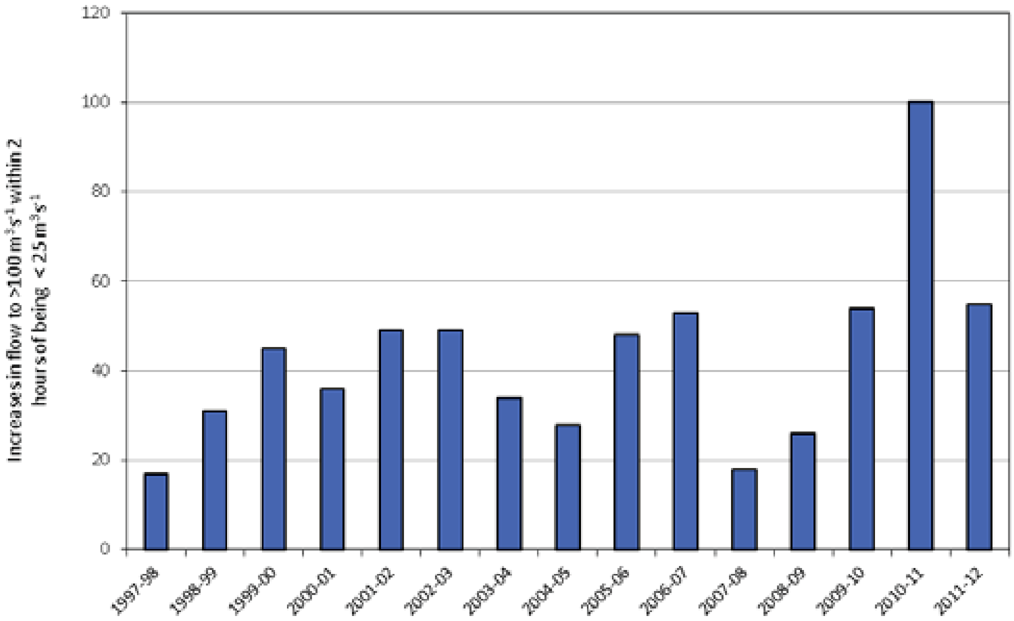


Figure 2-14 Rapid flow increases ( <25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each year where hourly data are available

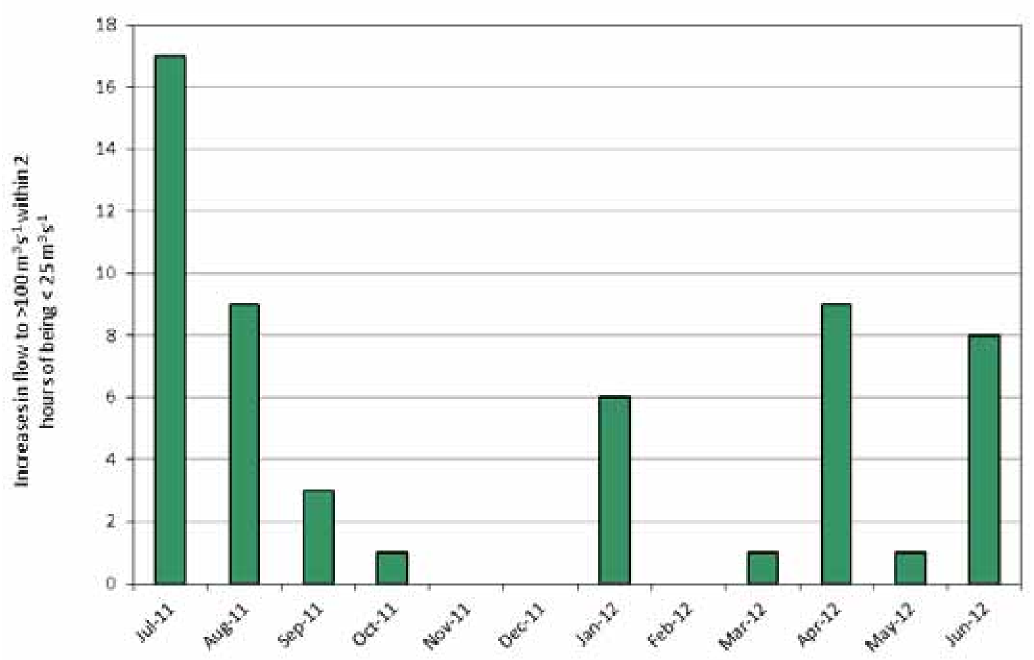


Figure 2-15 Rapid flow increases ( <25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon Power Station discharge for each month during 2011–12

### 2.1.7.7 *Conformance with ramp-down rule*

There were two ramp-down rules in place during 2011–12. The original rule, as discussed in section 2.1.4.1 was applicable from 1 July 2011 to 31 March 2012. The new rule as described in section 2.1.4.2 was brought into operation from 1 April 2012 and is based upon the saturation of the banks.

A total of 10 potential exceedences of the ramp-down rule were recorded between 1 July 2011 and 31 March 2012. Of these, one was outside the tolerances defined in the Special Water Licence Agreement. This non-conformance occurred on 24 July 2011. It occurred as a result of the operator misjudging that the power station had been discharging for more than one hour at greater than 180 $m^3 s^{-1}$. As a result, the power station discharge was reduced without ramping to below 150 $m^3 s^{-1}$.

Since the improvements to the ramp-down rule were implemented, there have been no non-conformances. Bank saturation has not exceeded 2.75 m on any occasion since 1 April 2012, and hence there has been no need to ramp flows at the prescribed 1 MW/min.

## 2.1.8 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.

#### *2.1.8.1 Flow*

Figure 2-16 shows the flow recorded at site 65 for 2011–12 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. It should be noted that in some cases, when there is little natural inflow, peaks in flow at site 65 are lower than those from the power station. It is considered than the flow attenuation that occurs between the discharge point at the power station and the 12 km distance to the compliance site is responsible for causing a reduction in the size of flow peaks.

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).

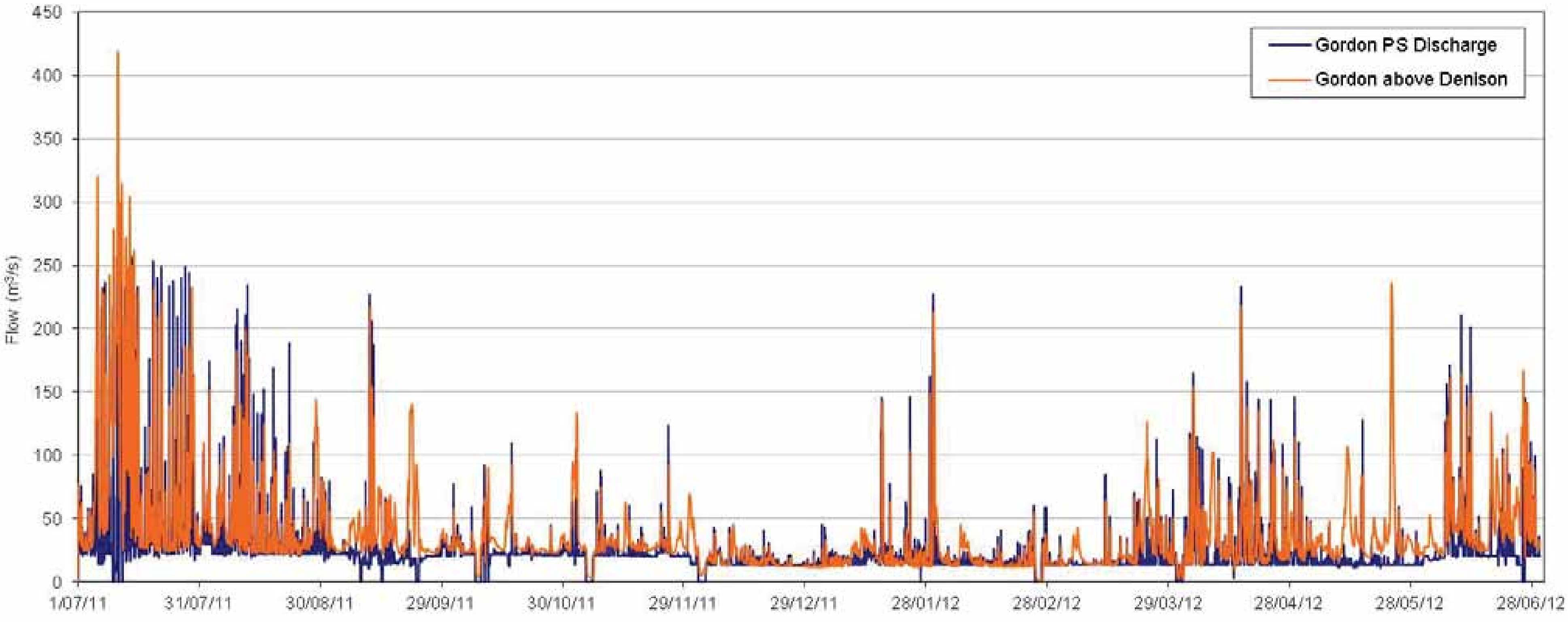


Figure 2-16 Flow recorded (hourly data) at site 65 (Gordon above Denison) showing full scale of flows, from July 2011 to June 2012

### 2.1.8.2 *Median monthly flows*

The median monthly flow for site 65 (Gordon above Denison) is shown in Figure 2-17. Comparison with historic average (2003–12) patterns shows all monthly median flows were lower than usual. A number of these were significantly lower, particularly those between December 2011 and June 2012.

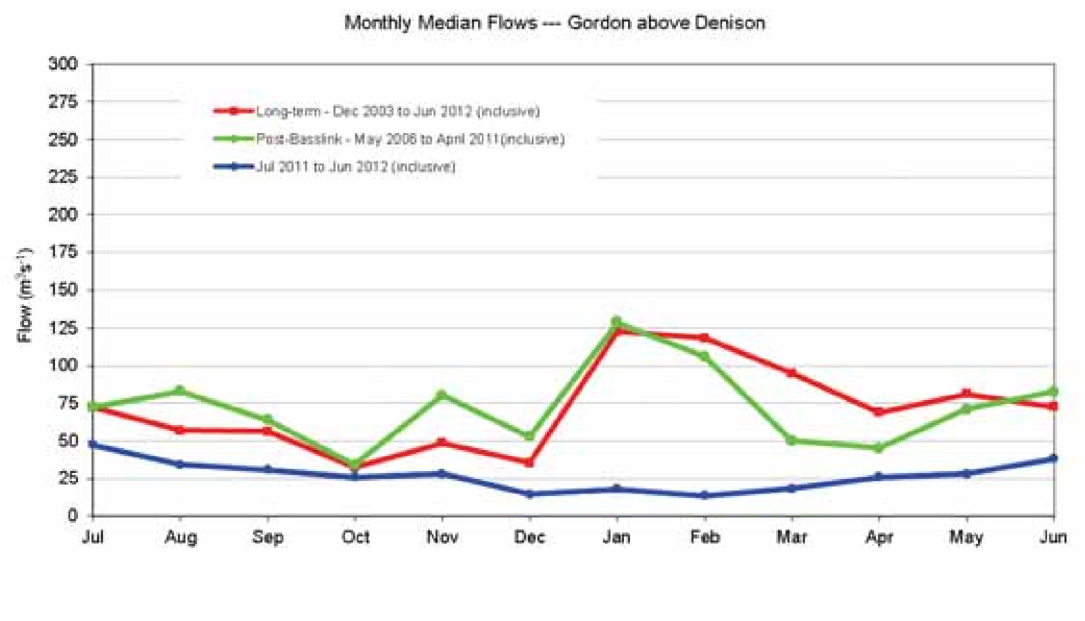


Figure 2-17 Median monthly flow at site 65 (Gordon above Denison) for 2011–12 compared with long-term median values and previous post-Basslink years

### 2.1.8.3 *Duration curves*

The duration curve for site 65 is shown in Figure 2-18. Comparison with the long-term curve shows a significantly lower flow for the 2011–12 year in most percentiles, as a result of lower power station discharge.

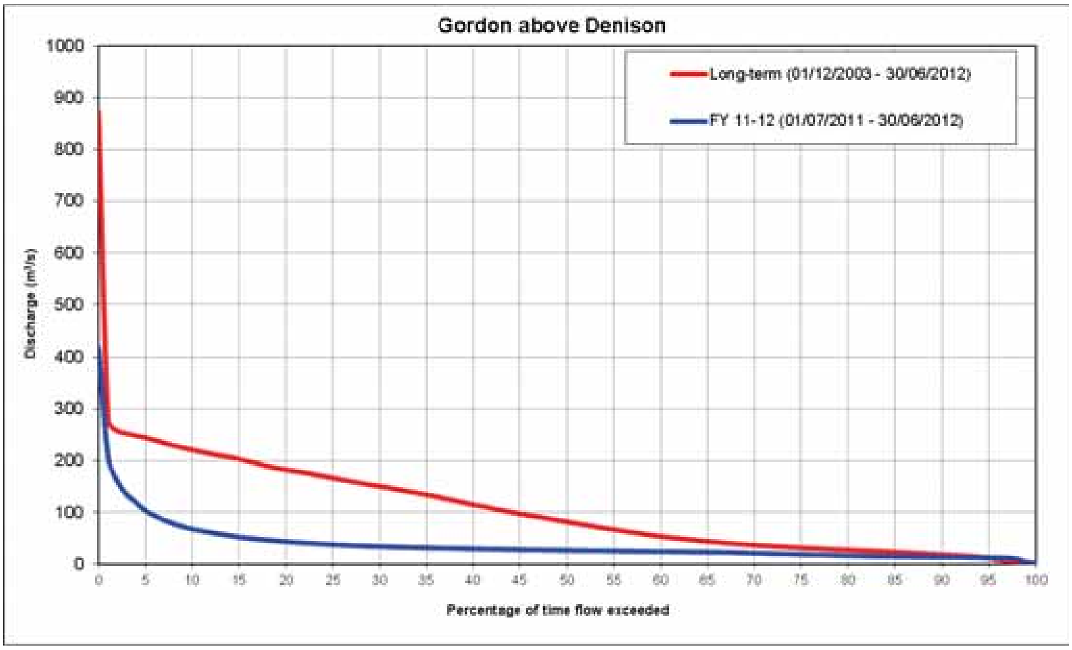


Figure 2-18 Flow duration curve for Gordon above Denison for 2011–12 compared with long-term and previous post-Basslink years

### 2.1.8.4 *Environmental flow compliance*

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

An analysis of hourly flows at site 65 (Figure 2-19) shows that for the winter periods (July–November 2011 and June 2012), the minimum flow requirement of 20 $m^3 s^{-1}$ was met 99.8% of the time. The minimum summer (December 2011–May 2012) flow requirement of 10 $m^3 s^{-1}$ was 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

| Period | Minimum environmental flow | Non-compliant hours | Compliance rate |
|---|---|---|---|
| Winter<br>(July–Oct 2011) | 20 | 7 | 99.8% |
| Summer<br>(Dec 2011–May 2012) | 10 | 0 | 100% |
| Winter<br>(June 2012) | 20 | 3 | 99.8% |

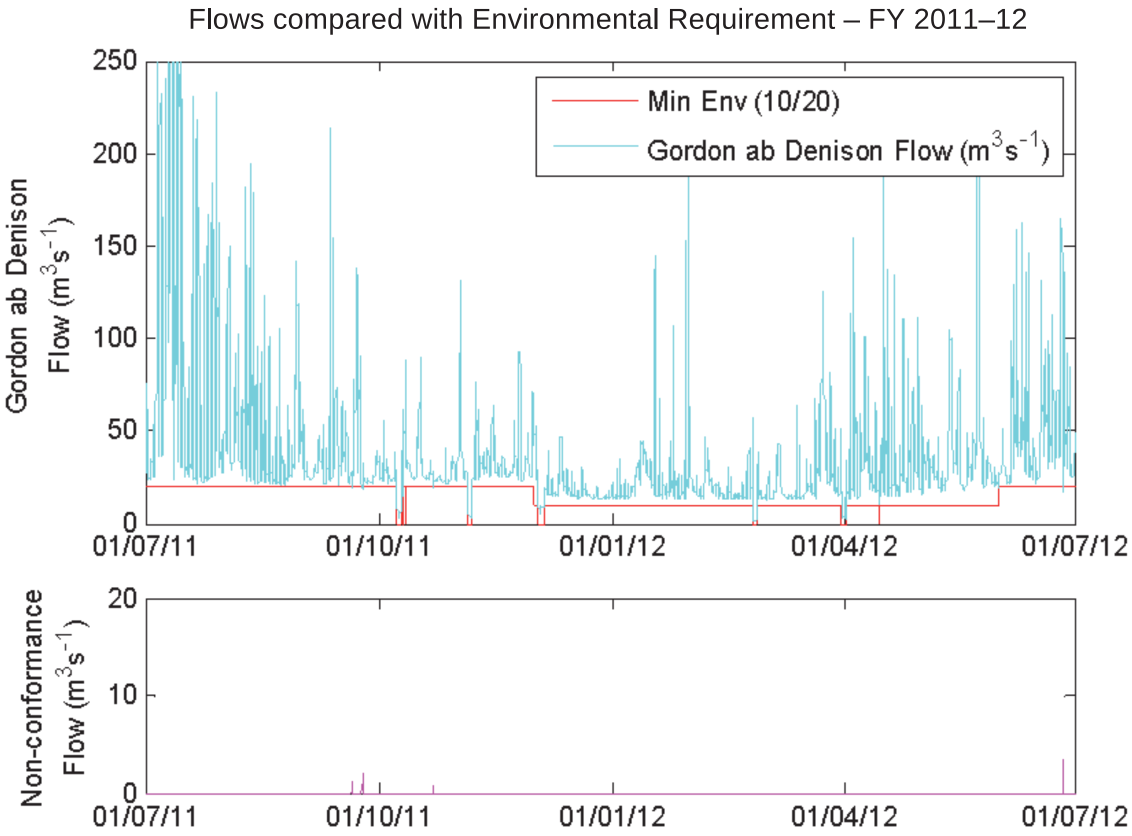


Figure 2-19 Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2010 to June 2011, and analysis of non-conforming flows

### 2.1.8.5 *Flow increase analysis*

Figure 2-20 presents analysis of flow increase or low flow range 'peakiness' at the Gordon above Denison site. This indicates, for the post-Basslink period, 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 $m^3 s^{-1}$. In 2011–12 there were 11 instances, which is a significant decrease from the previous year in 2010–11, which had 39 instances. The annual number of events is less than half of that recorded for the Gordon Power Station in most years (Figure 2-14) and this is due to the downstream attenuation of flows and tributary inputs. In 2011–12 the number of instances were even less, and were five times lower than those experienced at Gordon Power Station as a result of the attenuation.

In 2011–12, rapid flow increases were most common from July and August 2011 (Figure 2-21), and coincided with the greater flow peakiness seen in the hydrograph (Figure 2-16).

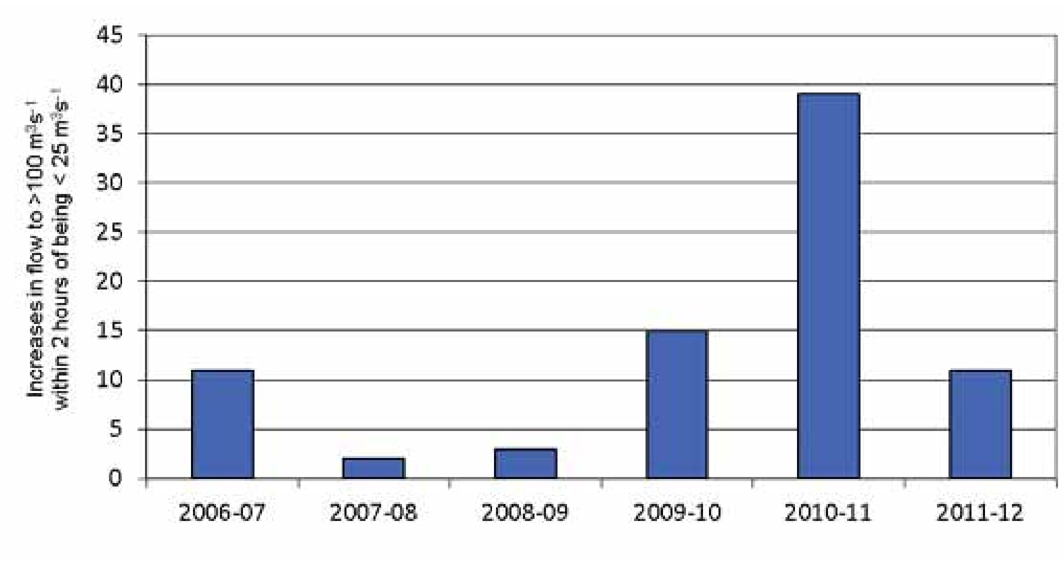


Figure 2-20 Rapid flow increases ( <25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon above Denison for each post-Basslink year

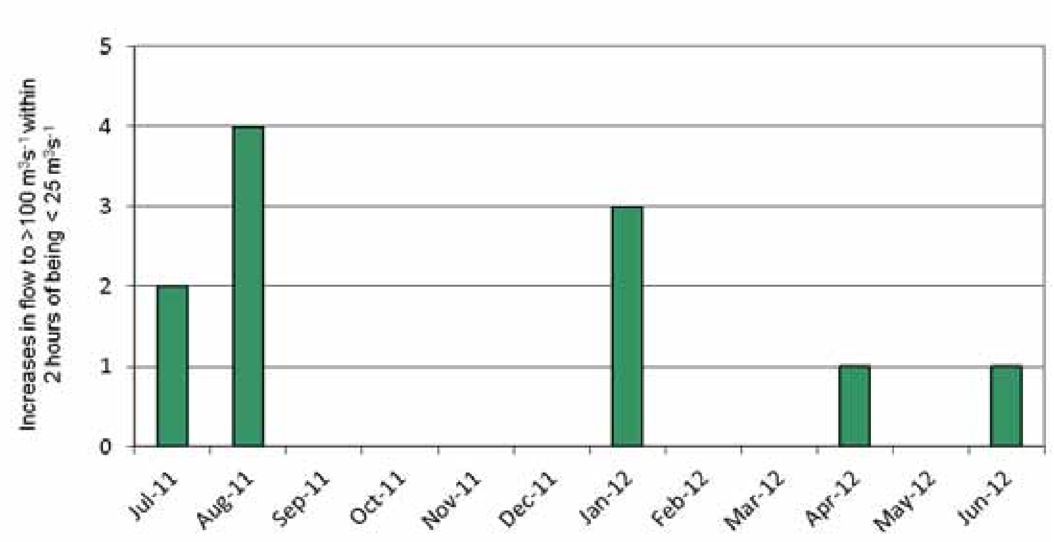


Figure 2-21 Rapid flow increases ( <25 to >100 $m^3 s^{-1}$ in two hours) at the Gordon above Denison for each month during 2011–12

## 2.1.9 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the furthest downstream monitoring site reported here. 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.

### *2.1.9.1 Flow*

Figure 2-22 shows the hourly flows at site 44 for 2011–12 compared with discharge from the Gordon Power Station. Missing data has been calculated for the period 1 July 2011 to 22 September 2011 using a relationship incorporating Gordon Power Station discharge and flows from Franklin River at Mt Fincham site.

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. Despite the inaccuracy of the rating, it can be determined that unlike previous years, power station discharge was not the dominant flow component at site 44. Instead, there was a clear divergence between the two hydrographs that is indicative of the dominance of tributary flows (i.e. Denison River) for most of the year. The maximum flow of 959 $m^3 s^{-1}$ for the year occurred in July 2011. This flow event was determined by calculation.

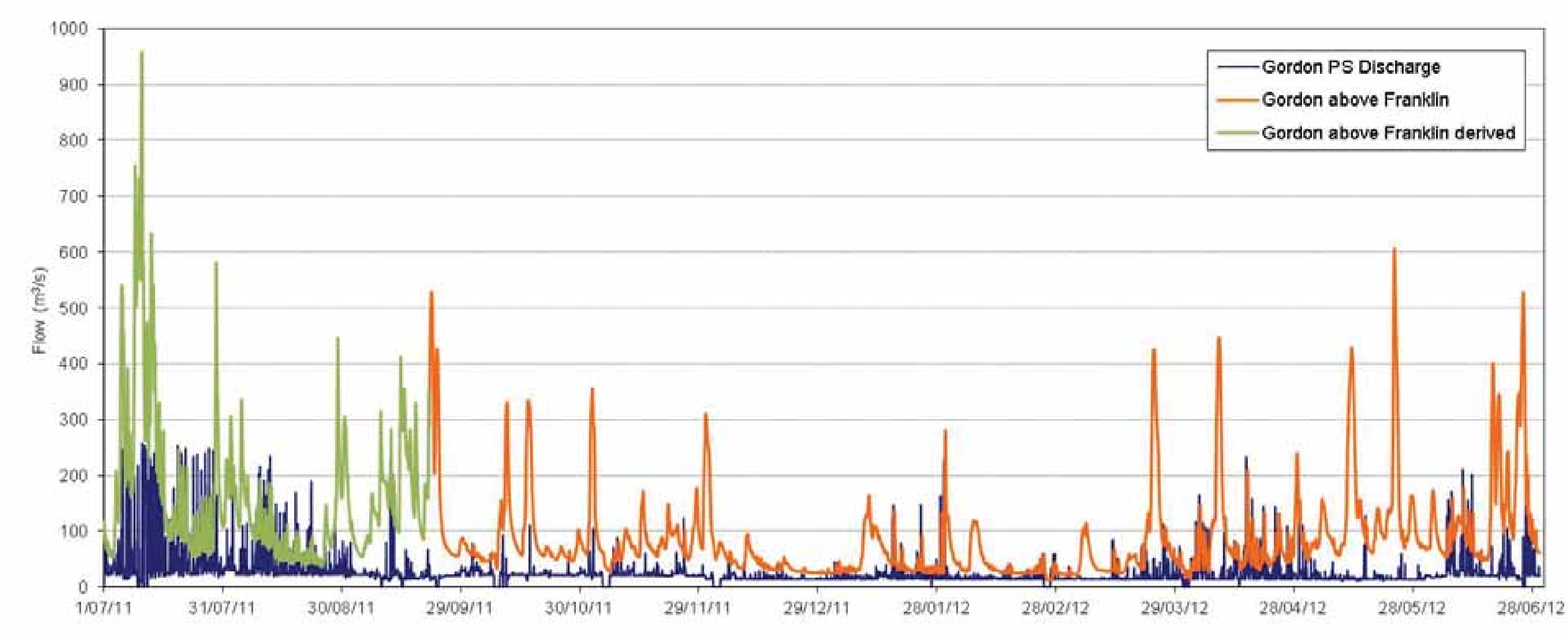


Figure 2-22 Flow recorded (hourly data) at site 44 (Gordon above Franklin) and Gordon Power Station discharge derived from the simplified three-dimensional rating during 2011–12

### *2.1.9.2 Median monthly flows*

Figure 2-23 shows the median monthly flow for the data at site 44 over the 2011–12 year, compared with the long-term post-dam (since January 1978) patterns. All months were lower than the long-term median. The most notable of these were December 2011 to May 2012, which were significantly below the long-term medians as a result of seasonally low power station use.

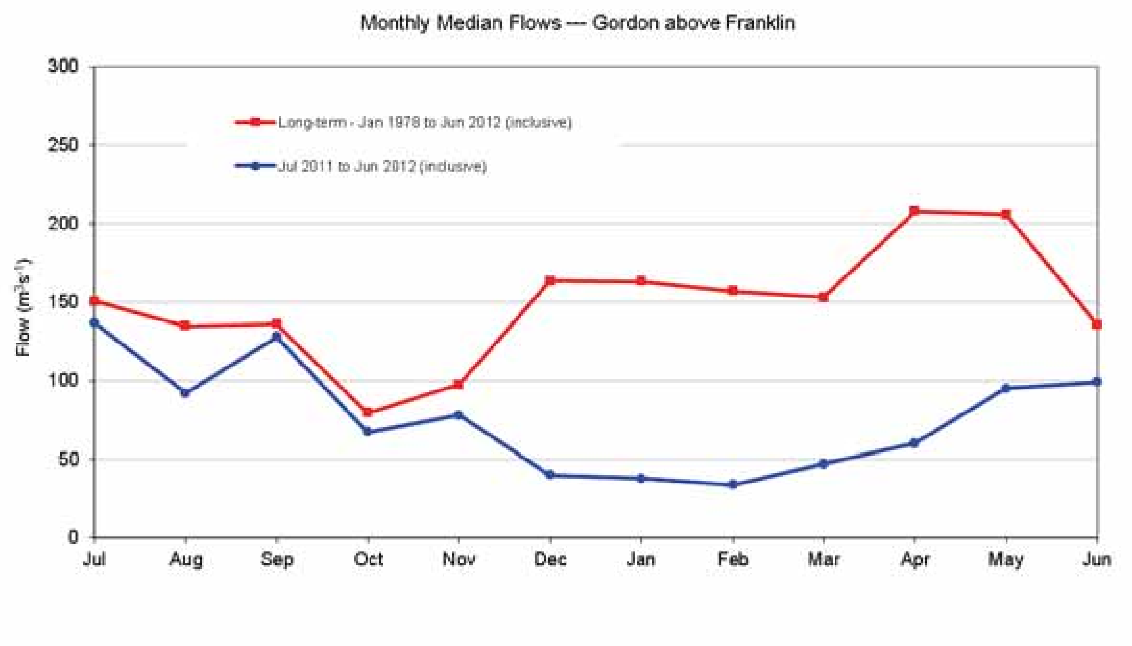


Figure 2-23 Median monthly flow at site 44 (Gordon above Franklin) for 2011–12 and the long-term monthly median values

### *2.1.9.3 Duration curves*

The duration curve for site 44 is shown in Figure 2-24 and incorporates the period of calculated data for July–September 2011. Comparison with the long-term curve is indicative of the significantly lower flows for the year, as a result of lower flows from the power station. The duration curve is more indicative of the natural tributary inflows above this site.

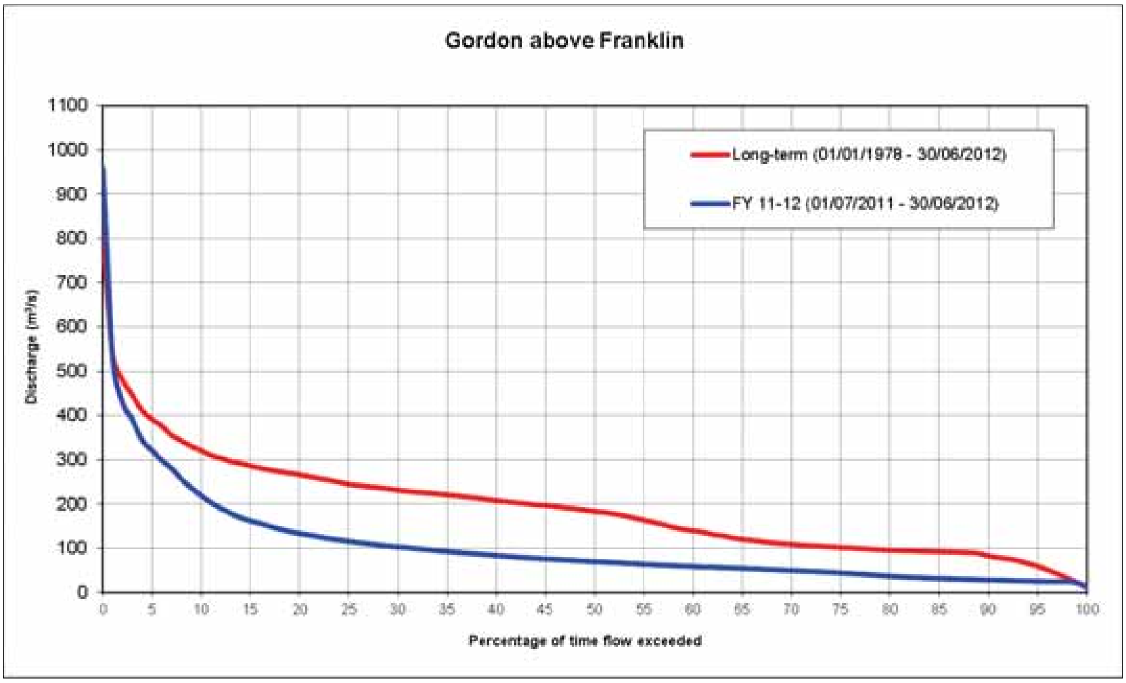


Figure 2-24 Duration curve for flow at site 44 (Gordon above Franklin)

## 2.6 Conclusions

The year was influenced by the relatively low operation of the power station as a result of prevailing market conditions.

The discharge from Gordon Power Station consisted of periods of regular hydro-peaking in July and August 2011 at levels corresponding to three-turbine operation. The months of April and June 2012 also had some periods of peaking operation that generally corresponded to two-turbine operation. However, as most of the year was dominated by the release of the environmental flow, the remaining part of the year had little peaking.

There was one non-conformance with the ramp-down rule outside the acceptable tolerances defined in the Special Water Licence were recorded for the period July 2011 to March 2012.

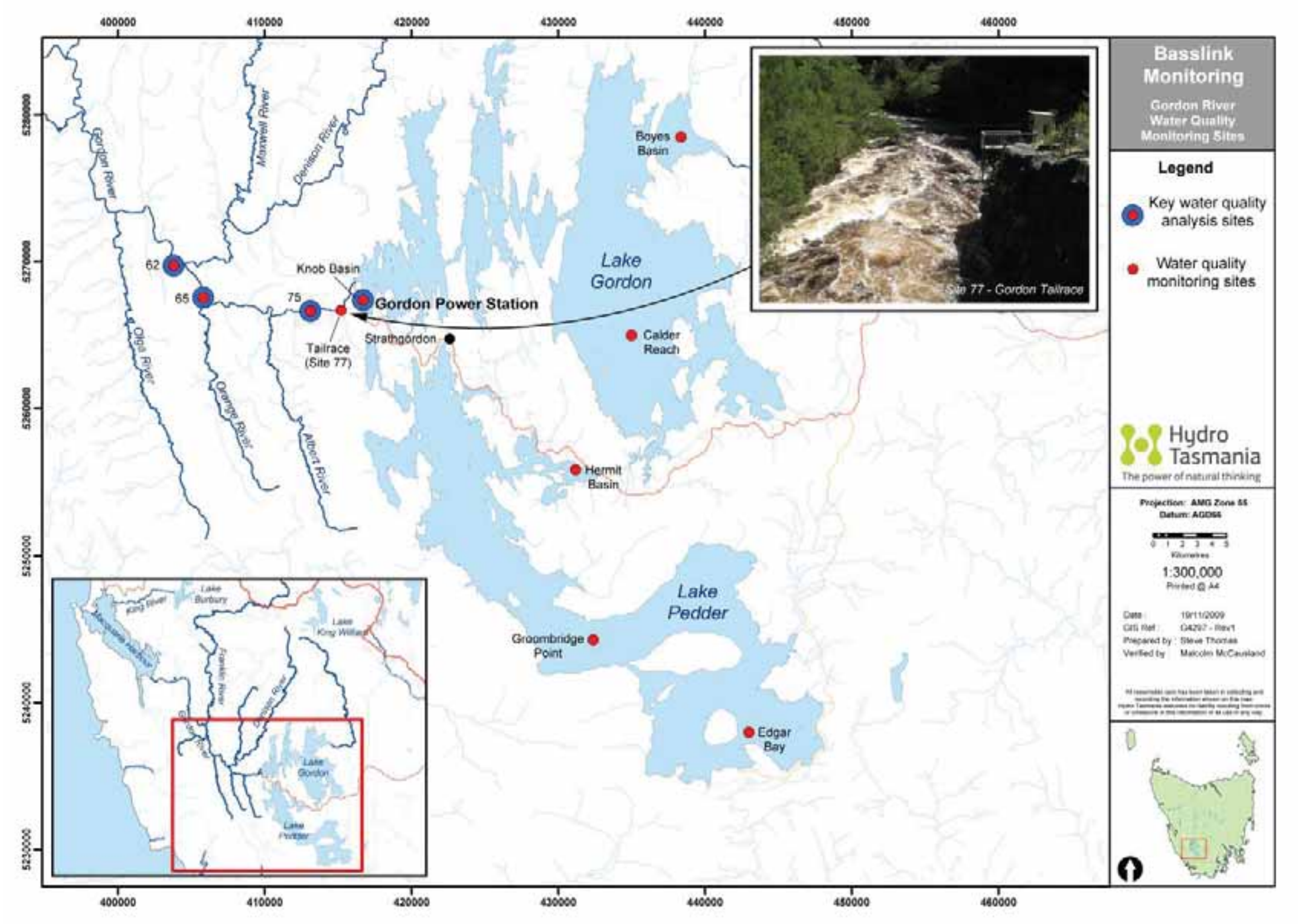
The minimum environmental flow was achieved 100% of the time in summer, while there was a total of 10 hours in the two separate winter periods when the environmental flow was not met. These accounted for a winter compliance rate of 99.8%.

Flow patterns at downstream sites were reflective of flows from the power station with lower flows in 2011–12 the most noticeable feature of the year. A significantly greater proportion of flows originated from tributaries as a result of the low power station discharge.

# 3 Water quality

Water quality parameters were measured in Lake Gordon and Lake Pedder, and in the Gordon River downstream of the power station between July 2011 and June 2012. The water quality monitoring sites are shown in Map 3-1.

Lake Gordon is a major source of water for the middle reaches of the Gordon River; the quality of water in the river is influenced by the conditions at the power station intake and the flow regime in the river. There are no trigger values for water quality, however water quality information is collected and reported to assist in the interpretation of biological monitoring data from the middle Gordon River.



Map 3-1 Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon and the Gordon River

## 3.1 Methods

### 3.1.1 Lake Gordon and Lake Pedder

During 2011–12, water quality monitoring was conducted in Lakes Gordon and Pedder on 18–19 July 2011, 18–19 October 2011, 18–19 January 2012 and 16–17 April 2012. Sampling sites in Lake Gordon were at Knob Basin (approximately 100 m from the power station intake), Calder Reach and Boyes Basin (adjacent to the upper Gordon River inflow). Sampling sites in Lake Pedder were at Groombridge Point, Hermit Basin and Edgar Bay.

Chemical analyses were carried out on surface water samples collected from each site. The following parameters were analysed, for each water sample, by Analytical Services Tasmania and Inland Fisheries Service Biological Consultancy (chlorophyll-*a* analysis only):

- total phosphorus and filterable reactive phosphorus (FRP);
- nitrite, nitrate, total Kjeldahl nitrogen (TKN) and ammonia;
- chlorophyll-*a*;
- metals (iron, manganese, zinc, cadmium, copper, aluminium, cobalt, chromium, nickel and lead);
- sulphate;
- alkalinity; and
- dissolved organic carbon.

Additionally, *in situ* depth profiles of basic physico-chemical parameters (water temperature, dissolved oxygen, electrical conductivity and pH) were taken at approximately 2 m vertical intervals at each of the Lake Gordon sampling sites and Groombridge Point in Lake Pedder.

### 3.1.2 Gordon River

Water quality monitoring data were collected from four sites on the Gordon River, downstream from the Gordon Power Station:

- Gordon Power Station tailrace (site 77);
- Gordon River at site 75 (G4 – Albert Rapids), located 2 km downstream of the tailrace;
- Gordon River at site 65 (upstream of the Denison confluence—compliance site), located 12 km downstream of the tailrace; and
- Gordon River at site 62 (downstream of the Denison confluence), located 15 km downstream of the tailrace.

Water temperature was logged at all sites, with dissolved oxygen also recorded at sites 65 (compliance site) and 77 (tailrace). The data from sites 65 and 77 is retrieved by telemetry, while data from sites 62 and 75 must be downloaded manually during field visits. For this reason, the data from sites 62 and 75 is analysed and presented from April 2011 to April 2012, while data from sites 65 and 77 is presented from April 2011 to June 2012.

### 3.1.3 Logistical issues

No water temperature data is available for site 62 (downstream of Denison River) for the period 2 June 2011 to 5 November 2011 due to software issues.

No dissolved oxygen data is available for site 65 (upstream of Denison confluence—compliance site) for the period from 27 February to 29 March 2012 due to a programming fault .

No water temperature data is available for site 75 from early December, as this was the last point at which the data was downloaded.

## 3.2 Results and discussion

### 3.2.1 Lake Gordon water quality

Profiles of water temperature, pH and dissolved oxygen for Boyes Basin, Calder Reach and at Knob Basin, in the vicinity of the intake, are shown in Figure 3-1 to Figure 3-3.

#### *3.2.1.1 Boyes Basin*

Boyes Basin is the shallowest of the three sampling sites in Lake Gordon, with water depths ranging between 31 m and 39 m during the year. It is the closest site to the upper Gordon River, which is one of the major inflows to the lake. In July 2011, temperatures through the water column ranged from 7.8°C at the surface to 4.8°C at 31 m. A thermal transition layer (thermocline) was evident at around 17–23 m. A higher oxygen level below the thermocline in July 2011 suggests that the thermocline was the result of recent cool inflows of water from the upper Gordon River. By October 2011, the thermocline at 17–23 m had begun to dissipate, with temperatures throughout the water column increasing, and a thermocline had developed at the surface with a temperature of 10°C at 2 m and a surface temperature of 14.2°C. In January 2012, a thermocline was again evident, with temperatures significantly decreasing at approximately 14 m. A gradient was present throughout the water column, with a surface temperature of 18.9°C to 9.7°C at 35.9 m. There was evidence of an oxycline at 14–28 m depth where dissolved oxygen decreased from 8.6 to 4.9 mg $L^{-1}$ and then continued to decrease with depth down to around 3.3 mg $L^{-1}$ at 35.9 m. In April 2012, water temperatures had cooled significantly (i.e. approximately 2–5°C) to a depth of 15 m, beyond which temperatures were slightly higher than those recorded in January (approximately 1°C).

Throughout the year pH values ranged from 5.9 to 7.1. The highest pH values were recorded in surface waters down to 30 m (where it dropped to 6.8) in April 2012. The lowest pH was recorded in January 2012 for waters up to 35.9 m deep, with concentrations increasing from 6.2 to 6.5 at 20 to 16 m. Some pH variability with depth corresponded with vertical variation in oxygen concentration and is indicative of the different chemical conditions through the water column. In shallow waters (up to 16 m) the pH gradient was relatively uniform throughout the year.

Dissolved oxygen in Boyes Basin was generally high (greater than 80% saturation or 8 mg $L^{-1}$) throughout the water column. Dissolved oxygen was greatest in surface waters in October 2011 and January 2012, when the associated increase in surface pH is an indicator of higher primary production occurring as surface water temperatures increase. Low dissolved oxygen concentrations (e.g. down to 38.3% or 4.3 mg $L^{-1}$) were only recorded in January 2012 at depths greater than 26 m.

Electrical conductivity (EC) at Boyes Basin tended to be slightly higher in summer at the surface than in winter. However there was a decrease with depth in the profiles for October 2011 and April 2012, with EC decreasing for April 2012 from 45 to 34 µS $cm^{-1}$) at depths of 19 to 31 m.

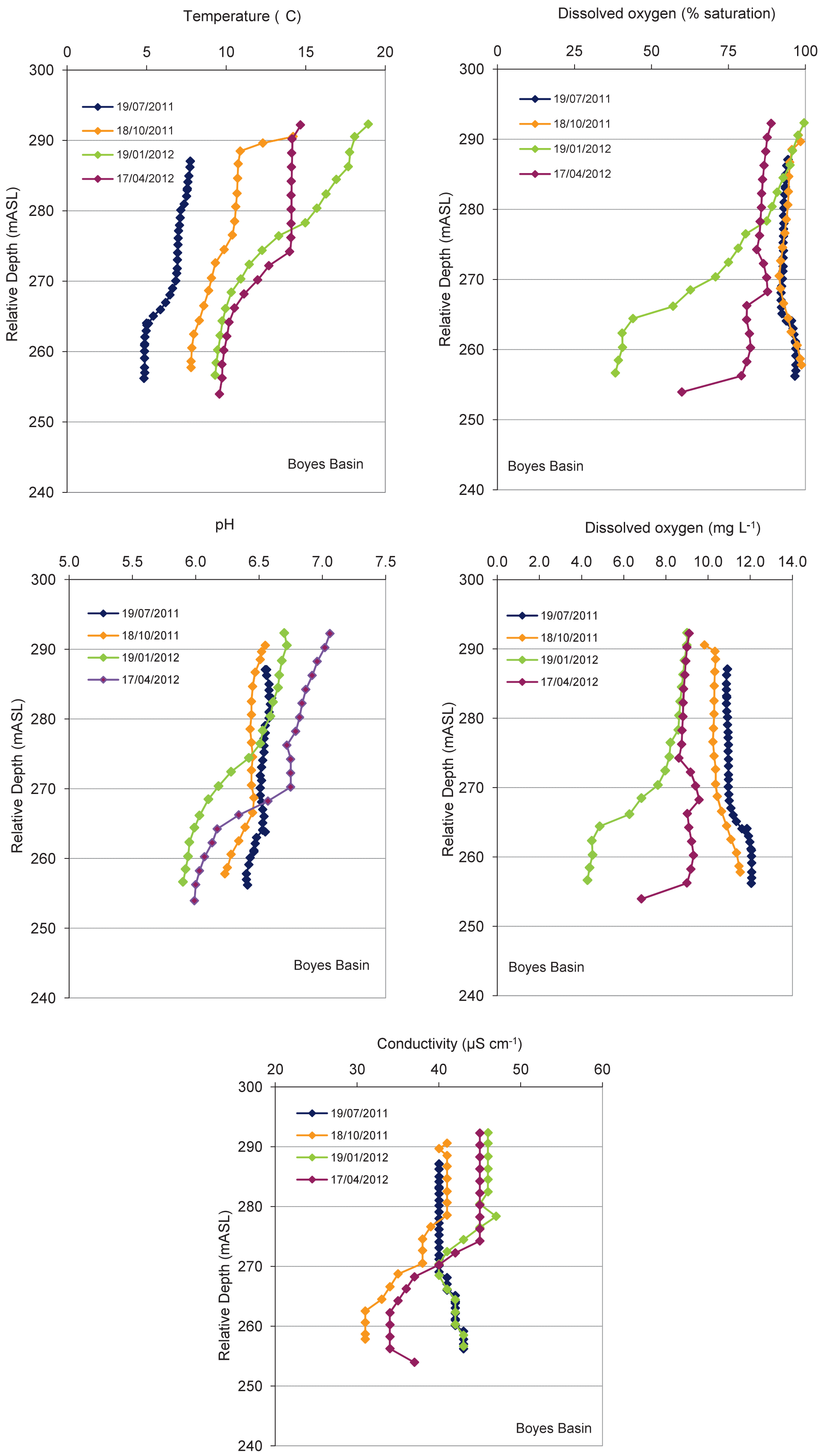


Figure 3-1 Depth profiles for temperature, pH, conductivity and dissolved oxygen at Boyes Basin in Lake Gordon

#### 3.2.1.2 Calder Reach

Calder Reach underwent a typical seasonal temperature cycle with surface water temperatures increasing from July 2011 through to January 2012 and then retracting slightly in April 2012. Temperatures ranged from near-isothermal conditions in July and October 2011, with the exception of a surface temperature gradient, (14.3°C at surface to 10.8°C at 1 m) in October 2011 to a stratified water column in January and April 2012 (Figure 3-2). A thermal gradient was evident in January 2012 with water temperatures decreasing gradually from 17.2°C at the surface to 10.7°C at 24 m. In April 2012 thermal stratification occurred at 23 m depth with temperatures falling from 13.7 to 10.1°C, and then continuing to decline gradually with depth, to a minimum of 9.1°C at 52 m. A similar pattern was observed for dissolved oxygen concentrations, which decreased from 88% to 55.7% saturation (6.26 mg $L^{-1}$) at 29 m in April 2012. The dissolved oxygen concentrations for January represented, comparative to previous results, a general decline at depth, falling from 91.9% saturation (9.24 mg $L^{-1}$) at 16.2 m down to 62.5 (7.06 mg $L^{-1}$) at 51.9 m. Dissolved oxygen concentrations were high and uniform throughout the water column in July and October 2011.

There was little difference in pH (6.65–6.35) for up to 50 m of water in October 2011 at Calder Reach. Unlike previous records, July’s pH was inverted with a slightly lower pH at the surface (6.23) and a higher pH at depth (6.64). In January and April 2012, pH was almost identical with January, recording 0.1 pH higher for the most part with a sharp decrease in pH at 23 m from 6.63 to 6.11 at 29 m. The pH of the surface mixed layer was highest in January 2012 (Figure 3-2), when pH decreased from 6.88 at the surface to 6.63 at 23 m.

The cause of the lower dissolved oxygen in the deepest waters in January and particularly April 2012 is bacterial consumption of oxygen without replenishment due to stratification. Similarly, the corresponding decline in pH is most likely related to the increase in concentration of carbon dioxide from bacterial respiration, which drives the pH down.

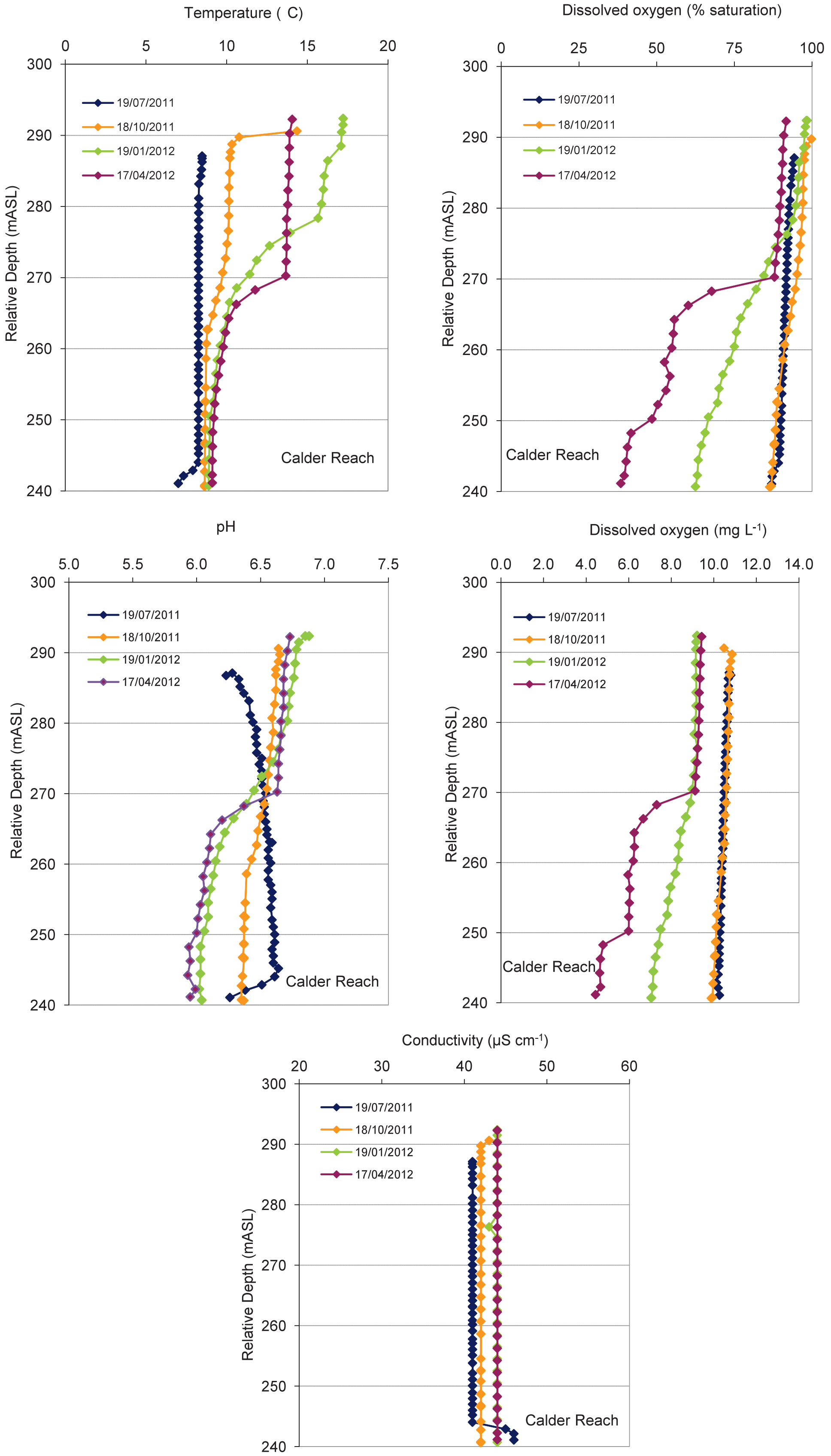


Figure 3-2 Depth profiles of temperature, pH, conductivity and dissolved oxygen at Calder Reach in Lake Gordon

#### *3.2.1.3 Knob Basin (intake) site*

A typical annual cycle of water quality profiles was observed at Knob Basin during 2011–12. The water temperature was cool (8.49–8.86 ℃) and uniform throughout the water column in July and October 2011. In January 2012, surface water temperatures had increased to 16.9 ℃ while water temperatures in the vicinity of the intake (intake depth range 250–255 mASL) remained low at ~10 ℃. In April 2012, there was evidence of shallow surface warming and thermal stratification at 14 m at which depth temperatures fell from 13.8 ℃ to 10 ℃ in the vicinity of the intake. On all sampling occasions water temperatures at, or below, 43 m of depth remained within the range of 8.4–8.8 ℃ (Figure 3-2).

Anoxic conditions were recorded for bottom waters at Knob Basin (deeper than 67–80 m) on all sampling occasions, due to the lack of mixing and bacterial respiration. In July 2011, surface waters were reasonably well oxygenated (~83% saturated or 9.3 mg $L^{-1}$) to 5 m deep and slightly less oxygenated (~ 74% saturated or 8.5 mg $L^{-1}$) from 5 m to the distinct oxycline at 61–70 m; a depth range that is 20–34 m deeper than the power station intake. At the oxycline, dissolved oxygen concentrations fell from 62.1% to 3.2% saturation (7.09–0.36 mg $L^{-1}$). Below this depth, from 71 to 85 m, typical anoxic conditions were observed. In October 2011 and January 2012 the oxycline was not as distinct. Dissolved oxygen levels declined gradually with depth to 46 m and concentrations at the intake range were similar for October 2011 and January 2012 (9.04 mg $L^{-1}$ and 7.9 mg $L^{-1}$, respectively). In April 2012, surface waters were well oxygenated, but an oxycline had developed at 17 m (associated with the thermocline) resulting in reduced oxygen concentrations of 46.4–50.5% saturation (5.38–5.81 mg $L^{-1}$) at the intake range. This can allow water with lower dissolved oxygen to be drawn into the power station and discharged into the tailrace and is the likely cause of slightly lower DO (~6 to 7 mg $L^{-1}$) observed in the tailrace over the last week of April (Figure 3-7).

Conductivity at Knob Basin ranged from 40 to 48 µS $cm^{-1}$ over the full profile depth, with increased conductivity observed at depth in response to anoxic conditions in July 2011, January 2012 and April 2012 and, to a lesser degree, in October 2011. The higher conductivity observed in deeper waters is most likely related to the ionisation of metals and nutrients under the influence of anoxic conditions.

There was some variation in pH with depth. In July and October 2011, pH in the surface waters was lower (5.7 and 5.95 respectively) and then increased with depth. The pH in July then stabilised at ~ 6.1 between 3 and 56 m of depth. October monitoring recorded a slight increase in pH at depths to 30 m and then declined in line with July and January results. January and April recorded higher surface pH that continued to decline with depth with a slightly noticeable decrease in pH around 48 m where the thermocline became more pronounced (59 m for July). Decreases in pH can be due to increased concentrations of carbon dioxide from bacterial respiration. Conversely, increases in pH near the surface can be due to primary production and a decline in carbon dioxide.

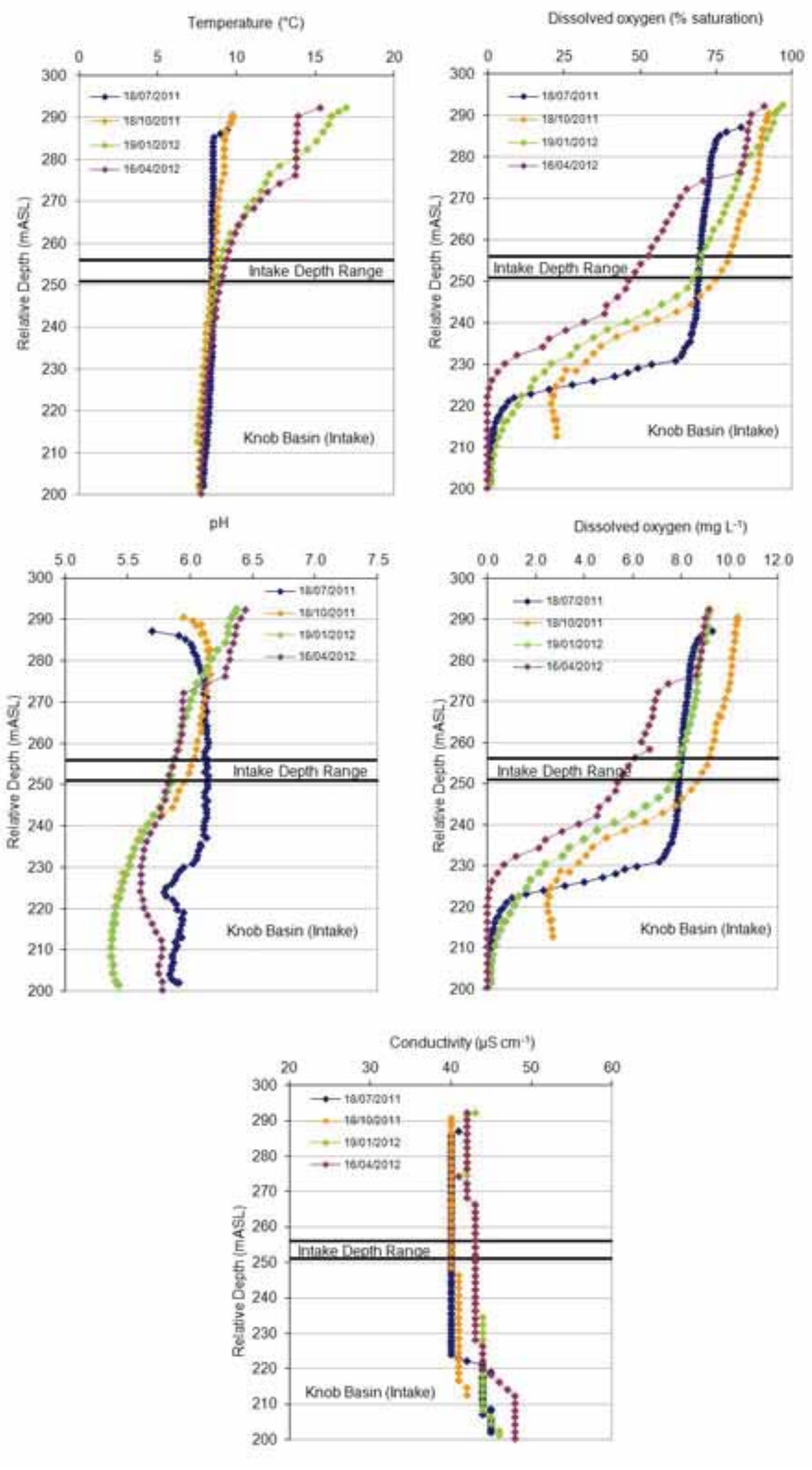


Figure 3-3 Depth profiles for the intake site located at Knob Basin in Lake Gordon for temperature, pH, conductivity and dissolved oxygen. Depths are represented as relative depth in mASL to demonstrate the potential fluctuations in water quality at the power station intake. The depth range of the power station intake is indicated by two heavy black lines

#### *3.2.1.4 Lake Gordon surface water quality*

The surface water quality data are presented in Table 3-1. The results are typical of fresh waters in Tasmania's south-western region—relatively high dissolved organic carbon and slightly acidic pH. Sulphate concentrations were within the range reported in previous years, while the low alkalinity measures continue to indicate that the water in Lake Gordon is 'soft' (i.e. low in carbonates).

Concentrations of nutrients were within ranges recorded for samples from previous years, with low concentrations of total phosphorus, total Kjeldahl nitrogen and filterable reactive phosphorus, and low to moderate concentrations of ammonia/ammonium[1] and nitrate.

Chlorophyll-*a* concentrations were slightly elevated at two of the three monitoring sites, with Boyes Basin January results showing 4.3 µg $L^{-1}$, and Knob Basin (intake) recording 8.12 µg $L^{-1}$ in April 2012. It is common for chlorophyll-*a* concentrations to be highest at Boyes Basin, and it is hypothesised that, as this site is in the vicinity of the inflowing upper Gordon River, there is a source of nutrients delivered by the river that has the potential to support a higher phytoplankton biomass. Any bioavailable nutrients may be rapidly utilised in the warmer shallower waters of Boyes Basin (and therefore difficult to detect by the current nutrient sampling program). At the other sites chlorophyll-*a* concentrations were generally less than 1 µg $L^{-1}$ but increased to 1.4 µg $L^{-1}$ in January 2012 at Calder Reach.

Metals concentrations in Lake Gordon were low except for aluminium, zinc and copper, which were higher than the ANZECC (2000) toxicity guidelines[2] on at least one occasion. However, elevated aluminium concentrations are typical of the naturally acidic waters of storages in western Tasmania and the toxicity of aluminium is known to be reduced by the presence of humic substances (ANZECC 2000), an effect likely to occur in Lake Gordon due to its high humic content.

Except for a single elevated copper concentration of 3 µg $L^{-1}$ recorded for Boyes Basin in July 2011, all other copper concentrations were low (near the detection limit of 1 µg $L^{-1}$). Elevated zinc levels were recorded from Knob Basin in April 2012 as have been previously reported from Calder Reach in July 2008 and from Knob Basin in April 2009.

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[1] The analytical method for the determination of ammonia transforms ammonium to ammonia and is therefore representative of the combined concentration of free ammonia and ionised ammonium. However, under the pH and temperature conditions in Lake Gordon, greater than 99% of the measured ammonia is present in the water as ammonium, and therefore concentrations of ammonia should be considered to be primarily representative of concentrations of ammonium

[2] Trigger values: 55.0 µg $L^{-1}$ for aluminium (at pH >6.50); 1.4 µg $L^{-1}$ for copper; 8.0 µg $L^{-1}$ for zinc

Table 3-1 The range of nutrients, metals, sulphate, alkalinity, dissolved organic carbon and chlorophyll-*a* levels recorded from surface waters at monitoring sites in Lake Gordon during 2011–12. Figures in bold indicate exceedence of ANZECC toxicity guidelines

| Parameter | Boyes Basin | Calder Reach | Knob Basin (Intake) |
|---|---|---|---|
| Specific conductivity (µS cm$^{-1}$) | 31 – 47 | 41 – 46 | 40 – 48 |
| Turbidity (NTU) | 1.79 – 3.49 | 1.98 – 4.49 | 0.80 – 1.25 |
| Chlorophyll-*a* (µg L$^{-1}$) | 0.38 – **4.3** | -0.43 – 1.42 | 0.11-**8.12** |
| Dissolved organic carbon (mg L$^{-1}$) | 7.7 – 8.4^ | 6.8 – 7.9^ | 7.5 – 8.0^ |
| Sulphate (mg L$^{-1}$) | 1.1 – 1.3 | 1.1 – 1.3 | 1.1 – 1.2 |
| Alkalinity (mg L$^{-1}$) | <2 – 4 | <2 – 3 | <2 – 3 |
| Total phosphorus (mg L$^{-1}$) | 0.006 – 0.012 | <0.005 – 0.008 | <0.005 – 0.012 |
| Filterable reactive phosphorus (mg L$^{-1}$) | <0.002 – 0.005 | <0.002 – 0.006 | <0.002 – 0.005 |
| Ammonia (mg L$^{-1}$) | 0.01 – 0.029 | 0.015 – 0.03 | 0.019 – 0.024 |
| Nitrate (mg L$^{-1}$) | 0.034 – 0.043 | 0.041 – 0.051 | 0.038 – 0.05 |
| Nitrite (mg L$^{-1}$) | 0.003 – 0.005 | 0.003 – 0.004 | 0.003 – 0.004 |
| Total Kjeldahl nitrogen (mg L$^{-1}$) | 0.27 – 0.031 | 0.022 – 0.34 | 0.023 – 0.3 |
| Aluminium (µg L$^{-1}$) | **133 – 194** | **132 – 191** | **125 – 165** |
| Cadmium (µg L$^{-1}$) | <0.1 | <0.1 | <0.1 |
| Chromium (µg L$^{-1}$) | <1.0 | <1.0 | <1.0 |
| Cobalt (µg L$^{-1}$) | <0.5 | <0.5 | <0.5 |
| Copper (µg L$^{-1}$) | <1.0 – **3** | <1.0 | <1.0 |
| Iron (µg L$^{-1}$) | 503 – 563 | 504 – 546 | 474 – 632 |
| Lead (µg L$^{-1}$) | <0.5 – 0.8 | <0.5 – 0.8 | <0.5 |
| Manganese (µg L$^{-1}$) | 6.0 – 7.2 | 4.8 – 6 | 5.1 – 8 |
| Nickel (µg L$^{-1}$) | 0.9 – 1.1 | 0.6 – 1 | 0.5 – 1.1 |
| Zinc (µg L$^{-1}$) | 1 – 4 | <1.0 – 2 | 2 – **9** |

^ not recorded in October 2011

### 3.2.2 Lake Pedder water quality

Lake Pedder is relatively shallow (~15 m deep) and well mixed, with depth profiles of temperature at the Groombridge Point site displaying isothermal conditions year round (Table 3-2). The temperature profiles also demonstrate a warming of the water body from ~6°C in winter to 16.7°C in summer. Dissolved oxygen, pH and conductivity were uniform throughout the water column, which is consistent with previous monitoring results. Surface water quality measurements from the Edgar Bay and Hermit Basin sites were generally of very similar ranges to those from Groombridge Point. Water samples from the surface at the Groombridge Point site were analysed for a range of parameters as outlined in Table 3-2 and Table 3-3. As in previous years, water quality was good in Lake Pedder. Conductivity, turbidity, chlorophyll-*a*, nutrient and metal concentrations were generally low (with the exception of aluminium, copper and lead). Dissolved oxygen concentrations in Lake Pedder were high in surface waters and pH was slightly acidic. Dissolved organic carbon concentrations were moderate, being slightly lower than those measured in Lake Gordon (Table 3-1). Chlorophyll-*a* levels were marginally higher than the guideline trigger of 3 µg $L^{-1}$ (ANZECC 2000) on one occasion at Hermit Basin (April 2012—4.84 µg $L^{-1}$) and at Groombridge Point (July 2011—4.24 µg $L^{-1}$), although, lower than the 2010–11 monitoring period at the same sites.

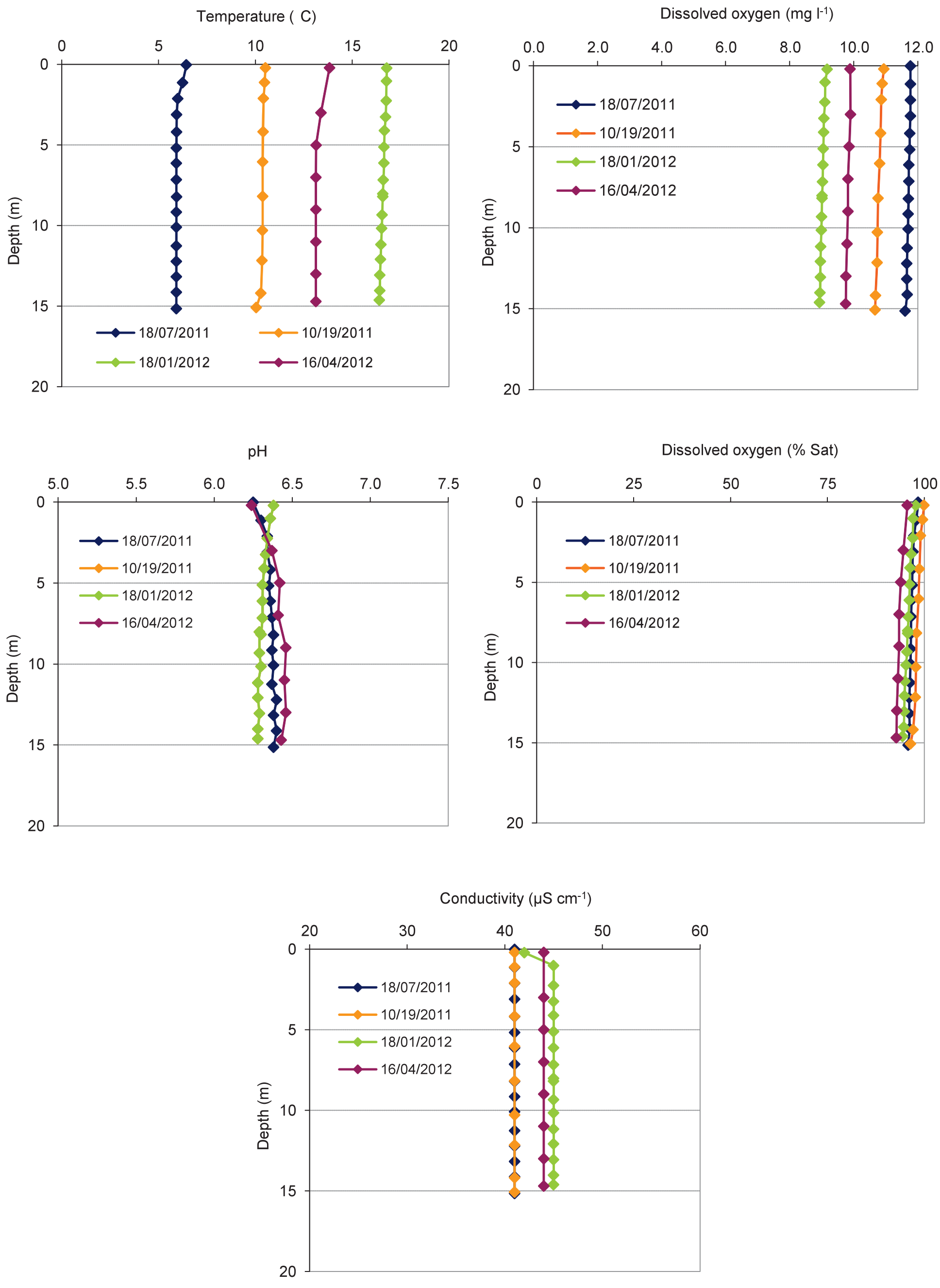

Figure 3-4 Depth profiles of water temperature, pH, conductivity and dissolved oxygen at Groombridge Point in Lake Pedder for 2011–12

Table 3-2 Water quality parameter ranges measured at the three monitoring sites in Lake Pedder during 2011–12

| Parameter | Edgar Bay (surface) | Hermit Basin (surface) | Groombridge Point (surface) | Groombridge Point (15 m) |
|---|---|---|---|---|
| Chlorophyll-*a* (µg L$^{-1}$) | 0.40 – **3.61** | 0.02 – **4.84** | 1.67 – 4**.24** | – |
| Dissolved oxygen (mg L$^{-1}$) | 9.17 – 11.65 | 8.94 – 11.58 | 9.17 – 11.77 | 8.93 – 11.61 |
| Dissolved oxygen (% saturation) | 93.2 – 99.2 | 93.6 – 99.8 | 95.6 – 99.9 | 92.8 – 96.4 |
| pH | 6.4 – 7.02 | 6.12 – 6.48 | 6.24 – 6.58 | 6.28 – 6.45 |
| Turbidity (NTU) | 0.86 – 1.71 | 0.72 – 0.98 | 0.5 – 1.09 | 0.50 – 1.3 |
| Conductivity (µS cm$^{-1}$) | 42 – 46 | 40 – 44 | 41 – 44 | 41 – 45 |
| Water temperature (°C) | 6.81 – 17.23 | 6.53 – 18.02 | 6.44 – 16.79 | 5.92 – 16.41 |

Table 3-3 Nutrients, metals, sulphate, alkalinity, and dissolved organic carbon levels at Groombridge Point, Lake Pedder during 2011–12. Figures in bold indicate elevated concentration potentially in exceedence of ANZECC toxicity guidelines

| Parameter | Range |
|---|---|
| Sulphate (mg L$^{-1}$) | 1.1 – 1.3 |
| Alkalinity (mg L$^{-1}$ as CaCO$_3$) | <2.0 – 2.0 |
| Dissolved organic carbon (mg L$^{-1}$) | 6.4 – 6.7^ |
| Total phosphorus (mg L$^{-1}$) | 0.006 – 0.016 |
| Filterable reactive phosphorus (mg L$^{-1}$) | <0.002 – 0.005 |
| Nitrite (mg L$^{-1}$) | 0.003 – 0.004 |
| Nitrate (mg L$^{-1}$) | 0.028 – 0.036 |
| Total Kjeldahl nitrogen (mg L$^{-1}$) | 0.20 – 0.24 |
| Ammonia (mg L$^{-1}$) | 0.012 – 0.023 |
| Aluminium (µg L$^{-1}$) | **94 – 120** |
| Cadmium (µg L$^{-1}$) | <0.1 |
| Chromium (µg L$^{-1}$) | <1 |
| Cobalt (µg L$^{-1}$) | <0.5 |
| Copper (µg L$^{-1}$) | <1 – **3.0** |
| Iron (µg L$^{-1}$) | 196 – 291 |
| Lead (µg L$^{-1}$) | <0.5 – **6.7** |
| Manganese (µg L$^{-1}$) | 2.3 – 3.1 |
| Nickel (µg L$^{-1}$) | <0.5 – 0.7 |
| Zinc (µg L$^{-1}$) | 1.0 – 4.0 |
| ^ not recorded in October 2011 | |

## 3.2.3 Water quality in the Gordon River

### *3.2.3.1 Water temperature*

The hydrological regime and conditions in Lake Gordon tend to govern water temperature in the Gordon River at, and immediately below, the power station (Figure 3-5 and Figure 3-6). For 2011–12, the temperature of water released into the river (site 77) was influenced by lake level, degree of thermal stratification and power station discharge.

A seasonal pattern was observed at sites 77, 75, 65 and 62. The seasonal temperature regime was primarily influenced by the temperature of water at the power station intake in Lake Gordon, discharge into the river and ambient air temperature (Figure 3-5).

Differences between the water temperatures at the different sites on the river can often be related to their distance downstream from the power station. For warmer parts of the year the coolest water was found in the tailrace, while the warmest was often found downstream and at confluence with the Denison River at sites 62 and 65 (Figure 3-5, Figure 3-6). The increase in temperature downstream is related to a combination of the influence of ambient air temperature and the greater proportion of water contributed from tributaries. In 2011–12 the higher temperature in summer at downstream sites has been accentuated compared to previous years. The low discharges of the power station has meant that their influence on the water temperature in the summer months were minimal. In addition to the higher temperature at site 65, there was a greater degree of diurnal water temperature variation at this site (Figure 3-6) due to the slower movement of water under low discharge. During the cooler months (May–August) the temperature trend along the river was largely reversed so that water was generally cooler further downstream due to the cooling effect of ambient air temperature, and the cooler water sourced from tributaries (Figure 3-5).

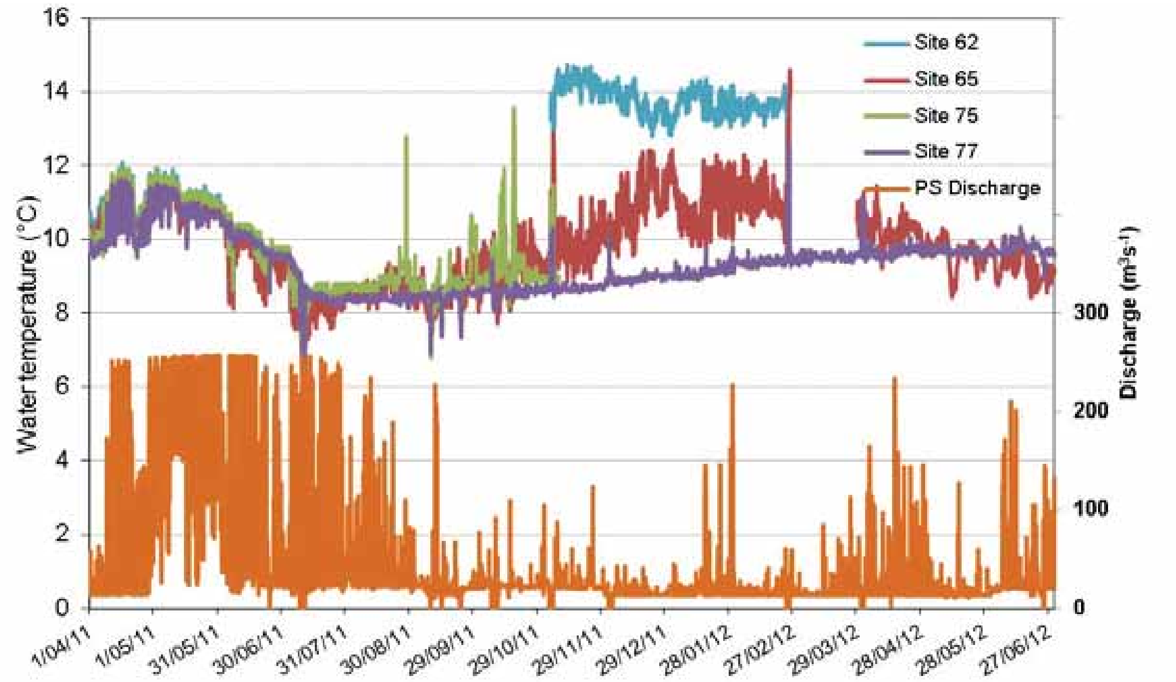

Figure 3-5 Water temperature data recorded for sites 77 and 65 from April 2011 to June 2012, site 62 from April 2011 to June 2011 and November 2011 to February 2012and site 75 recorded from April 2011 to December 2012

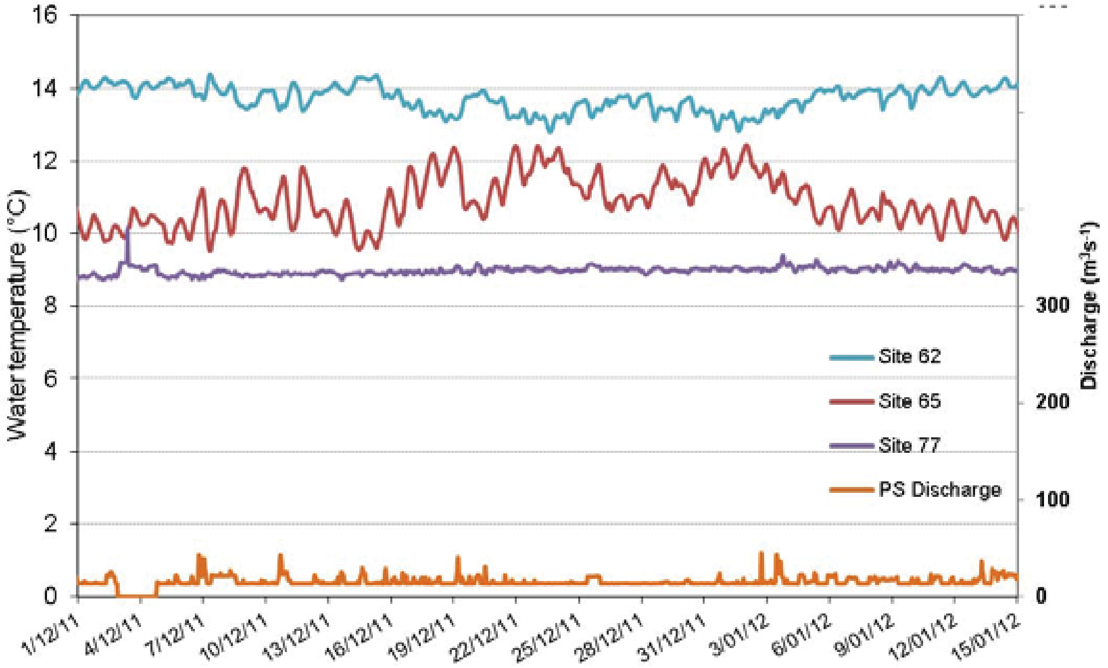

Figure 3-6 Water temperature at Gordon River sites 77, 65 (12 km downstream) and 62 (15 km downstream) and the corresponding tailrace discharge for early december 2011 to mid January 2012

#### *3.2.3.2 Dissolved oxygen*

Dissolved oxygen concentrations at the tailrace (site 77) and compliance site (site 65) for July 2011 to June 2012 are shown relative to the dissolved oxygen measurements at the intake level in Figure 3-7.

The lowest dissolved oxygen level recorded at site 77 was 6.43 mg $L^{-1}$ on 16 April 2012. Thus there was no evidence of low dissolved oxygen concentrations at the compliance site or in the tailrace over the monitoring period.

The mean hourly concentration of dissolved oxygen at the compliance site was 12.14 mg $L^{-1}$, with a standard deviation of 0.56 mg $L^{-1}$, and range of 10.08–14.04 mg $L^{-1}$. The mean hourly concentration of dissolved oxygen in the tailrace was 12.96 mg $L^{-1}$, with a standard deviation of 1.79 mg $L^{-1}$, and range of 6.43–15.25 mg $L^{-1}$. This indicates marginally more oxygenated water, though similar to the range reported over the last two monitoring periods, being driven by large daily fluctuations. This daily variability is primarily the result of the changing loading of the power station and its subsequent effect on dissolved oxygen concentrations.

Figure 3-8 shows examples of daily variability for April 2012. Under low to mid-range turbine operations, air injection occurs automatically to prevent cavitation in the turbines and has the effect of increasing the concentration of dissolved oxygen in the discharge waters. Low dissolved oxygen concentrations at high turbine load, when air injection is not required, therefore reflects the concentration of dissolved oxygen in Lake Gordon at the intake site (Figure 3-7 and Figure 3-8). In addition to the daily variation, some seasonal variation in dissolved oxygen (for example the lower dissolved oxygen concentrations in April) occurred in response to changing stratification relative to the intake in Lake Gordon (Figure 3-3).

There appears to be little relationship between variation in concentrations in dissolved oxygen in the tailrace and the compliance site.

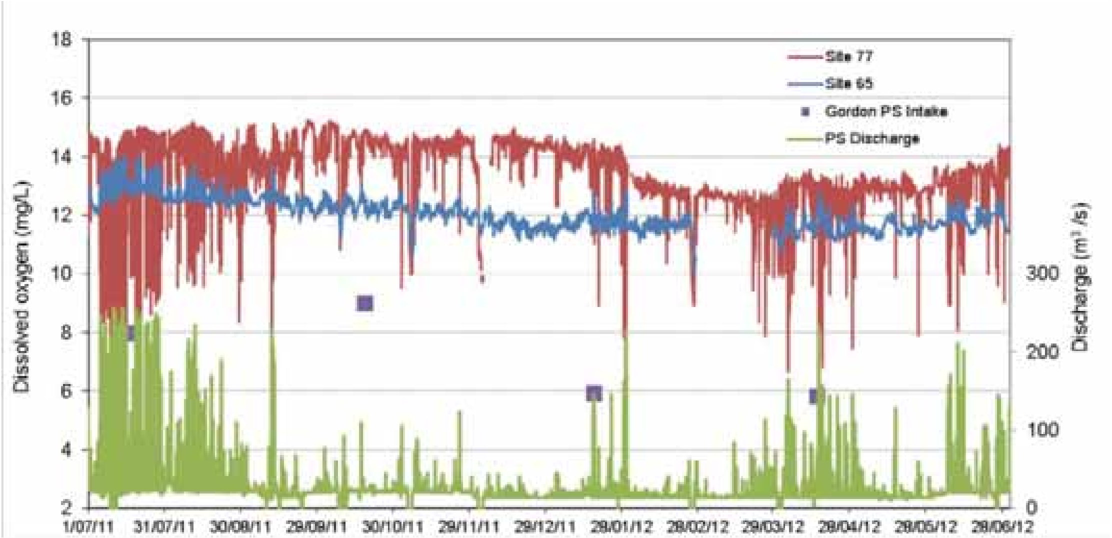

Figure 3-7 Dissolved oxygen levels at site 77 (tailrace) and site 65 (compliance site) for 2011–12 in comparison to dissolved oxygen levels at the same depth of the intake (256 mASL: 24–29 m deep dependant on lake level) in Lake Gordon at the Knob Basin site. Power station discharge is presented to compare its influence on dissolved oxygen concentration at each site

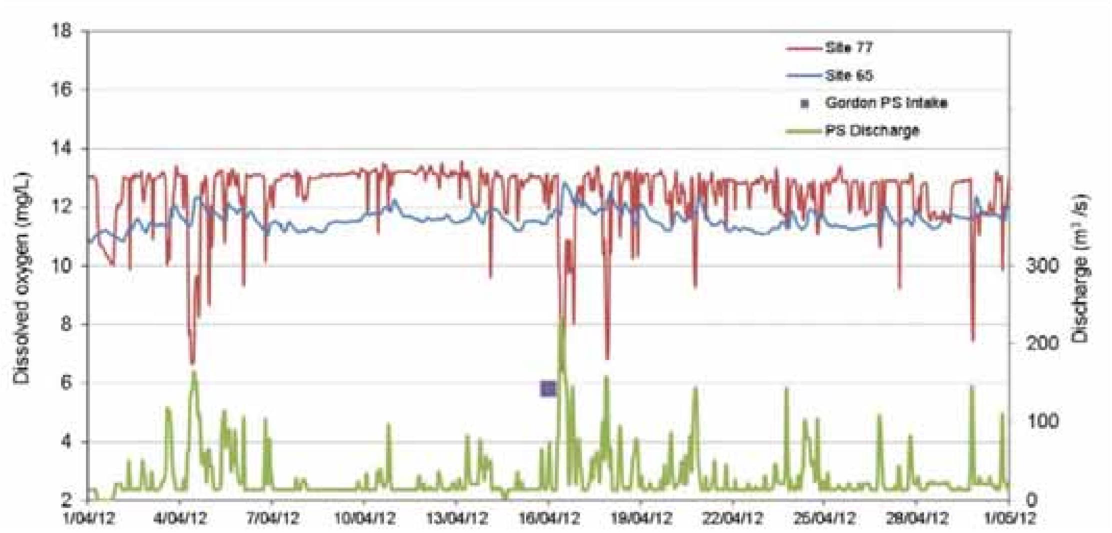

Figure 3-8 Dissolved oxygen concentrations at site 77 (tailrace) and site 65 (compliance site) relative to power station discharge 1–30 April 2012

## 3.3 Conclusions

The physico-chemical conditions recorded for both lakes Gordon and Pedder were similar to previous years. Surface water quality was generally good in both lakes and was characterised by low nutrient, turbidity and dissolved metals. Zinc and copper levels were occasionally elevated at some sites, and high concentrations of aluminium were recorded at all sites (the latter due to the naturally low pH).

The thermal structure of lakes Gordon and Pedder were also similar to previous years. Anoxic conditions were recorded for deeper waters at the Knob Basin (at least 20 m deeper than the intake) for the months of July 2011 and January and April 2012. The power station intake was within the depth range of the oxycline measured at Knob Basin on only one of the sampling occasions, comparative to three times for the 2010–11 monitoring period. As a result of this, reduced dissolved oxygen concentrations (5.38–5.81 mg $L^{-1}$) were recorded at the intake range in April 2012.

Water quality in Lake Pedder was good overall and remained well mixed at the Groombridge profile sites during 2011–12.

Water temperatures in the Gordon River differed between sites due to the effects of tributary inflows.

Water temperature in the Gordon River was also sensitive to fluctuations in power station discharge. All sites were sensitive to reductions in discharge, with significant increases or decreases in temperature observed under the influence of ambient air temperatures and greater relative volume of water from tributaries at low power station discharge. The relatively low discharge from the power station over summer resulted in warmer water temperatures at downstream sites and significant diurnal temperature variation compared to previous years.

Dissolved oxygen concentrations in the tailrace were highly variable as a result of changes to power station discharge and the resultant changes in aeration in the turbines. The dissolved oxygen at full-gate power station operation was reflective of the concentration in Lake Gordon at the intake level. Dissolved oxygen concentrations at the compliance site were generally high and did not reflect the concentration of dissolved oxygen in Lake Gordon or in the tailrace. Changes in dissolved oxygen concentration at the compliance site appear to be influenced by flow rate, with higher dissolved oxygen coinciding with higher flows.

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# 4 Fluvial geomorphology

## 4.1 Introduction

This report summarises the Basslink fluvial geomorphology monitoring results for the period March 2011–February 2012. The aims of geomorphology monitoring in the Gordon include:

- to document fluvial geomorphological processes and changes in the Middle Gordon River between the power station tailrace and the mouth of the Franklin River (defined as the middle Gordon River);
- to relate these changes to power station operations or other factors wherever possible; and
- to compare results collected since the introduction of Basslink with pre-Basslink results to determine whether changes in the river are within ‘limits of acceptable change’ (trigger values).

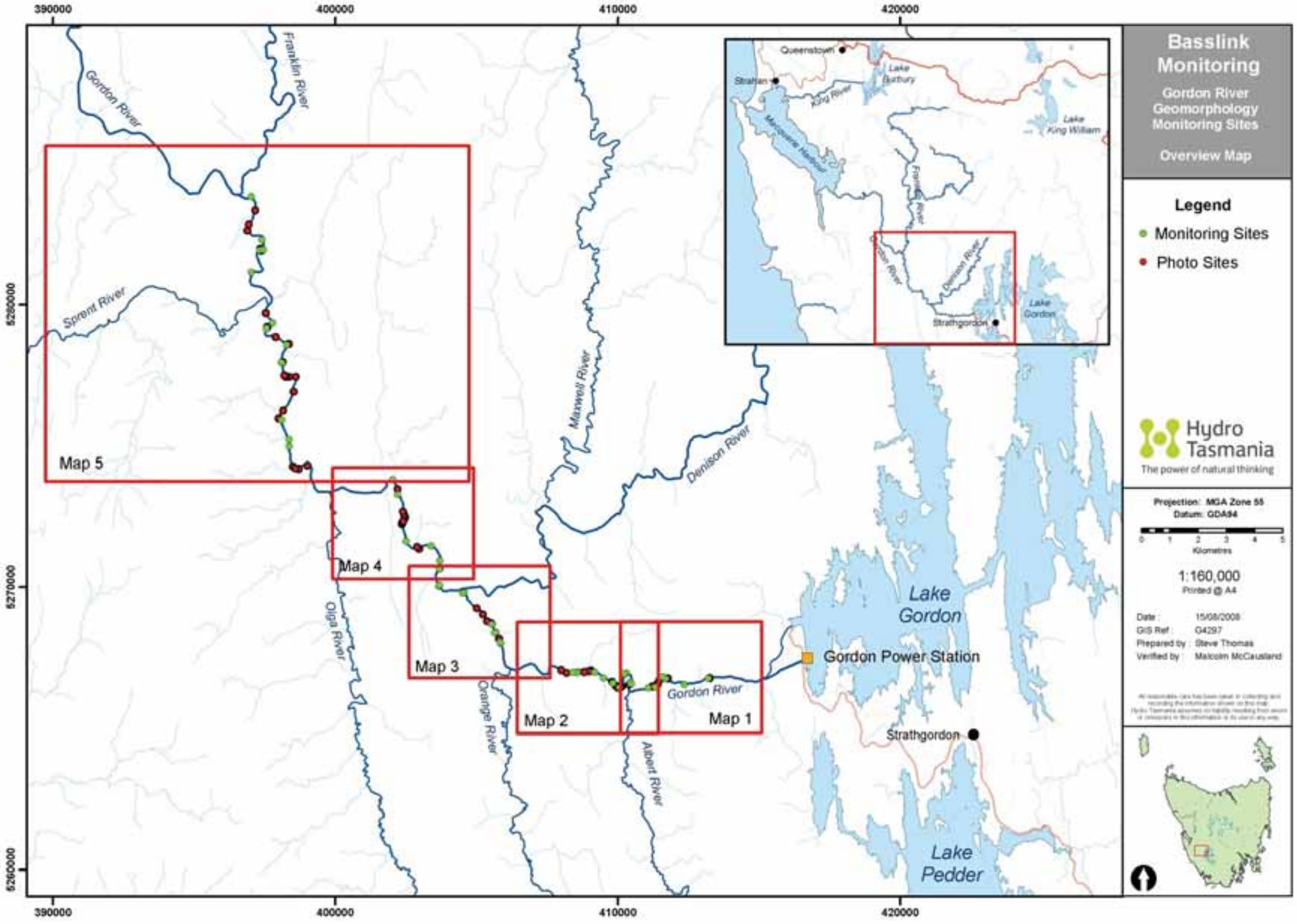
Post-Basslink limits of acceptable change were identified based on pre-Basslink erosion trends in the river as indicated by grouping erosion pins results collected between 2001 and 2005 by zones. Although these trends have been quantified and trigger values established, it has been recognised that over time rates are likely to change in the presence or absence of Basslink due to the non-equilibrium condition of the river which continues to adjust to the initial damming of the river and introduction of a third turbine in 1989. These issues were discussed in the Basslink Three Year Review Report (Hydro Tasmania 2010a) and a recommendation was made to reduce the reliance on ‘trigger values’ for detecting change in the Gordon River. It was recommended that a multiple-lines-of-evidence approach be adopted instead, which incorporates erosion pin results, photo-monitoring, bank profiling, field observations, piezometer results and a large-scale conceptual model to interpret post-Basslink changes in the river. Erosion pin results are still presented as ‘trigger values’ consistent with Hydro Tasmania’s Special Water Licence, however the discussion focuses on a multiple-lines-of-evidence approach.

## 4.2 Methods

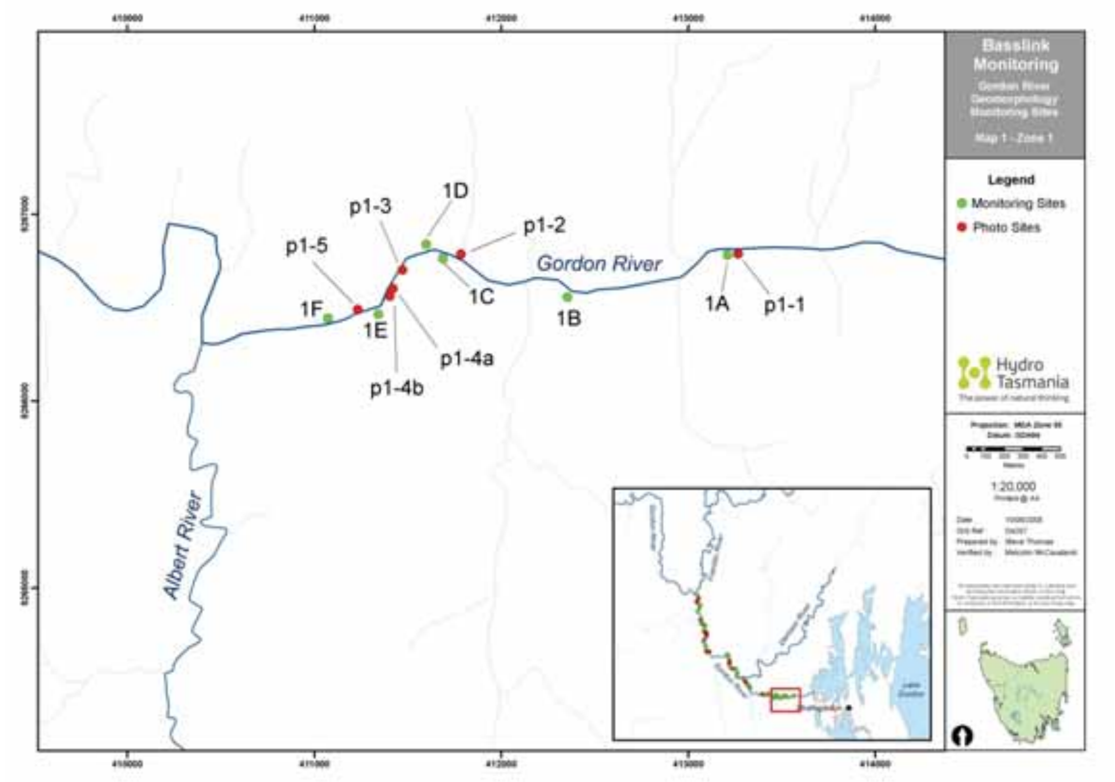
Geomorphology monitoring is described in detail in the first Pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2001) and the BBR (Hydro Tasmania, 2005a) and these documents should be consulted for a detailed description and background material pertaining to the monitoring program. 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 BBR (Hydro Tasmania, 2005a). The following is a brief summary.

Geomorphology monitoring includes field observations and the measurement of ~250 erosion pins and 25 scour chains located at 47 monitoring sites in the middle Gordon River twice per year (usually October and March), and photo-monitoring of an additional 54 sites on an annual basis in March each year. The monitoring sites are distributed over five geomorphic zones in the river, which have been identified based on hydrologic and hydraulic attributes and shown in Map 4-1 to Map 4-6. Erosion pins are located in sandy alluvial banks along the middle Gordon within the height affected by power station operation. The location of pins at each site have also been classified according to the 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 have not been done.

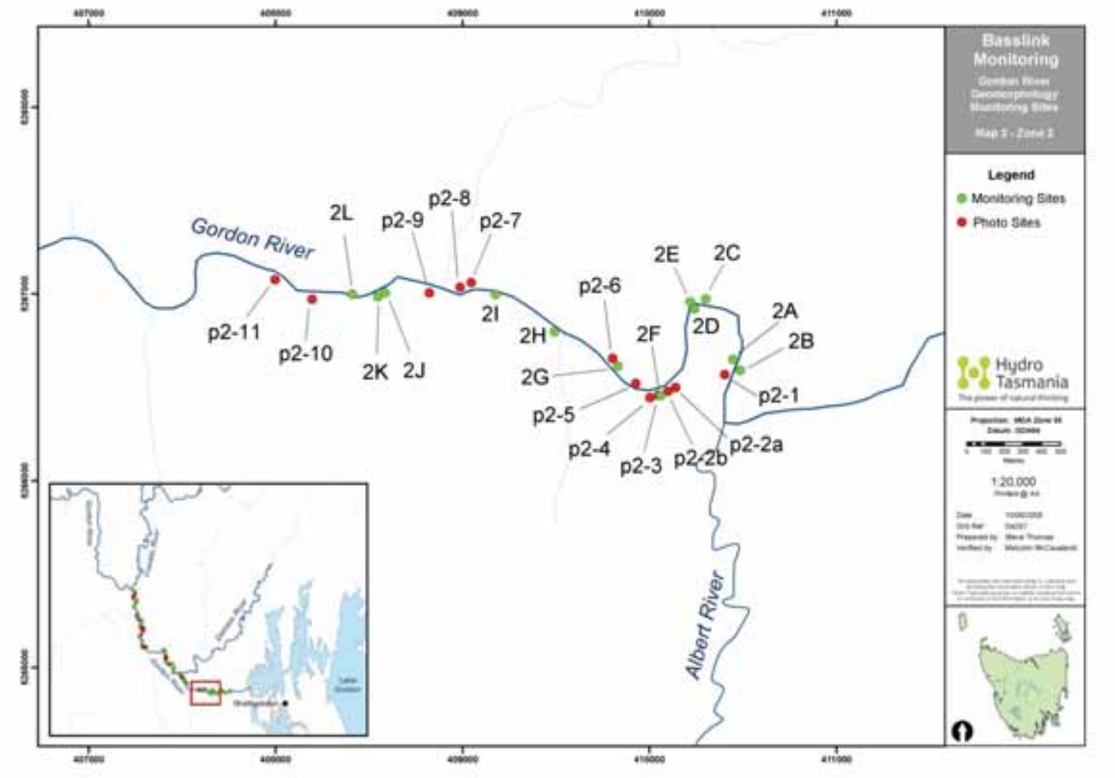
Observations, photos and erosion pin measurements are collected by two boat-based teams during the October and (usually) March monitoring trips. Additional field observations are collected opportunistically when access to the middle Gordon River is possible.



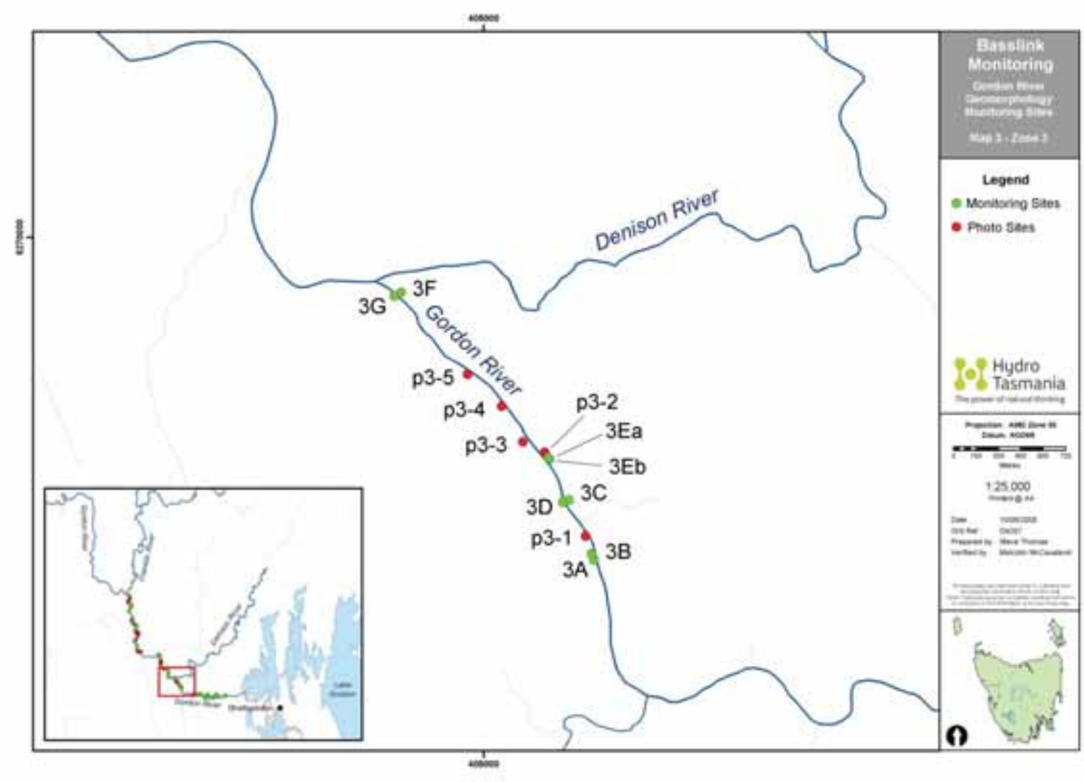
Map 4-1 Overview of Gordon River geomorphology monitoring sites



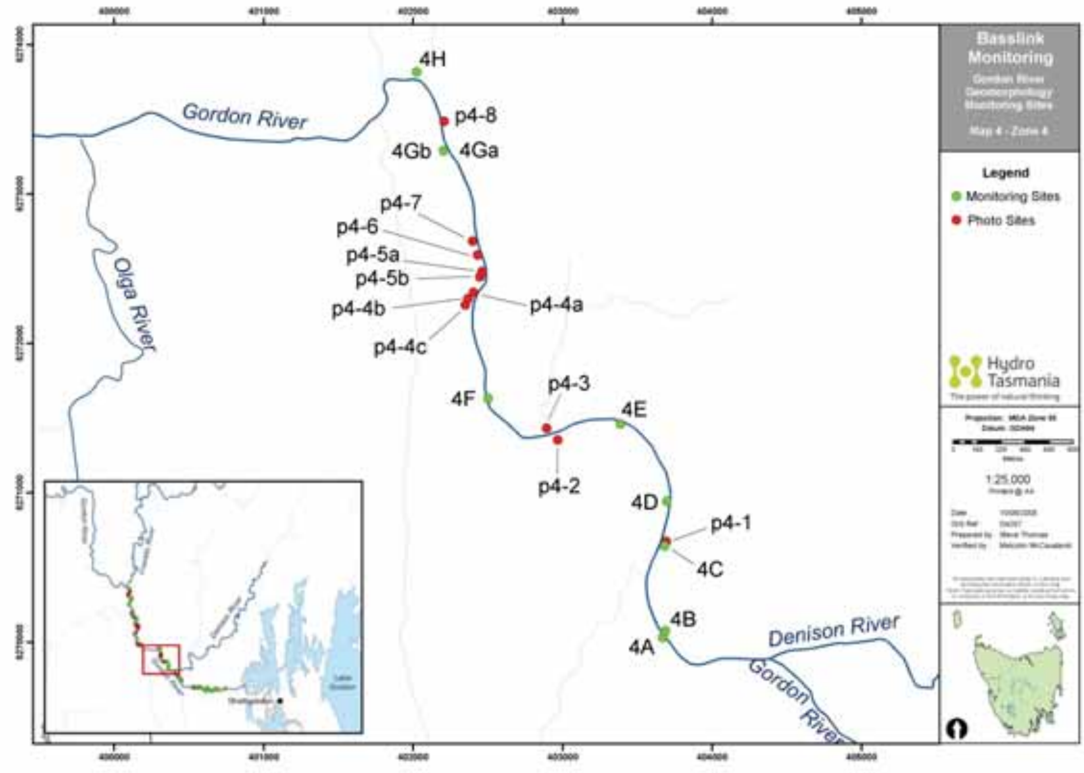
Map 4-2 Gordon River geomorphology monitoring sites, zone 1



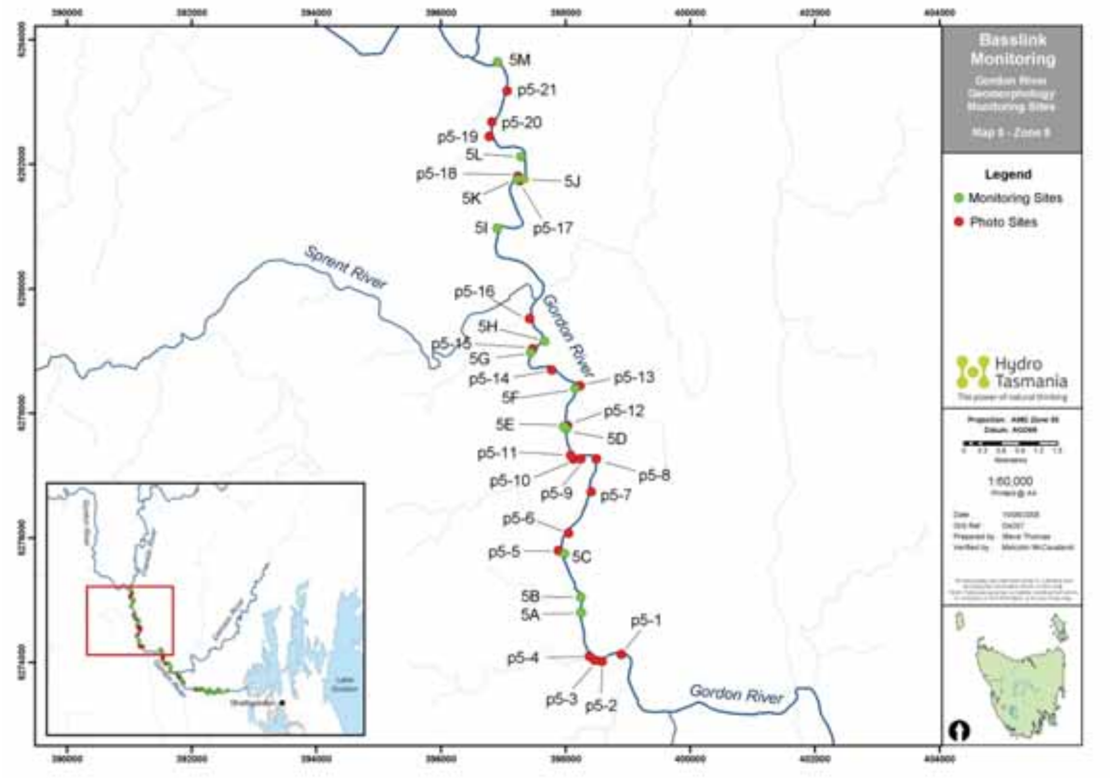
Map 4-3 Gordon River geomorphology monitoring sites, zone 2



Map 4-4 Gordon River geomorphology monitoring sites, zone 3



Map 4-5 Gordon River geomorphology monitoring sites, zone 4



Map 4-6 Gordon River geomorphology monitoring sites, zone 5

Table 4-1 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

| **Monitoring Type** | **Triggers: Derivation or Test** | **Season** | **Dates** | **Monitoring completed** |
|---|---|---|---|---|
| Pre-Basslink | Initial investigations | | 11 Dec 99<br>18 Dec 99<br>4 Mar 00<br>25 Mar 00<br>22 Jul 00<br>2 Sep 00<br>4 Aug 01 | Investigations for IIAS:<br>Field observations<br>Erosion pin measurements<br>Photo-monitoring<br>Scour chains<br>Painted cobbles |
| | Derivation | Spring 2001 | 23 Nov<br>9 Dec | Field observations<br>Erosion pin measurements |
| | | Autumn 2002 | 10 Feb<br>9 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2002 | 5 Oct<br>16 Dec | Field observations<br>Erosion pin measurements |
| | | Autumn 2003 | 29 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2003 | 18 Oct | Field observations<br>Erosion pin measurements |
| | | Autumn 2004 | 6 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2004 | 9 Oct | Field observations<br>Erosion pin measurements<br>Bank profiling |
| | | Autumn 2005 | 2 Apr | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2005 | 15 Oct | Field observations<br>Erosion pin measurements |
| Transition | Test | Autumn 2006 | 11 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| Post-Basslink | Test | Spring 2006 | 17 Oct | Field observations<br>Erosion pin measurements |
| | | Autumn 2007 | 17 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2007 | 20 Oct | Field observations<br>Erosion pin measurements |
| | No | Spring 2007 | 1 Dec | Field observations |

Table 4-1 *continued next page*

| Monitoring Type | Triggers: Derivation or Test | Season | Dates | Monitoring completed |
|---|---|---|---|---|
| Post-Basslink | Test | Autumn 2008 | 1 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2008 | 17–19 Oct | Field observations<br>Erosion pin measurements |
| | | Autumn 2009 | 21–22 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2009 | 17 Oct (zones 3and4)<br>31 Oct (zones 1,2,5) | Field observations<br>Erosion pin measurements |
| | | Autumn 2010 | 12–14 Mar | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2010 | 19 – 20 October | Field observations<br>Erosion pin measurements |
| Ramp-rule investigations | No | Summer 2011 | 7-days in Jan – Mar | Observations of ramp-downs and drawdowns at varying levels of bank saturation associated with investigations to revise ramp-rule. |
| Post-Basslink | Test | Autumn 2011 | 26–27 Feb | Field observations<br>Erosion pin measurements<br>Photo-monitoring |
| | | Spring 2011 | 5 – 6 Nov | Field observations<br>Erosion pin measurements |
| | | Autumn 2012 | 25 – 26 Feb | Field observations<br>Erosion pin measurements<br>Photo-monitoring |

Table 4-1 continued

Table 4-2 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 |

### 4.2.1 Monitoring in November 2011 and February 2012

Geomorphology monitoring was completed twice during the 2011–12 year. The spring monitoring occurred on 5–6 November 2011 and the autumn investigation was completed on 25–26 February 2012. The spring monitoring was completed a few weeks later than in previous years due to inclement weather in October. The autumn monitoring was completed a week earlier than usual due to logistical constraints on the power station.

The pins which were not found in November 2011 or February 2012, but were located in March 2011, are listed in Table 4-3. Several of the zone 5 pins which were not located in November 2011 were found in February 2012 with the assistance of a metal detector.

Table 4-3 List of erosion pins not located in November 2011 and February 2012

| Pin | Monitoring period | Change(s) to site (e.g. tree fall etc) | Comment |
|---|---|---|---|
| 2K/1 | Nov 2011, Mar 2012 | Veg collapse in Nov 11 | Presumed buried |
| 4A/3 | Nov 2011 | None | Presumed buried. Duplicate pin previously installed. Found in Mar 2012 |
| 4H/5 | Nov 2011 | Fallen tree washed onto bank | Pin knocked over. Reset for future measurement. Measured in Feb 2012 |
| 5B/1 | Nov 2011 | None | Measured in Feb 2012 |
| 5B/5 | Nov 2011 | None | Measured in Feb 2012 |
| 5L/2 | Nov 2011 | None | Measured in Feb 2012 |

## 4.3 Flow characteristics relevant to geomorphology results

A detailed discussion of the hydrology of the Gordon River during the monitoring year is contained in chapter 2 Hydrology and water management. The following aspects of the hydrology are relevant to the geomorphology monitoring results:

- from April to July 2011 the power station was used frequently, with discharge characterised by short-duration and high flow (peaking mode). From mid-April through the end of June, discharge remained high for prolonged periods; and
- after August 2011, discharge from the power station was very low, with the environmental flow being the dominant power station operating mode.

These two distinct periods resulted in the annual discharge from the power station being very low, with a median discharge for the year of <25 $m^3 s^{-1}$, and flows in excess of 200 $m^3 s^{-1}$ occurring less than 7% of the time, with the majority concentrated in the winter period.

Catchment inflows were moderate during the year, with the Gordon above Denison site recording only a few flow events in excess of 300 $m^3 s^{-1}$.

Discharge prior to each monitoring event was very different. Between March 2011 and November 2011, discharge from the power station was characterised by daily peaking events of over 200 $m^3 s^{-1}$ for most of the winter (June –August 2011), with infrequent and generally low discharge events in September and October. Tributary inflows to the Gordon River were low during the November 2011 monitoring period. Between November 2011 and February 2012, the power station was used infrequently, for short durations and at low discharge, with the environmental flow being the dominant operating mode. Chapter 2 describes the flow characteristic of the monitoring year in detail.

## 4.4 Sediment transport capacity

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). 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 4-1 compares the model results for the 2011–12 monitoring year with previous years and the unregulated (natural) flow regime.

The results show that total sediment transport remained low during the 2011–12 monitoring year, and was very similar to the 2010–11 model results. The total calculated sediment capacity for the year was about 62 kg, which is similar to the 2010–11 value of 63 kg. A larger percentage of the total sediment transport is attributable to flows >185 $m^3 s^{-1}$ in the 2011–12 year as compared to the previous three years, but this component still only contributes about one-third of the total transport capacity. Similar to all post-Basslink years, flows in the range of 64–185 $m^3 s^{-1}$ (approximately equivalent to 1–2 turbine power station discharge) contribute the majority of the sediment transport capacity of the river. The sediment transport capacity for this flow range in 2011–12 (35 kg), is similar to the 'natural' sediment transport capacity in the 64–185 $m^3 s^{-1}$ range (38 kg). The overall low sediment transport capacity of the river is likely a contributing factor to the ongoing stability of vegetation on the banks of the Gordon River. The results demonstrate that four out of the six post-Basslink years have had the lowest sediment transport of the Gordon River.

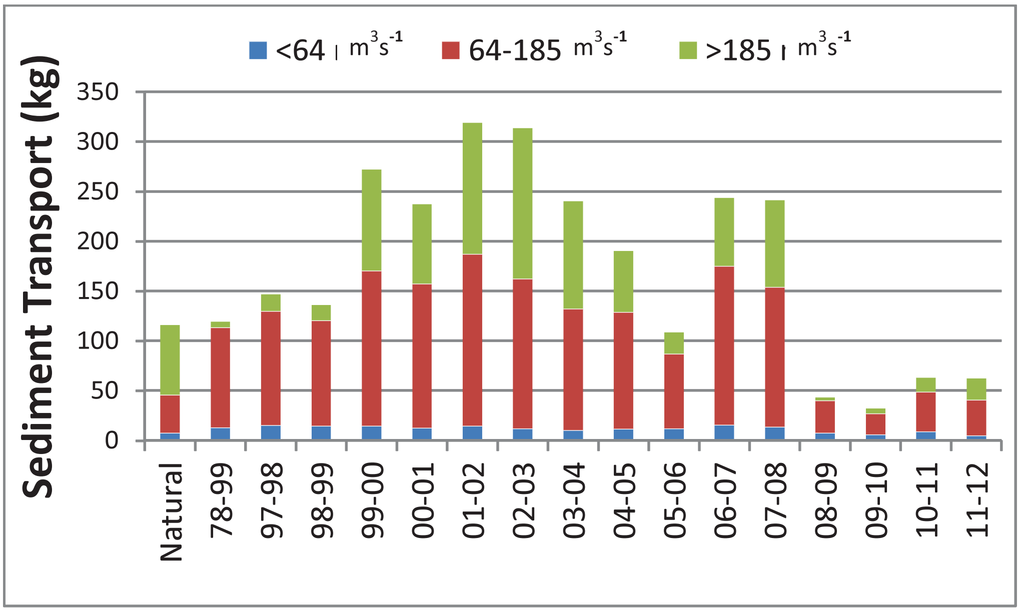


Figure 4-1 Theoretical sediment transport in zone 1 of the Gordon River due to power station discharge. Total calculated sediment transport is divided into flow levels approximately equivalent to 1, 2 and 3-turbine power station operation. Model developed by Wilkinson and Rutherfurd during Basslink IIAS

## 4.5 Monitoring results

### 4.5.1 Field observations—November 2011

Field observations in November 2011 were consistent with low levels of power station operation during the previous several months, combined with relatively low winter storm events. The following were observed:

- deposition of locally derived organic matter in the 1–2 and 2–3 turbine level of the banks indicative of lower power station discharge in the weeks prior to monitoring, (generally <100 $m^3 s^{-1}$);
- the toes of the banks were wet, but upper banks were dry, which is consistent with the recent low power station usage;
- abundant mosses and seedlings in the 2–3 turbine level of the banks are also consistent with low power station usage in the preceding months (Photos 4-1 and 4-2);
- the presence of mud veneers on the bank faces is most likely due to deposition associated with the rainfall event which occurred on 1–2 November (Photo 4-3);
- rilling on bank toes, but not in the upper banks (2–3 turbine bank level);
- no evidence of active seepage flows in the 2–3 turbine bank level, however evidence of previously occurring seepage flows, likely associated with the winter peaking operations (Photos 4-4 and 4-5);

- a new tree fall in zone 2, and ongoing collapse of the root mat at erosion pin site 2G (Photos 4-6 and 4-7); and
- a large tree washed up onto erosion pin site 2H dislodging an erosion pin (Photo 4-8).

Photo 4-1 Mosses on bank toes in zone 2. View is upstream towards erosion pin site 2A

Photo 4-2 Vegetation in back channel behind erosion pin monitoring site 2A

Photo 4-3 Mud veneer on bank in zone 2

Photo 4-4 Dried sediment flow at erosion pin site 2C indicative of past seepage erosion, probably during prolonged high flows during winter

Photo 4-5 Sediment flows in 1–2 turbine bank level at erosion pin site 2H. White sands are being transported from under deteriorating root mat

Photo 4-6 New tree fall in zone 2, right bank downstream of erosion pin site 2D

Photo 4-7 Erosion pin site 2G showing vegetation on bank in power station-controlled operating level, and collapse of root mat on left side of photo

Photo 4-8 Dead tree washed up on erosion pin site 2H, located just upstream of Sunshine Gorge. Tree knocked down an erosion pin

### 4.5.2 Field observations – February 2012

Field observations in February 2012 were consistent with the continuation of long periods of low power station discharge over the spring and summer. Field observations included:

- dried algae present on bank toes and in the 1-turbine bank level throughout the river. The presence of the algae is consistent with the very low power station discharge which allowed light penetration into the shallow water over the summer period (Photo 4-13);

- a widespread and substantial increase in vegetation on bank faces in both the 1–2 and 2–3 turbine bank levels. Examples of the increase in vegetation on the bank faces between February 2011 and February 2012 are shown in Photos 4-9 to 4-12;
- deposition of locally derived organic matter on the banks above the environmental flow level indicative of low power station discharge (Photo 4-14);
- mud veneers were present on banks, indicative of natural sediment deposition (Photo 4-14;
- no evidence of recent seepage flows in the 2–3 turbine bank level;
- using a metal detector, scour chains were located in zone 5 which had not been found for several years. The chains were found at depths ranging up to 200 m and show that deposition on the bank toes occurs in the downstream zone (Photo 4-15); and
- additional bank failure was observed in the lower Albert River in the cobbles along the left bank of the river (Photo 4-16).

Photo 4-9 Vegetation in backwater channel behind site 2A in February 2011 indicative of low levels of inundation and high light conditions. Compare with Photo 4-10

Photo 4-10 Vegetation in backwater channel behind site 2A in February 2012 showing increase in vegetation indicative of low levels of inundation

Photo 4-11 Vegetation in the 1–2 turbine bank level at site 2G in February 2011. Compare with Photo 4-12

Photo 4-12 Erosion pin site 2G showing increase in vegetation relative to February 2011

Photo 4-13 Dried algae on bank toe in zone 2, right bank downstream from piezometer site

Photo 4-14 Break in slope at ~1–2 turbine discharge level, algal deposit upslope of break in slope, and mud veneers and organic debris on bank face at erosion pin site 2D, February 2012

Photo 4-15 Recovery of scour chain at site 5F with help of metal detector

Photo 4-16 Aerial view of recent bank failure in the Albert River, left bank upstream from Gordon confluence

### 4.5.3 Zone 2 piezometer results

Piezometer results from the zone 2 piezometer site are shown in Figure 4-2 for the entire monitoring year and in Figure 4-3 to Figure 4-4 in greater detail. The results show that water level within the alluvial bank was consistent with river level, with higher levels of bank saturation occurring during the first part of the monitoring year, when the power station was used frequently at high discharge. Maximum bank saturation occurred during May 2011 (Figure 4-3) when power station discharge remained high for prolonged periods. When the power station was run in a peaking mode, with flow between the peaks reducing to or near the environmental flow level, water level in the banks decreased considerably (Figure 4-4). In-bank water levels were at a minimum during the second half of the year when the power station was used sporadically and for short durations (Figure 4-5).

Similar to previous years, results from the zone 2 piezometer site have been used to assess the risk of seepage erosion. Seepage risks are considered high when the water level at piezometer 2, which is located at 10 m inland, exceeds 2.75 m *and* the in-bank water slope between piezometer 2 and the river level exceeds 0.1 (positive slope indicates water draining out of the bank). The results of this analysis are shown in Figure 4-6, with the grey bars showing the water slope throughout the monitoring period, and the black bars indicating when the above conditions were met. Also shown in the graph is the discharge from the Gordon Power Station.

The results show that there were several periods of high seepage risk occurring in late May and June 2011. During May 2011, several time-lapse cameras were located within zone 2 and recorded bank changes at 15-minute intervals. The photos corresponding to the high seepage risk periods show evidence of sediment flows and deep rilling, indicative of seepage processes (Photo 4-17). The photos confirm that the flow and bank saturation conditions used to assess seepage erosion risks during the Basslink monitoring program are appropriate, and that the newly formulated and implemented ramp-rule should prevent these conditions from occurring in the future.

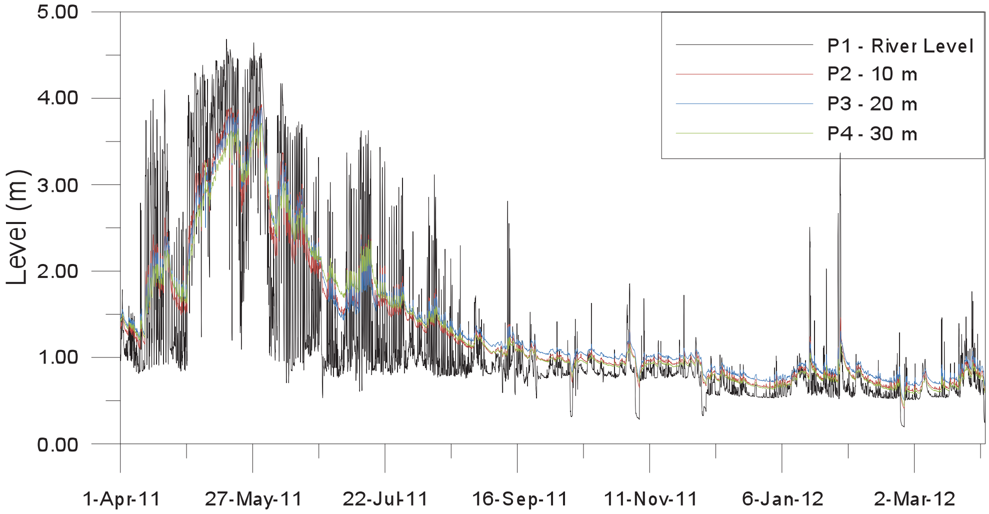


Figure 4-2 Hourly piezometers results at zone 2 piezometer site between 1 April 2011 and 30 March 2012

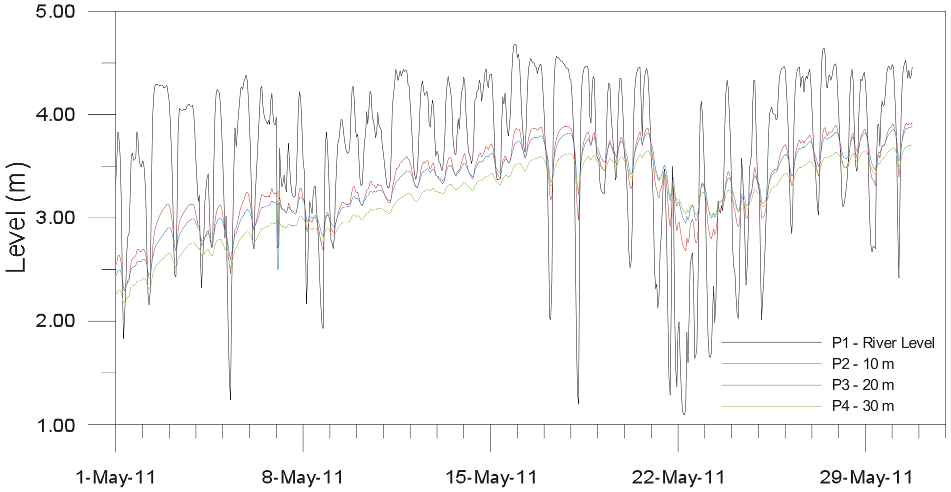


Figure 4-3 Hourly piezometer results at zone 2 piezometer site during May 2011 during a period of extended power station operation

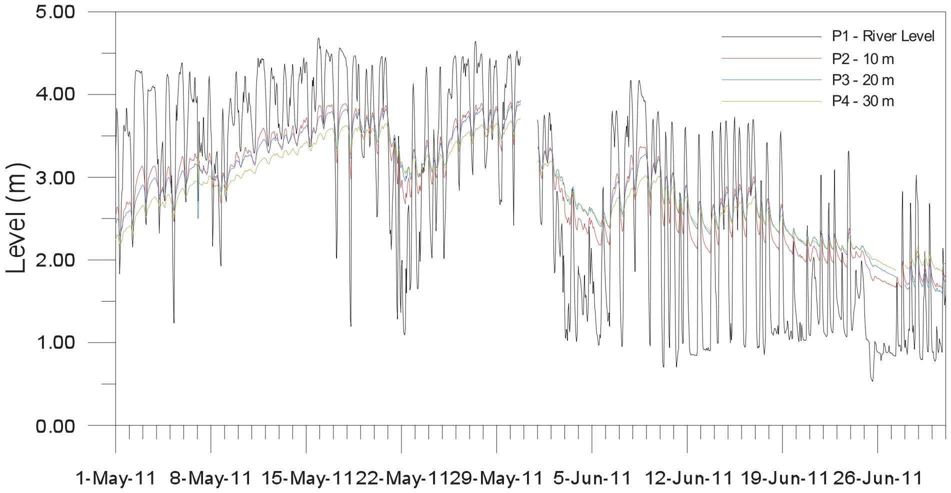


Figure 4-4 Hourly piezometer results from zone 2 piezometer site during May and June 2012 showing reduction in piezometer water levels during peaking operation in June

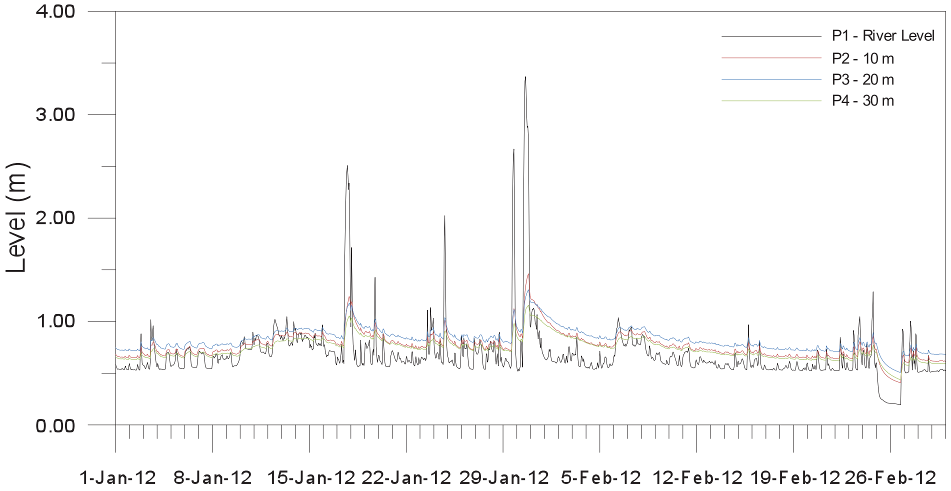


Figure 4-5 Hourly piezometer results from zone 2 piezometer site during January and February 2012 period of low power station usage

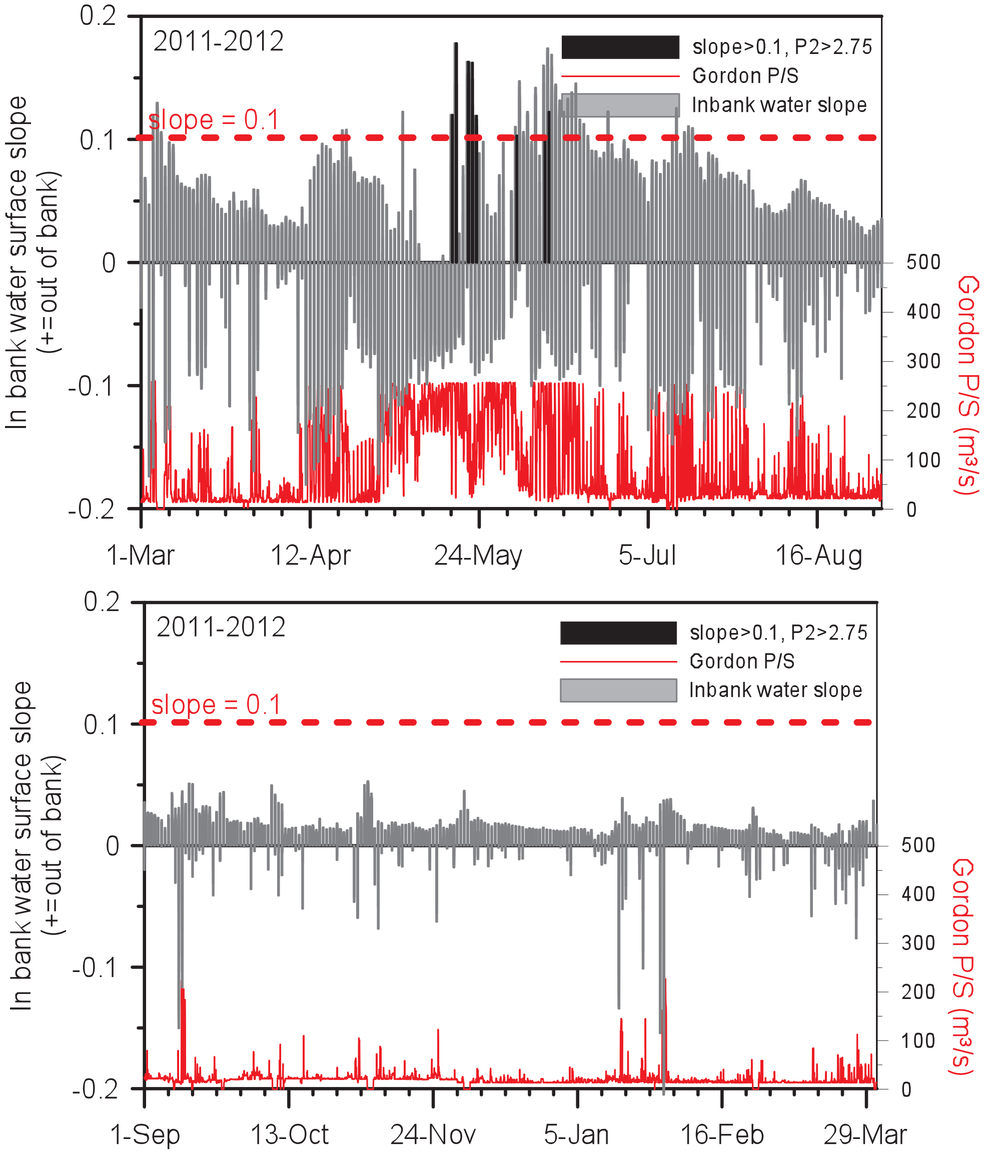


Figure 4-6 In-bank water slopes at zone 2 piezometer site and Gordon Power Station discharge. Grey lines show water slopes based on difference in water level between piezometer 2 (10 m inland) and river level. Positive slope indicates water is draining from the bank towards the river. Black lines indicate periods when the in-bank water slope exceeds 0.1 and the water level at piezometer 2 >2.75 m. The red line indicates discharge from the Gordon Power Station with the scale shown on the right side of the graph

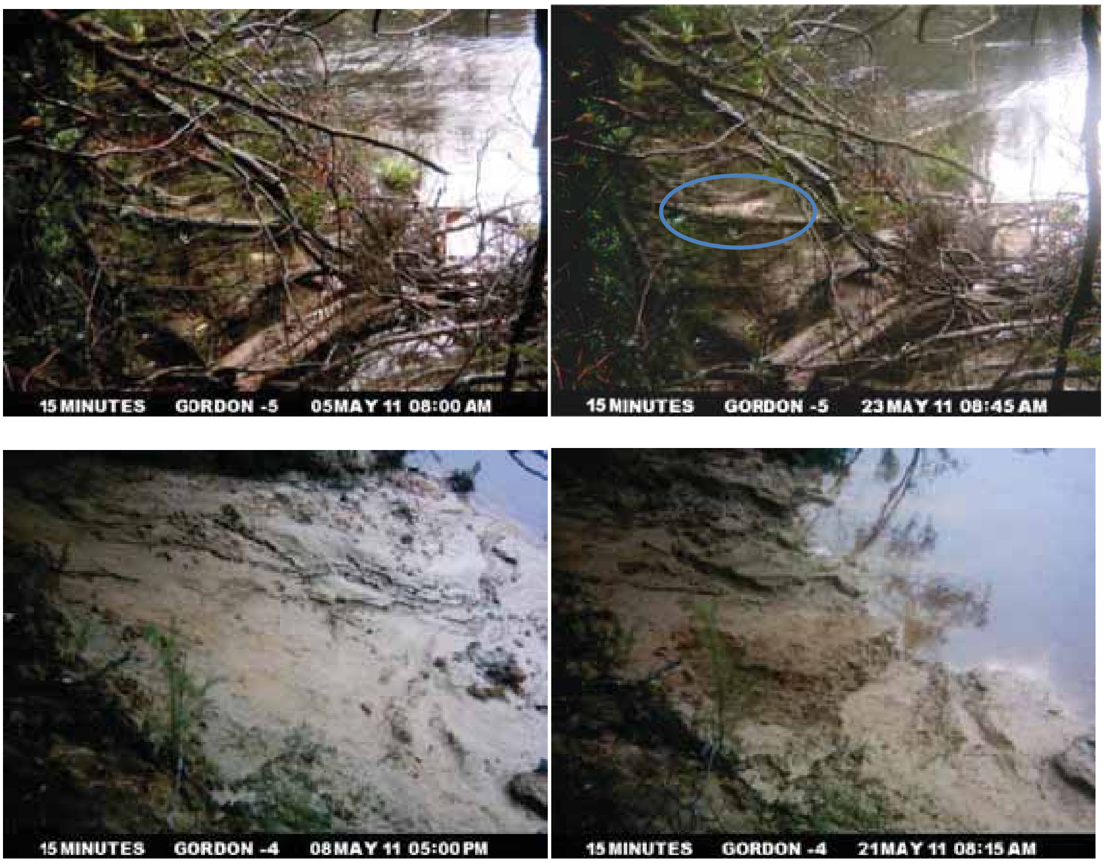


Photo 4-17 Photos obtained using PlantCams in zone 2 of the Gordon River. Top photos obtained on 5 May and 23 May and show evidence of seepage erosion on the bank near the piezometer array. Blue circle shows a newly deposited seepage flow following draw-down. Bottom photos obtained on 8 May and 21 May and show deep rilling on bank in zone 2

### 4.1.1 Erosion pin results

#### *4.1.1.1 Results grouped by zones*

Graphs showing the erosion pin results are contained in Appendix 3.The raw results for erosion pins and scour chains are contained in Appendix 4.

Erosion pin results grouped by zones are plotted inFigure 4-7 to Figure 4-11. This is the grouping that was used to derive trigger values, although it is now recognised that a multiple lines of evidence approach is a more reliable indicator of change.

For each zone, several data sets are presented on the graphs. The central data set shows the average change of all pins in the grouping using spring 2001 as the baseline (value indicates net change since 2001). The difference between data points on the graphs indicates the relative difference in erosion or deposition between the two dates. The ‘net erosion’ data set is further divided into pre- and post-Basslink periods. The pre-Basslink results (spring 2001–spring 2005) were used to predict a trend into the future, as shown by the line in each graph. The 95th percentile confidence interval for each projected trend was also calculated and is shown on the graphs in dashed lines. This 95th percentile envelope defines the Basslink trigger values, and post-Basslink results are discussed with respect to this envelope in Section 4.5.5 of this report.

Two additional data sets on each graph show the average change for pins recording erosion (compared to spring 2001) during the monitoring period in the grouping, and the average change for pins showing deposition (compared to spring 2001) during the monitoring period. The relative changes between data points in these data sets shows whether erosion or deposition has increased or decreased between monitoring periods. The positioning of the data sets relative to the mean values provides an indication of the relative number of pins recording erosion or deposition (e.g. if the trend for all results is closer to the erosion trend, more pins are showing erosion than deposition).

A summary of the net changes for each zone relative to the previous monitoring period (rather than spring 2001) for the 2011–12 monitoring year is shown in Figure 4-12, with annualized erosion rates summarized in Figure 4-13.

In zone 1 (Figure 4-7) net erosion rates for November 2011 and February 2012 are similar and remain close to zero and within the predicted ‘envelope’. The autumn results show a slight increase in pins recording erosion, and a similar decrease in pins recording deposition, resulting in little net change. The increase in the erosional component during a period of very low power station usage suggests that sub-aerial processes may be responsible for some of the changes.

In Figure 4-12, the erosion pin results for zone 1 are compared to the previous season, rather than spring 2001. The November 2011 results show an increase in deposition, which may reflect seepage associated with the high flow peaking periods in May and June 2011, and very little change in February 2012, consistent with the low levels of power station operation. On an annualized basis (Figure 4-13) the 2011–12 results show deposition equivalent to the erosion recorded in 2010–11. The annual average post-Basslink rate of change remains low, at <-2 mm/yr.

The erosion pin results for zone 2 (Figure 4-8) show a small net increase in November 2011, and little change in February 2012. The net increase in November suggests that seepage-induced deposition was not a dominant process, and rather scour associated with peaking may have driven the change. The results remain below the predicted ‘envelope’ based on pre-Basslink results, and remain within the same 20–40 mm band as all other post-Basslink results. Comparing the results to the previous monitoring periods highlights that most of the change occurring in the 2011–12 year was associated with the first half of the year, with virtually no net change between November 2011 and February 2012 (Figure 4-12). The annualized results (Figure 4-13) show that post-Basslink changes in zone 2 continue to alternate between erosion and deposition within a range of ~8 mm. The average annual post-Basslink rate of change is similar to zone 1 at <2 mm $yr^{-1}$.

Zone 3 (Figure 4-9) recorded a net decrease in erosion rate in the spring, followed by an increase in autumn 2012, consistent with results obtained since spring 2008. The increased deposition during the first half of the year may be indicative of increased deposition associated with seepage processes, and a decrease in natural sedimentation during the summer period. The erosional and depositional components, as well as the net result for February 2012, are the same as in autumn 2006, at the beginning of the post-Basslink monitoring period. Relative to previous monitoring periods, zone 3 recorded net deposition of ~15 mm in November 2011 and net erosion of ~5 mm in February 2012 (Figure 4-12). On an annualized basis (Figure 4-13), zone 3 has shown a relatively large depositional change over the past year, which is similar in magnitude to the erosional change recorded in 2008–09. The post-Basslink average annual change is -0.1 mm yr$^{-1}$, which is considerably lower than the average pre-Basslink rate of change off ~14 mm yr$^{-1}$.

Results from zone 4 (Figure 4-10) continue to show a slowly decreasing rate of net erosion, a trend that began in autumn 2010. The results continue to fall well below the projected rate of change based on the pre-Basslink monitoring results. In contrast to the upstream zones, a slightly higher rate of change was recorded over the summer (November 2011–February 2012) as compared to the first half of the monitoring year (Figure 4-12). This may be attributable to deposition from unregulated tributaries during summer when power station operation was limited. The annualized result (Figure 4-13) shows the change over the past year is small compared to the previous two years. The average annual post-Basslink rate of change is ~-2 mm yr$^{-1}$, which is lower than the pre-Basslink rate of change of ~10 mm yr$^{-1}$.

Zone 5, the most distal zone, continues to be the only zone in which recorded erosion rates exceed those predicted based on the pre-Basslink results, recognising that zone 5 was the only zone in which net deposition was predicted. The February 2012 net erosion change of 11.7 mm is higher than the predicted value of 7 mm, though lower than the November 2011 result of 17 mm. Similar to zones 1 to 3, the zone 5 erosion pins showed higher net changes relative to the previous monitoring period in November 2011, when net deposition in excess of 10 mm was recorded, as compared to February 2012 when <2 mm of erosion was measured. The annualized results (Figure 4-13) show a small decrease in erosion (increase in deposition) for the 2011–12 monitoring year. The average annual post-Basslink rate of change is approximately 2 mm yr$^{-1}$ compared to a pre-Basslink average rate of change of ~-2 mm yr$^{-1}$.

The net change in pins for all zones relative to spring 2001 (Figure 4-14) shows that similar to previous years, zone 3 has recorded the largest change followed by zones 4 and 2. Zone 1 is the only zone which has recorded net deposition since monitoring began in 2001.

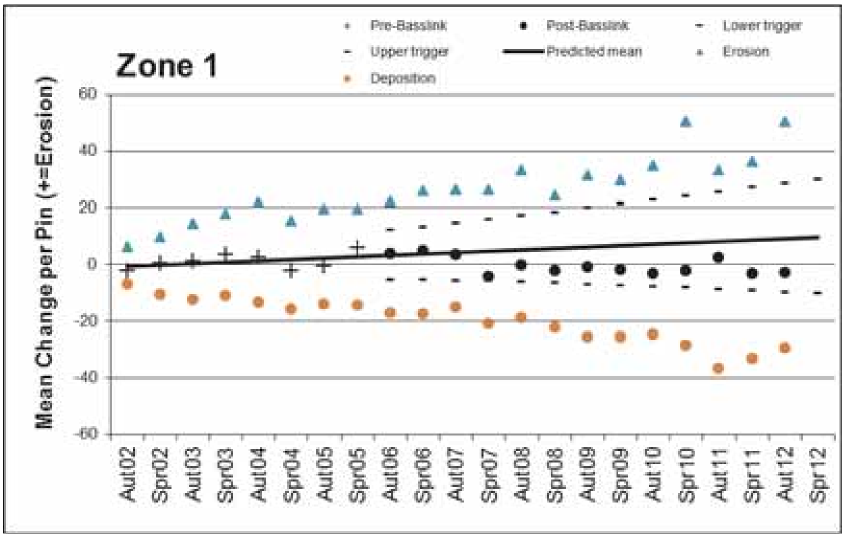


Figure 4-7 Erosion pin results grouped by zones for zone 1. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

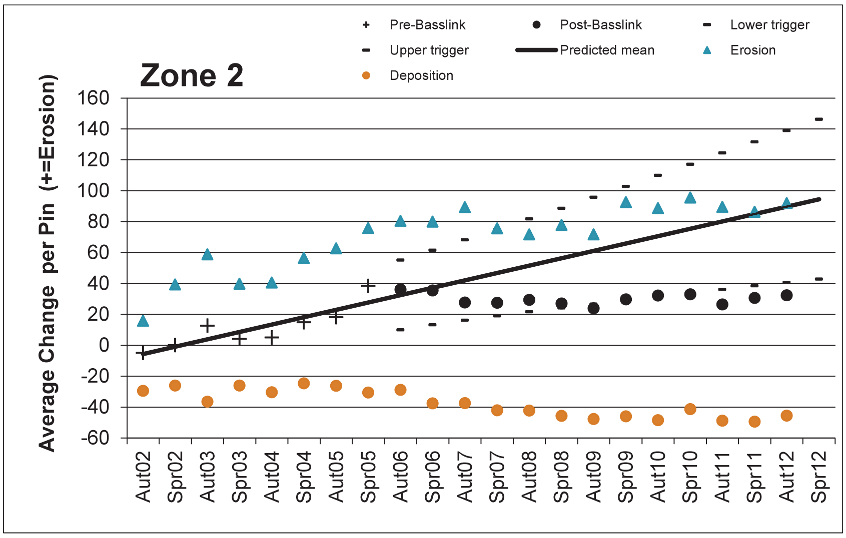


Figure 4-8 Erosion pin results grouped by zones for zone 2. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

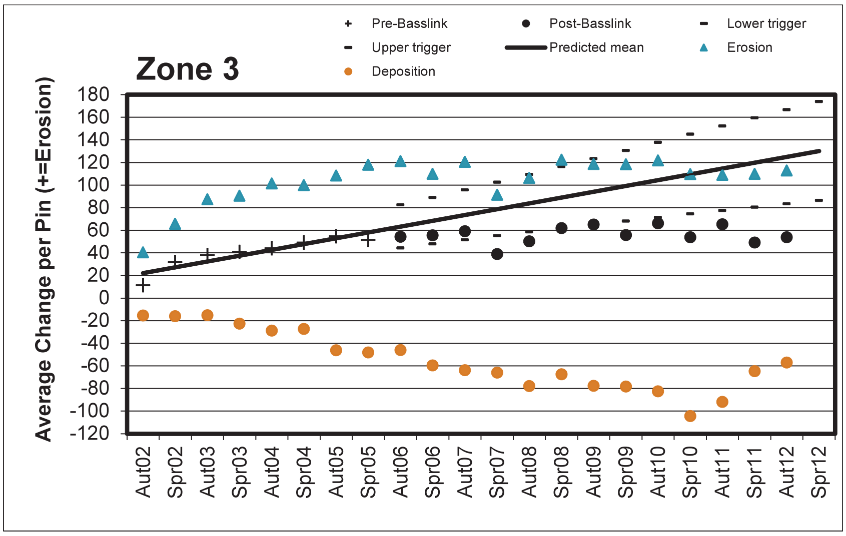


Figure 4-9 Erosion pin results grouped by zones for zone 3. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

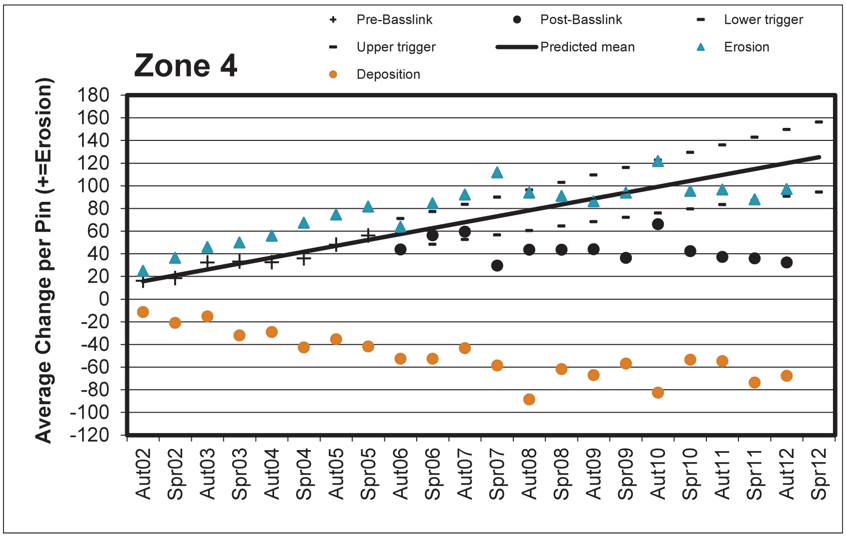


Figure 4-10 Erosion pin results grouped by zones for zone 4. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

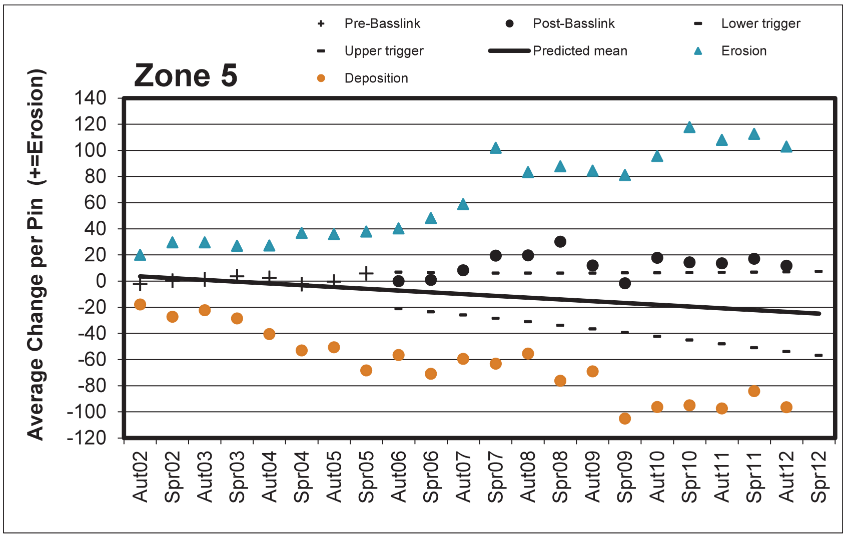


Figure 4-11 Erosion pin results grouped by zones for zone 5. Black crosses show mean change for all pins relative to spring 2001 in zone during the pre-Basslink monitoring period. Solid line shows projection of mean based on pre-Basslink monitoring results. Dashed lines show 95th percentile confidence interval for this projected mean. Black circles show mean change relative to spring 2001 for all pins in zone post-Basslink. Triangles show mean erosion rate for pins recording erosion in each monitoring period. Orange circles show mean deposition rate for pins recording deposition in each monitoring period

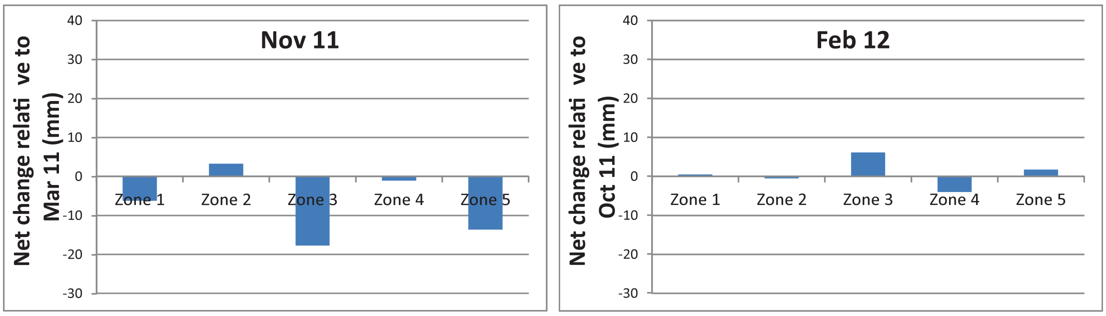


Figure 4-12 Net erosion (+ = erosion, - = deposition) results by zones compared to previous monitoring period. November 2011 monitoring results compared to March 2011, February 2012 results compared to October 2011

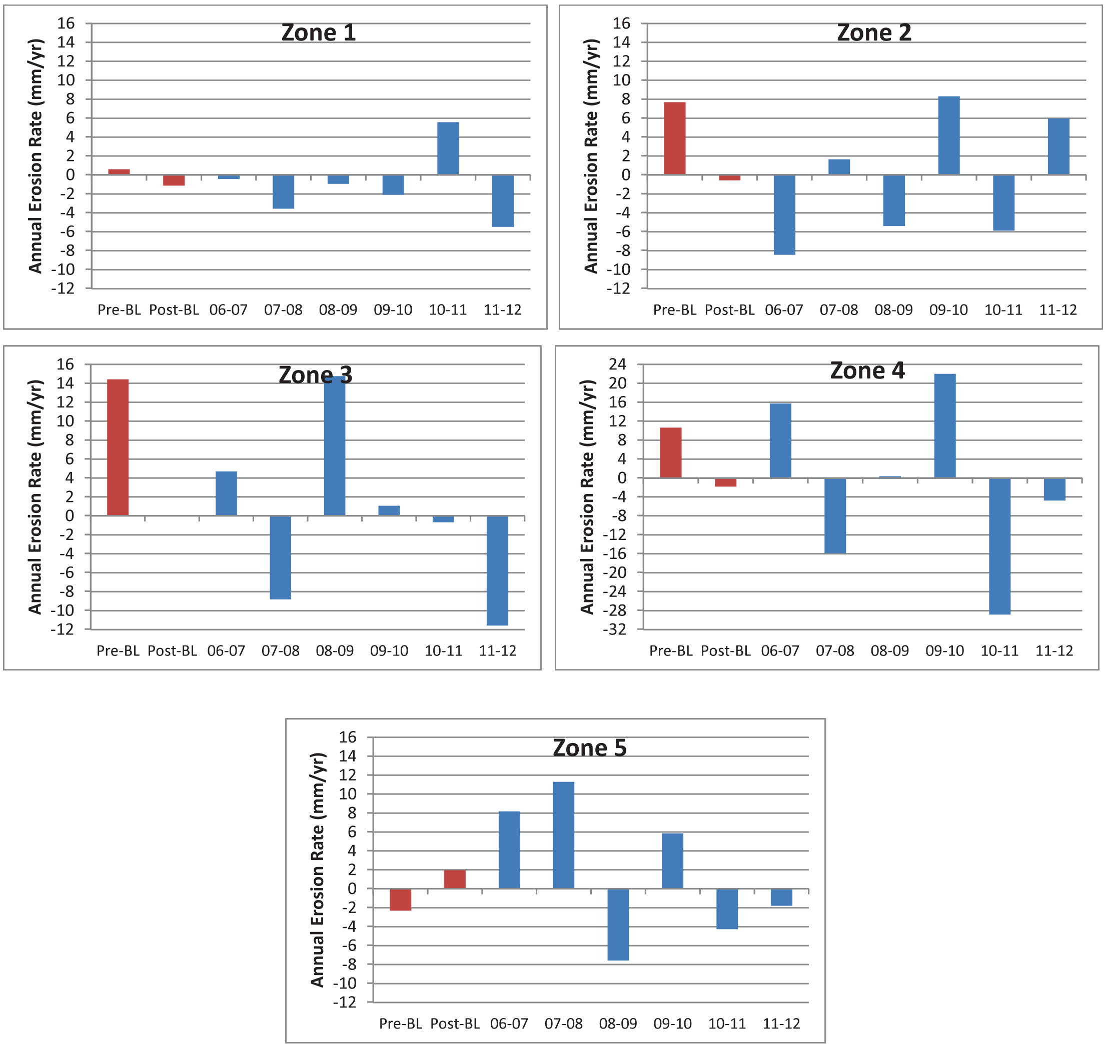


Figure 4-13 Annual erosion rates (+ = erosion, - = deposition) for zones. First two bars in each data set show the average annual erosion rate for the pre- and post-Basslink periods, respectively based on March results. The annual ‘bars’ show the rate of change based on changes between the autumn (February/March) monitoring results for each year (e.g. 06–07 = change between March 06 and March 07). Note the scale for zone 4 differs from the other zones

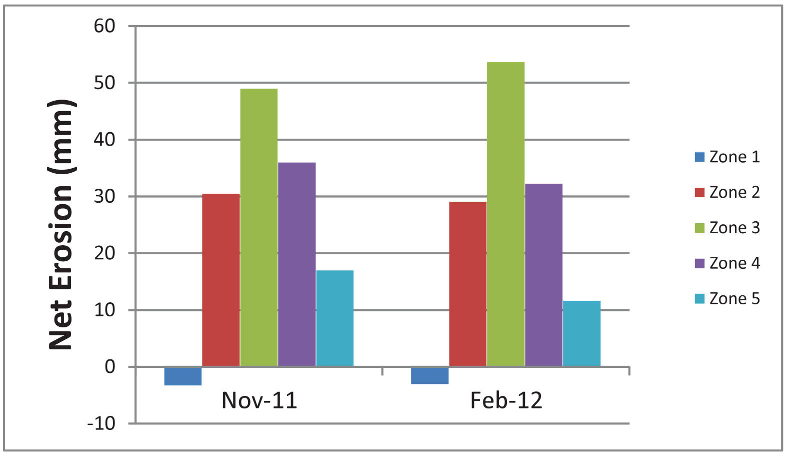


Figure 4-14 Comparison of net erosion rates for November 2011 and February 2012

### 4.5.4.2 *Results grouped by zones and turbine levels*

Figure 4-15 to Figure 4-17 contains the same erosion pin results grouped by turbine levels across the five zones, for zones 2 and 3, and for zones 4 and 5, respectively. The results show the net change for each turbine level relative to the beginning of monitoring in October 2001. The results for all zones suggest that little change has occurred in the 1–2 or 2–3 turbine bank level, but a relatively large decrease has occurred in the <1 turbine zone. This may be associated with the environmental flow which has increased saturation, and hence seepage processes on the bank toe, and/or the retention of sediments delivered by unregulated tributaries. It continues a trend which began in 2008–09, which is when the typical power station discharge decreased substantially compared to previous years.

The subset of results from zones 2 and 3 show more variability, with the November 2011 results showing an increase in erosion in the 1–2 turbine bank level, and decrease in erosion in the <1 and 2–3 turbine bank levels. These changes are consistent with seepage processes occurring in the 2–3 and <1 turbine bank level, and scour of the 1–2 turbine level bank associated with peaking. The February 2012 results show almost no change relative to November 2011, consistent with the low power station discharge during this period.

In contrast to zones 2 and 3, the results for zones 4 and 5 show a sharp decrease in erosion (increase in deposition) on bank toes (<1 turbine level) for both monitoring periods. Because these zones are located farther from the power station, and are less impacted by seepage processes, it is likely that this deposition is attributable to sedimentation from unregulated tributaries, rather than seepage processes. The November 2011 results in zones 4 and 5 show erosion in the 1–2 and 2–3 turbine bank levels, which may reflect scour associated with station peaking operations during the first half of the year.

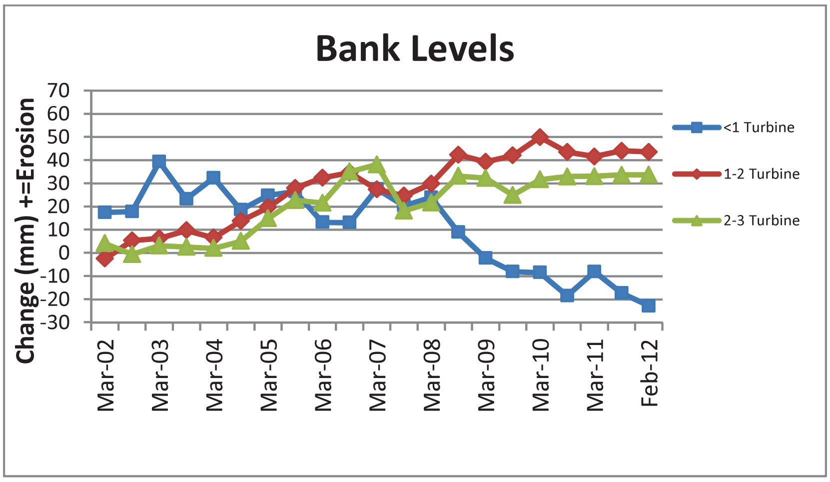


Figure 4-15 Erosion pin results grouped by turbine level. Results are relative to October 2001

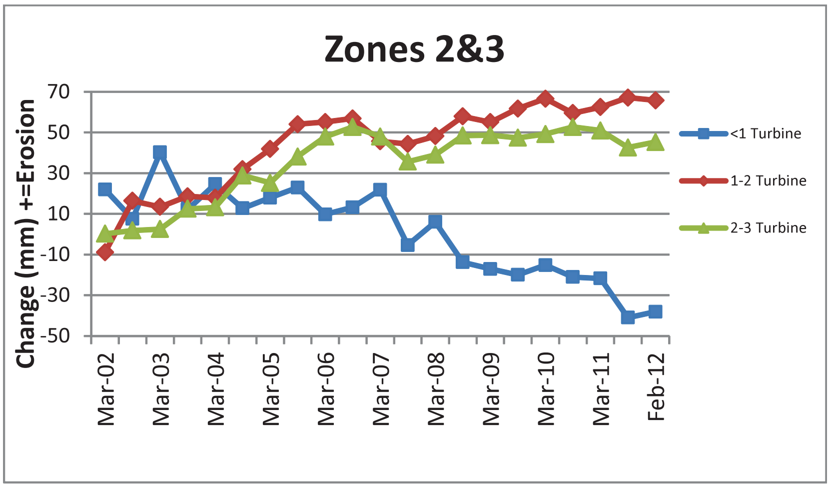


Figure 4-16 Erosion pin results grouped by turbine levels for zones 2 and 3. Results are shown relative to October 2001

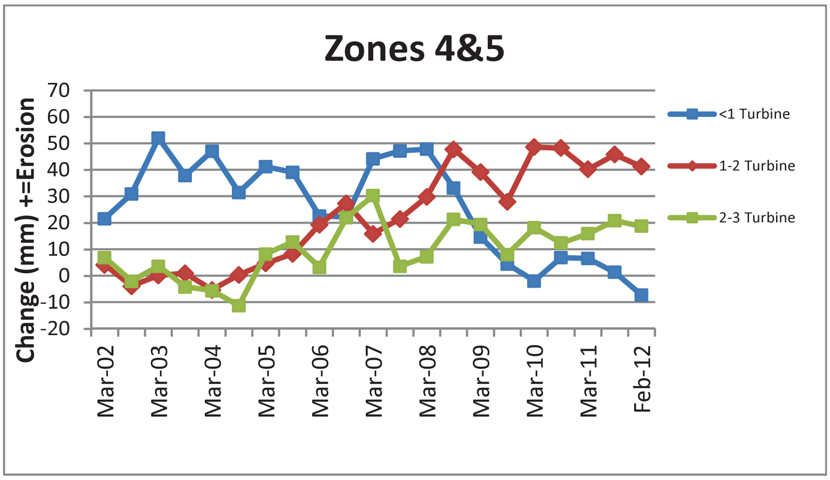


Figure 4-17 Erosion pin results grouped by turbine levels for zones 4 and 5. Results are shown relative to 2001

A comparison of net erosion since spring 2001 by turbine level for all zones, zones 2 and 3 and zones 4 and 5 is presented in Figure 4-18, and shows that zones 2 and 3 have undergone the largest changes for each bank grouping, with the 1–2 and 2–3 turbine levels recording erosion, and the <1 turbine level showing deposition. This is consistent with previous results, and the conceptual model in which a low angle bank extends to a break in slope.

The lower rates of change recorded in February 2012 relative to November 2011 (Figure 4-19) are consistent with the low volumes of water discharged from the power station during the summer period.

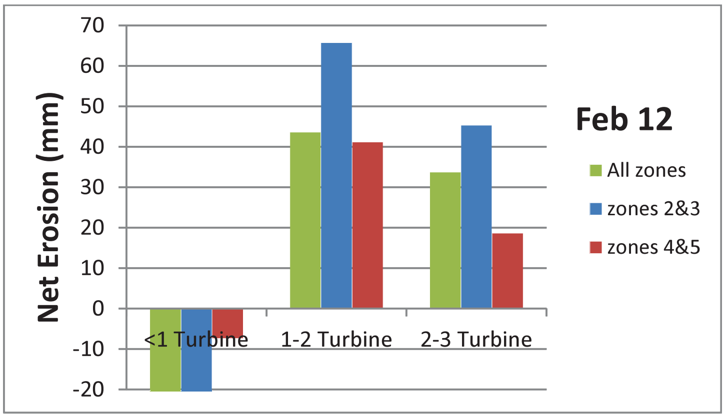


Figure 4-18 Net erosion pin results grouped by zones and turbine levels. Results are relative to spring 2001

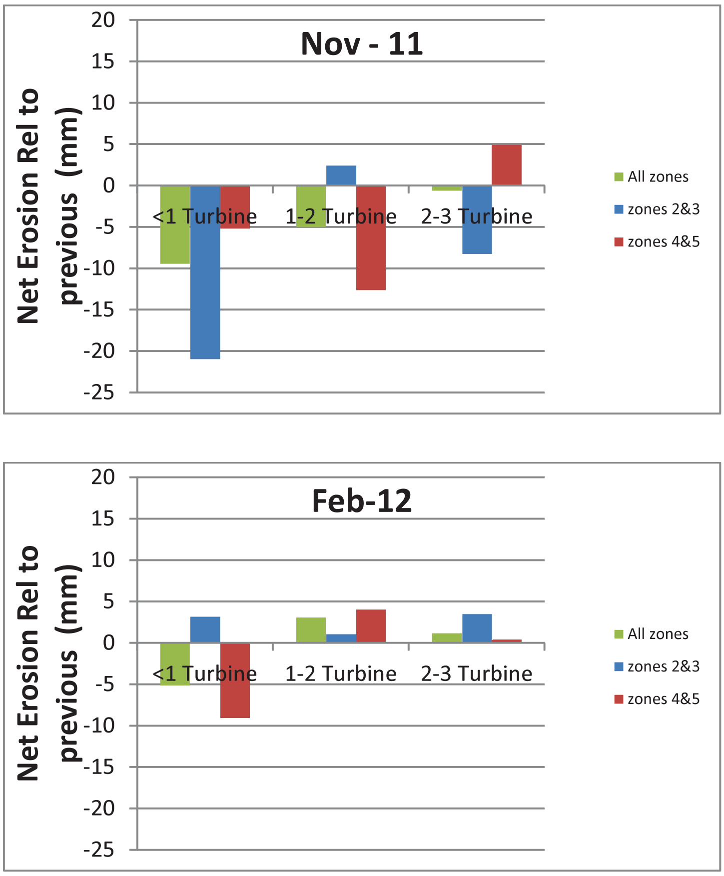


Figure 4-19 Comparison of net erosion rates relative to previous monitoring period for November 2011 (top) and February 2012

## 4.5.5 Trigger values

Trigger values based on the erosion pin results grouped by zones were developed for the Basslink Baseline Report (Hydro Tasmania 2005a). The trigger values are defined by 95th percentile confidence interval of the projected net erosion rate for each of the zones based on the 2001–05 monitoring results, and are shown in Figure 4-7 to Figure 4-11. Since the Basslink Three Year Review Report (Hydro Tasmania 2010a), a 'multiple-lines-of-evidence' approach has been adopted to assess changes to the river, which includes erosion pin results, hydrology, field observations, piezometer results, photo-monitoring results (presented in section 4.5.6), and the conceptual model. The integration of these results is presented in chapter 10 Discussion of trigger results.

Similar to the previous few years, the net erosion pin results for zones 2–5 fall outside of the projected 'envelope' derived from the pre-Basslink results. The results for zones 2–4 fall below the projected erosion rate, and the results for zone 5 are above the projected rate, which was depositional. The rates have been outside of the projected 'envelope' since late 2007, following a large flood event. The low rates of change in all zones over the past few years have resulted in the rates remaining outside of the projections for most of the post-Basslink monitoring period. It is unknown if the relative increase in erosion rate in zone 5 is related to the reduction in erosion in the upstream zones, to other hydrological factors, or to variability which was not captured in the pre-Basslink data set.

As demonstrated in Figure 4-13, each of the zones shows variability in the post-Basslink period, but the overall average erosion rate is lower than the pre-Basslink rate. This is likely attributable to the much lower volumes of water which have been discharged from the power station post-Basslink as compared to pre-Basslink (chapter 2 Hydrology and water management) and, possibly, due to a reduced rate of bank adjustment by the river as compared to the early 2000s.

The erosion pin results for 2011–12 are consistent with the conceptual model of the river, with higher rates of change occurring between March 2011 and November 2011. The higher rates of change are the result of higher flow rates, resulting in periods of high bank saturation, and peaking operations which can potentially increase scour of bank faces. The May through June 2011 period clearly demonstrates that the risk of seepage erosion is increased following periods of extended high discharge from the power station, rather than during periods when discharge is reduced to the environmental flow between peaking events. This is consistent with modelling and field observations.

### 4.5.6 Photo-monitoring results

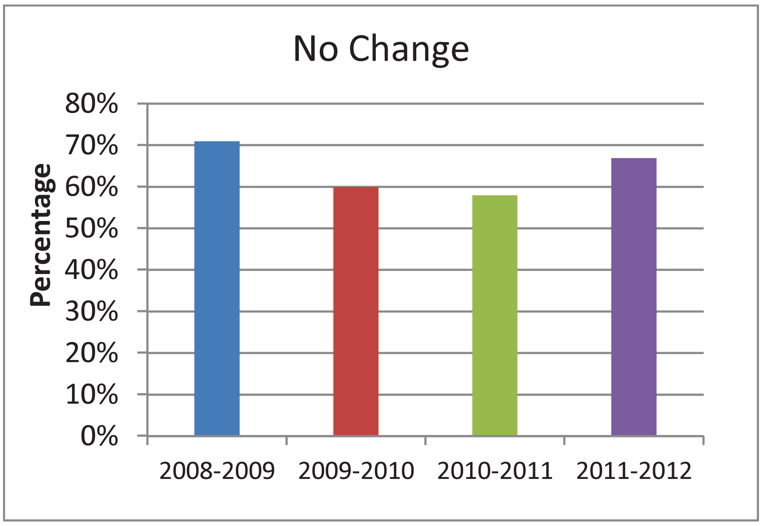
Photo-monitoring at 61 sites was completed in February 2012. The photos are contained in Appendix 5, along with a table summarizing changes observed in 2012. The results are summarized in Figure 4-20, which also contains results from previous monitoring years for comparison.

In 2012, the most notable change at photo-monitoring sites, as well as in the river overall, was the increase in vegetation on the banks *within* the power station operating range. This change was not quantified for each photo-monitoring site as it was a widespread phenomenon related to the overall hydrology.

Similar to previous years, in February 2012 there were a high number of sites (41) which recorded no net change relative to February 2011. In contrast to other years, there was only one site where an additional tree fall was recorded upslope of the power station operating level. This may be attributable to the overall low river flows through the year.

Within the 'other' category, the movement of woody debris on bank toes accounted for the majority of the changes. The second most common category was increased vegetation above the power station-controlled high-water level, which was noted at three sites.

One photo was not obtained, and four photos were obtained but of very poor quality due to harsh or poor lighting conditions. Several of the sites are becoming difficult to identify due to increased vegetation coverage.



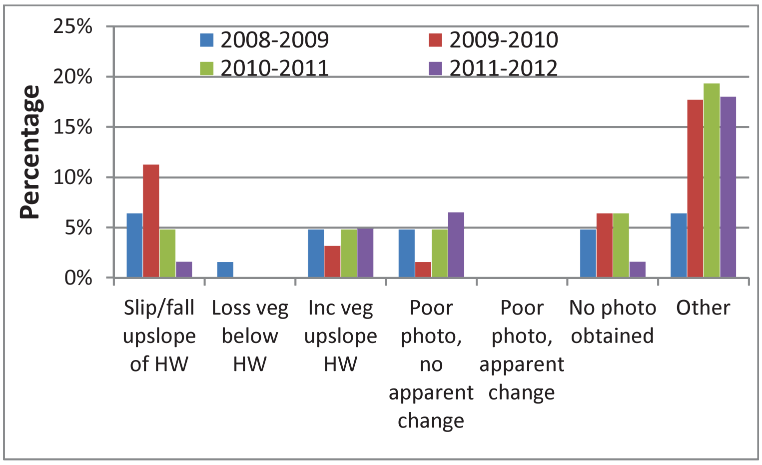


Figure 4-20 Summary of photo-monitoring results for 2011–12 indicating presence of changes at photo-monitoring sites relative to the power station-controlled high-water level (HW) and the type of change in the previous year. Previous year's results included for comparison

## 4.6 Summary

The 2011–12 monitoring year was similar to the previous few years in that low volumes of water were discharged from the power station relative to pre-Basslink or historic periods. Overall rates of change were low in the river which is consistent with previous results, sediment transport modelling and the conceptual model.

The 2011–12 monitoring year was interesting in that the flow regime was markedly different between the March 2011 and November 2011 monitoring runs, and the November 2011 and February 2012 monitoring runs, with the first period characterised by power station peaking operations, and the second by very low power station usage. During May 2011, when the power station was maintained at a high discharge between peaking events, bank saturation levels increased leading to a number of high-risk periods for seepage erosion. Seepage events were captured in photos during this period, which confirmed the conditions. Erosion pin results and field observations showed some evidence of seepage processes and bank scour in November 2011, but overall rates of change remained low and similar to the past few years based on erosion pin results.

The extended high flow and peaking operations during the autumn and winter were not sufficient to remove the vegetation on the bank faces which has established over the past two years, and the vegetation *may* have reduced the impact of peaking on the banks. The revegetation of the bank faces continued throughout the monitoring year, resulting in the most widespread vegetation cover of the entire Basslink monitoring program being present in February 2012.

The results from zones 4 and 5 suggest that the lack of power station discharge in the second half of the monitoring year also promoted the deposition of sediment derived from unregulated tributaries on bank toes in the lower river.

Based on the piezometer results, bank saturation occurred following periods of extended power station operation, but decreased during periods when flow was reduced to the environmental flow between peaking events. This is consistent with the field observations and modelling completed in association with revision of the ramp-rule and supports the changes made to the rule.

# 5 Karst geomorphology

## 5.1 Introduction

The specific objectives of monitoring the karst areas along the Gordon River are to:

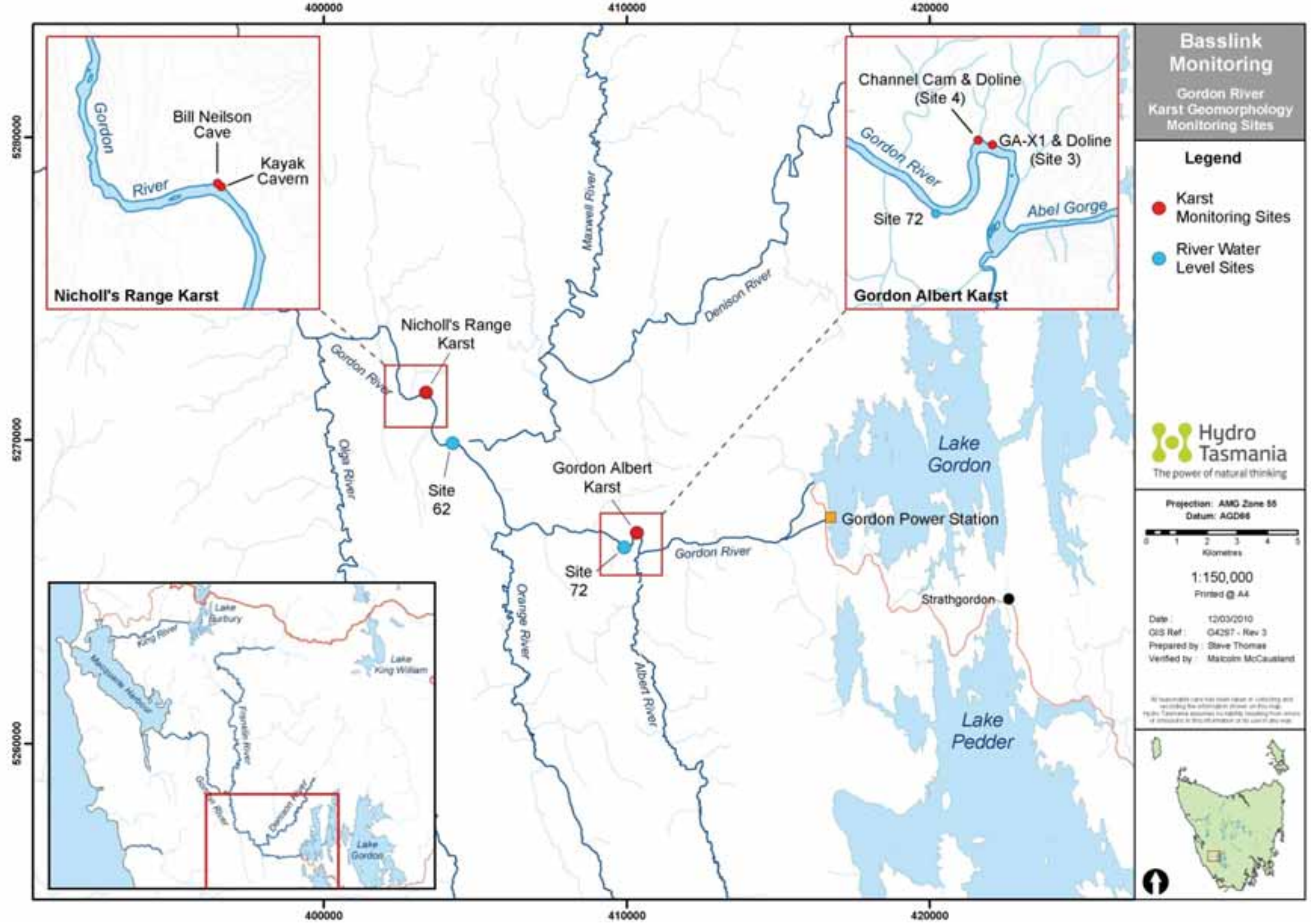
- provide an understanding of the sediment fluxes occurring in the caves, and to determine how these may relate to the hydrology of the Gordon River; and
- monitor dolines to gather evidence for whether they may be affected by repeated drawdown in the river channel under the predicted Basslink operation.

This report provides a summary of:

- the karst monitoring data (erosion pin and water level data from Bill Neilson Cave, Kayak Kavern, GA-X1, Channel Cam and dolines) obtained during the 5 November 2011 and 25 February 2012 field trips, including a brief discussion of the results; and
- analysis and discussion of the monitoring results in the context of the informal trigger values determined as part of the baseline review.

### 5.1.1 Karst areas

Key karst features are monitored in both the Gordon-Albert and Nicholls Range karst areas twice per year. Map 5-1 shows the location of the two karst areas investigated by the monitoring program.



Map 5-1 Map of the karst monitoring sites in the Gordon River

## 5.2 Site description and methods

### 5.2.1 Gordon-Albert karst area

There are four karst monitoring sites in the Gordon-Albert karst area. Site 1 is a backwater channel known as Channel Cam, site 2 is GA-X1 cave with a doline at its entrance, and sites 3 and 4 are dolines. Each site has a number of stainless steel erosion pins installed and a photo-monitoring site marked with a red metal peg. A water level recorder is installed in GA-X1 and in the Gordon River below the confluence with the Albert.

The GA-X1 cave is 28 m long (including the large entrance chamber), 10 m deep and is located approximately 10–20 m from the Gordon River. There are two entrances to the cave—the smaller entrance is a short, near-vertical shaft leading down into the main chamber, the second entrance is much larger and is effectively the base of a second large doline. The cave has a sump at its lowest level, which is at approximately the same elevation as the Gordon River.

### 5.2.2 Nicholls Range karst area

There are two karst monitoring sites in the Nicholls Range karst area—site 5 in Kayak Kavern and site 6 in Bill Neilson Cave. Kayak Kavern contains a large sediment bank and has six erosion pins installed and a photo-monitoring site. Bill Neilson Cave is a 500 m long cave which contains large caverns and a cave stream. There are three sub-sites within the cave which are designated 6A–C and comprise various arrays of erosion pins. There are also three lightweight capacitive water level probes deployed in the cave. Bill Neilson Cave and Kayak Kavern are accessed by boat.

### 5.2.3 Water level recorders

Water level recorders located in Bill Neilson Cave (3 no.) and GA-X1 (1 no.) are used together with site 62 (Gordon below Denison), site 72 (Gordon above Albert) and power station discharge data, to assist in interpreting the effects of the Gordon River flow on the cave sediment erosion and deposition. Data are presented on a March to March cycle, as this corresponds with the period preceding monitoring events.

This year, all the data from the karst monitoring site recorders were successfully retrieved, although there were some issues with some of the Gordon River data. The Gordon below Denison site (site 62) was struck by lightning in 2010 and was repaired in June 2011, the available downloaded data is presented from June 2011 to February 2012. In this instance, an understanding of the natural pick up from the tributaries is usually gained by referring to the Gordon above Franklin dataset. Comparisons have been made with the available data, together with the Gordon above Denison compliance site data, and a reasonable estimate has been made of the likely water level regime in the caves.

### 5.2.4 Erosion pin data

Erosion pin measurements and photo-monitoring were undertaken during the site visits on 5 November 2011 and 25 February 2012. The height of all erosion pins was measured to the nearest millimetre using a steel ruler placed to the right side of the pin, on the contour level. Data for all sites are presented in appendix 6 and are illustrated graphically in sections 5.3.2–5.3.5. The sum of the distances between the tops of the pins located in the dolines at sites 3 and 4 was also measured to determine whether any major structural change had occurred. These measurements are also provided in appendix 6 and are presented graphically in section 5.3.6. Erosion pin data are interpreted in the context of the water level recorder data. Data collected in the spring are considered to be indicative of winter operating conditions, while data collected in the autumn are considered to be indicative of summer operating conditions. The winter data are usually collected in early October and the summer data are usually collected in early March, however this year the monitoring trips had to be rescheduled to November 2011 and February 2012 for weather and operational reasons. This has meant that the two monitoring trips this year are unusually close together in time. This has been taken into consideration in the interpretation of the results.

### 5.2.5 Photo-monitoring

Photos were taken at all photo-monitoring sites as planned. The photo-monitoring does not have the aim of comparison of changes at specific sites over time as in some of the other disciplines, but is used to aid interpretation of data by providing a record of the sites that are difficult to see in the dark conditions in the caves. It is also used for detecting any macro-scale changes that have occurred at the monitoring sites, including identification of features that are not the focus of the monitoring program (e.g. collapse of cave wall, deposited tree branches), but have potential to affect the results of the pin measurements. These photos are kept on file by Hydro Tasmania.

## 5.3 Results and discussion

### 5.3.1 Power station and river flow

The power station was operated again this year with relatively low discharge in comparison to the pre-Basslink years. The flow duration curve for power station discharge (Figure 2.8) shows that flows were either very high or very low, with few mid-range discharge events occurring. Discharges higher than 70 $m^3 s^{-1}$, the equivalent of one turbine operations, occurred just over 5% of the time for the period 1 July 2011 to 30 June 2012. The hydrographs of the flows in the river at the stations relevant to the karst monitoring programme (Figure 5-1) shows that there was a high frequency of three-turbine peaking operations between April and August 2011, and that the flows were very low from September 2011 to February 2012.

The peak flow in the river, as measured at the Gordon below Denison gauging site (site 62), occurred on 8 June 2011 and was 6.51 m, some 30 cm higher than the pre-Basslink maximum. This was due to a combination of relatively high flows in the tributaries coincident with three-turbine power station flows.

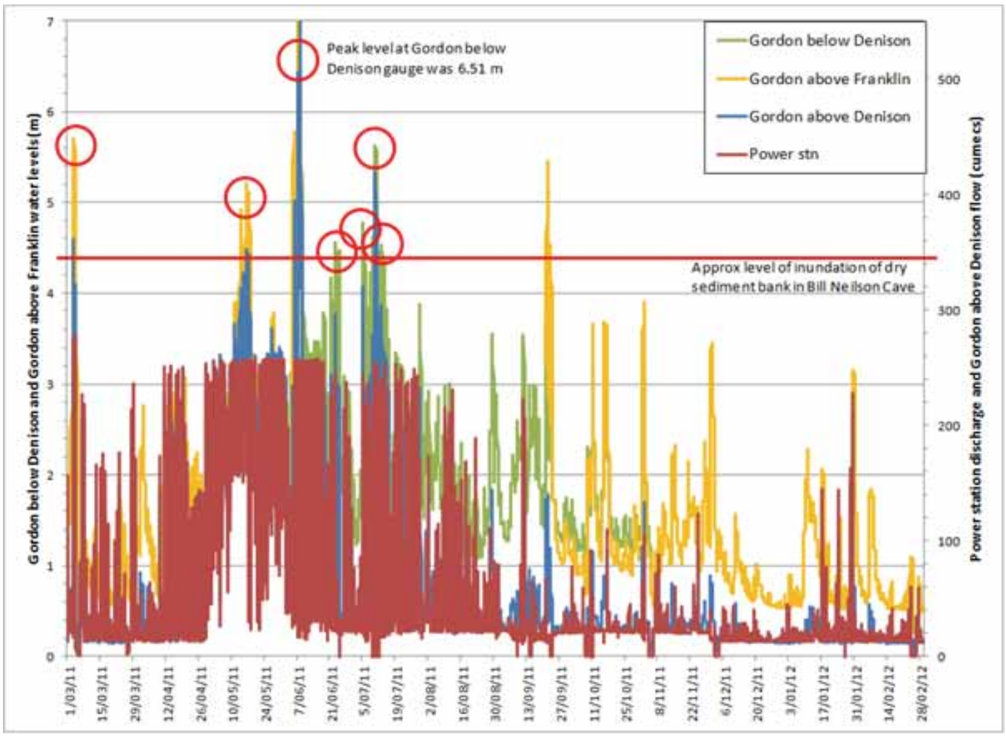


Figure 5-1 Flow and water levels at the power station and relevant Gordon River monitoring points for the 2011–12 monitoring year. Red circles show the peak flows likely to have inundated the dry sediment bank in Bill Neilson Cave

## 5.3.2 Bill Neilson Cave

### 5.3.2.1 *Sediment transfer*

There are three sets of erosion pins in Bill Neilson Cave located in:

- the wet sediment bank in the entrance chamber (pins 20–22);
- the second wet sediment bank 5–10 m further into the cave (pins 25–27); and
- the dry sediment bank 175 m into the cave (pins 23–24).

The November 2011 sampling data show that during the winter period there was a 3–4 mm increase in sediment at the lower (pin 20) and higher (pin 22) levels of the first wet sediment bank, with 2 mm of erosion occurring at the mid level (pin 21) (Figure 5-2a). At the second wet sediment bank, the trends were exactly in the mid level, but less obvious (pin 26), with just 1 mm of erosion, while there was 2 mm of erosion at the lower level (pin 25) and no change higher up (pin 27) (Figure 5-2b).

During the summer period, there was zero change at most of the pins in the wet sediment banks. The exceptions were 3 mm of erosion at the lower level in the first bank (pin 20), and 2 mm of deposition at the highest pin at the second bank (pin 27) (Figure 5-2b).

Over the 12-month monitoring period, there were similar trends at the higher and mid levels of both wet sediment banks, with the second bank showing a more dampened expression of the changes. There was 2–3 mm of net sediment deposition at the higher levels (pins 22 and 27) and 1–2 mm of erosion at the mid levels (pins 23 and 26). The lowest levels of the banks, near the cave stream, experienced contrasting net change; there was 1 mm of deposition at the wet sediment bank closest to the river (pin 20), and 2 mm of erosion further back into the cave (pin 25).

At the dry sediment bank, there was no change recorded at either of the two pins during the winter period but, unusually, 3 mm and 2 mm of erosion were recorded at pins 23 and 24 respectively, during the February trip (Figure 5-2c).

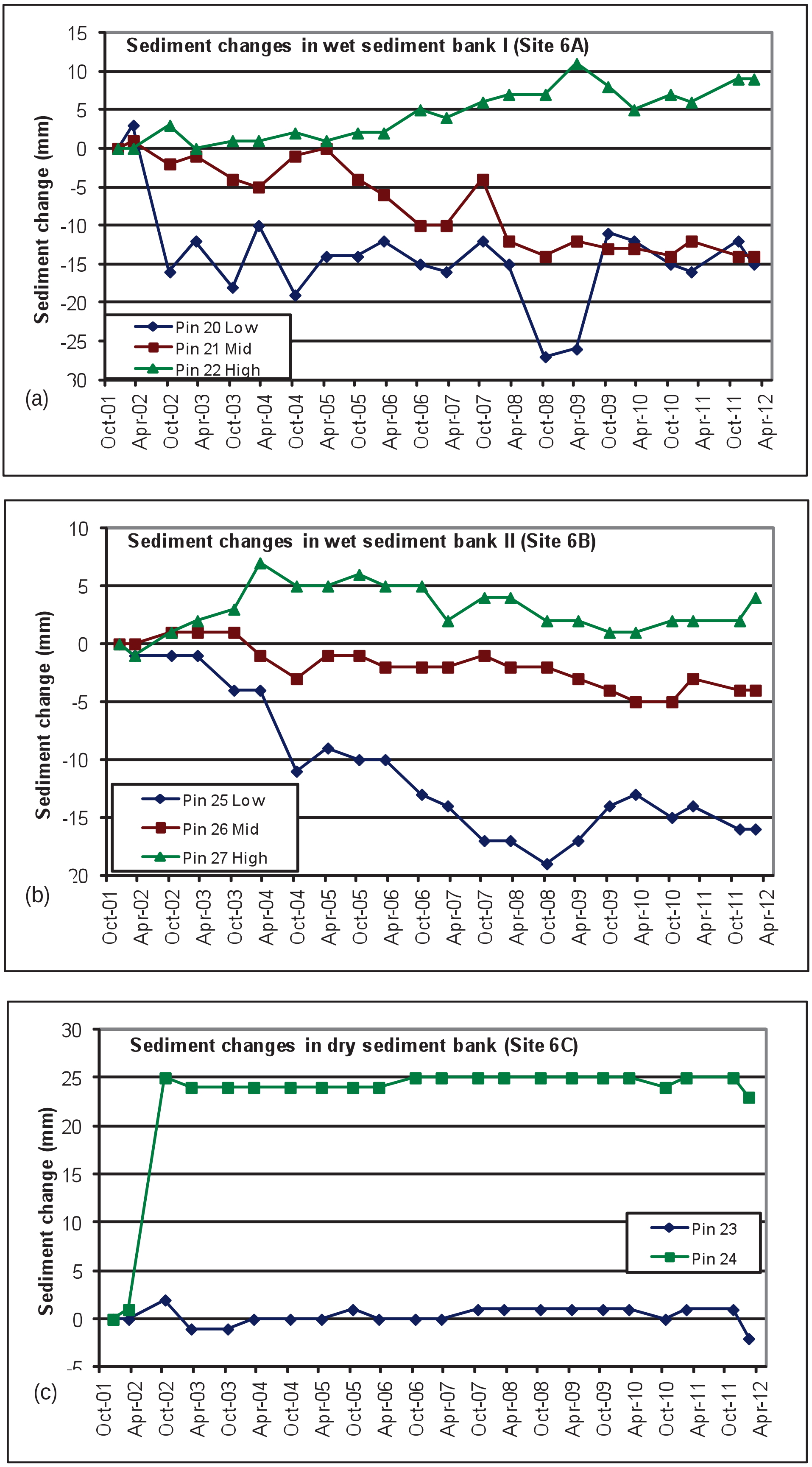


Figure 5-2 Changes in erosion pin lengths at the three sites in Bill Neilson Cave over time

### 5.3.2.2 Water level monitoring

The sediment changes at the erosion pins closely reflected the activity at the power station this monitoring year. When the sediment banks are inundated and quiet backwater conditions are created, sediment is deposited on the banks. Erosion occurs when the water levels in the Gordon River fluctuate, or in the case of the lower levels of the sediment banks, when rainfall is high and the flow in the cave stream dominates the flow regime in the cave.

During the period April to August 2011, the power station was operated with peaking up to 250 $m^3 s^{-1}$ which has given rise to the deposition occurring at the higher levels in the first wet sediment bank located in the entrance chamber of the cave. During this period in April–early May 2011, there were fluctuations in operations between 150 and 250 $m^3 s^{-1}$, which resulted in the erosion at the mid level pins. During late May 2011, the power station discharged flows more often at 100 to 150 $m^3 s^{-1}$ which created sufficiently stable conditions at the cave entrance to generate deposition at the lower levels of the first wet sediment bank. The second wet sediment bank is located at a place in the cave where the channel is constricted, and the impacts of the flow in the cave stream are often greater than those of the backwaters from the Gordon River. This has resulted in erosion being the dominant sediment transfer process at this level at this location.

Over the summer monitoring period, the flows at the power station were seldom above 40 $m^3 s^{-1}$ (<10% of the time) which has given rise to little inundation in the cave and therefore little change in the sediments. The erosion at the lower level at the first sediment bank has likely occurred due to the action of the cave stream in response to the few summer rainfall events. The increase in sediment at the higher level in the second wet sediment bank is likely to be a result of the brief three-turbine operations at the end of January which were not high enough to reach the highest pin at the first wet sediment bank.

There were at least five, and potentially seven, inundation events at the dry sediment bank this winter (Figure 5-1), with the peak level reached being some 30 cm higher than in the pre-Basslink years. Despite these inundation events, there were no changes to the dry sediment bank over the winter. The 2–3 mm of erosion during the summer months, when no inundation occurred, is unusual and difficult to explain. It is possible that this is a result of the change in personnel reading the pins for the February 2012 monitoring trip, or some other external influence such as an animal or drips from the roof. It is clear however, that this is not a change that is related to the flow in the river.

### 5.3.2.3 Conclusion

Power station operations have been relatively low overall again this year, particularly during the summer months. Three-turbine peaking operations over winter have given rise to deposition at the higher levels of the wet sediment banks, and fluctuations between 150 and 250 $m^3 s^{-1}$ have resulted in erosion at the mid levels. The cave stream has dominated the sediment transfer regime at the lower levels, particularly at the second wet sediment bank where the cavern is constricted, and minor erosion has consequently occurred. Despite at least five, and potentially seven inundation events over winter, there was no change to the dry sediment bank.

There was little change in the wet sediment banks during the summer months as the discharge from the power station was low and there was little flow in the river. Unusual summer erosion at the dry sediment bank has occurred without any inundation from the river.

### 5.3.3 Kayak Kavern

#### *5.3.3.1 General observations*

The sediment bank at Kayak Kavern showed evidence of cracking during the February trip, which is consistent with the general lack of inundation this period.

#### *5.3.3.2 Sediment transfer*

Measurements from the November 2011 sampling (Figure 5-3a) showed that deposition was the dominant process over winter at the sediment bank in Kayak Kavern—19–20 mm of sediment was deposited at pins 17 and 30 on the active slope, while 10 mm of deposition took place on the top flat at pin 18. Coincidently there was 35 mm of erosion at pin 19 in the eddy. The active slope pins are all inundated when the power station is operating at up to 140 $m^3 s^{-1}$, so the slope would have been inundated for much of the winter, inducing stabilised conditions suitable for deposition. The top flat is inundated at approximately 180 $m^3 s^{-1}$, and while there were fluctuations between 150 and 250 $m^3 s^{-1}$, which would have resulted in more favourable conditions for erosion, there was obviously sufficient inundation time and input of sediment from the Denison River for the net change to be deposition. These are relatively typical winter trends.

During the summer months, there was little change at most of the pins due to the general lack of power station activity. There was just 4 mm of deposition on the top flat at pin 18 and 16 mm of deposition at pin 33 on the active slope. This deposition likely occurred during the brief period in late January 2012 when the power station flow was greater than 200 $m^3 s^{-1}$.

Overall, the results from Kayak Kavern are consistent with the broad seasonal trends which have occurred in previous post-Basslink years of winter deposition, and smaller mixed changes over the summer.

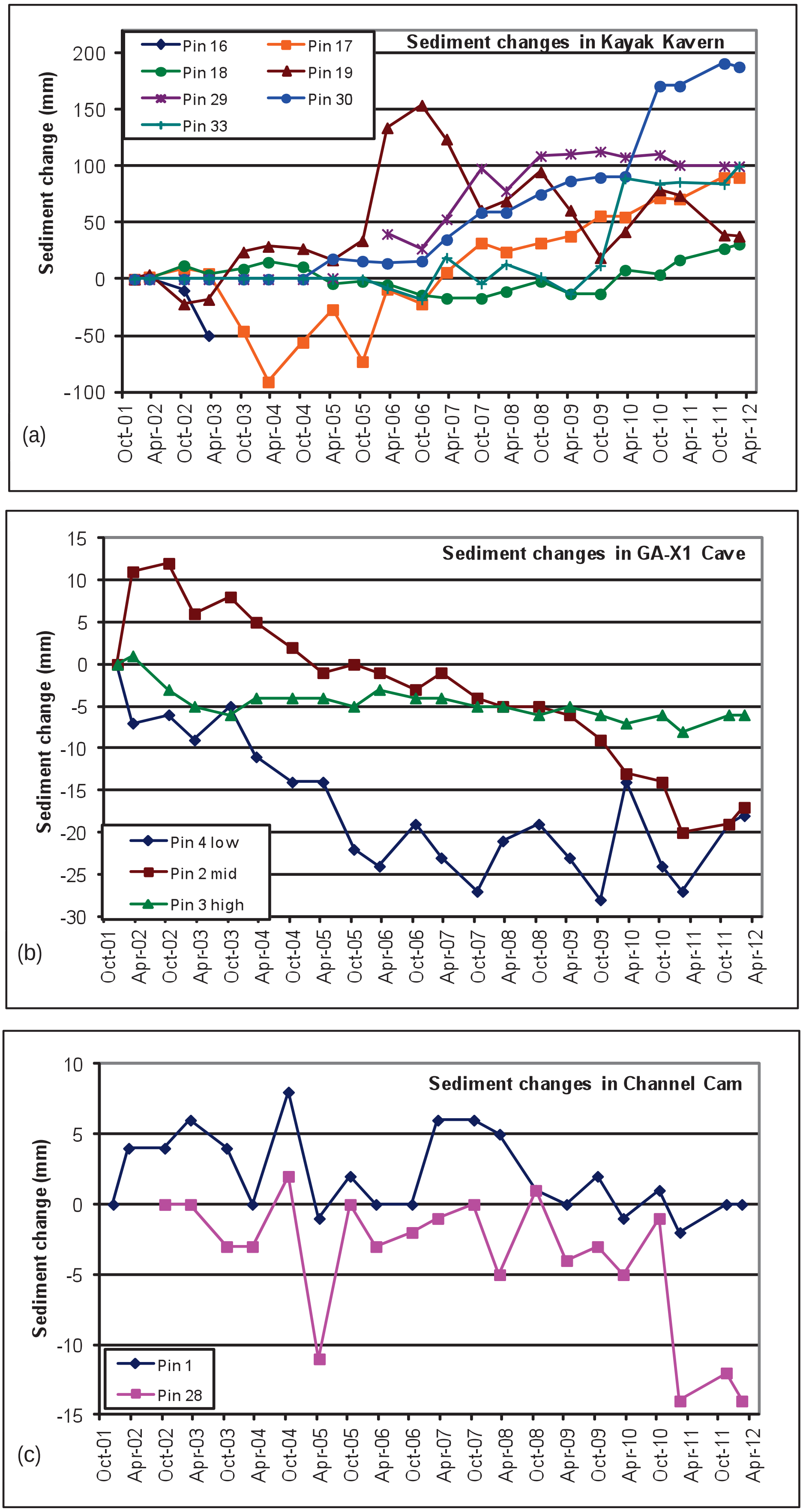


Figure 5-3 Changes in erosion pin lengths at Kayak Kavern, GA-X1 and Channel Cam over time

#### *5.3.3.3 Conclusion*

The pins in Kayak Kavern have demonstrated that deposition has generally occurred in winter on the sediment bank, due to the period of consistent inundation at the low to mid range flows in May which lead to periods of stable conditions. Over the summer, there was generally little change in the sediments due to the lack of power station activity.

### 5.3.4 GA-X1

#### *5.3.4.1 Sediment transfer*

Measurements from the November sampling trip indicated that during the winter period there was 1 to 8 mm of deposition across all levels within the cave, with the greatest change (8 mm) taking place at pin 4 at the lowest level in the cave, followed by the highest level (pin 3; 2 mm) and the smallest change at the mid level (pin 2; 1 mm) Figure 5-3b).

During the summer period, the deposition continued at all levels although was less, ranging from 0 to 2 mm. This time the largest change of 2 mm was at the mid level in the cave, while there was no change at all at the highest level.

Over the 12-month period there has been net deposition at all levels, with the extent of change increasing with depth into the cave. The net changes were 2 mm at the higher level, 3 mm at the mid level, and 9 mm at the lower level.

#### *5.3.4.2 Water level monitoring*

During the winter, the extended peaking period with flows often greater than 150 $m^3 s^{-1}$ has resulted in consistent inundation at the lowest levels (Figure 5-4) and consequently the relatively high levels of deposition. The rate of deposition decreases moving up into the cave reflecting the decrease in inundation time. The fluctuating discharges at the mid flow range has likely redistributed the sediment at that level in the cave and has resulted in less change there than at the other levels.

During the summer months, the low power station operations is reflected in the minor changes in the sediments in the cave, the majority of which took place at the mid flow range at pin 2.

#### *5.3.4.3 Conclusion*

A period of power station discharges greater than 150 $m^3 s^{-1}$ over winter has resulted in deposition occurring in the cave, particularly at the lower levels, in contrast to the summer months when the flows were low and the sediment changes were very minor. The mid range fluctuations in flow over winter between 150 and 250 $m^3 s^{-1}$ have not been strong enough to cause erosion at the mid levels but have reduced the extent of the deposition. This year has been a year of net deposition at all levels in the cave.

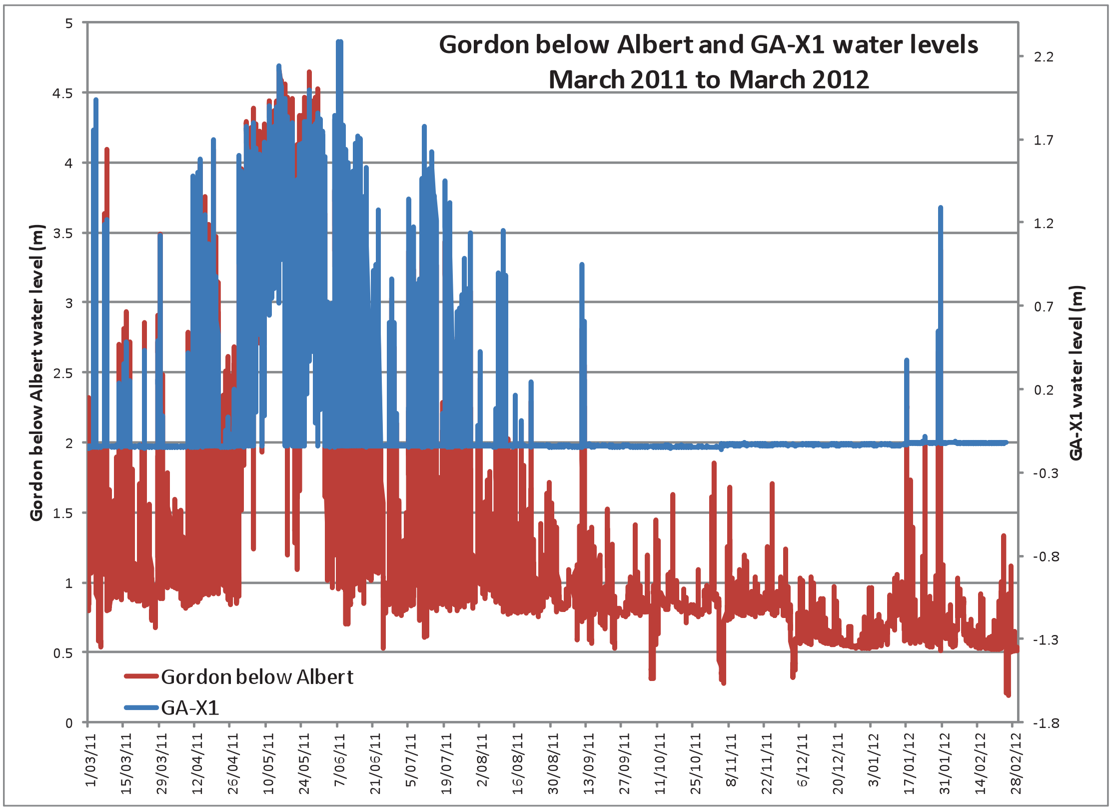


Figure 5-4 G5a (river probe) water level data, together with the GA-X1 water levels

### 5.3.5 Channel Cam

The build-up of thick mud and mosses has remained around both pins at Channel Cam again this year, reflecting the generally lower proportion of three-turbine operation flows within the system in comparison to the pre-Basslink years.

This winter period, 2 mm of deposition has occurred at both pins (Figure 5-3c). This is likely a response to the inundation by the Gordon River in May when the power station was operating at the three-turbine level and backwater conditions were created. The sediment is likely to have come from either a redistribution of the channel sediments or from the small tributary that backfloods into the channel when the river is high. It has been noted from previous trips that extended periods of fluctuating inundations from the Gordon River usually have a tendency to remove sediment, while sediment increases with higher rainfall. The net winter balance of deposition this year reflects the relative lack of high power station flows.

During the summer months, there was 2 mm of erosion at pin 28 (which is closest to the river), and zero change at pin 1. The channel is only inundated when the power station flows are of the order of 230 to 235 $m^3 s^{-1}$, and therefore there was only one very brief event this summer, of a matter of probably less than an hour, when the backwaters would have reached the lower parts of the Channel. This inundation and the affects of local rainfall would have given rise to the erosion at pin 28.

Over the 12-month period, there was a small 2 mm increase in sediment at pin 1, and no change nearest the river.

### 5.3.6 Dolines

There were relatively small mixed changes to the debris in the dolines at sites 3 and 4 this winter, with three of the eight pins showing an increase of 1–3 mm, three showing a decrease of 1–2 mm, and two showing no change at all (Figure 5-5a, b). The pattern of change in the dolines is typically a decrease in depth of debris from the higher rims of these circular features in winter, and an increase towards the bases, probably reflecting the movement of the debris downslope with rainfall. The results this year are consistent with the usual trends.

During the summer months, the two pins in the base of the small doline at site 4 showed a relatively large decrease in debris of 15 mm, probably reflecting movement or rotting of a stick or larger piece of leaf litter. Otherwise there was little change or slight reduction in debris at the other pins. There were no significant changes to the pins in the doline at the entrance to GA-X1, which suggests that the sediment on the back wall has remained stable again this year (Figure 5-5c).

As noted in previous trip reports, the changes in the lengths of the erosion pins (which only measure the changes in leaf litter in the dolines), are of less importance than changes in the distances between the tops of the pins (which measure any significant structural change). Consistent with previous trips, there were no significant changes between the pins within the precision of the measuring method (Figure 5-6). This suggests that the morphology of the dolines has remained stable since the program commenced.

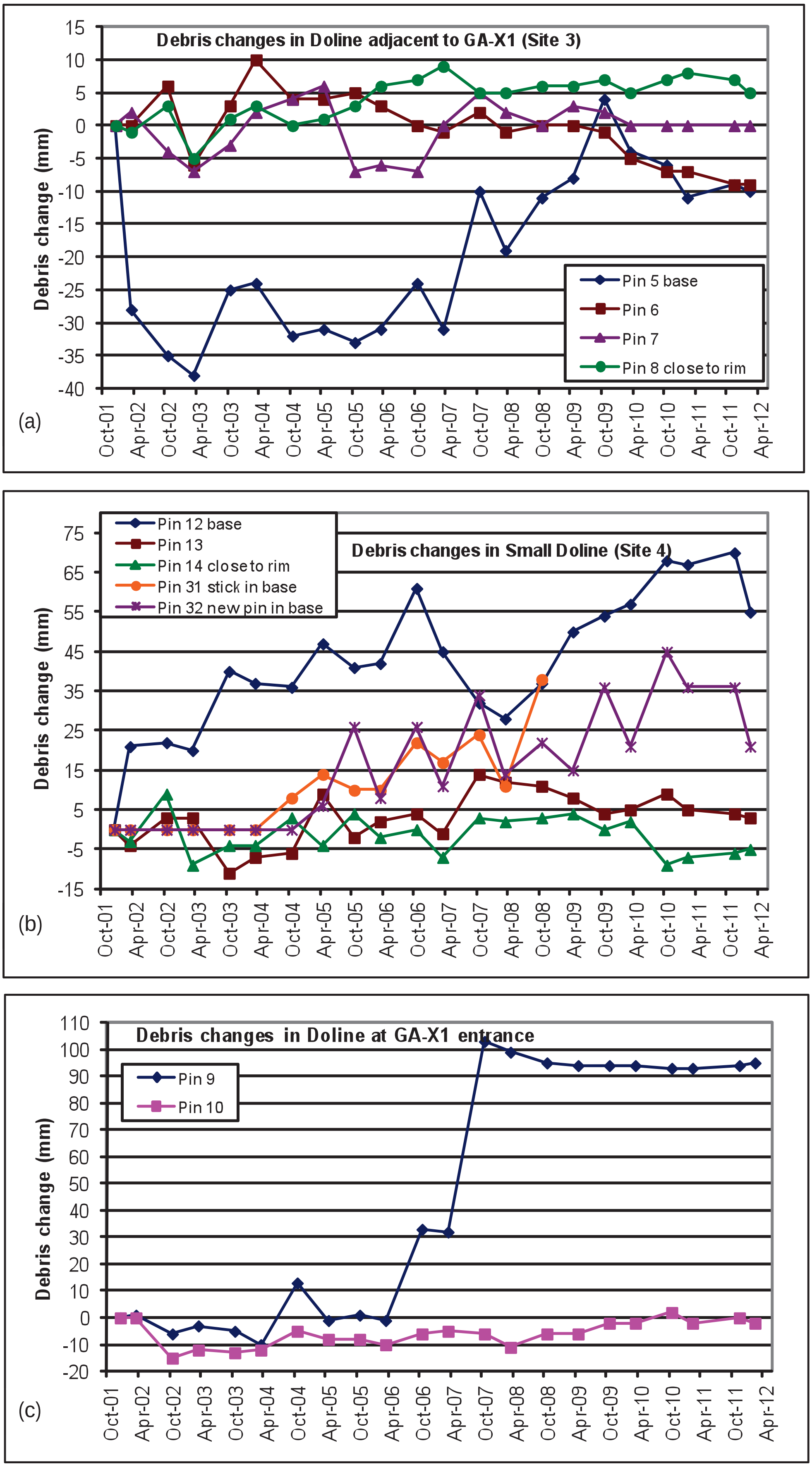


Figure 5-5 Changes in erosion pin lengths in the three dolines over time

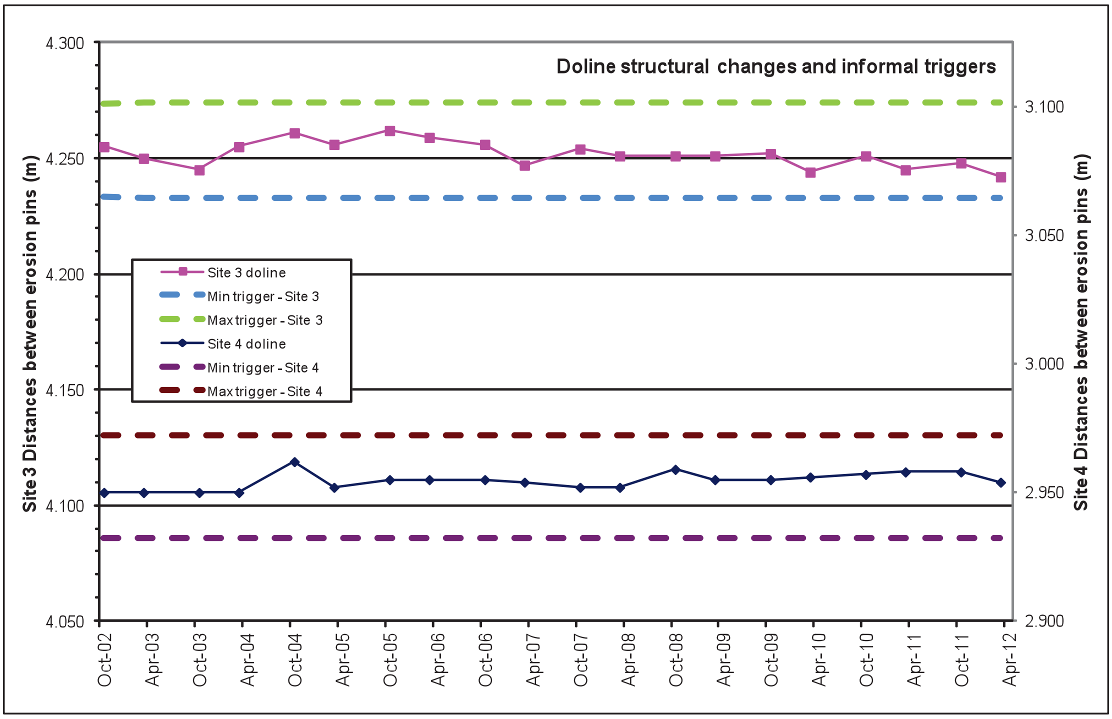


Figure 5-6 Sum of the distances between erosion pins (survey data), with informal trigger levels, in the dolines at sites 3 and 4

## 5.4 Comparison with the informal trigger values

As recommended in the Basslink Baseline Report, and in the subsequent review of trigger values report in the 2005–06 Gordon River Basslink Monitoring Annual Report (Hydro Tasmania 2006), the primary indicator variables for assessing potential Basslink effects can be divided into three main groups:

- sediment changes at erosion pins;
- inundation of the dry sediment bank in Bill Neilson Cave; and
- structural change in the dolines.

Within each group, there are three, two and one indicators, respectively, which are used to assess whether there is significant change occurring.

The Basslink Baseline Report (Hydro Tasmania 2010) identified that it was not feasible to determine formal trigger values for these karst indicator variables, as have been developed for the other disciplines. This is because averaging across karst sites and zones is not possible and there is no reasonable alternative consistent with the methodology being used by other disciplines.

Nevertheless, an assessment of the possible changes in patterns at the erosion pins must be made and an informal basis for alerting to possible changes has been developed. A series of informal trigger values has been determined for the indicator variables which are used to detect if potentially significant change is occurring. Should change be detected, the next step is to determine whether the cause of the change is Basslink-related or due to one of the other potential drivers of change in the system.

### 5.4.1 Sediment change at erosion pins

Sediment change at erosion pins is being assessed and monitored in three ways:

- inter-seasonal and long-term maximum changes in erosion or deposition;
- inter-seasonal and long-term average changes; and
- changes in seasonal (i.e. winter and summer) or long-term trends.

Changes identified through all three methods of analysis are required for the informal trigger to be exceeded, thereby prompting the need for further investigation and/or analysis of the data. Analysis of the erosion pin data for the 2011–12 monitoring season shows that while there were some changes compared to the pre-Basslink ranges of change at some of the pins, there were no changes across all of the change criteria at any of the pins, and therefore there were no exceedances of the informal triggers.

In previous post-Basslink monitoring years, some potential changes were beginning to become apparent at pin 4, the lowest of the pins in GA-X1 Cave. There were new maximum seasonal and long-term changes, a new average seasonal change, and a trend change from net erosion during the pre-Basslink period to net deposition during the post-Basslink period. This year there are no sediment changes at pin 4 that are outside the existing pre- or post-Basslink ranges of change. This is likely to be simply due to the relative lack of power station activity this monitoring year.

### 5.4.2 Inundation of the dry sediment bank in Bill Neilson Cave

The dry sediment bank, located approximately 175 m into the cave from the cave entrance, is being monitored for the extent and duration of inundation by the Gordon River. The dry bank is not typically significantly inundated unless there are three turbines operating at the power station, in conjunction with reasonably high flows in the tributaries. Under pre-Basslink conditions, the bank was inundated relatively infrequently.

The two informal triggers relating to the inundation of the dry sediment bank in Bill Neilson Cave are:

- the percentage of time in any given season, and overall, that the pins in the dry sediment bank are inundated; and

- the maximum height of inundation in Bill Neilson Cave, estimated based on the height of the peak flow at the Gordon below Denison gauging station, together with any available water level markers inside the cave.

The pins in the dry sediment bank in the cave are inundated when the river level at the Gordon below Denison gauge is greater than approximately 4.4 m. During the pre-Basslink period, the pins were inundated just over 1% of the time, with the majority of peak flow events occurring during the winter months. The maximum peak flow measured during the pre-Basslink monitoring program was 6.1 m at the Gordon below Denison gauge on 12 June 2002.

#### *5.4.2.1 2011–12 monitoring season*

Part of the data record is missing from the Gordon below Denison gauge this season and therefore an estimate as to the extent of inundation has been made using data from the Gordon above Franklin and compliance sites, and power station discharge (Figure 5-1).

The data suggest that at least five, and potentially seven, peak flow events were higher than the trigger level of 4.4 m at the Gordon below Denison gauge. The five known events resulted in levels higher than the trigger level for a duration of 73 hours or 0.8% of the time. The duration of the two additional suspected inundation events is estimated, based on the levels at the Gordon above Franklin and compliance site gauges, at approximately a further 25.5 hours, giving a total of 98.5 hours or 1.1% of the time. This best estimate figure is just higher than the 1% of the time recorded during the pre-Basslink period and therefore represents a minor exceedance of the informal trigger.

The maximum level at the Gordon below Denison gauge this monitoring season was 6.51 m, some 30 cm higher than the pre-Basslink maximum. This therefore means that there was also an exceedance of the second of the informal triggers.

Despite the two exceedances, the erosion pin data show that there were no changes to the dry sediment bank during the period when the breaches occurred. Interestingly, the only changes that did occur happened when there was no inundation at all, which means that they were a consequence of some other external factor. These exceedances are also much lower than those that occurred during the 2007–08 season when the peak level was 7.3 m and the inundation occurred for 2% of the time.

It is therefore considered that while there were exceedances of both the maximum inundation and duration of inundation informal triggers this year, there were no consequent changes to the dry sediment bank and therefore the exceedances are not significant.

### 5.4.3 Structural change in the dolines

Structural change in the dolines is assessed by measuring the distances between the tops of a number of erosion pins installed in a transect up the sides of the features. The average sum of the distances between the pins at site 3 was 4.25 m during the pre-Basslink sampling period and the informal trigger value was therefore determined in the Basslink Baseline Review Report (Hydro Tasmania 2005a) to be 4.25 ± 0.02 m to allow for the level of accuracy inherent in the measurement technique. The pre-Basslink average sum of the distances between the pins at site 4 was 2.95 m and the informal trigger value was 2.95 ± 0.02 m. In carrying out the assessment, consideration is always given to whether pins could have been interfered with by wildlife or falling debris.

#### *5.4.3.1 2011–12 monitoring season*

During the 2011–12 monitoring season, the sum of the distances between the pins at site 3 was 4.248 m during the November 2011 sampling trip and 4.242 m during the February 2012 sampling trip. At site 4, the equivalent values were 2.958 and 2.954 m respectively. The informal trigger values were therefore not exceeded.

## 5.5 Conclusions

The power station was operated again this year with very low discharge overall in comparison to the pre-Basslink years. Flows were either very high or very low, with few mid-range discharge events occurring. Mid range flows that did occur tended to be fluctuating. Sediment changes in the caves this year closely reflect the power station discharge regime.

In Bill Neilson Cave, the high flows over winter have given rise to deposition at the higher levels of the wet sediment banks, while the fluctuations between 150 and 250 $m^3 s^{-1}$ have resulted in erosion at the mid levels. The cave stream has driven sediment erosion at the lower levels when power station discharges were low. Despite some inundation events over winter, there was no change to the dry sediment bank. During the summer months, the discharge from the power station was low and there was consequently little change in the wet sediment banks.

In Kayak Kavern, deposition occurred over winter on the sediment bank, due to the period of consistent inundation in May 2011, which led to periods of stable conditions. Over the summer, there was generally little change in the sediments due to the lack of power station activity.

In GA-X1, the period of power station discharges greater than 150 $m^3 s^{-1}$ over winter has resulted in deposition occurring in the cave, particularly at the lower levels, in contrast to the summer months when the flows were low and the sediment changes were very minor. The mid range fluctuations in flow over winter were not significant enough to cause erosion at the mid levels but have reduced the extent of the deposition.

In Channel Cam, there was minor deposition during the winter months from the limited inundation from the river and the adjacent small tributary. This sediment was removed again over the summer at the pin closest to the river due to the action of possibly one short inundation event and the impact of the rainfall.

In the dolines, consistent with previous trips, there were no significant changes between the pins, indicating that their morphology has remained stable since the program commenced.

None of the informal triggers for sediment change at the erosion pins were exceeded this monitoring period. The informal triggers relating to the maximum level of inundation, and the duration of inundation of the dry sediment bank in Bill Neilson Cave, were both exceeded due to the high flow events over the winter, but the erosion pins showed there were no changes to the dry sediment bank as a result.

The surveys in the dolines and the structural change informal triggers have shown no exceedances at any stage throughout the program, indicating that there has been no structural change in the dolines during this time.

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# 6 Riparian vegetation

## 6.1 Introduction

Riparian vegetation monitoring is undertaken along the banks of the Gordon River to measure riparian vegetation attributes to determine if Basslink operations are resulting in changes. The aims of the riparian vegetation monitoring program are to:

- characterise and monitor the abundance and composition of vegetation at permanent sites along the river;
- relate changes in vegetation abundance and composition to changes in the flow regime; and
- assess these results against a set of pre-Basslink baseline condition metrics.

Vegetation and flora data were collected for four years prior to the operation of Basslink (known as the pre-Basslink period) to determine a baseline for the system. These data have subsequently been used to develop a set of quantitative and qualitative trigger values to detect changes in the post-Basslink operational period (see Hydro Tasmania, 2006).

This chapter presents the results of Basslink riparian vegetation monitoring program for the 2011–12 monitoring period. Summer monitoring was undertaken from 2 to 4 December 2011 in the Gordon River, Franklin and Denison Rivers (tributary monitoring). Autumn monitoring was undertaken from 30 March to 1 April 2012.

These are the sixth and final year of results that have been compared against the trigger values based on an analysis of vegetation and ground cover data, and summary variables calculated from these data (species richness and evenness, similarity indices between sites and monitoring events).

The implementation of the Basslink Review Report 2006–09 recommendations has retained all triggers assessing community integrity (species/taxa richness and evenness, community structure and community composition) in zones 3 to 5 and the photo-monitoring assessments in all zones (Hydro Tasmania, 2010a). This has resulted in a total of 37 triggers being reported on, which is a decrease from the previous 91 triggers. To ensure that effective assessments of vegetation continue, greater emphasis has been placed on general observations and correlating observations with geomorphology, where appropriate (noting the monitoring constraints mentioned above).

Details of the monitoring methods and monitoring program can be found in previous annual reports and the Basslink Baseline Report (BBR) (Hydro Tasmania, 2005a and b). The BBR also includes general vegetation descriptions and vegetation responses to regulated rivers and should be referred to for further information or explanation.

## 6.2 Methods

The riparian vegetation monitoring program comprises two methods of assessment: quantitative monitoring consisting of permanent quadrat and transect sites, and photo-monitoring sites. Permanent quadrat studies involve the assessment of ground species cover, seedling numbers and ground conditions. These quadrat studies are undertaken annually in autumn in the Gordon River and at reference river sites. Sampling within the Gordon River is stratified by zones delineated by tributary confluences and inflows. Seedling recruitment monitoring is undertaken twice yearly, in autumn and summer, to determine seasonal recruitment patterns. Monitoring is also undertaken at sites in the Franklin and Denison Rivers. The monitoring program schedule, covering both seasons for all rivers, is presented in Table 6-1.

Table 6-1 Annual schedule for the riparian vegetation monitoring program

| Sites | Season | Monitored variable/method of assessment | | |
|---|---|---|---|---|
| | | **Quadrat studies** | **Seedling recruitment** | **Photo-monitoring** |
| Gordon zones 2–5 | Autumn | ✓ | ✓ | |
| | Summer | ✓* | ✓ | ✓ |
| Tributary sites | Autumn | ✓ | ✓ | |
| | Summer | ✓* | ✓ | |
| * Composite vegetation cover and bare ground measures only | | | | |

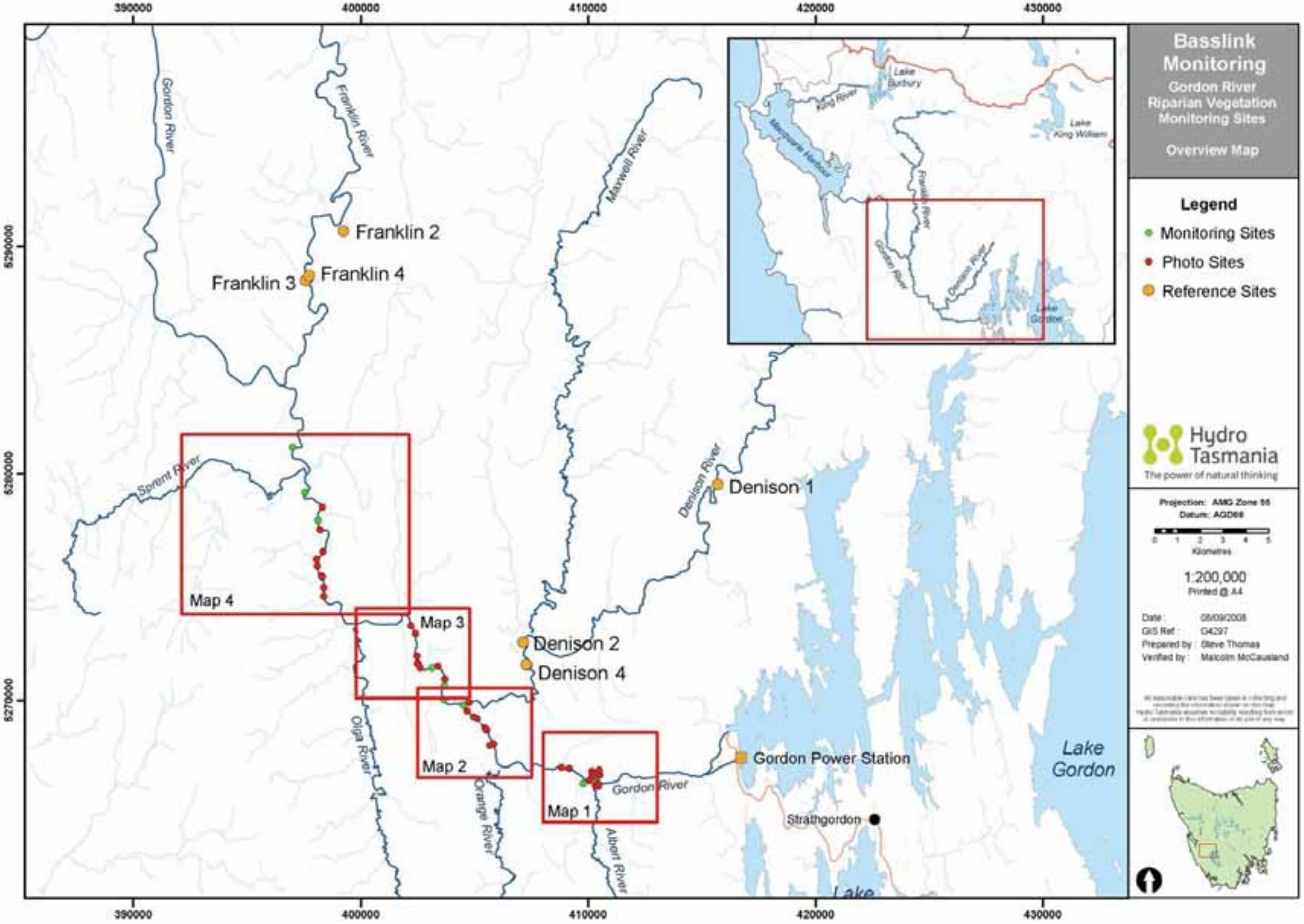
### 6.2.1 Photo-monitoring

Photo-monitoring points have been established at representative sites covering all substrate types within each major river reach to obtain representative data on vegetation patterns and processes within the rivers. These photo-monitoring points allow for accurate, objective measurements of the canopies of shrub and tree species to be made, determine the presence/absence of ground layer species and an assessment of vegetation health indicators.

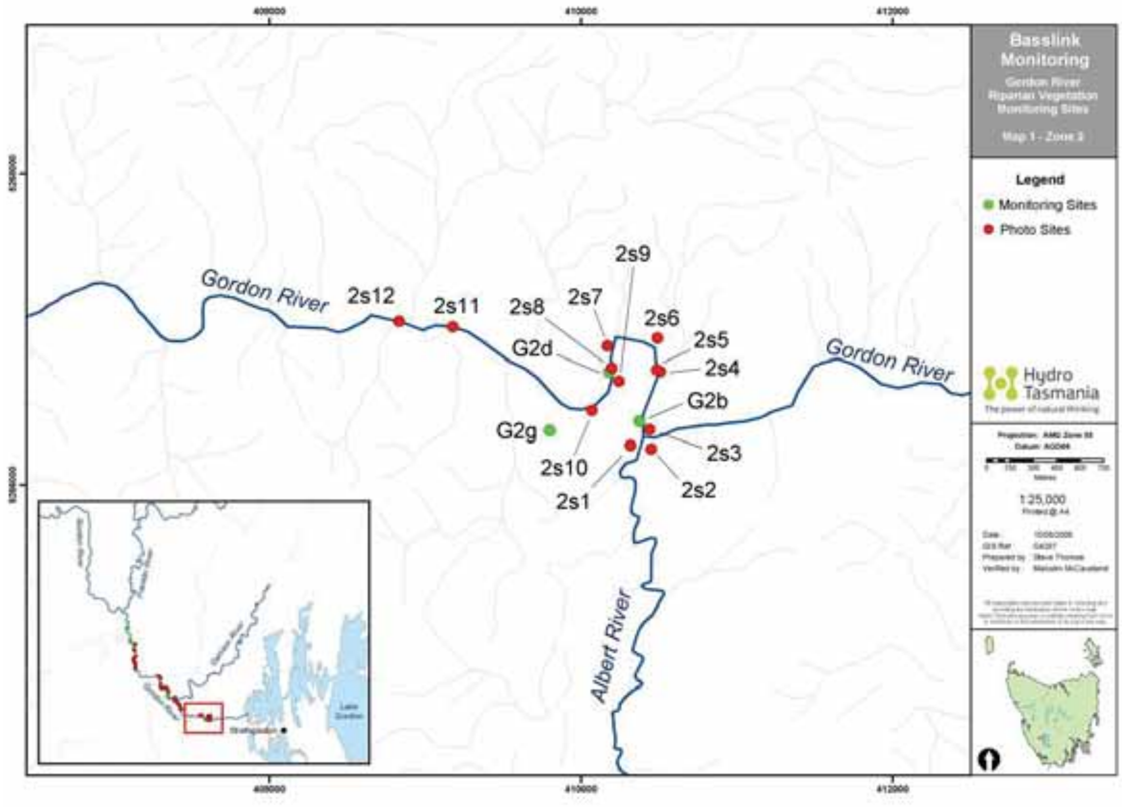
Site photographs are compared between concurrent years to identify trends between years, that is, the 2010 photograph is compared with the 2011 photograph. The results are summarised as the proportion of photograph pairs showing:

- canopy expansion or contraction and/or ground cover expansion or contraction; and
- no discernible change or no data (no photograph to compare).

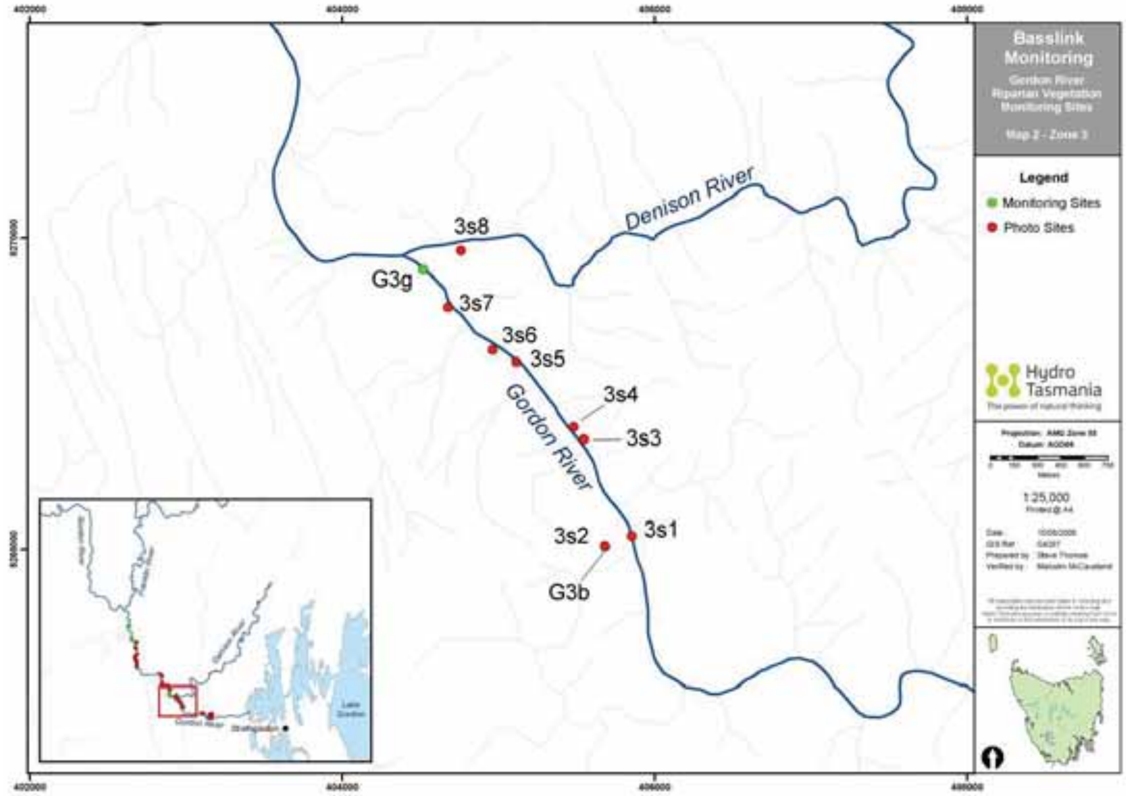
It should be noted that the results indicate the number of sites showing changes but do not detail the magnitude of changes. A change of 10% or more in any variable is recorded for the comparison. The locations of photo-monitoring points in the Gordon River are shown in Map 6-1 (all sites), Map 6-2 (zone 2 sites), Map 6-3 (zone 3 sites), Map 6-4 (zone 4 sites) and Map 6-5 (zone 5 sites).



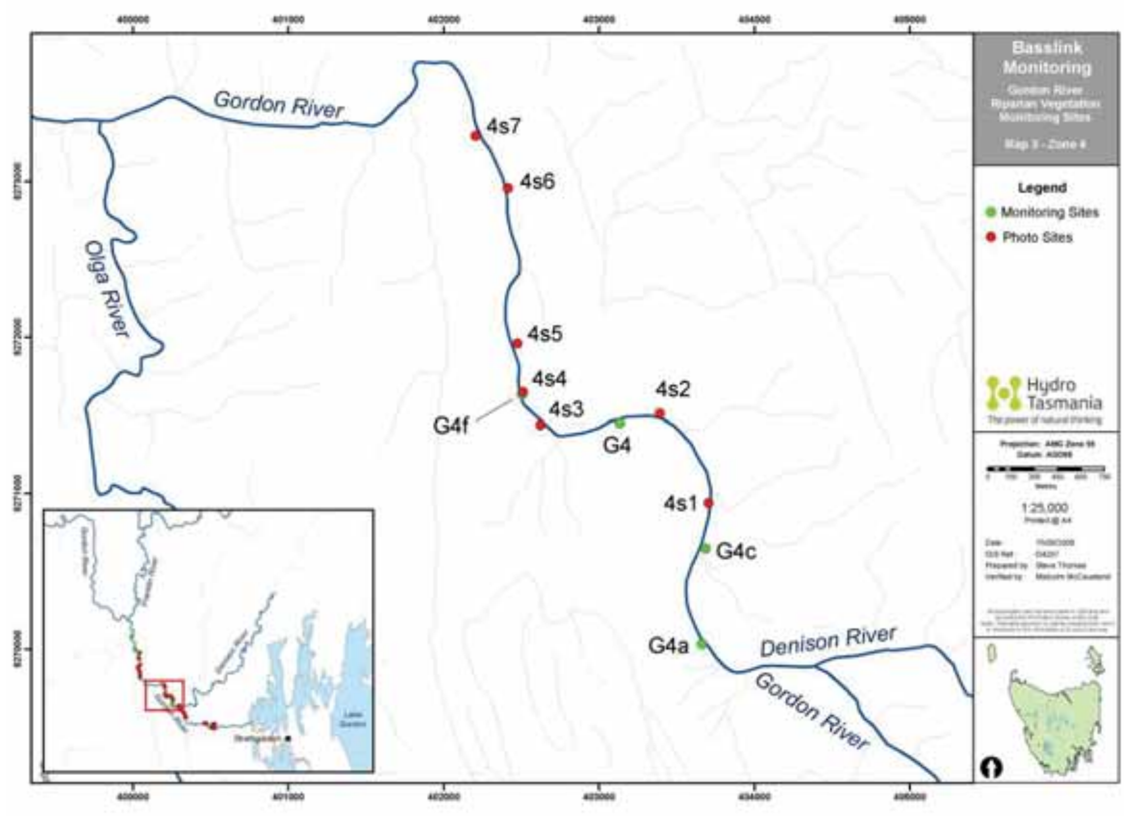
Map 6-1 Gordon River riparian vegetation photo-monitoring sites



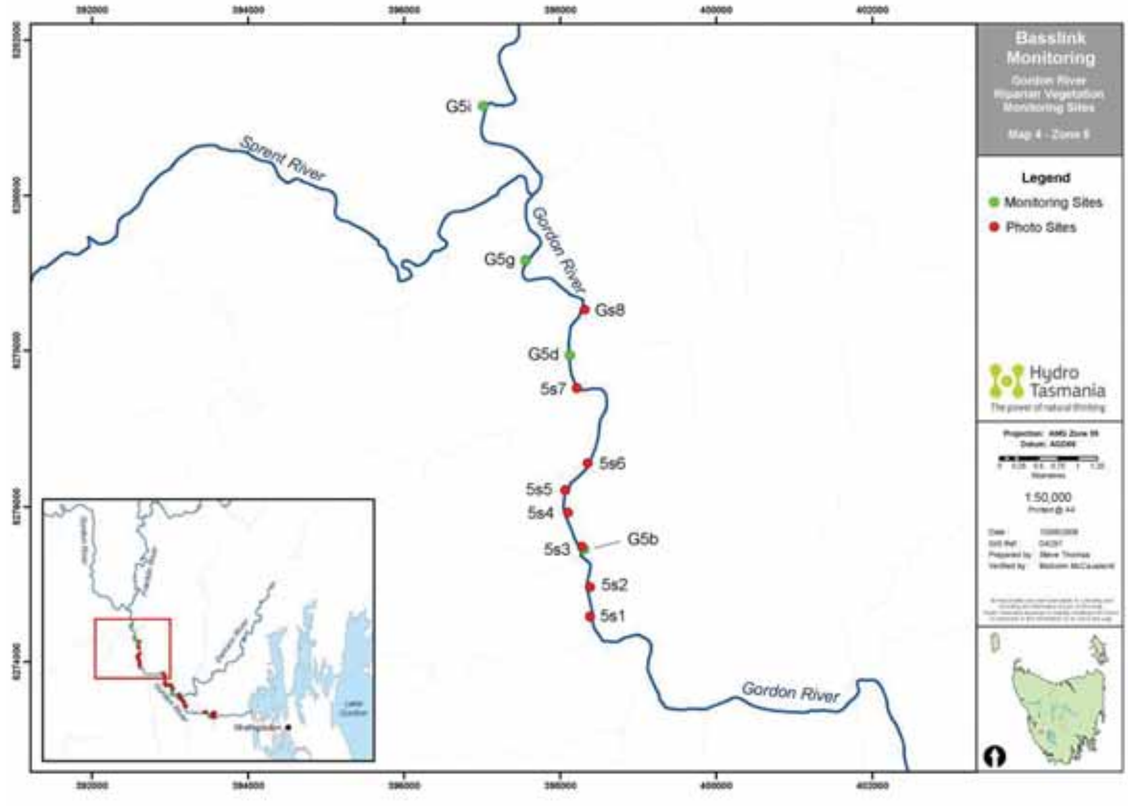
Map 6-2 Gordon River riparian vegetation photo-monitoring sites, zone 2



Map 6-3 Gordon River riparian vegetation photo-monitoring sites, zone 3



Map 6-4 Gordon River riparian vegetation photo-monitoring sites, zone 4



Map 6-5 Gordon River riparian vegetation photo-monitoring sites, zone 5

### 6.2.2 Quantitative vegetation monitoring

Field data collection includes an assessment of seedling recruitment and vegetation cover in permanent plots in the Gordon, Denison and Franklin Rivers. Bank sampling sites were established in four of the five zones of the Gordon River. These zones correspond with those determined in initial geomorphic studies, which divided the middle Gordon River into five zones based on the presence of hydraulic controls such as gorges or the confluence of tributaries (Koehnken *et al*. 2001). No bank sites were established in zone 1, the zone closest to the power station, because it is predominately bedrock substrate and has little or no vegetation cover.

Vegetation monitoring in the Gordon River includes assessments of vegetation metrics at 16 permanent plots in zones 2, 3, 4 and 5 using quadrat and belt transect-based methods. At each of these permanent sites, six 1 $m^2$ quadrats are monitored. The position of the quadrat is designed to approximately correspond with river heights under the operation of two and three turbines and above the level of 3-turbine operation at the commencement of the monitoring program. The bank location has been used to label the quadrats; ‘low’ , ‘high’ and ‘above’ respectively. Quadrats were located with reference to the high–water mark, as shown in Figure 6-1, and offset by 0.5 m from the transect line to avoid trampling impacts. Quadrat locations have been permanently marked using steel pins.

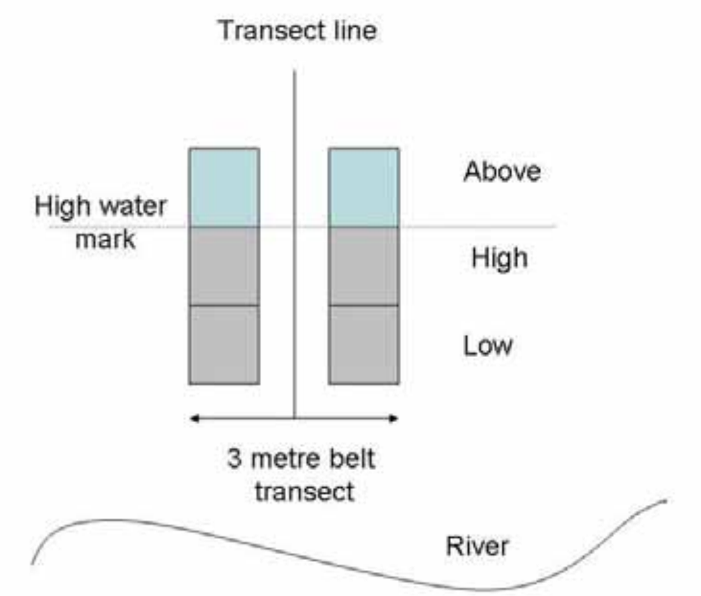


Figure 6-1 Diagrammatic representation of quadrat positions along transects in Gordon, Franklin and Denison Rivers

For each quadrat, measurements were made of ground species cover, seedling numbers, cover of trees and shrubs, and the health of vegetation and environmental variables including substrate type, geomorphologic characteristics and aspect was also recorded. Vegetation types were sorted by taxonomic class. However the bryophytes class includes some other life forms, such as algae and fungi, therefore this term should be interpreted as non-vascular plant cover. This term has not been altered in this report, to allow for consistency with previous reports.

### 6.2.3 Geomorphological–vegetation process monitoring

Due to the difficulty of linking the vegetation and geomorphological monitoring, because of the scale of changes occurring on the river, it was decided to set up some simple vegetation measurements at geomorphic monitoring sites. Full vegetation monitoring occurs near geomorphic monitoring sites but can be 15–20 metres away. However the processes occurring at the two sites can be quite different due to small-scale changes in river flow or bank formation.

At a number of geomorphological sites measuring tapes running 15–25 metres up the river bank perpendicular to the river, were laid out and secured in an easy to find location such as a large tree. The tapes were positioned so as to run in line with as many existing erosion pins as possible. Additional pins were placed at changes of slope along the transect to ensure the tape followed the ground contours as closely as possible.

#### *6.2.3.1 Bank profiles*

Bank profiles were measured using an electronic surveying device. At the start of the transect measurements were taken to the first change in slope. The horizontal distance and vertical distance along the transect and slope angle were recorded at this point. Measurements were continued until the end of the transect was reached. Bank profiles were plotted on return from the field.

Starting at the bottom of the transect, the distance from the starting point to all of the erosion pins was measured. The following ecological variables were also measured (distance from start) within a two metre belt transect (one metre on either side of the tape) along the tape. A two metre pole was run down the tape and the following variables were recorded where they intersected with the pole:

- the rooted section of the following significant bank species, *Leptospermum riparium, Blechnum nudum, Blechnum wattsii* occurring closest to the river;
- the last occurrence of bryophytes (including algae, lichen and moss on the ground) down the transect (i.e. the last occurrence of bryophytes closest to the river);
- the final extent of loose litter (leaves, twigs and other non-fixed material on the ground). Litter was defined as more than five pieces per 20 x 20 cm area. This excluded single leaf falls;
- the occurrence of coarse woody debris on the ground (exposed branches and trunks >4 cm in diameter);

- the distance from the start of the transect of the final dicot seedlings and species identification if possible;
- the distance from the start of the transect of the final monocot seedlings and species identification if possible;
- the start of the combination bare ground and root mat. This often occurred in combination and was considered important in bank stabilisation; and
- the start of continual bare ground.

## 6.3 Data analysis

### 6.3.1 Derivation of amended trigger values for comparisons

Following the recommendations in the Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) zone 2 has been excluded from the zone trigger reporting for community composition, species/taxa richness, species richness and species/taxa evenness. However only the one site (2D) was excluded from the 'whole-of-river' scale triggers as only this site was severely impacted and it was considered appropriate to retain the other zone 2 sites in the whole-of-river analysis.

Whilst zone 2 data has been excluded from the trigger analysis, graphs of results for these variables include the results for zone 2 for reference purposes where zone data is presented separately.

### 6.3.2 Community composition (Bray-Curtis similarity index)

The Bray-Curtis similarity index provides a comparison of presence-absence data for pairs of years at the zone level, providing an indication of changing community composition over time. The index was calculated for all quadrats based on presence-absence data for each monitoring period. The Bray-Curtis similarity index ranges between 0 and 100—100 indicating that all the same species were present and absent in both plots between time periods (completely similar), and values approaching zero indicating that no species were either present or absent in the same plots (completely dissimilar).

In the current study, plots showing a lower value between monitoring periods are less similar than those with a higher value. The trigger value range has been developed from the average similarity of pre-Basslink sites compared between the monitoring events. That is, the average similarity of the 2002–03 comparison, the 2003–04 comparison and the 2004–05 comparison. This comparison was selected, rather than a direct comparison with the pre-Basslink data, because the system is acknowledged to be changing over time. This average similarity for the pre-Basslink period is used to determine if sites are becoming more dissimilar over a period of time, and to prompt further investigation of the causes.

### 6.3.3 Species richness

Species richness is a diversity index or measure of the total number of different species, or taxa (taxonomic units including groups of subspecies or unidentified species), found in a quadrat or the belt transect of tree data. The richness is calculated annually for each quadrat type and compared with pre-Basslink trigger values that incorporate the mean and a 95% confidence interval around the mean values.

### 6.3.4 Species evenness

Species evenness is a diversity index or measure that numerically quantifies how equal the abundances of species are within the quadrats. The evenness of vegetation communities along the Gordon River was determined using Pielou’s evenness index for quadrat abundance data. This calculation gives a value constrained between 0 and 1, with higher values showing greater evenness of taxa within the quadrat (Kent and Coker 1994). This measure is now calculated with vascular species only, compared with previous reports where non-vegetation variables such as bare ground and litter were included. These values are calculated for each quadrat type annually and compared with pre-Basslink trigger values that incorporate the mean and a 95% confidence interval around the mean values.

### 6.3.5 Tributary data

Data for the Denison and Franklin Rivers is presented as total vegetation cover and bare ground percentages to provide an indication of trends over time in these measures at these sites. Data is presented for sites Denison 1, Denison 2, Denison 4 and Franklin 2, Franklin 3 and Franklin 4. The sites at Denison 3 and Franklin 1 are no longer monitored as they were severely impacted by floods in the past.

## 6.4 Results—photo-monitoring analysis

Photo-monitoring was completed at 32 of the 35 permanent sites in the 2011–12 monitoring period (Appendix 7). Three photos sites were missed due to water flows being such that once past a site it is not possible to motor back upstream against the flow, and sites being missed because they could not be located (e.g. loss of flagging tape).

### 6.4.1 Zone 2 photo comparisons

The pattern of vegetation establishment on the lower banks noted in December 2008, 2009 and 2010 continued in the 2011–12 monitoring period. Over 30% of sites in zone 2 showed an expansion of the ground layer, confirming observations and anecdotal evidence of the growth of mosses and liverworts and grasses on bare substrates (Figure 6-2), particularly in low slope areas with alluvial sediments. Colonisation by the fern species *Sticherus tener* and *Blechnum nudum* and grass and graminoid species including *Juncus* spp., *Baloskion tetraphyllum* and *Isolepis* sp. continued at these sites (Photo 6-1). The remaining sites showed no discernible change in the ground or canopy cover, or changed less than the 10% discernible change threshold. The contraction of canopy vegetation recorded in preceding years appears to have slowed and no discernible change was noted at all other sites monitored.

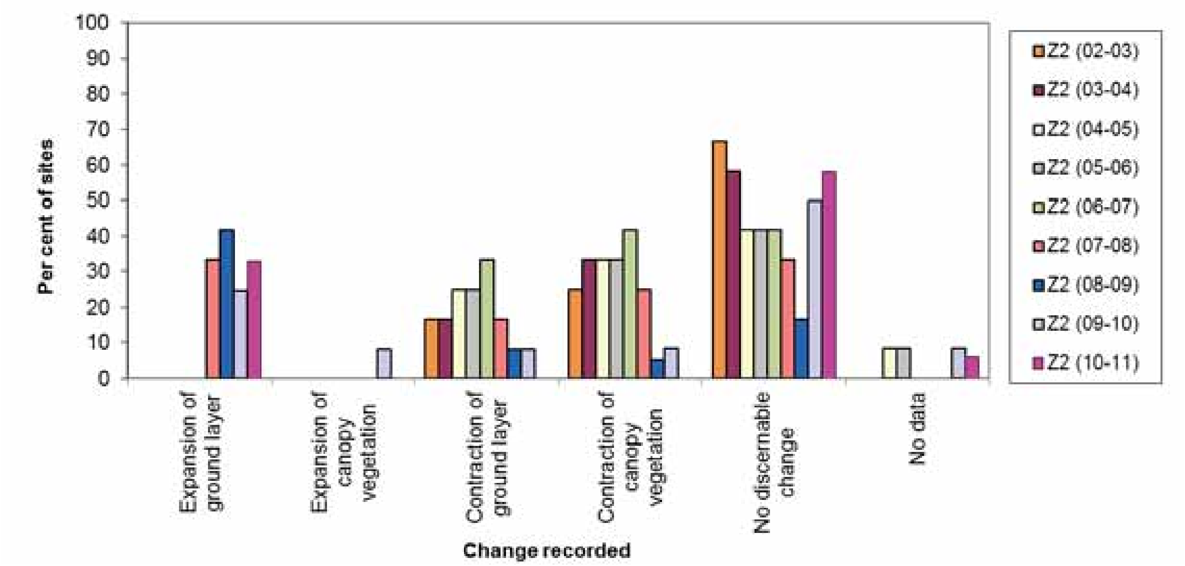


Figure 6-2 Proportion of sites in zone 2 showing either expansion or contraction of canopy and ground layers, no discernible change, or no data for photo-monitoring analysis results from the start of the program 2002–11

Photo 6-1 Expansion of graminoids (highlighted by red ovals) on a muddy bank in zone 2 in December 2010 (left), and continued colonisation of the site in December 2011 (right)

Photo 6-2 Expansion of graminoids on a muddy bank in zone 2 in February 2010 (left), continued colonisation of the site in April 2012 (right)

### 6.4.2 Zone 3 photo comparisons

Sites in zone 3 were mostly stable, 63% showed no discernible change greater than 10% in either canopy or ground vegetation (Figure 6-3). Twelve per cent of sites showed change due to the expansion of ground layer components including the aforementioned species in zone 2, while 25% of sites showed contraction of the canopy layer due to the occurrence of tree falls.

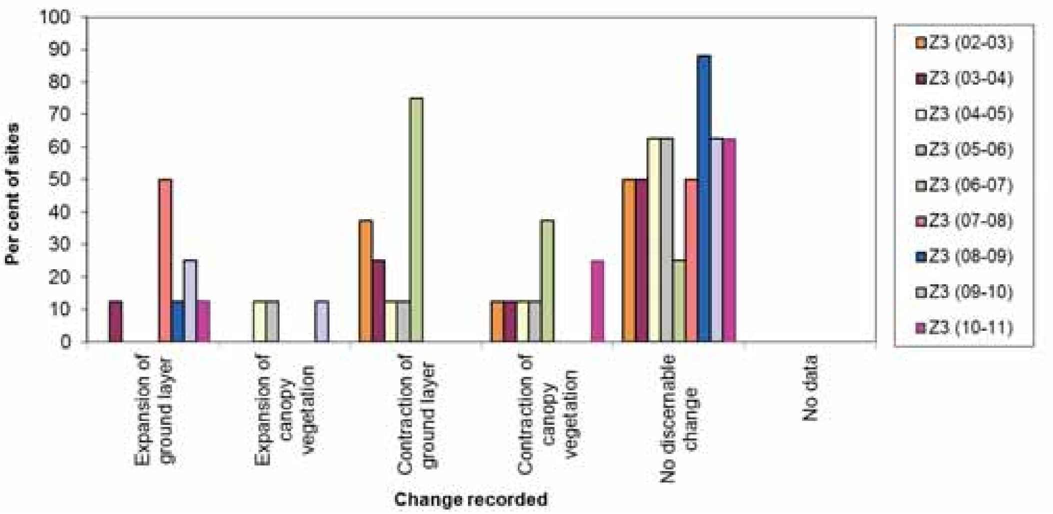


Figure 6-3 Proportion of sites showing either expansion or contraction of canopy and ground layers, no discernible change or no data for photo-monitoring analysis results in zone 3 from the start of the program 2002–11

Photo 6-3 Contraction of the canopy at site due to tree fall (highlighted by red oval) on a steep bank in zone 3 in December 2011 (right). Prior to tree fall in December 2010 (left)

### 6.4.3 Zone 4 photo comparisons

The majority of sites in zone 4 (72%) showed no discernible change (Figure 6-4); however one site continued to exhibit an expansion of ground layer. The changes recorded in 2011–12 continued the trend identified in December 2008 with the expansion of ferns (*Blechnum nudum* and *Sticherus tener*) and herb species in alluvial deposits between cobbles. The graminoid species *Juncus* spp. continued to expand its colonisation of lower banks (Photo 6-4).

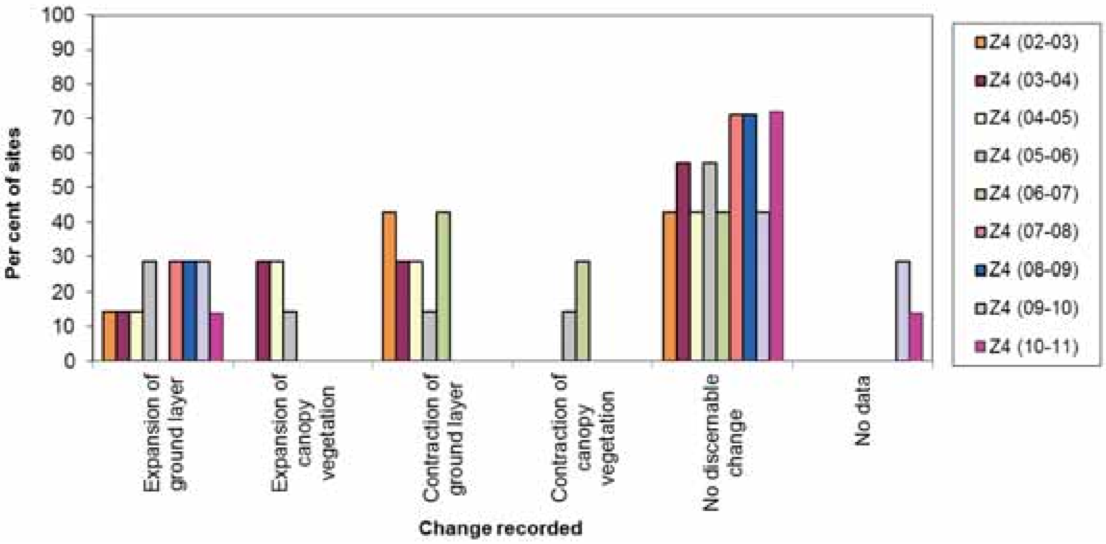


Figure 6-4 Proportion of sites showing either expansion or contraction of canopy and ground layers, no discernible change or no data for photo-monitoring analysis results in zone 4 for the Gordon River from the start of the program 2002–11

Photo 6-4 Expansion of graminoids (*Juncus* spp.— highlighted by red ovals) on muddy bank in zone 4 in December 2010 (left). Continued growth and colonisation in December 2011 (right)

### 6.4.4 Zone 5 photo comparisons

Of the sites monitored in zone 5, half had no discernible change from 2010, while 40% of sites exhibited an expansion of the ground layer on lower banks (Figure 6-5). This expansion of the ground layer was largely the result of further colonisation and growth of sedge (*Juncus* spp.), as seen in Photo 6-5.

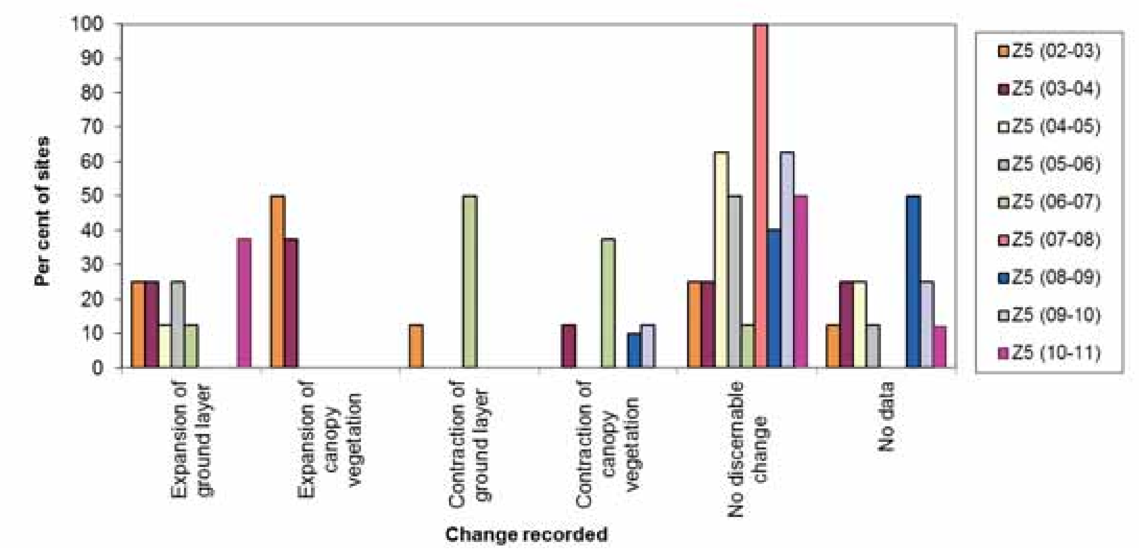


Figure 6-5 Proportion of sites showing either expansion or contraction of canopy and ground layers, no discernible change or no data for photo-monitoring analysis results in zone 5 for the Gordon River from the start of the program 2002–11

Photo 6-5 Expansion of graminoids (*Juncus* spp.—highlighted by red ovals) on muddy bank in zone 5 in December 2010 (left). Continued growth and colonisation in December 2011 (right)

## 6.5 Results—geomorphological–vegetation process monitoring

Bank profiles were recorded from eleven geomorphic sites along the river. Four profiles were measured in zones 2 and 3, and three profiles were measured in zone 4. Profiles have been recorded in October 2010 and were recorded again in December 2011. Following the second measurement of the bank profiles it was recognised that there was a problem with the profiling method that was used in the October 2010 survey. There were large discrepancies between the two measurements for some sites that could not be explained by real changes in the banks but were thought to be due to problems with the method.

Due to the environmental and site conditions experienced in the field (rain and high humidity, overhanging vegetation that could not simply be slashed, rough terrain all affecting the measuring device or its use) it is thought that the some of the original bank profiles are in error. Those profiles that were considered in error have been removed and only the December 2011 profiles are shown for those sites.

No real changes to the bank profiles have occurred between the monitoring periods. Any differences are thought to be within the accuracy of the methods used. Given the relatively short period of time between the monitoring event and the low flows experience it is not surprising that little change to the bank profile has occurred. The profiles are provided in Appendix 8.

The occurrence of various ground cover variables were measured from the start of the transect, in conjunction with bank profiles. These variables have been measured in October 2010, December 2010, February 2011, October 2011 and April 2012.

The occurrence of the riparian species (*Blechnum nudum, Blechnum wattsii* and *Leptospermum riparium*) remained relatively stable through the monitoring period as would be expected for large rooted plants. Small changes in the extent of occurrence of these plants along transects likely reflect either the removal of small plants by high water flows or are within the measuring accuracy of the recording methods.

The occurrence of seedlings on the bank was generally found to retreat up the banks in the October 2011 monitoring period following the higher flows in winter and then move down the banks in the lower flows over the 2011–12 summer.

Litter also exhibited a similar trend and was generally recorded higher on the toe of the bank in the October 2011 monitoring period and then moved further down the bank during the lower flows in summer. It is likely that both the occurrence of seedlings and litter on the banks is highly sensitive to water flows. Litter distribution is also likely to be affected by localised events (e.g. high winds occurring immediately prior to the monitoring event).

Coarse woody debris (CWD) was also generally stable but movement of woody material at three sites was recorded. Two sites exhibited movement of debris up the toe of the bank between the October 2011 and April 2012 monitoring events and at one site woody debris was recorded in April 2012 where it had not been before. This was due to the movement of flood debris. However the size of woody debris is not categorised and so there is no ability to distinguish between large and small logs. It is likely that it was only small CWD that was mobile during the monitoring periods and the stable sites had larger CWD on bank toes.

The most notable results of this monitoring are the colonisation of the lower banks by moss and other vegetation. Bryophytes and the start of bare ground (where all vegetation ceased) were recorded lower on the banks at the majority of sites. Bryophytes were recorded lower on the banks at seven of the eleven sites since February 2011, and bare ground was recorded lower on the bank at all sites. This is in keeping with the photo-monitoring sites and anecdotal evidence of the colonisation of lower banks by moss and sedges.

These results are generally consistent with erosion studies which found little geomorphological change in the river during the 2011–12 year.

## 6.6 Results and trigger comparisons—quantitative vegetation monitoring

Vegetation monitoring was completed at all permanent sites in both summer and autumn for the 2011–12 monitoring period. As outlined in the introduction, data collected in zone 2 have been excluded from trigger analyses and zone summary graphs where triggers have been calculated at the zone level scale. The site in zone 2 which had exhibited slumping (2D) was removed from the calculation of trigger values for whole-of-river scale triggers.

## 6.6.1 Community composition

### *6.6.1.1 Community composition trigger value comparison*

Community composition values all fell outside the trigger value ranges for the 2011–12 monitoring event (Table 6-2). The average similarity of between-year comparisons for the post-Basslink period are outside the ranges calculated for the pre-Basslink period. This is not unexpected given that the pre-Basslink ranges were calculated from only three years of data and was unlikely to capture the degree of variability present in the system and the sensitivity of the metric, particularly with small sample sizes. Generally ‘above’ quadrats remain relatively stable while lower quadrats are becoming less similar. Changes in similarity of ‘high’ and ‘low’ quadrats are largely due to small shifts in presence of a few species. These changes are small, and are often attributable to the turnover in a few herb and grass species. This is largely the result of the relatively few species present in these quadrats cycling through the quadrats over the course of several years. That is, a species is present over a few years and then disappears and is replaced by others. This has been particularly evident in 2011–12 with the continuing establishment of herbs and graminoids.

Table 6-2 Mean values and trigger range for Bray-Curtis similarity index for zones 3–5 based on annual similarity values calculated on presence-absence data

| Zone | Quadrat | Mean | Confidence interval range | 2011–12 result |
|---|---|---|---|---|
| 3 | Above | 53.94 | 51.95 – 55.17 | **57.13*** |
| | High | 59.05 | 56.42 – 62.45 | **40.25*** |
| | Low | 59.99 | 52.43 – 66.41 | **28.15*** |
| 4 | Above | 41.37 | 37.86 – 45.52 | **57.70*** |
| | High | 35.98 | 35.59 – 36.39 | **39.54*** |
| | Low | 38.01 | 36.13 – 40.32 | **41.27*** |
| 5 | Above | 59.10 | 53.31 – 66.35 | **49.84*** |
| | High | 59.40 | 57.18 – 61.08 | **41.34*** |
| | Low | 61.55 | 57.33 – 65.51 | **33.25*** |
| Figures in bold and * indicate a value outside the trigger range | | | | |

## 6.6.2 Species/taxa richness

Species richness is measured as the number of different flora species recorded in a quadrat. In the pre-Basslink monitoring period, there were small fluctuations in species richness but was generally considered to be relatively stable (Hydro Tasmania, 2005b). Differences in species richness were generally found to be between zones and quadrats, rather than between monitoring periods.

There has, however, been a small change in species richness for the 2011–12 monitoring period compared to the previous years (Figure 6-6). Most notably the increase in species richness is in ‘high’ and ‘low’ quadrats.

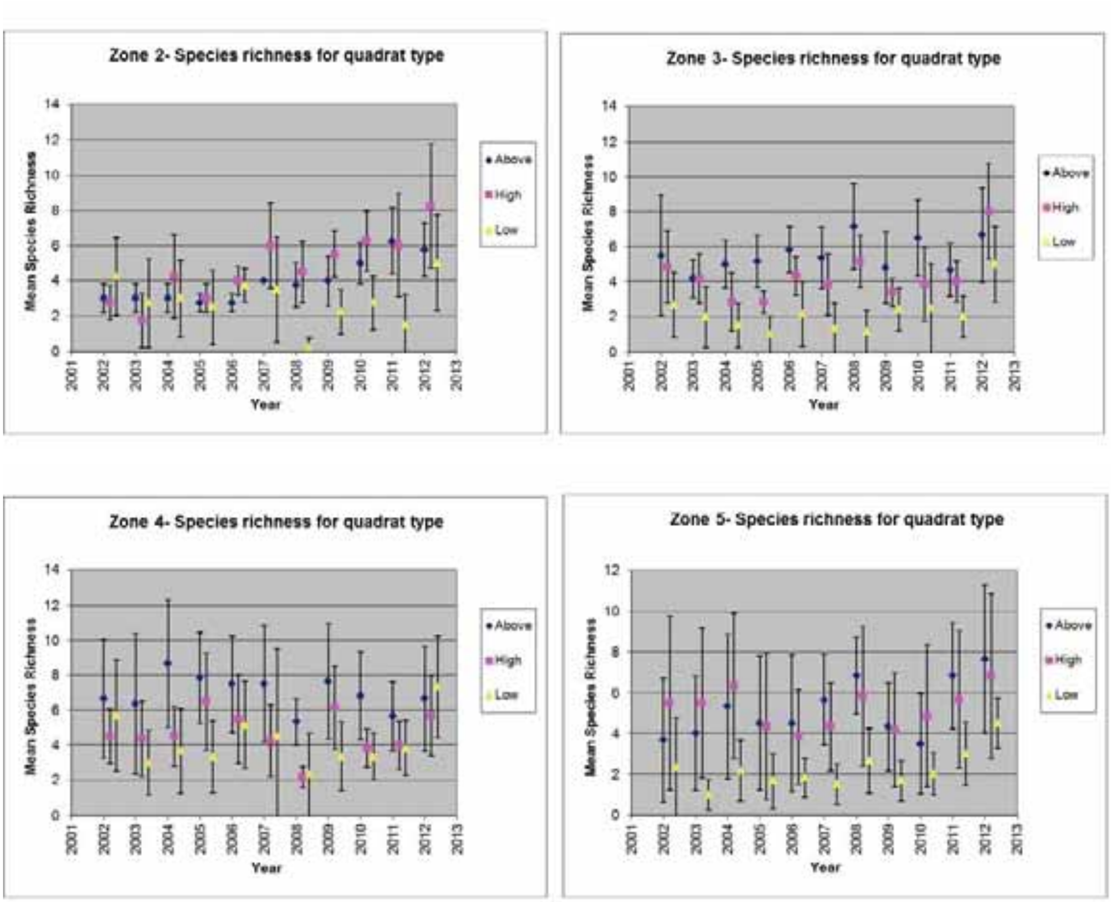


Figure 6-6 Mean species richness (± 2 SE) for the zones and quadrat types by monitoring event for ‘above’, ‘high’ and ‘low’ quadrats

### 6.6.2.1 Species richness trigger value comparison

Five of the nine trigger values recorded for species richness in 2011–12 are outside the trigger ranges (Table 6-3). Species richness is highly sensitive to small changes in the number of species found in plots. Generally an increase in species richness was recorded primarily for ‘low’ and ‘high’ quadrats and also for one ‘above’ quadrat in zone 5. The exceeding of trigger values in zone 3 is due to high values recorded at site 3b, with a number of sedges and herbs being recorded this year that were not present last year. Similarly high values in ‘low’ quadrats in zone 4 are attributable to high values in site 4a which also recorded a number of herbs, ferns and grass species that were not recorded in the preceding year. In zone 5 the species richness values are only slightly beyond the trigger ranges.

Table 6-3 Mean values and trigger range for species richness for zones 3–5 calculated from pre-Basslink data and the results of monitoring for the sixth year (2011–12) in the post-Basslink period

| Zone | Quadrat type | pre-Basslink mean | pre-Basslink trigger range | 2011–12 result |
|---|---|---|---|---|
| 3 | Above | 4.89 | 2.74-7.04 | 6.67 |
| | High | 3.94 | 2.18-5.70 | **8.00*** |
| | Low | 2.06 | 0.48-3.63 | **5.00*** |
| 4 | Above | 7.15 | 3.26-11.04 | 6.67 |
| | High | 4.45 | 2.53-6.37 | 5.67 |
| | Low | 4.00 | 1.40-6.60 | **7.33*** |
| 5 | Above | 4.33 | 1.30-7.36 | **7.67*** |
| | High | 5.78 | 2.14-9.41 | 6.83 |
| | Low | 1.83 | 0.17-3.50 | **4.50*** |
| Figures in bold and * indicate a value outside the trigger range | | | | |

### 6.6.3 Species/taxa evenness

Species or taxa evenness is a measure of the degree to which the abundance species or taxa within a quadrat is evenly spread. Higher values indicate that species are distributed evenly in the quadrat or they are abundant, whilst lower values indicate that a few species or taxa may be more abundant and other species comprise only a small proportion of the cover. The graphs in Figure 6-7 show species evenness values for 2011–12 with species or taxa only in the calculation.

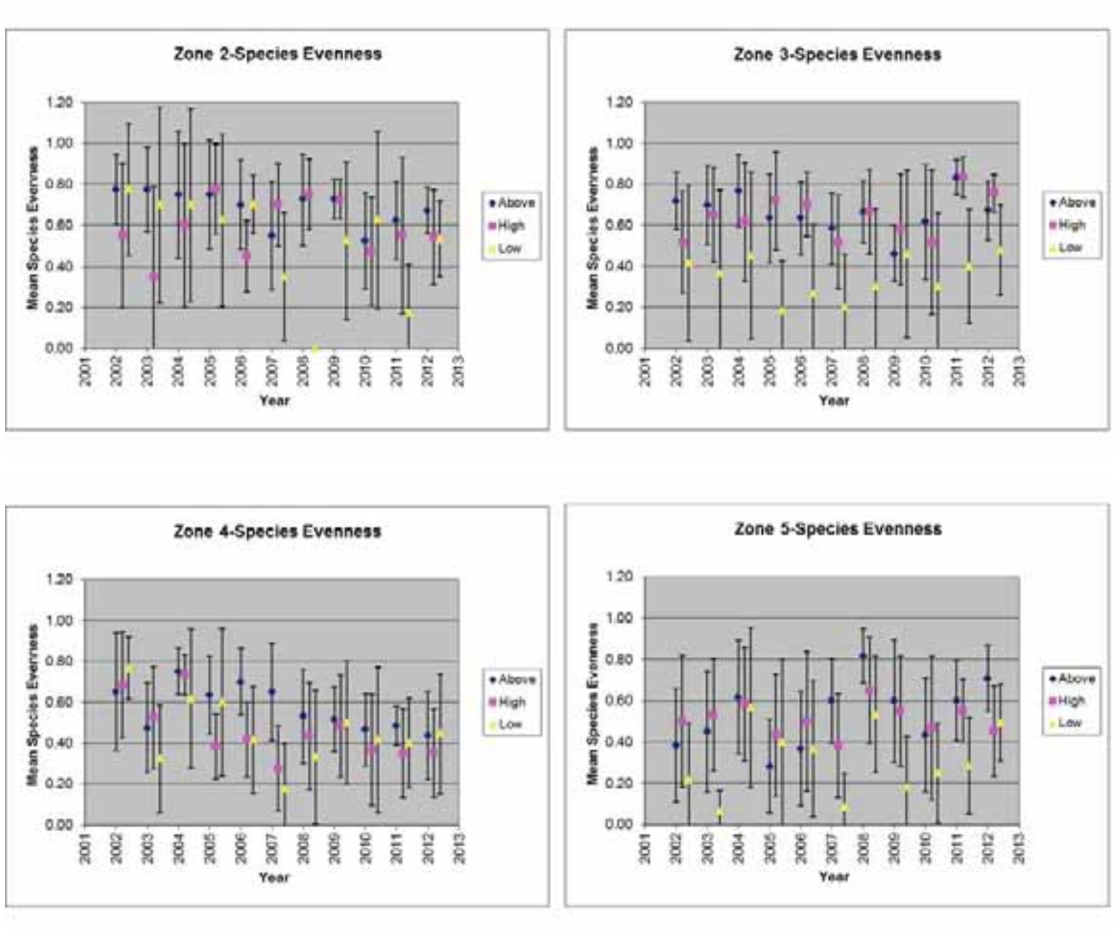


Figure 6-7 Mean species evenness (± 2 SE) for the zones and quadrat types by monitoring event for 'above', 'high' and 'low' quadrats

Overall, the species evenness values do not show any real trends but do show a high degree of variability. Evenness in 'above' and 'high' quadrats remained relatively stable, however evenness in 'low' quadrats in zones 3, 4, and 5 all increased. This is likely due to the greater cover of species being recorded in 'low' quadrats in 2011–12 rather than a very low cover of just one or two species.

### *6.6.3.1 Trigger value comparison for species evenness*

Mean species evenness was outside the trigger values for only the 'high' quadrats in zone 4 (Table 6-4). This low evenness in 'high' quadrats is largely influenced by one site (4EC). This site has low species richness with vegetation in the 'high' quadrats largely dominated by only one species (*Leptospermum riparium*). This site is on a cobble bar which is continuing to erode and 'high' quadrats are being regularly inundated and few other species present are persisting. Site 4F is also influencing this low species evenness as 'high' quadrats at this site are again dominated by two shrubs species (*Bauera rubioides* and *Orites diversifolia*). These species are increasing their proportional representation as they grow, thereby decreasing the species evenness in the quadrat. This is a similar result to that which was recorded in the last monitoring period.

Table 6-4 Mean values and trigger range for species evenness for zones 3–5 calculated from pre-Basslink data and the results of monitoring for the sixth post-Basslink year (2011–12)

| Zone | Quadrat type | pre-Basslink mean | pre-Basslink trigger range | 2011–12 result |
|---|---|---|---|---|
| 3 | Above | 0.73 | 0.56–0.89 | 0.67 |
| | High | 0.59 | 0.35–0.84 | 0.76 |
| | Low | 0.41 | 0.04–0.79 | 0.48 |
| 4 | Above | 0.61 | 0.37–0.85 | 0.44 |
| | High | 0.64 | 0.40–0.87 | **0.35*** |
| | Low | 0.55 | 0.24–0.85 | 0.45 |
| 5 | Above | 0.48 | 0.21–0.76 | 0. 71 |
| | High | 0.54 | 0.27–0.81 | 0.46 |
| | Low | 0.28 | 0–0.60 | 0.49 |

* Figures in bold and * indicate a value outside the trigger range

### 6.6.4 Bare ground cover

As noted in previous reports, for data grouped for the whole-of-river, differences are most apparent between quadrat types due to the stratification of disturbance and inundation along the river (Figure 6-8). The total area of bare ground is higher in the lower, more frequently inundated quadrats, compared to those higher on the bank.

Following a slight increase in the extent of bare ground in all quadrat types in the 2011 monitoring event there has been a reduction of bare ground in all quadrats types in 2012. This is the result of considerably lower flows released from the power station for much of the 2011–12 monitoring period. This is consistent with observations on the river as well as photo-monitoring and geomorphological–vegetation process monitoring, which all recorded recolonisation of vegetation on the lower banks.

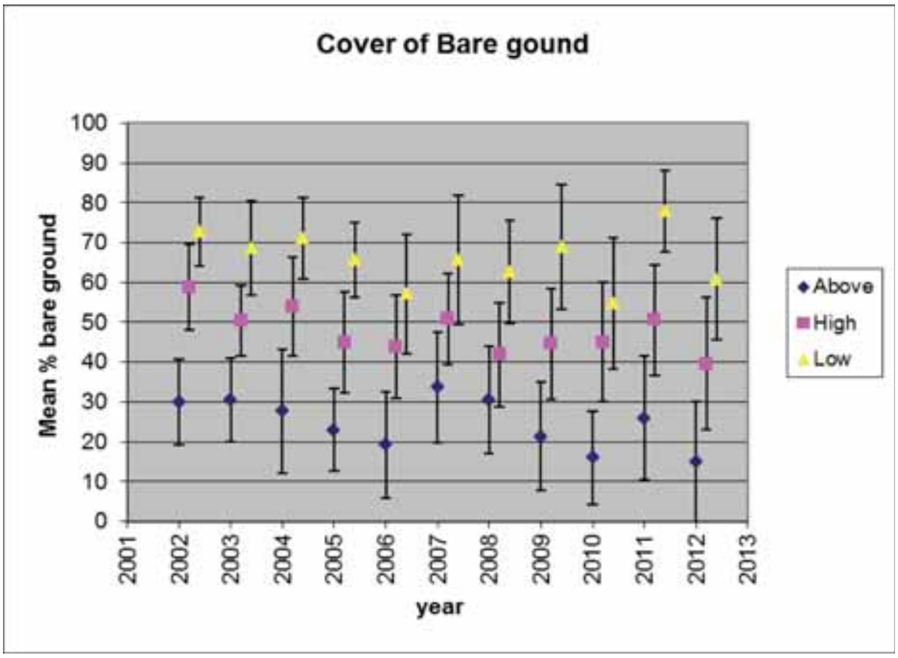


Figure 6-8 Mean per cent cover ( ±2 SE) of bare ground cover in zones 3–5 for ‘above’, ‘high’ and ‘low’ quadrats in the Gordon River for autumn monitoring events

### *6.6.4.1 Trigger value comparison for bare ground*

The bare ground cover trigger is calculated from the ratio of bare ground cover between the ‘above’ quadrats and the ‘high’ quadrats, and between the ‘above’ quadrats and the ‘low’ quadrats at the whole-of-river scale. These data aim to show the relative changes in the extent of bare ground in the quadrats using the ‘above’ quadrat as a reference for the lower sites.

The comparisons for the 2011–12 period show the ratios between ‘above’ and ‘high’ quadrats to be within the trigger ranges while the ratios between ‘above’ and ‘low’ quadrats are on the lower boundary of trigger ranges. This is likely to be the result of the proportionally greater decrease of bare ground in ‘above’ quadrats given the observed decrease in bare ground in ‘low’ quadrats. At the whole-of-river scale, bare ground in ‘above’ quadrats was reduced by approximately 40%, while being only 20% less in ‘low’ quadrats.

Table 6-5 The trigger value range for per cent bare ground represent the range within which 95% of mean values are expected for zones 2 to 5. Results for one-year (2011–12) and six-year (2006–12) assessments are compared against the one-year and six-year trigger ranges

| **Variable** | **Comparison** | **pre-Basslink trigger one-year mean range** | | **2011–12 one-year result** | **pre-Basslink trigger six-year mean range** | | **2006–12 six-year result** |
|---|---|---|---|---|---|---|---|
| | | **Lower** | **Upper** | | **Lower** | **Upper** | |
| Per cent bare ground | Ratio (% above+1) to (% high+1) | 0.32 | 0.78 | 0.38 | 0.46 | 0.59 | 0.54 |
| | Ratio (% above+1) to (% low+1) | 0.44 | 0.65 | **0.21*** | 0.40 | 0.48 | **0.36*** |
| Figures in bold and * indicate a value outside the trigger range | | | | | | | |

At the zone level, the data show that the patterns between the zones are relatively consistent (Figure 6-9). There has been a decrease in the amount of bare ground in all quadrat types in all zones except for ‘high’ quadrats in zone 4 since the last monitoring period. This is likely to be due to the more favourable growing conditions occurring under the low flows of the 2011–12 period, with fewer periods of inundation and the disturbing effects of higher flows.

There is a trend of decreasing bare ground in ‘above’ quadrats in zones 2, 3 and 5 since the flood events in 2007, while no real trends are evident in ‘high’ and low’ quadrats.

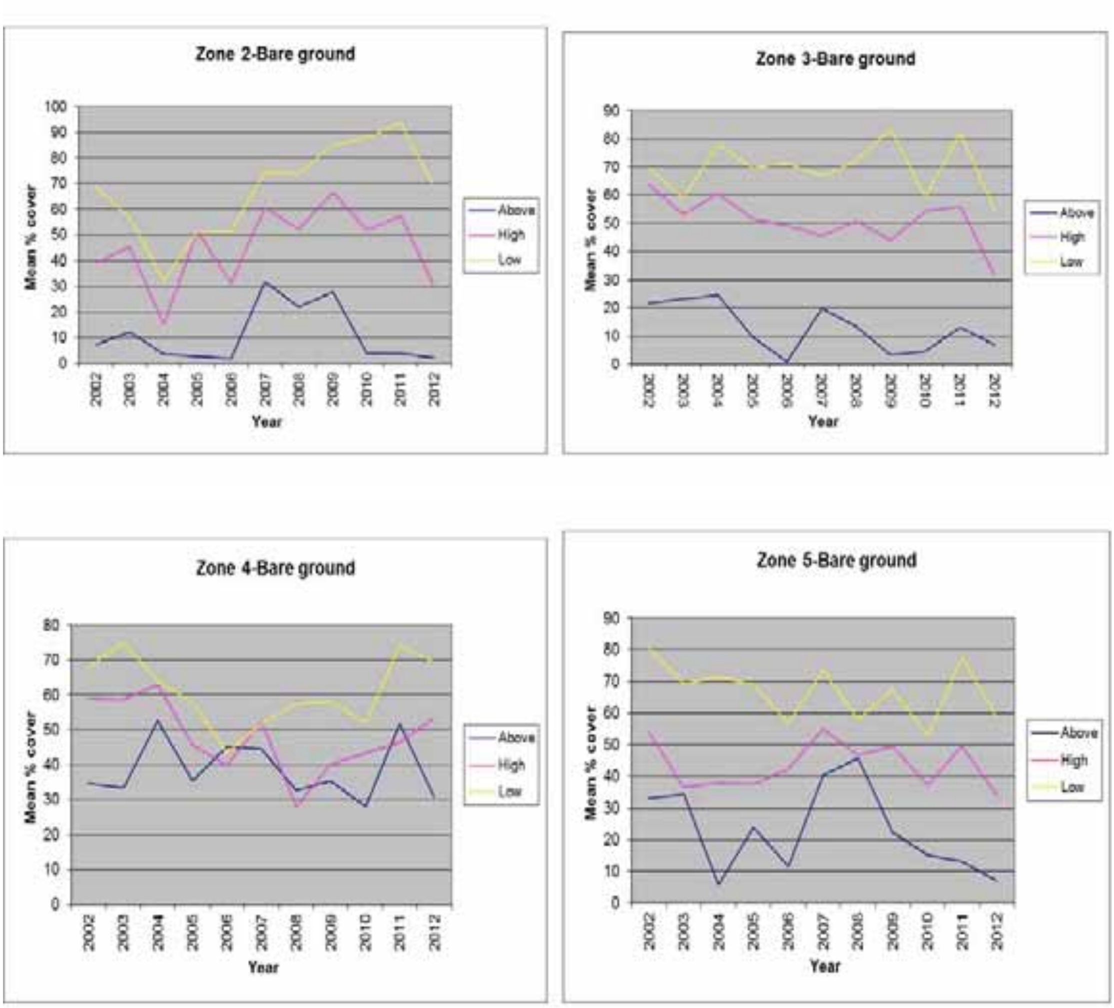


Figure 6-9 Mean per cent cover of bare ground cover for zones by monitoring event for ‘above’, ‘high’ and ‘low’ quadrats from April 2002 to March 2012

## 6.6.5 Total vegetation cover

Total vegetation cover is the sum of all vascular vegetation cover within the quadrats. This measure is used at the zone and whole-of-river scale to develop and report against trigger values (Figure 6-10, Table 6-6).

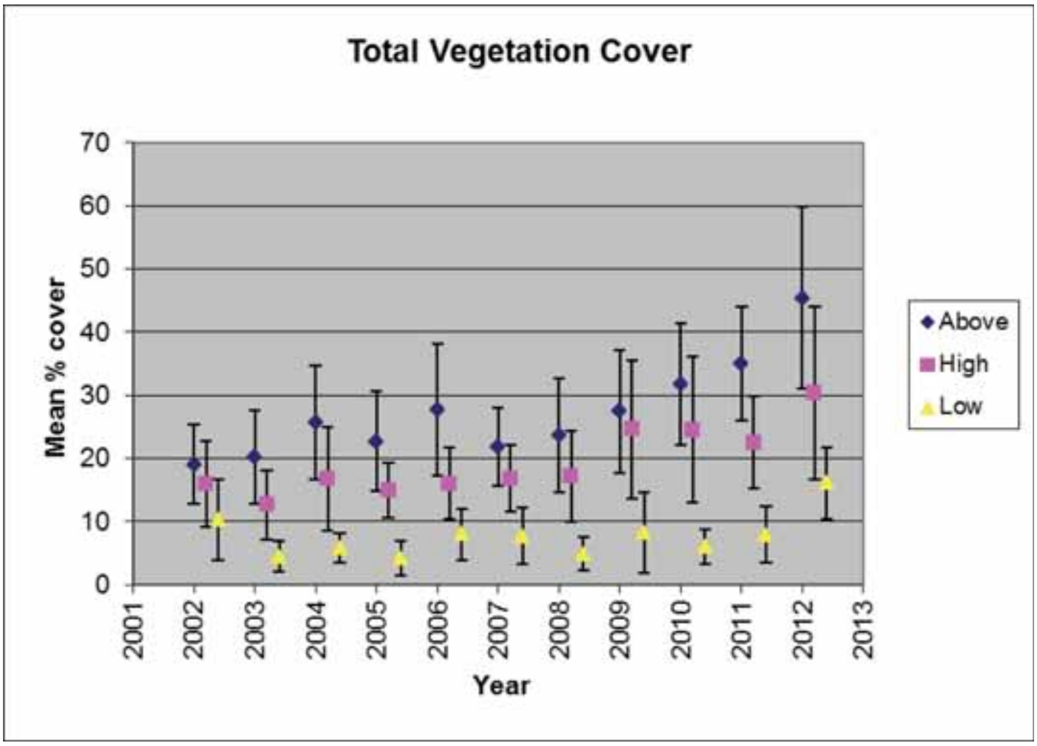


Figure 6-10 Mean per cent total vegetation cover (±2 SE) in zones 3–5 by monitoring event for ‘above’, ‘high’ and ‘low’ quadrats

The mean proportion of total vegetation cover for the whole-of-river showed a slight trend of increasing vegetation cover in the ‘above’ quadrats over the past five years (Figure 6-10). The trend is not as readily apparent in ‘high’ and ‘low’ quadrats and the variation around the mean is high, indicating that there is a high degree of variability in the data both between and within the zones. There has been an increase in total vegetation cover in all quadrat types in the 2011–12 monitoring period.

### *6.6.5.1 Trigger value comparison for total vegetation cover*

The relative difference in the proportions of vegetation cover between the quadrat types is used to test for differences in the total vegetation cover and to calculate a ratio of differences for comparison with trigger values. The results for both the ‘above’/’low’ ratio and the ‘above’/’high’ ratio variables show slight changes in the relative amounts of total vegetation cover in the 2011–12 period compared with the pre-Basslink period (Table 6-6). Trigger values were marginally outside the range for the one-year and six-year cumulative ratio comparisons for the ‘above’/’low’ ratios and outside the six-year cumulative ratio for the ‘above’/’high’ ratios.

The lower than expected result for the ‘high’/’low’ ratios for the one-year result is likely to be due to the recovery of vegetation in ‘low’ quadrats this year, while the exceedance of the upper trigger for the six-year cumulative measure is the result of a number of high values over the past six years, particularly 2008 and 2011. This may reflect the recovery of the ‘above’ quadrats in comparison to the relative abundance of total vegetation cover found in the ‘high’ and ‘low’ quadrats (Figure 6-10 and Figure 6-11).

Table 6-6 The trigger value range within which 95% of values are likely to lie for one-year (2011–12) and six-year (2006–12) mean values of ratios of total vegetation cover based upon pre-Basslink monitoring and values recorded for variable in the 2011–12 period

| Variable | Comparison | pre-Basslink trigger one-year mean range | | 2011–12 one-year result | pre-Basslink trigger six-year mean range | | 2006–12 six-year result |
|---|---|---|---|---|---|---|---|
| | | Lower | Upper | | Lower | Upper | |
| Per cent total vegetation | Ratio (% above+1) to (% high+1) | 1.11 | 2.13 | 1.57 | 1.42 | 1.71 | **1.81*** |
| | Ratio (% above+1) to (% low+1) | 5.00 | 7.92 | **4.79*** | 4.44 | 5.55 | **6.44*** |
| Figures in bold and * indicate a value outside the trigger range | | | | | | | |

Total vegetation cover increased in all quadrat types except ‘high’ quadrats in zone 2. This increase in vegetation was largely related to increases in the ferns *Blechnum nudum, B. wattsii* and *Gleichenia microphylla,* and shrubs in upper quadrats, and increases in herbs and sedges in lower quadrats. A possible trend of increasing vegetation cover continued in ‘above’ quadrats in zone 3 ,while cover in ‘high and ‘low’ quadrats in this zone remained relatively stable. No other trends were apparent.

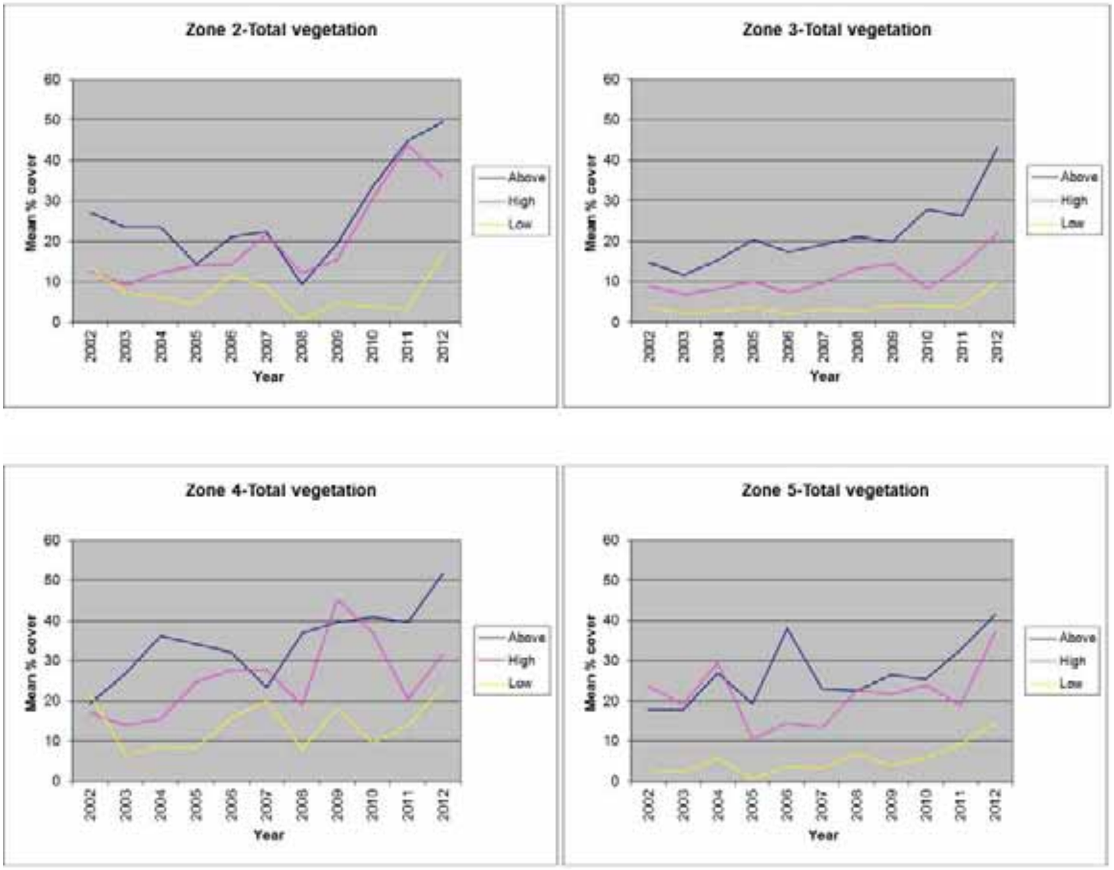


Figure 6-11 Proportion of total vegetation for each quadrat type by zone for each monitoring event

## 6.6.6 Plant abundance by life form

### *6.6.6.1 Non-vascular plants*

Non-vascular plants (termed bryophytes here for consistency with previous reports but including mosses, algae and liverworts) continued to have the highest cover in the 'above' quadrats in the region above the three-turbine level (Figure 6-12) in the 2011–12 monitoring period (whole-of-river data).

Mean per cent cover of the bryophytes at the whole-of-river scale showed no consistent trends in the data in 2011–12 year. The cover of bryophytes remained relatively stable in 'above' and 'high' quadrats, but an increase was noted in 'low' quadrat compared to the preceding year (Figure 6-12). Bryophyte cover has a high degree of variability both between and within the zones.

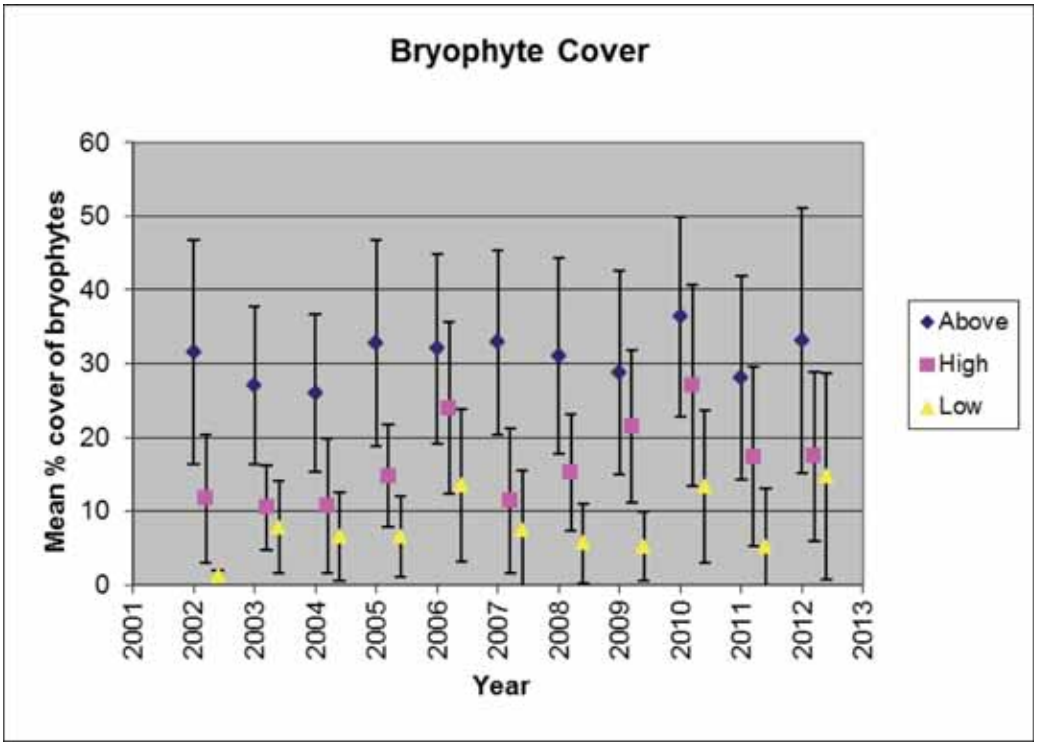


Figure 6-12 Mean per cent cover (± 2 SE) of bryophytes (including all non-vascular plants) in zones 3–5 by monitoring event for ‘above’, ‘high’ and ‘low’ quadrats in the Gordon River

### *6.6.6.2 Trigger value comparison for non-vascular plants*

The results for both the ‘above’/’low’ ratio and the ‘above’/’high’ ratio variables show little change in the relative amounts of total bryophyte cover in the 2011–12 period compared with the pre-Basslink period (Table 6-7). There were no values outside the trigger range for either the one-year ratio comparisons or for the six-year cumulative ratio comparisons.

Table 6-7 The trigger value range within which 95% of values are likely to lie for the one-year (2011–12) and six-year (2006–12) mean values of ratios of bryophyte cover based on pre-Basslink monitoring and values recorded for variable in the 2011–12 period

| **Variable** | **Comparison** | **pre-Basslink trigger one-year mean range** | | **2011–12 one-year result** | **pre-Basslink trigger six-year mean range** | | **2006–12 six-year result** |
|---|---|---|---|---|---|---|---|
| | | **Lower** | **Upper** | | **Lower** | **Upper** | |
| Per cent bryophytes | Ratio (% above+1) to (% high+1) | 1.60 | 7.19 | 5.24 | 3.33 | 4.92 | 4.41 |
| | Ratio (% above+1) to (% low+1) | 12.54 | 21.23 | 10.43 | 10.89 | 14.19 | 13.82 |

The relative patterns of bryophyte abundance in zones 2 to 5 are generally consistent with those recorded in the both the pre- and previous post-Basslink results (Figure 6-13). Bryophyte cover continues to have highest values in zones 2 and 3 and in the ‘above’ quadrats. No real trends are apparent in the data.

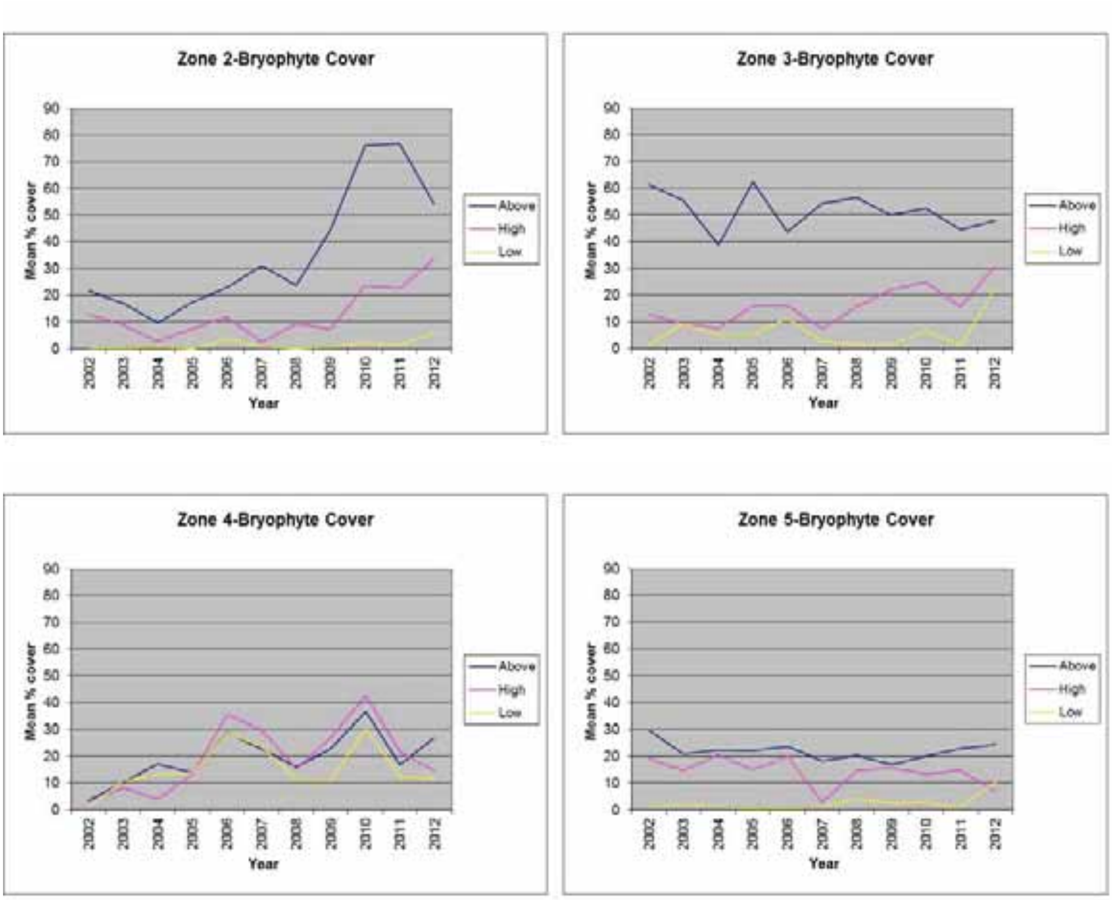


Figure 6-13 Per cent cover of bryophytes (including non-vascular species) for each quadrat type by zone for each monitoring event

### 6.6.6.3 *Ferns*

Mean per cent cover of ferns at the whole-of-river scale showed no discernible trends in the data over the entire monitoring period (Figure 6-14). An increase in cover of ferns occurs in the 2012 event for ‘above’ and ‘high’ quadrats and continues the trend noticed in the past three years, however variability is high. ‘Low’ quadrats continue to have a low cover of ferns as would be expected. Both the whole-of-river and zone scale fern data (Figure 6-15) indicate the low total percentage cover that ferns comprise in zones 3–5, compared to zone 2.

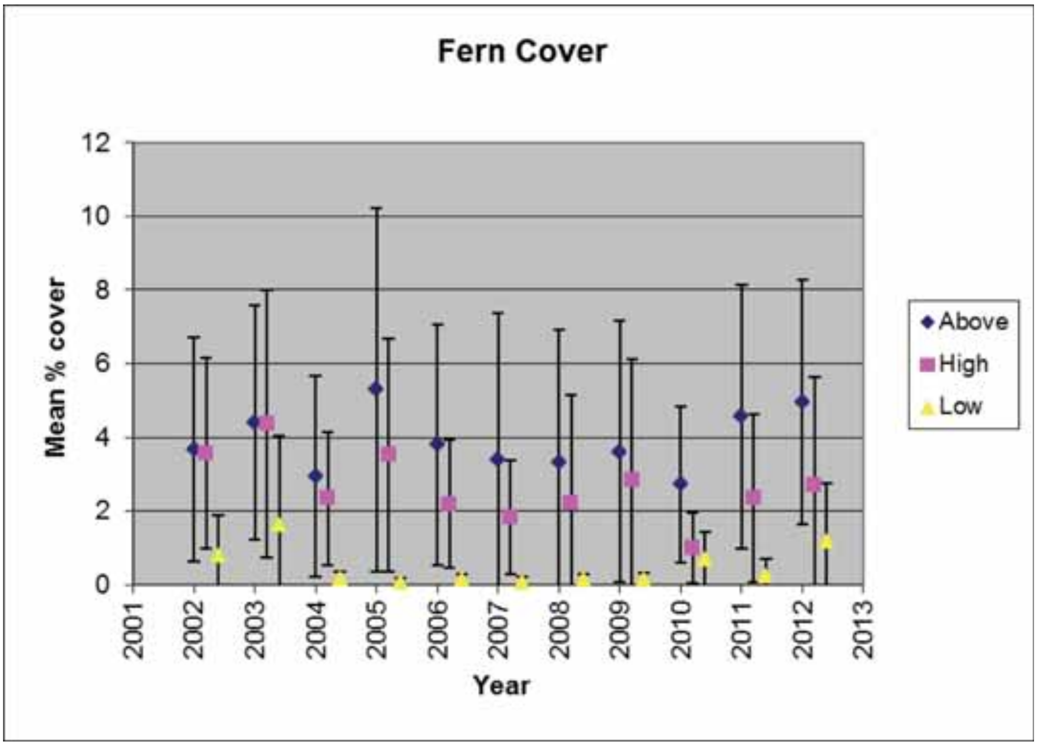


Figure 6-14 Mean per cent cover (±2 SE) of fern cover in zones 3–5 by monitoring event for 'above', 'high' and 'low' quadrats

### 6.6.6.4 Trigger value comparison for ferns

The results for both the 'above'/'high' ratio and the 'above'/'low' ratio variables show some changes in the relative amounts of fern cover in the 2011–12 period compared with the pre-Basslink period (Table 6-8). The 'above'/'low' ratios for the 2011–12 one-year result were within trigger ranges. The six-year 'above'/'low' ratio was not calculated due to the very low abundance of ferns in low quadrats. Even in zone 2, which generally has a higher proportion of ferns, 'low' quadrats had very little cover and four of the six quadrats had no ferns recorded.

Values were outside the trigger range for the one-year and six-year cumulative ratio comparisons for the 'above'/'high' ratios for the whole-of-river data. Trigger values have been marginally exceeded and is likely to be the result of a relative increase in ferns in the 'above' quadrats and a decline or continuance of low cover of ferns in 'high' quadrats in all zones (Figure 6-15).

Table 6-8 The trigger value range within which 95% of values are likely to lie for one-year (2011–12) and six-year (2006–12) mean values of ratios of fern cover based on pre-Basslink monitoring and values recorded for variable in the 2011–12 period

| Variable | Comparison | pre-Basslink trigger one-year mean range | | 2011–12 one-year result | pre-Basslink trigger six-year mean range | | 2006–12 six-year result |
|---|---|---|---|---|---|---|---|
| | | Lower | Upper | | Lower | Upper | |
| Per cent ferns | Ratio (% above+1) to (% high+1) | 0.80 | 1.96 | **2.68** | 1.16 | 1.49 | **2.41** |
| | Ratio (% above+1) to (% low+1) | 3.13 | 5.12 | 5.11 | 2.76 | 3.51 | **N/A** |

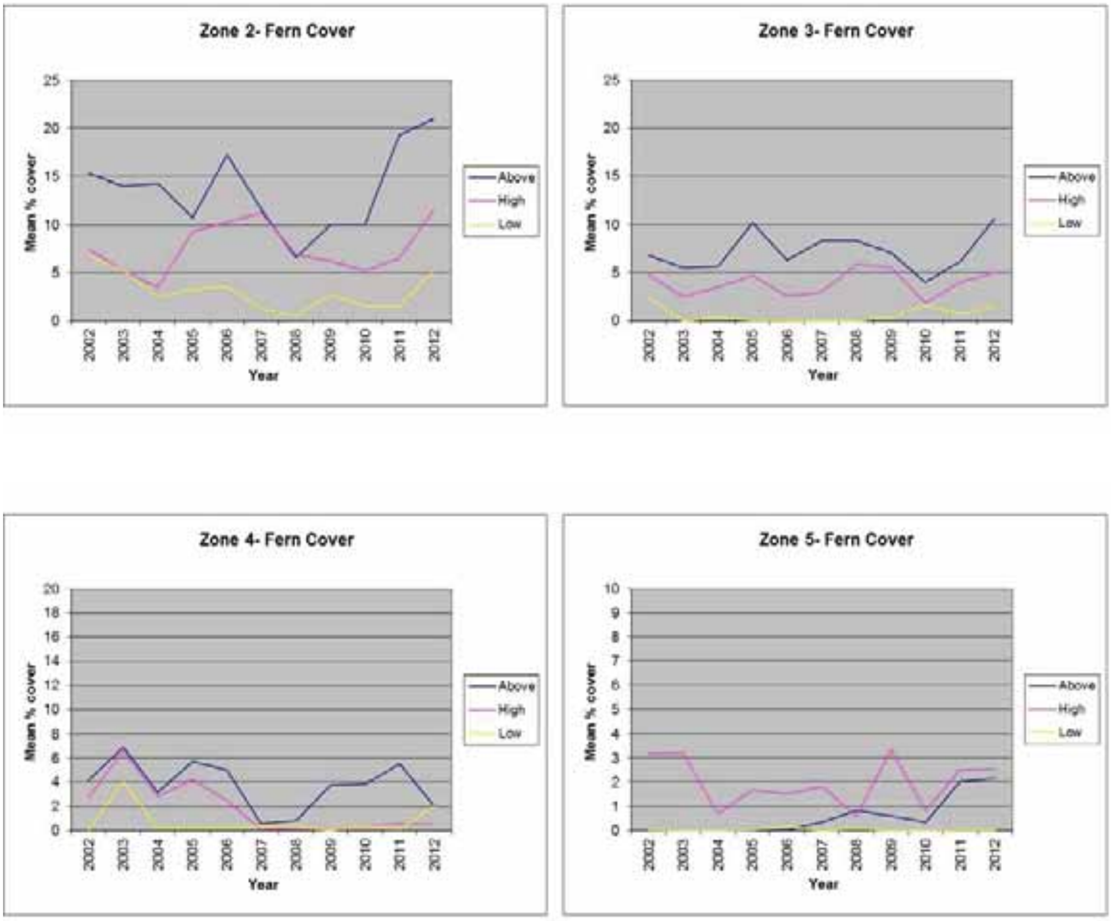


Figure 6-15 Per cent cover of ferns for each quadrat type by zone for each monitoring event

#### *6.6.6.5 Shrubs*

Mean per cent cover of shrubs at the whole-of-river scale showed a slight trend of increase over the monitoring period, with shrub cover showing elevated levels particularly over the last four years in ‘above’ and ‘high’ quadrat, though variability remains high (Figure 6-16). Zone 4 continued to show the greatest cover of shrubs (Figure 6-17). The decrease in shrub cover noted in zone 4 in the 2010–11 monitoring period has recovered this year and is largely attributable to increases in Bauera in both ‘above’ and ‘high’ quadrats, particularly at site 4EC on a cobble bar in the river. It was suggested that the decrease last year was associated with high flows immediately preceding the monitoring event ‘shifting’ the shrubs out of quadrats, and the rapid recovery this year supports this.

It should be noted that the changes in per cent cover in zones 2, 3 and 5 are very minor and are likely to be close to the ability of the recorders to identify discernible change and this is reflected in the relative high variability in this measure.

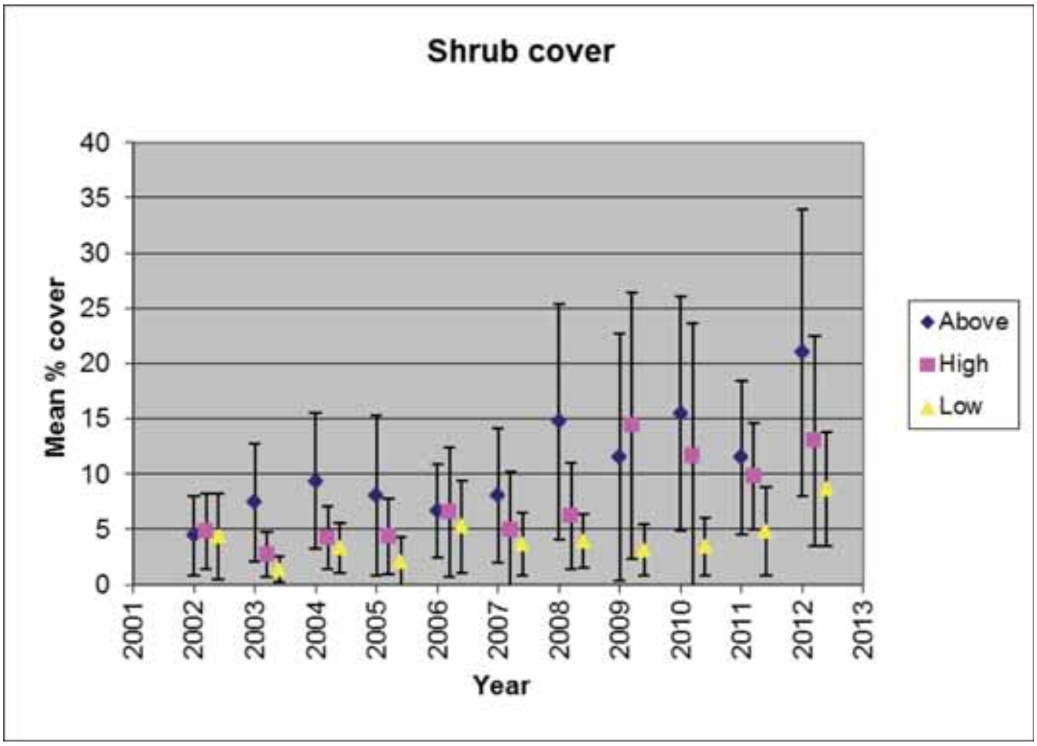


Figure 6-16 Mean per cent cover (±2 SE) of shrub cover in zones 3–5 by monitoring event for ‘above’, ‘high’ and ‘low’ quadrats in the Gordon River

### *6.6.6.6 Trigger value comparison for shrubs*

The results for both the ‘above’/’high’ and ‘above’/’low’ ratios show some minor changes in the relative amounts of shrub cover over the entire monitoring period compared with the pre-Basslink period (Table 6-9). Values were outside the trigger range for six-year cumulative ratio comparisons for both the ‘above’/’high’ and ‘above’/’low’ ratios for the whole-of-river data (Table 6-9). This indicates that there have been elevated measures in these values in the past six years relative to the pre-Basslink mean, rather than major changes this year.

Table 6-9 The trigger value range within which 95% of values are likely to lie for one-year (2011–12) and six-year (2006–12) mean values of ratios of shrub cover based on pre-Basslink monitoring and values recorded for the 2011–12 period

| Variable | Comparison | pre-Basslink trigger one-year mean range | | 2011–12 one-year result | pre-Basslink trigger six-year mean range | | 2006–12 six-year result |
|---|---|---|---|---|---|---|---|
| | | Lower | Upper | | Lower | Upper | |
| Per cent shrubs | Ratio (% above+1) to (% high+1) | 0.95 | 2.29 | 2.08 | 1.37 | 1.75 | **2.24*** |
| | Ratio (% above+1) to (% low+1) | 2.60 | 4.20 | 3.51 | 2.30 | 2.90 | **3.91*** |

Figures in bold and * indicate a value outside the trigger range

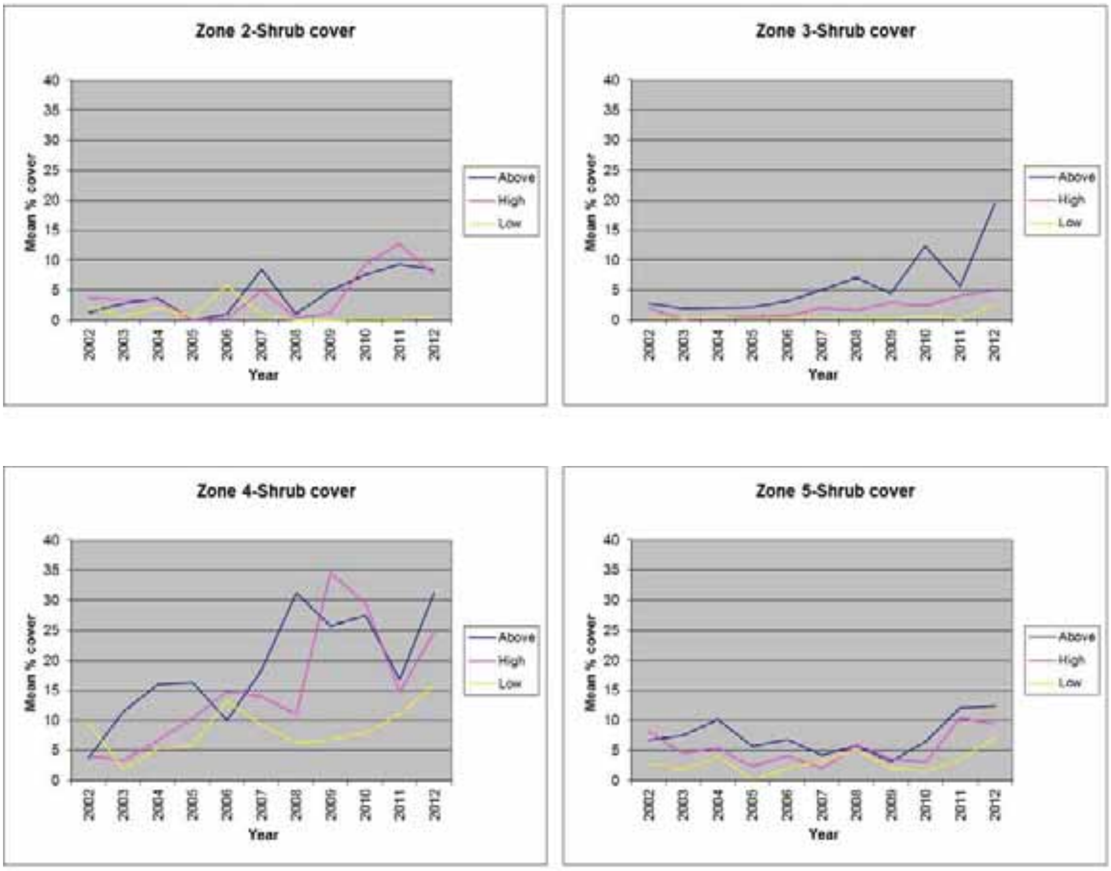


Figure 6-17 Per cent cover of shrubs for each quadrat type by zone for each monitoring event

## 6.7 Results—Denison and Franklin Rivers

Tributary monitoring was included in the program to provide a ‘reference’ for seasonal, regional-scale effects such as drought or climatic changes. The intention was to use these data when changes were detected in the Gordon River, to provide evidence or otherwise of a Basslink effect.

The tributary sites should not be viewed as a ‘control’ for post- Basslink comparisons due to the very different nature of the rivers, substantially different processes affecting the vegetation and significantly different hydrology. As such, vegetation communities in these rivers are typical of riparian vegetation in undisturbed rivers in south-western Tasmania (Hydro Tasmania, 2005a). A broad band of riparian vegetation persists from the boundary of low summer flows to the limits of the recent flood events. A complete description of the vegetation of these rivers and the differences with the vegetation of the Gordon River is presented in the IIAS study undertaken by Davidson and Gibbons (2001).

The following discussion refers to the quadrats in the studies as ‘above’, ‘high’ and ‘low’. Whilst these quadrats relate to different positions up the banks in the reference rivers, they do not reflect the distinct bank stratification that they do in the Gordon River, where they are responding to different regulated flow levels. The nomenclature used here is consistent with the Gordon River to enable easier comparisons of patterns at different bank levels. Data from 2002 to 2012 are included in this report to provide an indication of patterns of vegetation cover in the Franklin and Denison Rivers.

### 6.7.1 Total vegetation cover

Mean total vegetation cover (a composite of all vegetation data) can be spatially variable within locations but overall appears to have changed little at the Denison and Franklin river sites since 2002 until the 2011 monitoring event (Figure 6-18). The increase in total vegetation cover recorded in both the Franklin and Denison Rivers in the 2011 monitoring event has slowed in ‘low’ and ‘above’ quadrats but has continued in ‘high’ quadrats. Increases in ‘high’ quadrats are largely driven by one site on the Denison River where the cover of the fern *Blechnum nudum* and the lily *Libertia pulchella* continue to expand.

Increase in total vegetation on the Franklin is largely due to the expansion of the shrubs *Pomaderris apetala* and *Eucryphia lucida* at one site and *Blechnum nudum* and *Diplarrena moraea* at another site. Both of these sites were affected by flood event in 2007 and the increased growth is likely to be the result of increased light availability following this event.

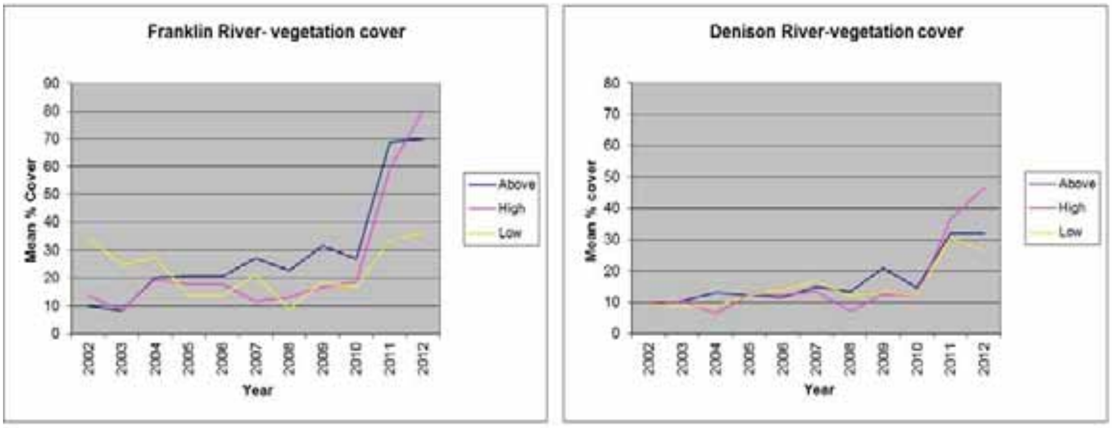


Figure 6-18 Mean percentage cover of vegetation at Denison River sites and Franklin River sites) by quadrat location (‘above’, ‘high’ and ‘low’) from 2002 to 2012

## 6.7.2 Bare ground

Total bare substrate (a composite of root exposure and bare ground) was highly variable both temporally and spatially in both rivers (Figure 6-19). A decline in total bare cover was reported in the Basslink Baseline Report for 2001–05 (Hydro Tasmania 2005a) however since then bare ground cover has fluctuated appreciably from year to year. The percentage cover of bare ground has remained stable or fallen since the last monitoring period in all quadrat types on both the Franklin and Denison Rivers, which is consistent with the trend reported on the Gordon River.

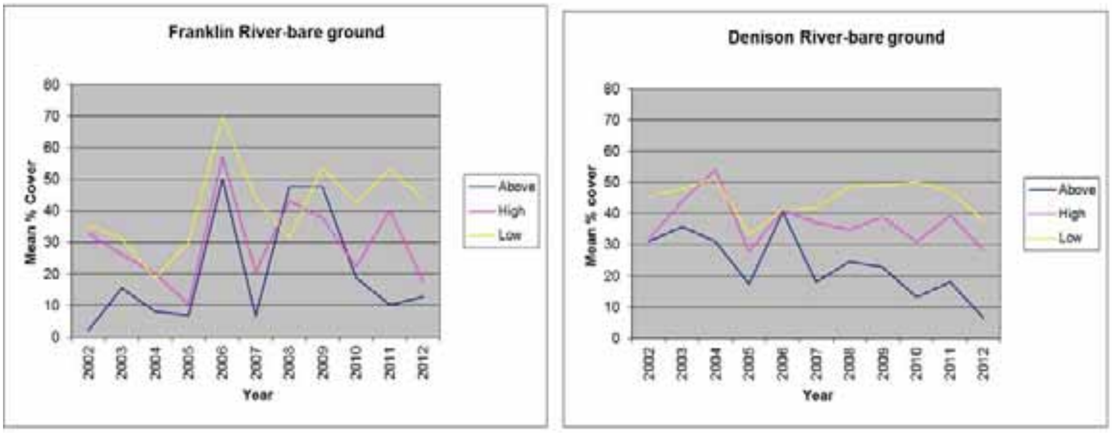


Figure 6-19 Mean percentage of total bare ground cover at Denison River sites (top row) and Franklin River sites (bottom row) by quadrat location (‘above’, ‘high’ and ‘low’ ) from 2002 to 2011

### *6.7.2.1 Identification of a threatening process in the Gordon River*

There has been dieback of *Richea pandanifolia* (pandani) plants observed in past years on the banks of the Gordon River along the middle Gordon River from Abel Gorge down to the Franklin confluence. This epacrid species is highly susceptible to the pathogen, *Phytophthora cinnamomi*. Commonly known as dieback, *Phytophthora cinnamomi* is a soil-borne pathogen, of the kingdom Chromista, which affects the roots of susceptible plants, starving them of nutrients and water. Long-distance spread of Phytophthora is principally by the transfer of infected soil or plant material by vehicles, people or animals. Dispersal of spores over short distances may occur via water movement in soil or along water courses.

Conclusive identification of a Phytophthora infection requires laboratory analysis of soil or root samples. All vegetation sites were assessed for symptoms of dieback (yellowing of leaves and necrosis) in susceptible species however no obvious symptoms were evident at any of the sites apart from the site that was identified last year (site 3EB) and subsequently tested positive for Phytophthora. It was assumed that this site would still be infected and no further samples were taken.

Previous testing has confirmed *Phytophthora* from many of the sites in all zones of the river. Some areas of dieback of *Richea pandanifolia* have in the past tested negative to *Phytophthora,* and localised scour and physical disturbance associated with flow impacts are also a likely cause of dieback in some situations.

## 6.8 Discussion

Conditions in the Gordon River over the 2011–12 monitoring period again were favourable for plant growth, continuing the pattern first noted in 2008–09. These conditions were the result of reduced inundation and water logging due to low frequency and duration of high flows. Flow duration curves for the 2011–12 year show considerably lower discharge than either the long-term average (2003–12) and the post-Basslink (2006–12) averages (see Chapter 2 Hydrology and water management). Recovery of vegetation establishment on the lower banks was noted in field observations for all zones and was also recorded in photo-monitoring (undertaken in December 2011) and geomorphological–vegetation process monitoring. The establishment of herbs and graminoids, particularly *Juncus*, *Baloskion*, and *Isolepis* was recorded on both alluvial and cobble substrates and continues the trend observed from 2008–09. Vegetation was often seen to persist in flat areas often below ‘low’ quadrats, however, this effect was not always captured in the quadrat data. Frequently the expansion in vegetation cover was due to the establishment of graminoid species such as grasses and sedges. These plant species tend to dominate flat, poorly drained areas and were often below ‘low’ quadrats and often largely absent from ‘high’ and ‘above’ quadrats.

Associated with the increase in total vegetation cover was a decline in the percentage of bare ground found in all quadrat types. This has been associated with the continued expansion of vegetation cover as a result of low frequency and duration of high flows on the river. Data collected in 2011–12 showed 21 of the 37 amended vegetation triggers to have values outside the trigger ranges (Table 6-10).

Table 6-10 Summary of trigger types, the variable measured, number of triggers and the number of triggers exceeded in 2011–12

| Trigger type | Variable measured | Number of triggers | Number of deviances |
|---|---|---|---|
| Community composition (zones 3–5 comparisons) | Similarity index | 9 | 9 |
| | Species/taxa richness | 9 | 5 |
| | Species evenness | 9 | 1 |
| Community structure (whole-of-river comparisons) | Abundance of life forms | 6 | 3 |
| | Abundance of bare substrate | 4 | 3 |

Trigger values were marginally outside the trigger range for a number of community composition measures. Community composition triggers for similarity indices were all outside pre-Basslink trigger ranges generally by only a small degree. The Bray Curtis similarity indices used are highly sensitive to small changes. This is particularly the case where the quadrat size is small and species numbers are low.

Pre-Basslink ranges were calculated from only three years of data and it is unlikely to have captured the degree of variation present in the system, so the metric is now capturing the additional variation present over an extended period. Higher quadrats tended to be comparatively stable, while lower quadrats were becoming less similar. Species in lower quadrats establish, persist for a period and then are lost or replaced by others. Due to the small plot size and small number of samples, only a small number of species occur in these plots. The species differ over time and are stochastically determined such that a different group of species can be found in any plot at any given time. No species were recorded in 2011–12 that had not previously been found, however some herbs and graminoids are becoming more prevalent in the lower quadrats due to the lower flows experienced in this period.

Mean values for species richness are above trigger range in five instances and generally in the lower quadrats. This was consistent with increased recruitment of species in periods of low flow. This metric measures the total number of species present and the sample size is small, so the recording of one or two additional species in quadrats is enough to exceed the trigger range and this is readily explained in years of enhanced recruitment.

Species evenness triggers were marginally below the pre-Basslink ranges for one quadrat type in zone 4 and is the result of the increased dominance of some shrub species, particularly at one site on a cobble bar in the middle of the river. This site is being eroded and inundated, which has resulted in the removal of smaller herb species, but the larger shrub species have persisted and are dominant and hence there has been a reduction in species evenness.

Trigger values based on life forms were variable. Bryophyte measures were within trigger values ranges and responses between zones were variable. The cover of bryophytes generally either increased slightly or remained stable compared to the previous year.

Trigger values for the comparisons ratios of ‘above’/’low’ for percentage cover of ferns was within trigger ranges but was outside the trigger ranges for ‘above’/’high’ ratios. This is likely to be the result of the continued expansion of ferns in the ‘above’ quadrats rather than any significant losses of ferns from the ‘high’ quadrats. Ferns tend to be more common on upper banks and are largely absent from ‘low’ quadrats.

The ratios for ‘above’/’high’ and ‘above’/’low’ for percentage shrub cover were within trigger ranges for one-year means, but fell outside the upper margins for the six-year means. This indicates that there has been elevated measures over the last six years rather than particularly high values this year.

Ratio of ‘above’/’high’ for percentage cover of bare ground were within trigger value ranges, however trigger values were below the lower trigger ranges for ‘above’/’low’ comparisons. This was more a result of a relatively greater decline in bare ground in ‘above’ quadrats than an expansion of bare ground in low quadrats.

Trigger values ratios of total vegetation cover were marginally outside the range for the one-year and six-year cumulative ratio comparisons for the ‘above’/’low’ ratios and outside the six-year cumulative ratio for the ‘above’/’high’ ratios.

The lower than expected result for the ‘above’/’low ratios for the one-year result is likely to be due to the recovery of vegetation in ‘low’ quadrats this year, while the exceedance of the upper trigger for the six-year cumulative measure is the result of a number of high ratio values over the past six years. This again may reflect the continued expansion of vegetation in the ‘above’ quadrats, in comparison to the relative abundance of total vegetation cover found in the ‘high’ and ‘low’ quadrats impacted by water flows.

Interpretation of changes in these cover ratios should be treated with caution and highlights the quite different processes that are occurring in these quadrat types. The trigger ranges can be exceeded due to changes in the impacted quadrats but also due to changes to the ‘above’ quadrats.

The recovery of the banks on the Gordon River that was recorded in 2008–09 has continued in 2011–12 and is consistent with the expansion of vegetation in the absence of high flows of long duration.

The increase in vegetation cover in higher quadrats was due to an increase in the fern cover (particularly in zone 2) and also to the growth of shrub species (in zones 3, 4 and 5). The increase in vegetation cover in the lower quadrats tended to be attributable to herbs as well as graminoid species such as *Microlaena stipoides, Isolepis* sp., *Uncinia* sp. and *Juncus* spp.

The graminoid species recorded colonising the Gordon River are generally absent from the tributary rivers because the vegetation on the tributaries is at a later successional stage compared to the more modified Gordon River. Additionally, the tributaries do not have the bare low flat bank toes present on the Gordon where these graminoids establish and rapidly grow in the absence of high flows.

The significant change in the hydrology due to the decreased operation of the power station in the post-Basslink period has had a positive effect on the recovery of the vegetation on the banks of the Gordon.

## 6.9 Conclusions

The recovery of the vegetation along the Gordon River noted since 2008 has continued in the 2011–12 monitoring period. Sites are generally showing an increase in total vegetation cover and a consequent reduction in bare ground in all quadrat types. Bryophyte and fern cover has either increased slightly or remained stable, while shrub cover has been seen to increase slightly. Associated with the recovery of vegetation is an increase in species richness as additional species colonise the lower quadrats.

A number of values were recorded outside the triggers for community composition and this has largely been due to small changes in the similarity indices and species richness, which is attributable to the change in the presence and absence of a few species.

The exceeding of trigger values is often due to the establishment and measurement of the trigger values over a short pre-Basslink period under very different flow regimes and therefore the ranges of the trigger values have not captured the range of variation present within the system.

The trends noted in 2011–12 are consistent with the growth and persistence of vegetation on the banks of the Gordon River and utilising multiple lines of evidence it can be seen that recovery of vegetation on the lower bank occurs in the absence of frequent high duration flows. This recovery is enhanced when lower flows occur over a number of consecutive years.

Recovery of the vegetation on the Gordon River can be attributed to the low power station discharges in the post-Basslink period. The reasons that determine the operating regime of the power station are complex, but at some level must be influenced by the operation of Basslink, and so can be considered a Basslink effect. However this has had a positive impact on the recovery of vegetation on the banks of the Gordon River in the post-Basslink monitoring period.

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# 7 Macroinvertebrates

## 7.1 Introduction

Macroinvertebrate sampling was conducted in spring (4–5 November) 2011 and autumn (25–26 February) 2012 in accordance with the requirements of the Basslink Monitoring Program for the Gordon River. 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 confluence. This sampling was also conducted at the six ‘reference’ sites located in rivers within the Gordon catchment.

This sampling completes the six years of post-Basslink macroinvertebrate monitoring being conducted in the Gordon River catchment.

This document reports on the results of field sampling for macroinvertebrates in spring and autumn 2011–12, provides a comparison of these results with those for the pre-Basslink period (years one to four of the monitoring program) and describes trends over the entire monitoring program to date.

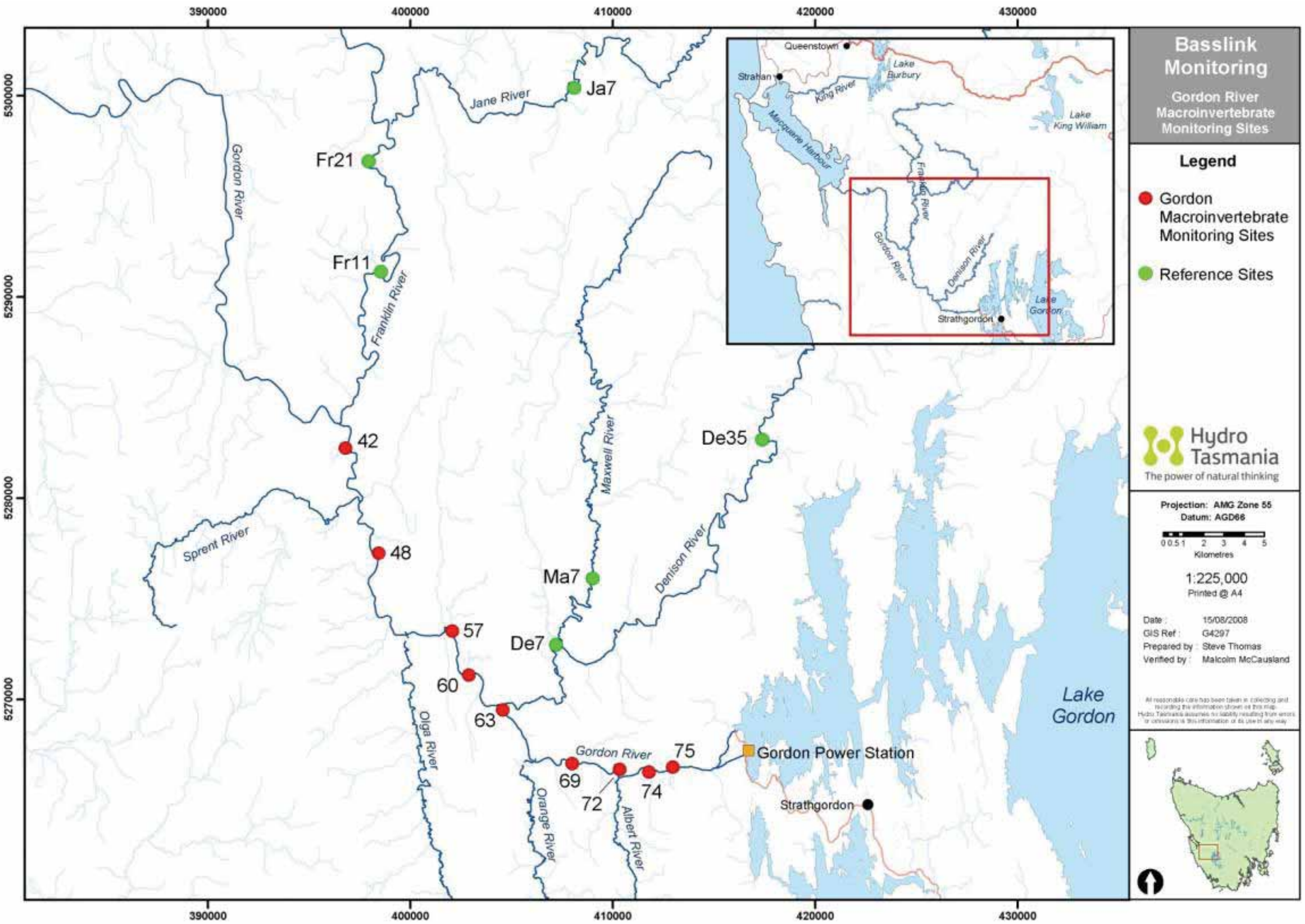
Results were also compared with triggers derived from pre-Basslink period data, as detailed in the Basslink Baseline Report (Hydro Tasmania 2005a).

A more complete analysis of flow regime variations and the implications of these for macroinvertebrate responses and potential for trends will also be conducted in the final Basslink review report.

## 7.2 Methods

### 7.2.1 Sample sites

The locations of the monitoring and reference sites are shown in Map 7-1. All sites sampled in 2011–12 are listed in Table 7-1.



Map 7-1 Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers

Table 7-1 Sites sampled in 2011–12 for macroinvertebrates

| River | Site Name | Site code | Distance from power station (km) | Easting | Northing |
|---|---|---|---|---|---|
| Gordon | Gordon R d/s Albert Gorge (G4) | 75 | 2 | 412980 | 5266630 |
| | Gordon R d/s Piguenit R (G4A) | 74 | 3 | 412311 | 5266383 |
| | Gordon R in Albert Gorge (G5) | 72 | 5 | 410355 | 5266524 |
| | Gordon R u/s Second Split (G6) | 69 | 8 | 408005 | 5266815 |
| | (Gordon R u/s Denison R (G7) | 63 | 14 | 404584 | 5269469 |
| | Gordon R d/s Denison R (G9) | 60 | 17 | 402896 | 5271211 |
| | Gordon R u/s Smith R (G10) | 57 | 20 | 402083 | 5273405 |
| | Gordon R d/s Olga R (G11A) | 48 | 29 | 398178 | 5278476 |
| | Gordon R @ Devil's Teapot (G15) | 42 | 35 | 396804 | 5282486 |
| Franklin | Franklin R d/s Blackman's bend (G19) | Fr11 | - | 398562 | 5291239 |
| | Franklin R @ Flat Is (G20) | Fr21 | - | 397939 | 5296733 |
| Denison | Denison d/s Maxwell R (G21) | De7 | - | 407206 | 5272718 |
| | Denison R u/s Truchanas Reserve (D1) | De35 | - | 417400 | 5282900 |
| Jane | Jane R (J1) | Ja7 | - | 408100 | 5300400 |
| Maxwell | Maxwell R (M1) | Ma7 | - | 409011 | 5276009 |

### 7.2.2 Macroinvertebrate sampling

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.

### 7.2.3 Habitat variables

A set of standard habitat variables were recorded at each site and a number of variables were recorded from 1:25000 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).

### 7.2.4 Analysis

No detailed analysis has been conducted for this report, other than to derive O/E scores and plot summary trends. 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 derived for the Basslink Monitoring 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 2011–12 data were compared against the relevant one-year trigger values (shown graphically in this report). In addition, cumulative mean values of the indicators were derived for the full six-year post Basslink period (2006–07 to 2011–12) and compared with the six-year trigger values.

# 7.3 Results

## 7.3.1 Spring 2011

### *7.3.1.1 Quantitative data*

Data from spring 2011 season surber samples are shown for family level identification and for EPT species in Appendix 9.

Diversity and total abundance at both family and species level, as well as the number and abundance of EPT species, fell generally within or close to the range observed in previous years (Figure 7-1 and Figure 7-2).

The relative (proportional) abundance of EPT species was substantially lower than pre-Basslink means for sites 57 to 63 (Figure 7-3). This was primarily due to a substantial decline in the relative abundance of Hydropsychid caddis of the genus *Asmicridea* to levels that now fall within the range observed at reference sites (Figure 7-3, Appendix 9). This decline occurred between 2008 and 2010, and Hydropsychid abundances have remained low in Zone 2 since that time (Refer also to Section 7.5.2 and Figure 7-36). Only zone 1 sites 69 and 74 now sustain relatively high abundances of *Asmicridea* caddisfly larvae (family Hydropsychidae).

The community compositional similarity of zone 1 Gordon River sites relative to the reference sites was greater than the pre-Basslink means, when measured by the mean Bray Curtis Similarity measure based on either abundance or presence/absence data (Figure 7-4).

#### 7.3.1.1.1 RBA data

Spring season RBA data is shown in Appendix 9. O/Epa and O/Erk values and their impairment bands are shown in Table 7-2.

O/Epa values in spring 2011 fell generally close to pre-Basslink means in the Gordon River (as did all reference site values except for site Ma7), though with a higher value at sites 60 and 75 (Figure 7-5). Values for 2011–12 were not significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2011 values, p >0.5).

O/Erk values in spring 2011 were generally close to pre-Basslink mean values in the Gordon River (Figure 7-5) and not significantly different (by paired t-test of spring pre-Basslink means with 2011 values, p >0.4), though values in zone 1 were higher than pre-Basslink means with the exception of site 72. Reference site O/Epa values were again not statistically significantly different from pre-Basslink means (by paired t-test of spring pre-Basslink means with 2011 values, p >0.2).

#### 7.3.1.1.2 Conclusions

Total abundance and diversity generally fell within the upper ranges of pre-Basslink values for zone 1 sites, while all indicators generally fell within pre-Basslink ranges, with little consistent difference from pre-Basslink means. The proportional abundance of EPT species fell below pre-Basslink ranges for sites in the immediate vicinity of the Denison confluence (sites 57–63).

Magnitudes of all variables generally fell within historical pre-Basslink ranges for reference sites.

### *7.3.1.2 Autumn 2012*

#### 7.3.1.2.1 Quantitative data

Data from autumn 2011 season surber samples are shown at family level and for EPT species in Appendix 9.

Total abundance and number of taxa at both family and species level for the Gordon River sites was generally within or higher than pre-Basslink ranges (Figure 7-6 and Figure 7-7), with total abundance falling well above pre-Basslink ranges at the three most downstream sites (Figure 7-6). These sites, as well as reference site Fr11, all had very high densities of blackfly larvae (simuliids), which seem to have peaked in recruitment again during the 2011–12 summer. Abundance was quite variable relative to the pre-Basslink means across the six reference sites (Figure 7-6).

The abundance of EPT species was variable among Gordon River sites, with five sites being higher than the pre-Basslink means and greatly exceeding the pre-Basslink range at site 74 (Figure 7-7). Five of the six reference sites had abundances of EPT species above the pre-Basslink means, especially at sites Fr11 and Ja7 (Figure 7-7). The number of EPT species fell above pre-Basslink means for all bar one of the Gordon sites (Figure 7-7), while reference site values were consistently below pre-Basslink means.

The proportional abundance of EPT species was generally lower in the Gordon River in zone 2 than pre-Basslink means, but substantially exceeded pre-Basslink means and ranges in zone 1 (Figure 7-8). Four of the six reference site values were well above their pre-Basslink means.

The community compositional similarity of the Gordon River sites relative to reference sites was greater than pre-Basslink means for all nine sites, for both similarity measures (Figure 7-9). Reference sites in autumn 2012 had inter-site compositional similarities that fell close to their pre-Basslink means.

#### 7.3.1.2.2 RBA data

Autumn season RBA data is shown in Appendix 9. O/Epa and O/Erk values and their impairment bands are shown, and plotted with pre-Basslink values, in Figure 7-10.

O/Epa values in autumn 2012 were higher than pre-Basslink means for five of the nine Gordon sites (Figure 7-10), and three of the six reference sites. These differences were not statistically significant (by paired t-test of pre-Basslink means with 2012 values, both p >0.2) for Gordon or reference sites. Gordon sites 57, 69 and 75 all fell above or at the upper margins of their observed pre-Basslink ranges, while the site 48 value fell below.

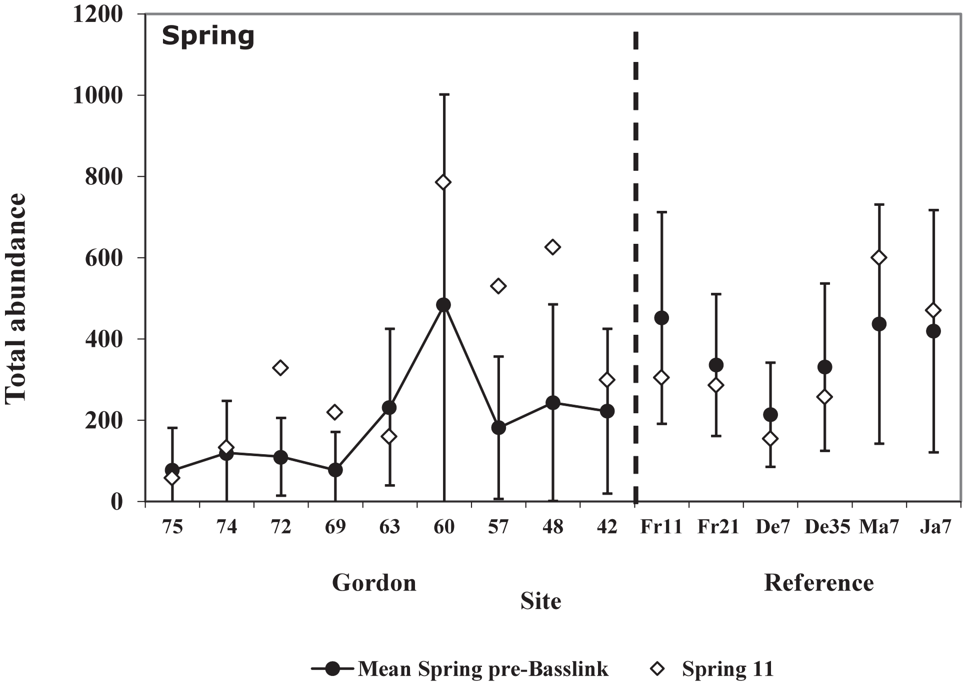
O/Erk values were higher than pre-Basslink means for four of the nine Gordon River sites (Figure 7-10), and substantially lower than pre-Basslink means for two of the six reference sites. These differences were not statistically significant overall (by paired t-test of pre-Basslink means with 2012 values, both p >0.3) for Gordon sites.

#### 7.3.1.2.3 Conclusions

Diversity (at family and species level), and the proportion of abundance of EPT species, was greater in most Gordon River sites (especially zone 1) than pre-Basslink values. This was accompanied by a general increase in overall community compositional similarity to reference sites. These changes were not observed at reference sites, and are likely a result of post-Basslink within-Gordon effects, most likely driven by the presence of minimum environmental flows (Hydro Tasmania 2010a). Further analyses to evaluate this hypothesis will be conducted in the final review report.

Table 7-2 O/Epa and O/Erk values for all sites sampled in spring and autumn 2011–12, for individual replicate samples, and averages. Impairment bands also indicated

| | | | Spring 2011 | | | | Autumn 2012 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **River** | **Site** | **Replicate** | **O/Epa** | **Band** | **O/Erk** | **Band** | **O/Epa** | **Band** | **O/Erk** | **Band** |
| Gordon R | 75 | 1 | 0.60 | B | 0.45 | B | 0.98 | A | 0.61 | B |
| | | 2 | 0.83 | A | 0.94 | A | 0.68 | B | 0.50 | B |
| | | Mean | 0.71 | B | 0.69 | B | 0.83 | A | 0.56 | B |
| | 74 | 1 | 0.74 | A | 0.82 | A | 0.88 | A | 0.66 | B |
| | | 2 | 0.81 | A | 0.87 | A | 0.88 | A | 0.56 | B |
| | | Mean | 0.77 | A | 0.85 | B | 0.88 | A | 0.61 | B |
| | 72 | 1 | 0.80 | A | 0.93 | A | 1.08 | A | 0.66 | B |
| | | 2 | 0.58 | B | 0.63 | B | 0.78 | B | 0.71 | B |
| | | Mean | 0.69 | B | 0.78 | A | 0.93 | A | 0.68 | B |
| | 69 | 1 | 0.98 | A | 1.08 | A | 1.08 | A | 0.78 | B |
| | | 2 | 0.91 | A | 0.95 | A | 1.37 | X | 0.88 | A |
| | | Mean | 0.95 | A | 1.01 | A | 1.22 | X | 0.83 | A |
| | 63 | 1 | 0.89 | A | 1.12 | A | 1.27 | X | 0.91 | A |
| | | 2 | 0.97 | A | 0.98 | A | 0.98 | A | 0.76 | B |
| | | Mean | 0.93 | A | 1.05 | A | 1.12 | A | 0.83 | A |
| | 60 | 1 | 1.12 | A | 1.16 | A | 1.47 | X | 1.01 | A |
| | | 2 | 1.05 | A | 1.18 | A | 1.17 | A | 0.86 | A |
| | | Mean | 1.09 | A | 1.17 | A | 1.32 | X | 0.93 | A |
| | 57 | 1 | 0.97 | A | 1.12 | A | 1.66 | X | 1.16 | A |
| | | 2 | 0.82 | A | 0.82 | A | 1.76 | X | 1.21 | X |
| | | Mean | 0.90 | A | 0.97 | A | 1.71 | X | 1.18 | A |
| | 48 | 1 | 1.12 | A | 1.06 | A | 0.78 | B | 0.64 | B |
| | | 2 | 0.96 | A | 0.98 | A | 0.88 | A | 0.74 | B |
| | | Mean | 1.04 | A | 1.02 | A | 0.83 | A | 0.69 | B |
| | 42 | 1 | 1.12 | A | 1.04 | A | 1.47 | X | 1.06 | A |
| | | 2 | 0.75 | A | 0.82 | A | 1.47 | X | 0.91 | A |
| | | Mean | 0.94 | A | 0.93 | A | 1.47 | X | 0.98 | A |
| Franklin R | Fr11 | 1 | 1.20 | X | 1.12 | A | 1.47 | X | 1.06 | A |
| | | 2 | 1.27 | X | 1.23 | X | 1.37 | X | 1.01 | A |
| | | Mean | 1.24 | X | 1.17 | X | 1.42 | X | 1.03 | A |
| | Fr21 | 1 | 1.50 | X | 1.52 | X | 1.57 | X | 1.31 | X |
| | | 2 | 1.05 | A | 1.06 | A | 1.66 | X | 1.11 | A |
| | | Mean | 1.27 | X | 1.29 | X | 1.61 | X | 1.21 | X |
| Denison R | De7 | 1 | 1.14 | A | 1.06 | A | 1.56 | X | 1.16 | A |
| | | 2 | 1.29 | X | 1.11 | A | 1.66 | X | 1.31 | X |
| | | Mean | 1.21 | X | 1.09 | A | 1.61 | X | 1.24 | X |
| | De35 | 1 | 0.95 | A | 0.94 | A | 1.56 | X | 1.01 | A |
| | | 2 | 0.87 | A | 0.85 | A | 1.17 | A | 0.86 | A |
| | | Mean | 0.91 | A | 0.89 | A | 1.37 | X | 0.93 | A |
| Maxwell R | Ma7 | 1 | 0.95 | A | 1.17 | A | 1.56 | X | 1.06 | A |
| | | 2 | 0.95 | A | 0.91 | A | 1.47 | X | 1.01 | A |
| | | Mean | 0.95 | A | 1.04 | A | 1.52 | X | 1.03 | A |
| Jane R | Ja7 | 1 | 1.28 | X | 1.15 | A | 1.57 | X | 1.11 | A |
| | | 2 | 1.35 | X | 1.29 | X | 1.57 | X | 1.11 | A |
| | | Mean | 1.31 | X | 1.22 | X | 1.57 | X | 1.11 | A |



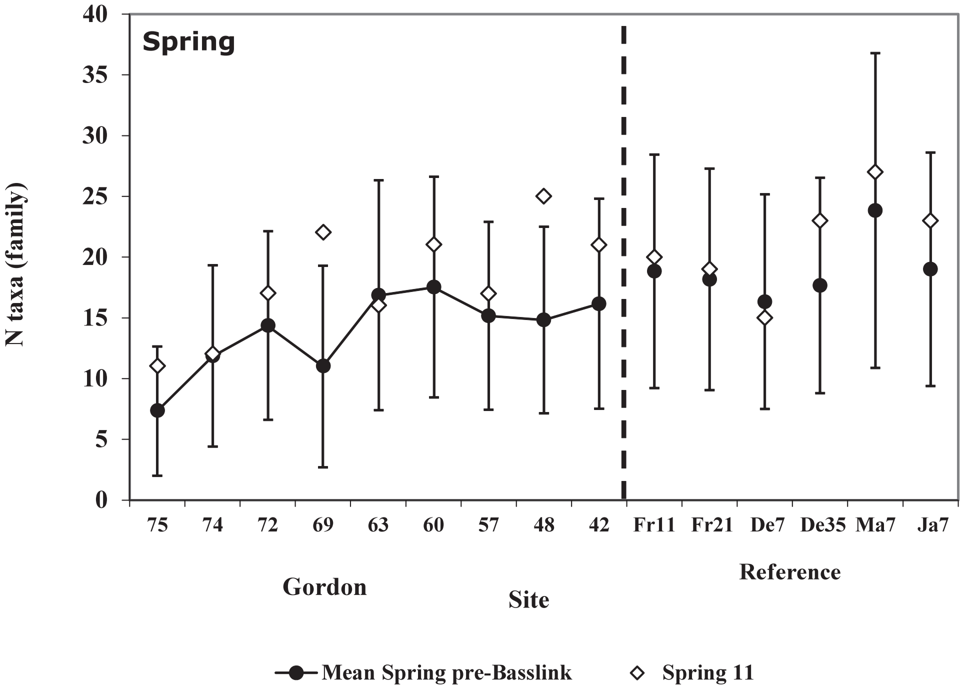


Figure 7-1 Comparison of total abundance of all benthic macroinvertebrates and diversity (number of taxa at family level) for spring 2011 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

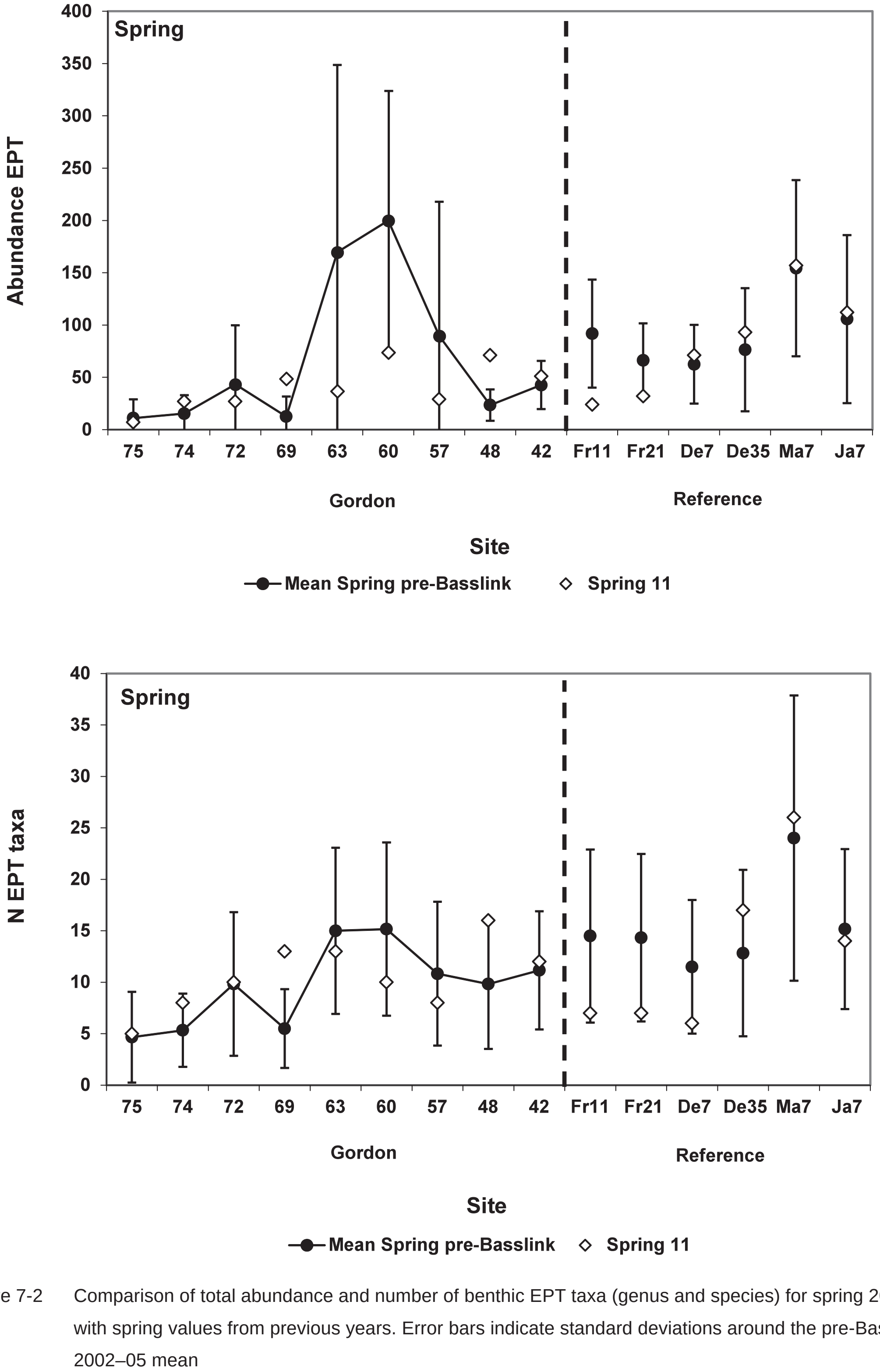


Figure 7-2 Comparison of total abundance and number of benthic EPT taxa (genus and species) for spring 2011 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

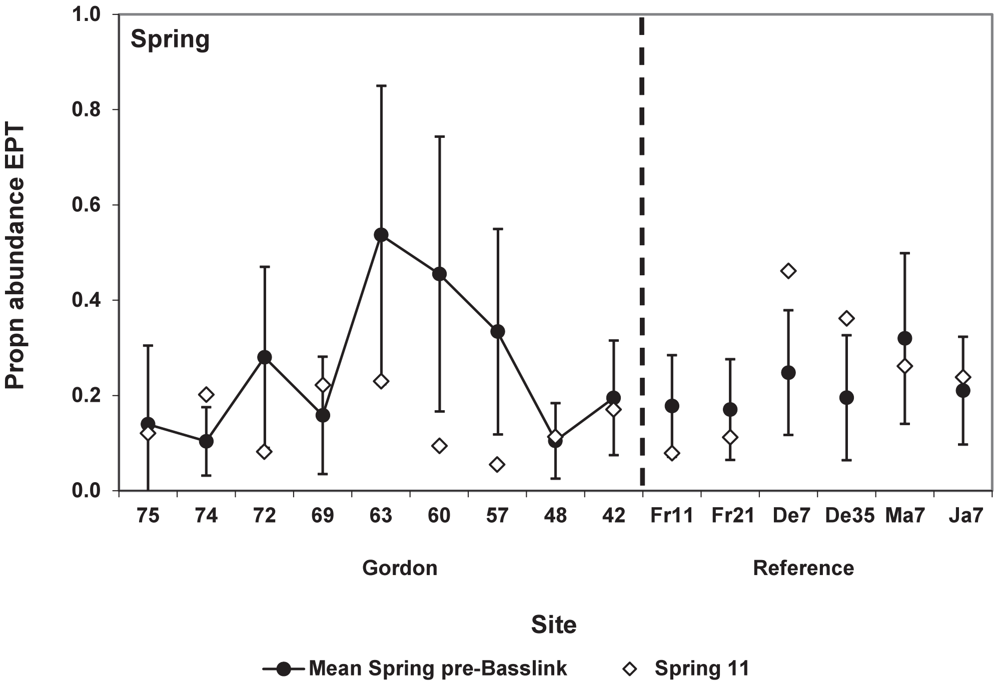
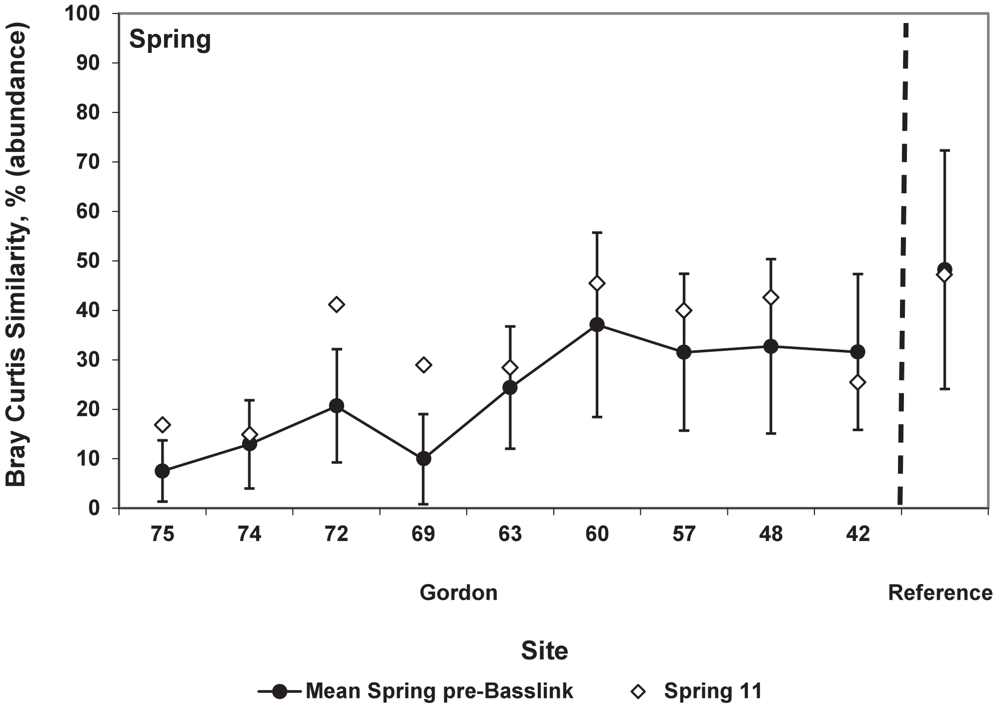


Figure 7-3 Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for spring 2011 with spring values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



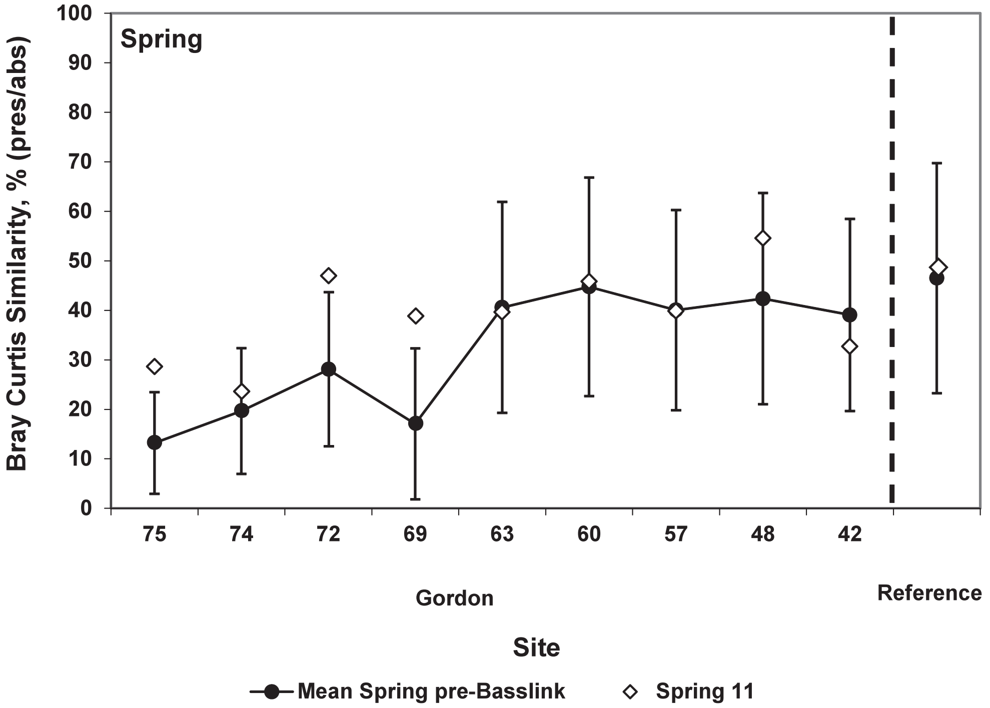


Figure 7-4 Comparison of values for the mean Bray Curtis Similarity between each sampled site and the reference sites for spring 2011 with spring values from previous years. Similarities are calculated with either abundance data (square root transformed) or presence/absence data. Error bars indicate 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

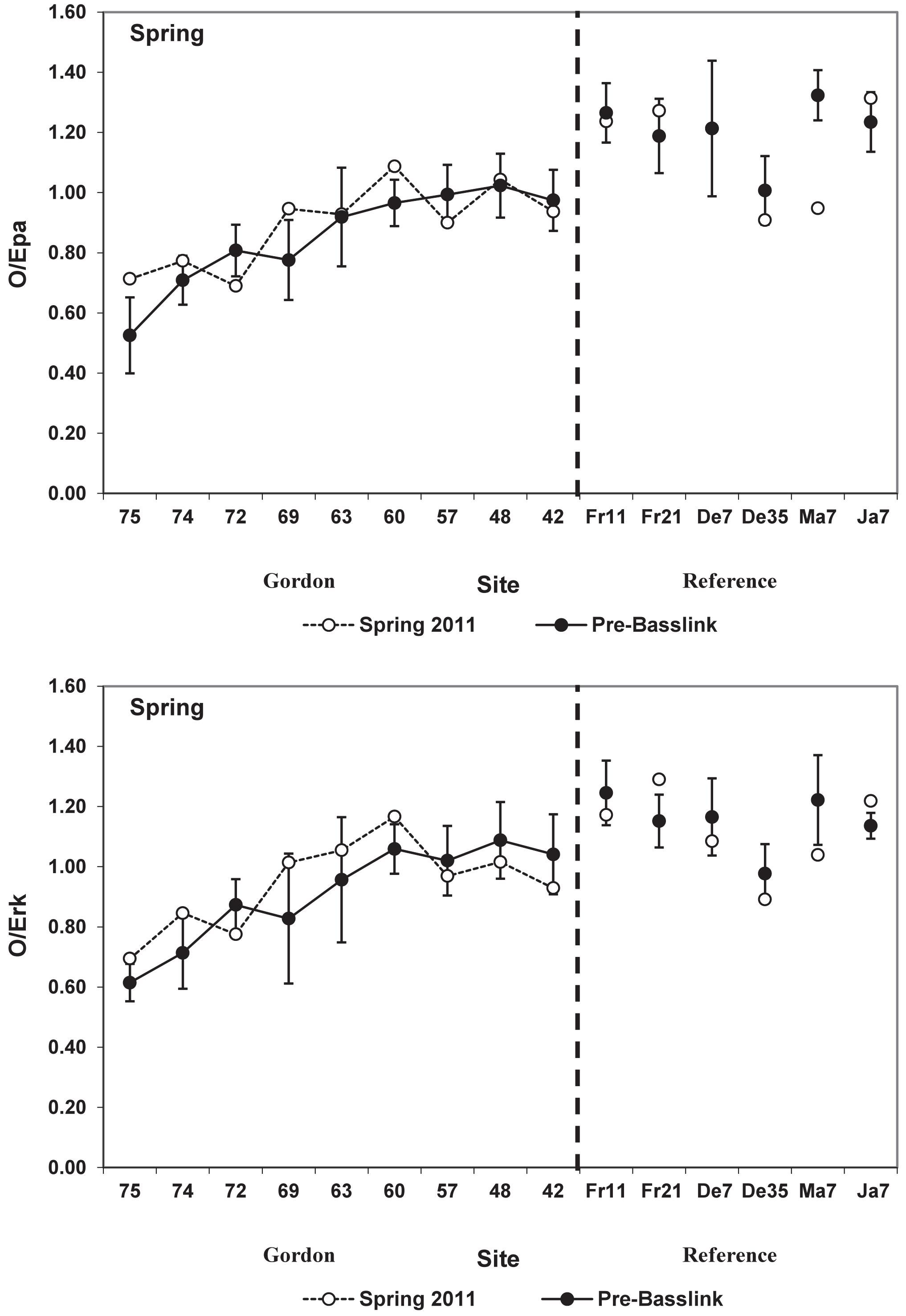
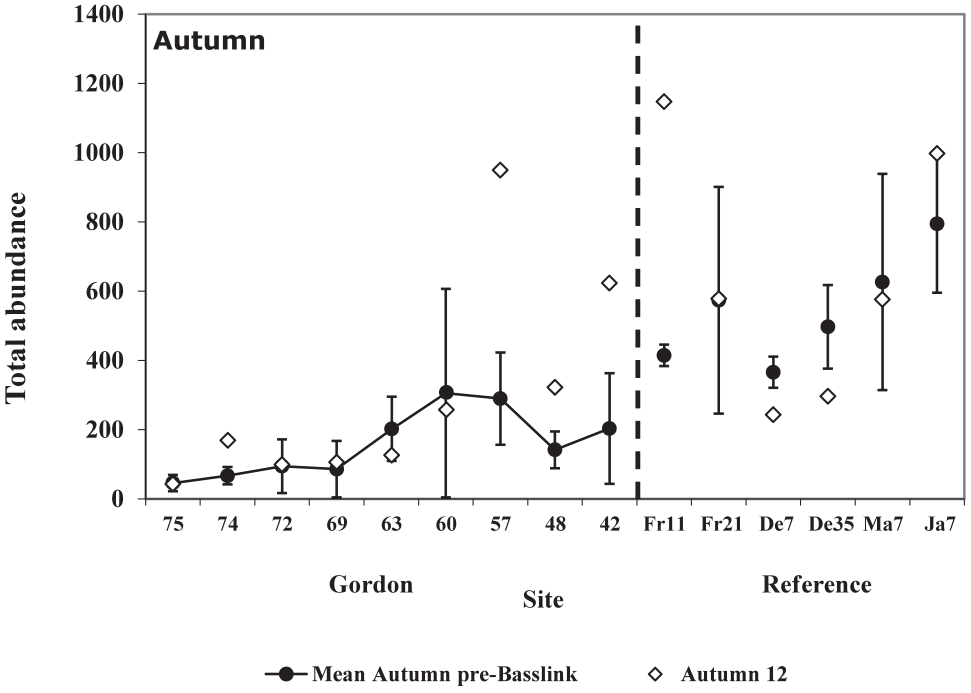


Figure 7-5 Comparison of O/Epa and O/Erk values for spring 2011 with values from previous years. Note consistently high O/Epa values at sites 69 – 75 upstream of Denison. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



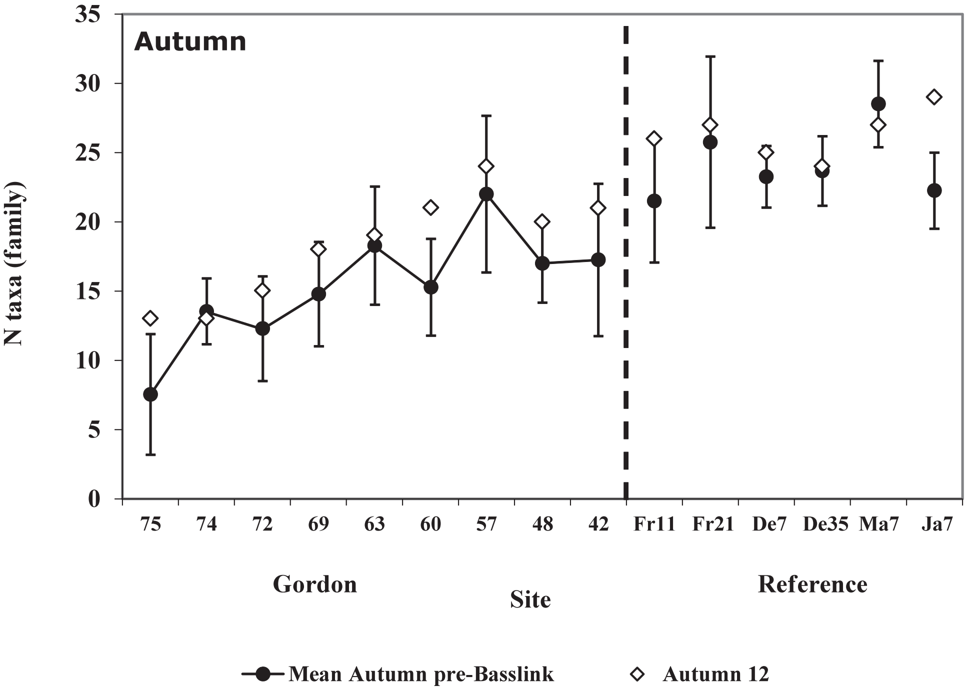
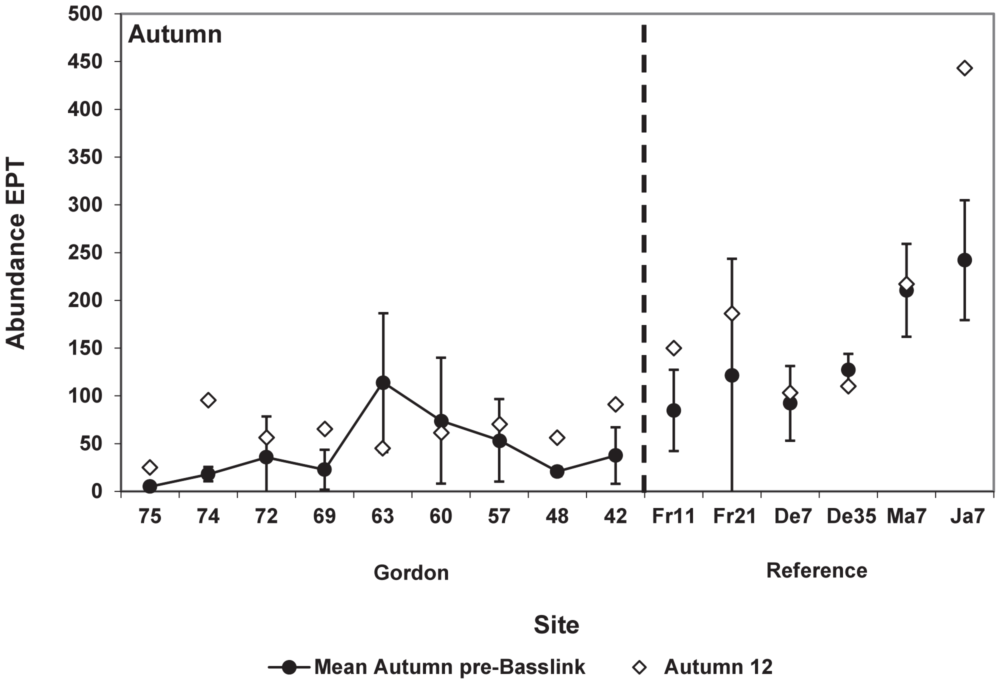


Figure 7-6 Comparison of total abundance and diversity (number of taxa at family level) for autumn 2012 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



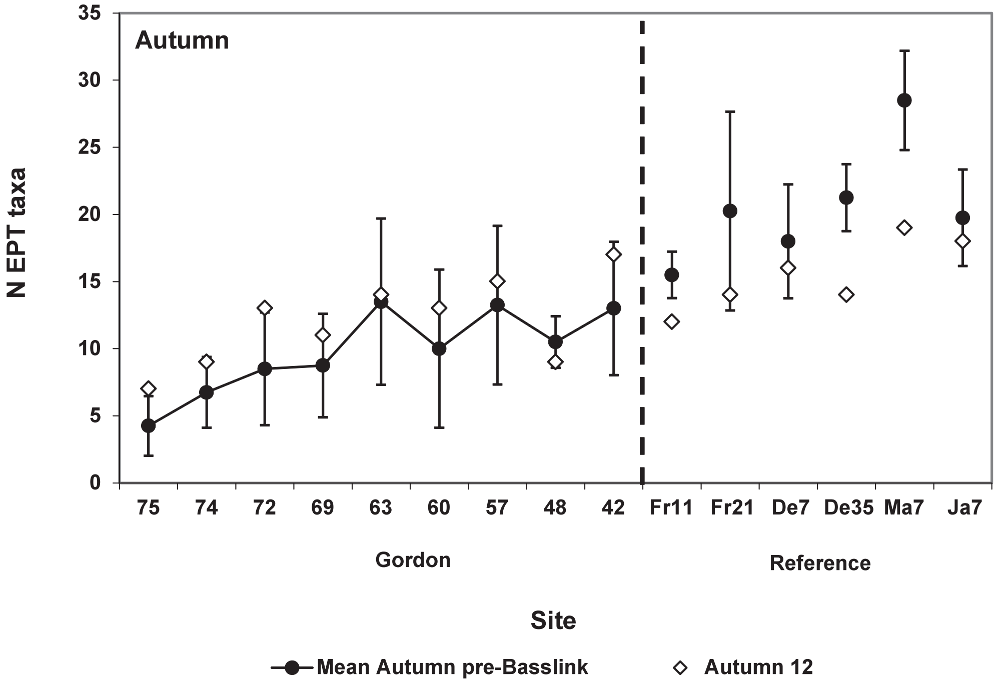


Figure 7-7 Comparison of total abundance and number of benthic EPT species for autumn 2012 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

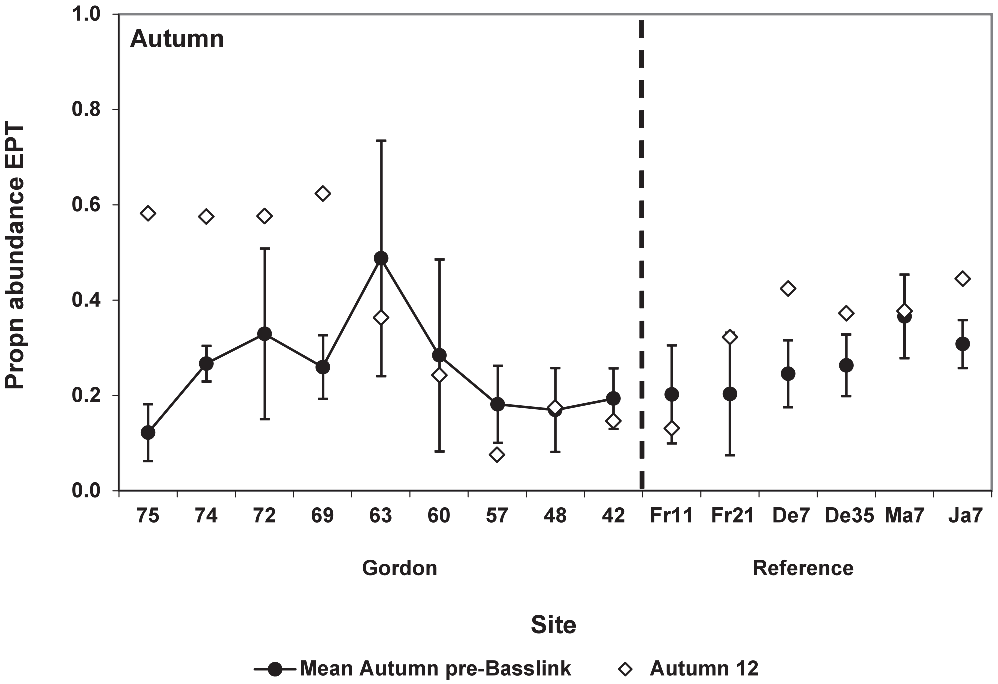
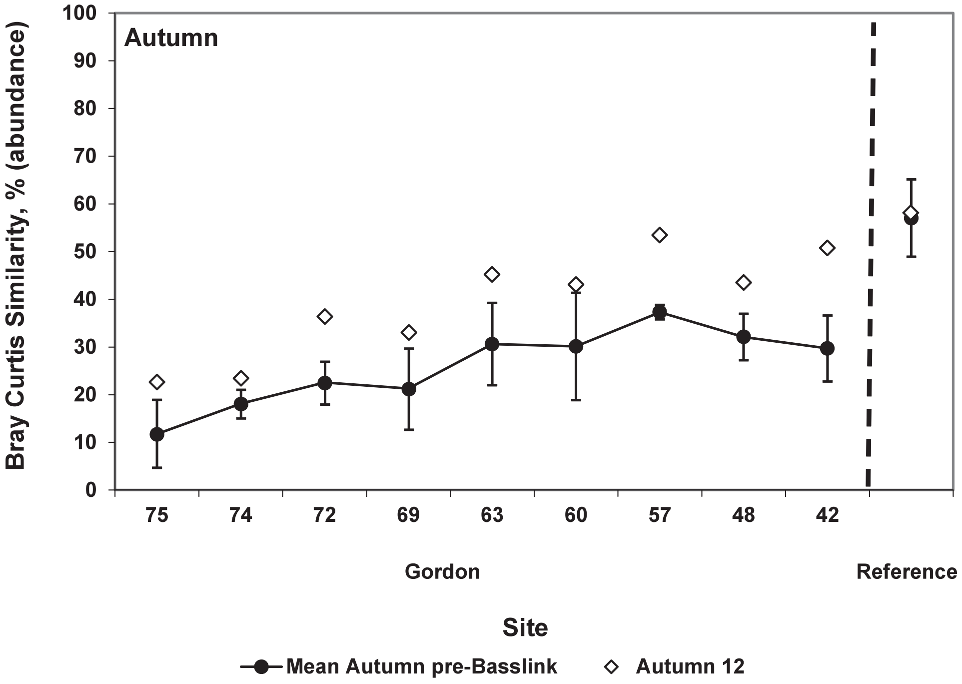


Figure 7-8 Comparison of proportion of total benthic macroinvertebrate abundance represented by EPT species for autumn 2012 with autumn values from previous years. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean



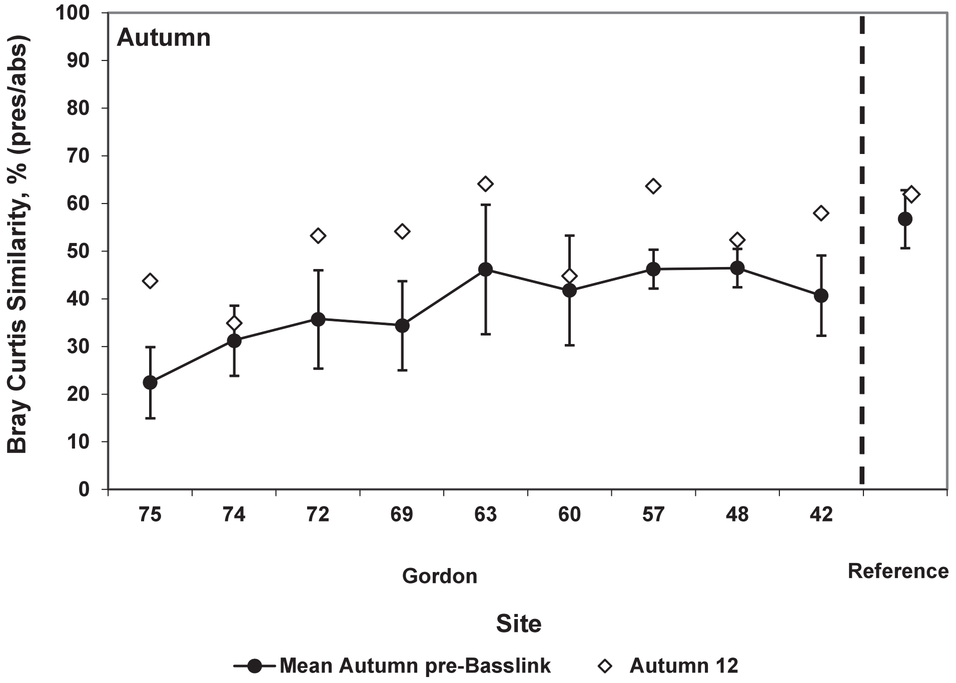


Figure 7-9 Comparison of values fo the mean Bray Curtis Similarity between each sampled site and the reference sites for autumn 2012 with autumn values from previous years. Similarities are calculated with either abundance data (square root transformed) or with presence/absence data. Error bars indicate 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

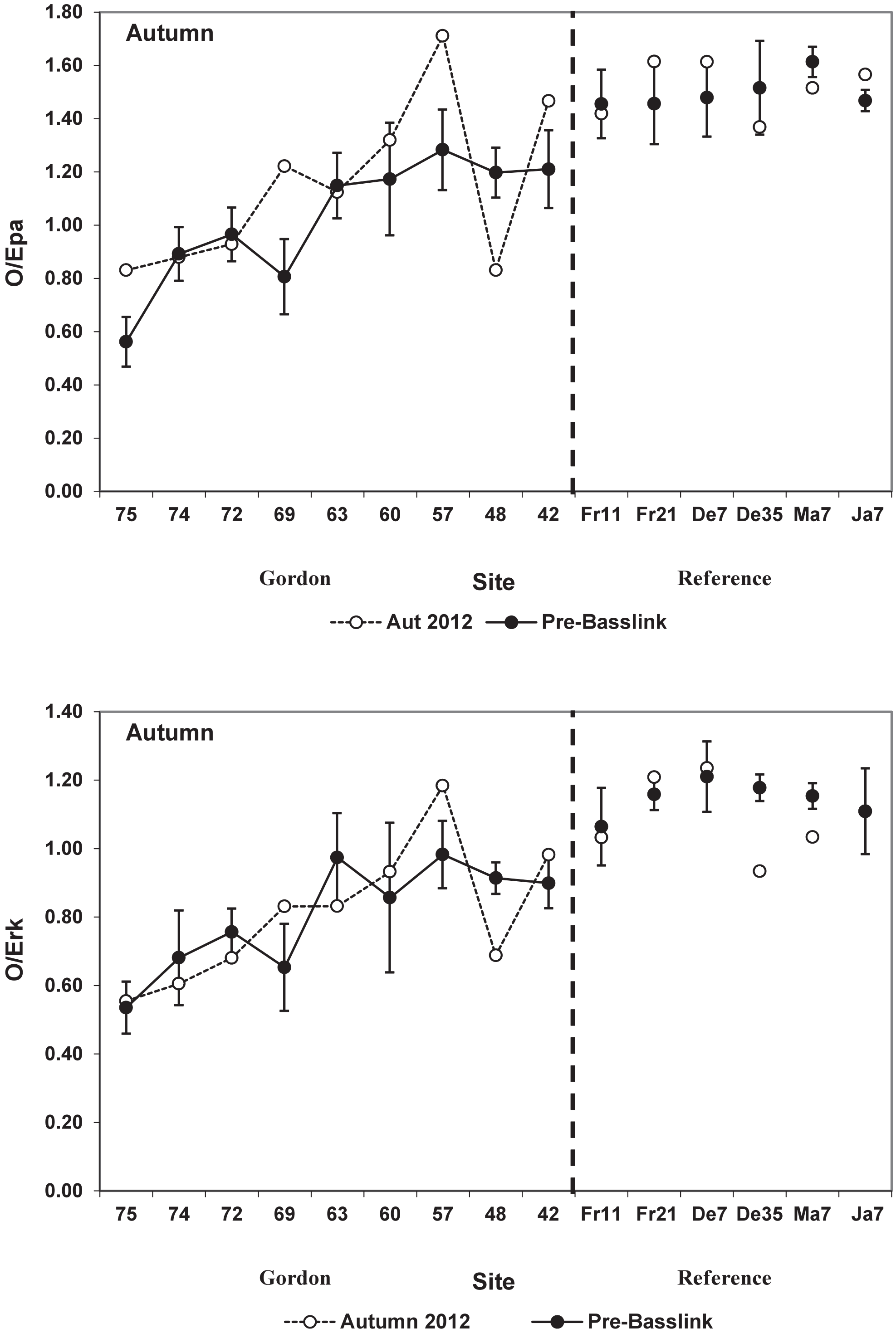


Figure 7-10 Comparison of O/Epa and O/Erk values for autumn 2012 with values from previous years. Note consistently high O/Epa values at sites 69–75 upstream of Denison River. Error bars indicate standard deviations around the pre-Basslink 2002–05 mean

## 7.4 Comparisons with triggers

### 7.4.1 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 follows:

1. Community Structure
    - Bray Curtis (abundance)
    - O/Erk
2. Community Composition
    - Bray Curtis (pres/abs data)
    - O/Epa
3. Taxonomic richness
    - N Taxa (fam)
    - N EPT species
4. Ecologically significant species
    - Proportion of total abundance as EPT
    - Abundance EPT
5. 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 or not post-Basslink. Triggers have been developed for each individual site in the Gordon River, as well as for the entire river (‘whole-of-river’) and zones within the river. Seasonal differences are also taken into account for the whole-of-river case. Two zones have been described for benthic macroinvertebrates—zone 1 (upstream of the Denison confluence (incorporating sites 69 to 75) and zone 2 downstream of the Denison confluence (incorporating sites 42 to 60).

Values of all metrics for 2011–12 are shown in Table 7-3. Plots of the trigger levels for each metric are shown below along with the value for the metric recorded in 2011–12, at individual site level (Figure 7-11 to Figure 7-15), and at whole-of-river and zone level (Figure 7-16 to

Figure 7-20). Similar plots are shown for trigger bounds and the mean value of each metric for the six-year post-Basslink period 2006–07 to 2011–12, again at individual site level (Figure 7-21 to Figure 7-25) and at whole-of-river and zone level (Figure 7-26 to Figure 7-30).

Table 7-3: Values of all metrics for each site sampled in spring 2011 and autumn 2012

Key : BP = biomass/productivity, BCPA = Bray Curtis (pres/abs data), NTF = N Taxa (fam)

| | | | Spring 2011 | | | | | | | | | Autumn 2012 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Community Structure | | Community Composition | | Taxonomic richness | | Ecologically significant species | | BP | Community Structure | | Community Composition | | Taxonomic richness | | Ecologically significant species | | BP |
| River | Site code | Old code | Bray Curtis (abund) | O/Erk | BCPA | O/Epa | NTF | N EPT spp. | Propn Abund EPT | Abund EPT | Density (Total abund) | Bray Curtis (abund) | O/Erk | BCPA | O/Epa | NTF | N EPT spp. | Propn Abund EPT | Abund EPT | Density (Total abund) |
| Gordon | 75 | G4 | 16.70 | 0.69 | 28.50 | 0.71 | 11 | 5 | 0.121 | 7 | 58 | 22.76 | 0.56 | 43.80 | 0.83 | 13 | 7 | 0.581 | 25 | 43 |
| | 74 | G4a | 14.76 | 0.85 | 23.47 | 0.77 | 12 | 8 | 0.201 | 27 | 134 | 23.56 | 0.61 | 34.97 | 0.88 | 13 | 9 | 0.575 | 96 | 167 |
| | 72 | G5 | 41.06 | 0.78 | 46.90 | 0.69 | 17 | 10 | 0.082 | 27 | 330 | 36.45 | 0.68 | 53.29 | 0.93 | 15 | 13 | 0.576 | 57 | 99 |
| | 69 | G6 | 28.84 | 1.01 | 38.73 | 0.95 | 22 | 13 | 0.222 | 49 | 221 | 33.13 | 0.83 | 54.19 | 1.22 | 18 | 11 | 0.623 | 66 | 106 |
| | 63 | G7 | 28.41 | 1.05 | 39.63 | 0.93 | 16 | 13 | 0.230 | 37 | 161 | 45.18 | 0.83 | 64.10 | 1.12 | 19 | 14 | 0.363 | 45 | 124 |
| | 60 | G9 | 45.46 | 1.17 | 45.82 | 1.09 | 21 | 10 | 0.094 | 74 | 786 | 43.06 | 0.93 | 44.80 | 1.32 | 21 | 13 | 0.242 | 62 | 256 |
| | 57 | G10 | 39.97 | 0.97 | 39.83 | 0.90 | 17 | 8 | 0.055 | 29 | 530 | 53.47 | 1.18 | 63.63 | 1.71 | 24 | 15 | 0.075 | 71 | 949 |
| | 48 | G11B | 42.62 | 1.02 | 54.54 | 1.04 | 25 | 16 | 0.113 | 71 | 626 | 43.50 | 0.69 | 52.35 | 0.83 | 20 | 9 | 0.174 | 56 | 322 |
| | 42 | G15 | 25.47 | 0.93 | 32.70 | 0.94 | 21 | 12 | 0.171 | 51 | 299 | 50.75 | 0.98 | 57.93 | 1.47 | 21 | 17 | 0.146 | 91 | 623 |
| **Reference** | | | | | | | | | | | | | | | | | | | | |
| Franklin | Fr11 | G19 | 44.41 | 1.17 | 46.92 | 1.24 | 20 | 7 | 0.079 | 24 | 305 | 60.25 | 1.03 | 66.97 | 1.42 | 26 | 12 | 0.131 | 150 | 1147 |
| | Fr21 | G20 | 47.48 | 1.29 | 48.63 | 1.27 | 19 | 7 | 0.112 | 32 | 286 | 66.68 | 1.21 | 70.34 | 1.61 | 27 | 14 | 0.322 | 186 | 578 |
| Denison | De7 | G21 | 51.85 | 1.09 | 52.38 | 1.21 | 15 | 6 | 0.461 | 71 | 154 | 62.21 | 1.24 | 62.85 | 1.61 | 25 | 16 | 0.424 | 103 | 243 |
| | De35 | D1 | 50.29 | 0.89 | 53.19 | 0.91 | 23 | 17 | 0.362 | 93 | 257 | 56.74 | 0.93 | 59.76 | 1.37 | 24 | 14 | 0.372 | 110 | 296 |
| Maxwell | Ma7 | M1 | 39.97 | 1.22 | 38.82 | 1.31 | 27 | 26 | 0.262 | 157 | 600 | 52.78 | 1.03 | 49.73 | 1.52 | 27 | 19 | 0.377 | 217 | 576 |
| Jane | Ja7 | J1 | 47.82 | 1.04 | 44.53 | 0.95 | 23 | 14 | 0.238 | 112 | 470 | 53.10 | 1.11 | 63.59 | 1.57 | 29 | 18 | 0.444 | 443 | 997 |

### 7.4.2 Trigger status

The following section summarises and comments on the observations for 2011–12 in comparison with the trigger values.

#### *7.4.2.1 Community structure*

*Bray Curtis (abundance):* All sites and zones fall within and generally close to the upper trigger bounds, except sites 72 and 57 which show a minor exceedance, while a minor exceedance is observed for the whole-of-river case both for all year and for the autumn season, and for zone 1 (Figure 7-11 and Figure 7-16).

*Comment*—Compliant, and represents a positive post-Basslink change due to increased abundance and number of aquatic insect species, though of limited ecological significance.

*O/Erk:* All sites compliant at site and whole-of-river and zone levels (Figure 7-11 and Figure 7-16).

*Comment*—Consistent with pre-Basslink conditions.

#### *7.4.2.2 Community composition*

*Bray Curtis (pres/abs data):* All sites compliant (Figure 7-12 and Figure 7-17), though exceeding upper trigger for sites 72 and 75 and for the whole-of-river case for all year and the autumn season.

*Comment*—Compliant, and represents a positive post-Basslink change due to increased abundance and number of aquatic insect species, though of limited ecological significance.

*O/Epa:* All sites compliant (Figure 7-12 and Figure 7-17), with minor exceedances of the upper trigger bound at sites 69 and 75.

*Comment*—Consistent with pre-Basslink conditions.

#### *7.4.2.3 Taxonomic richness*

*N Taxa (fam):* All sites and zones compliant, with a minor exceedance at site 48, and for the whole-of-river case both for all year and for the autumn season (Figure 7-13 and Figure 7-18).

*Comment*—Consistent with pre-Basslink conditions but improvement overall in autumn.

*N EPT Species:* All sites and zones compliant, with a minor exceedance of the upper trigger bound for the whole-of-river case in autumn (Figure 7-13 and Figure 7-18).

*Comment*—Consistent with pre-Basslink conditions.

### *7.4.2.4 Ecologically significant species*

*Proportion of total abundance as EPT:* Compliant, lying inside triggers at all sites in zone 2, for whole-of-river and zone 1, though falling close to lower trigger bound values for both zones and in spring. Values fall above upper trigger levels for sites 69, 72 and 75 (Figure 7-14 and Figure 7-19).

*Comment*—Consistent with pre-Basslink conditions for zone 2, improvement above trigger bounds for zone 1.

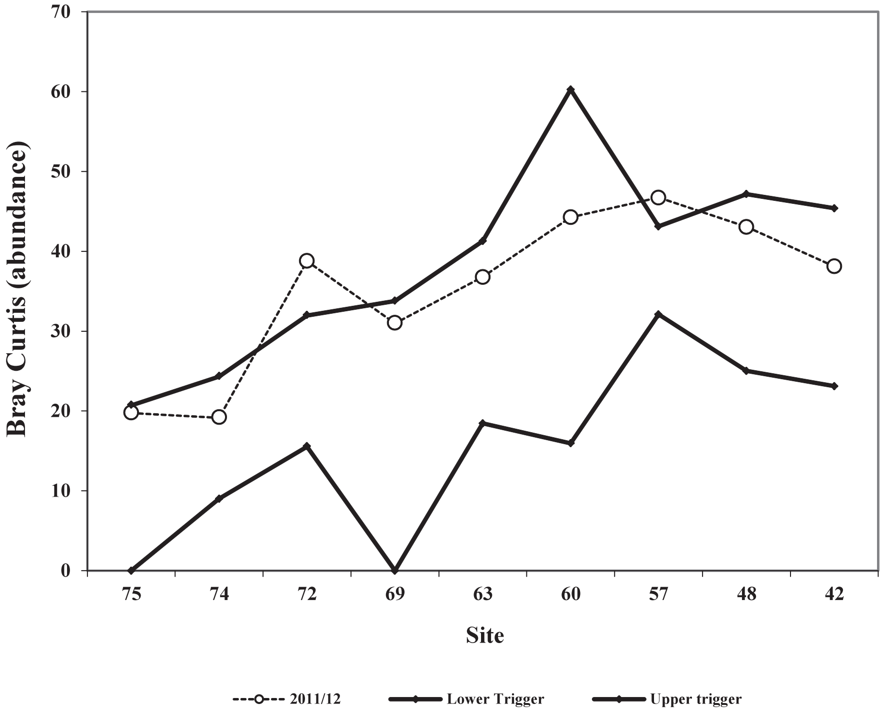
*Abundance EPT:* High at all sites and greatly exceeding upper trigger bounds except at site 60; exceeds for whole-of-river (all year and both seasons) and both zones (Figure 7-14 and Figure 7-19).

*Comment*—High densities of *Asmicridea* caddis especially at sites 69–74, contribute to this metric, though other taxa now also contribute (e.g. Grypopterygidae, Hydrobiosidae). Enhanced densities are believed to be a product of post-Basslink environmental flow constancy, interacting with food inputs from the tributary streams.

### *7.4.2.5 Biomass/productivity*

*Total abundance:* all sites compliant, with exceedances above the upper trigger values for sites 48 and 57; values above upper bound for whole-of-river (all year and both seasons) and zone 2 (Figure 7-15 and Figure 7-20).

*Comment*—Compliant and slightly improved.



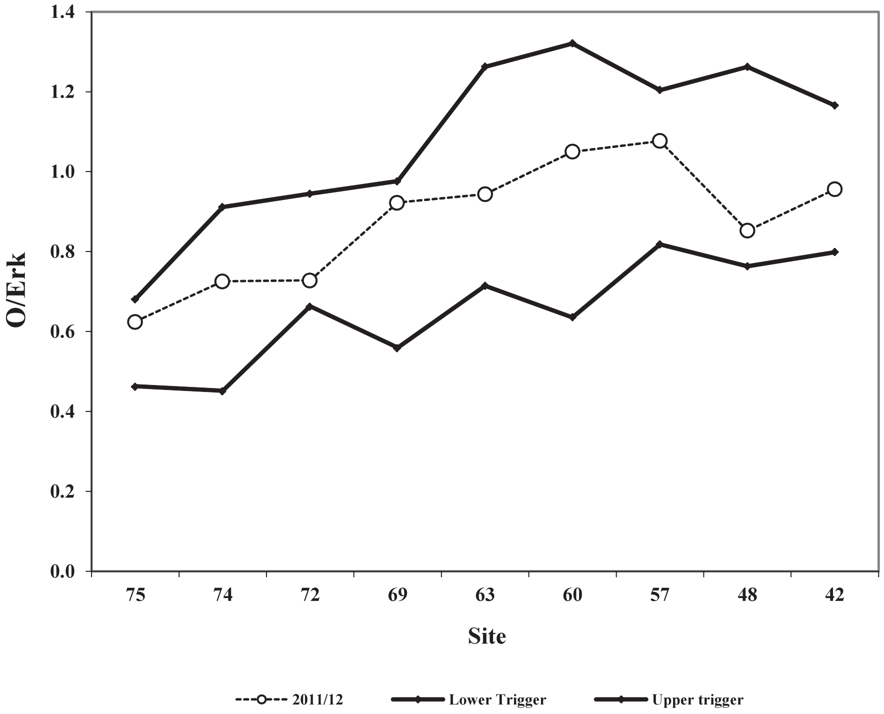
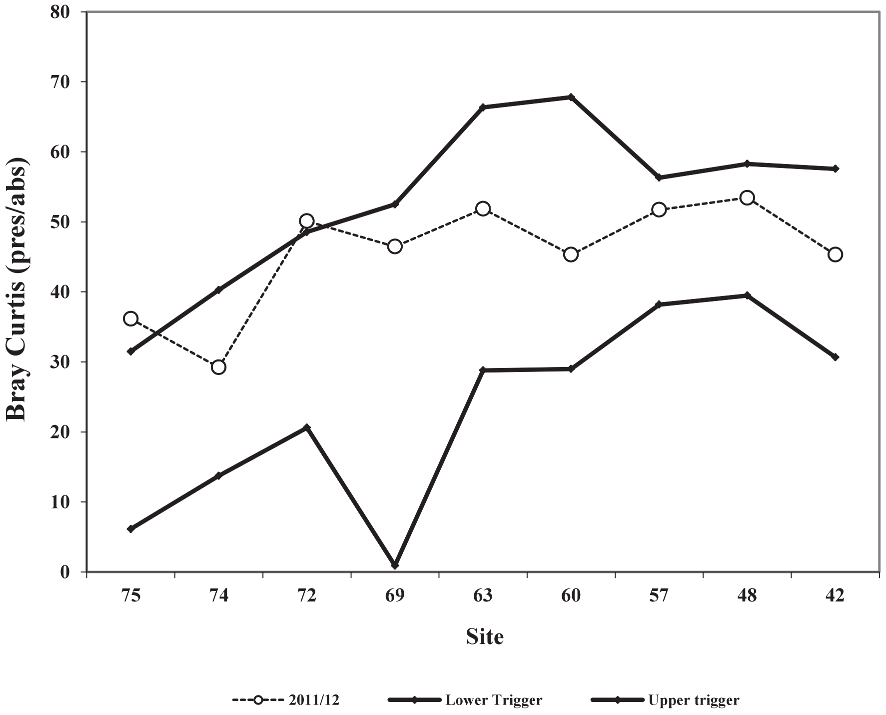


Figure 7-11 Community Structure metric values for 2011–12 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



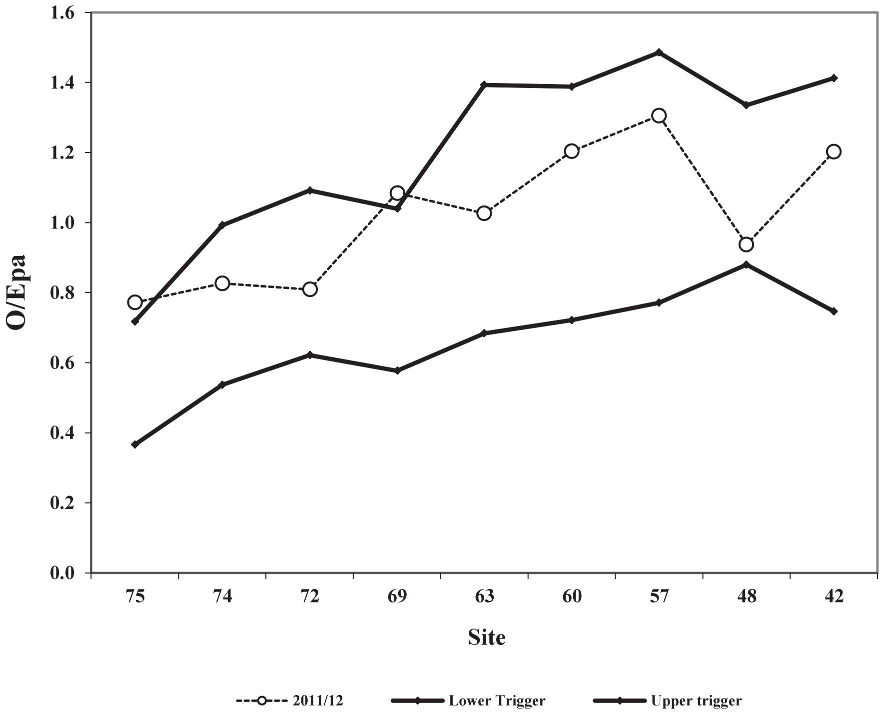
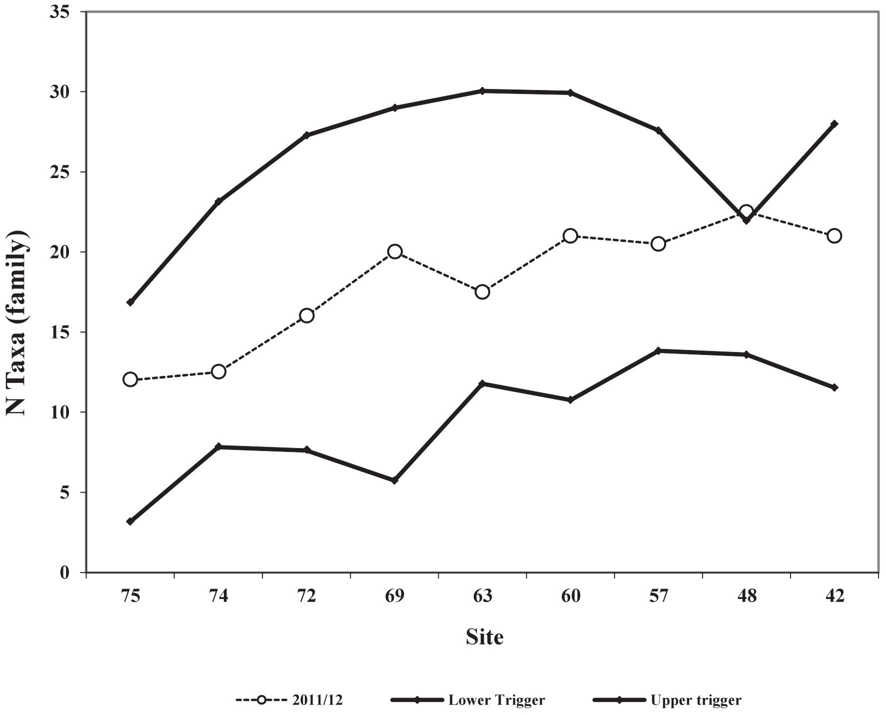


Figure 7-12 Community Composition metric values for 2011–12 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



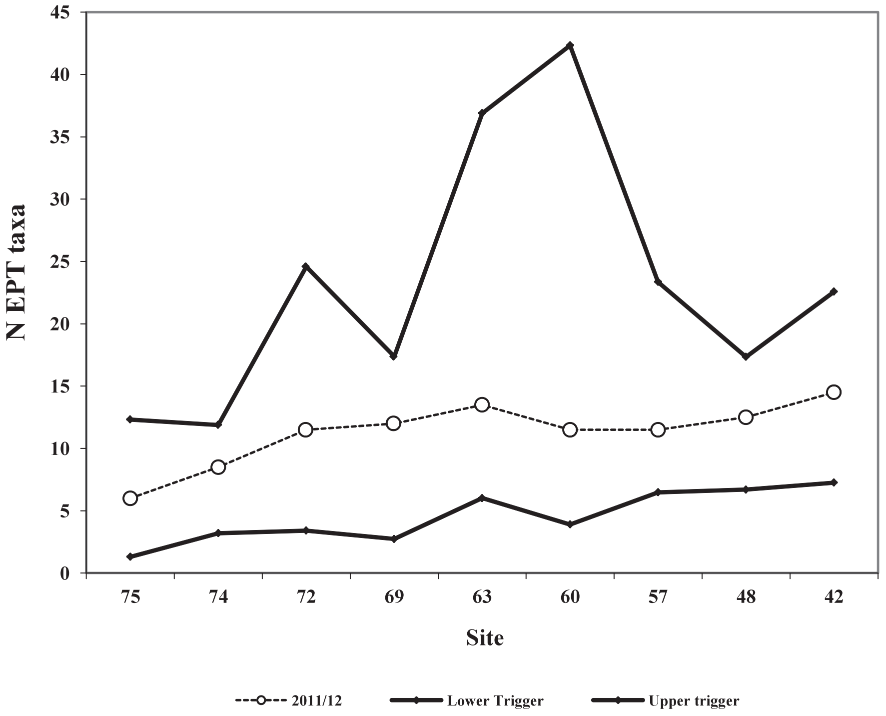
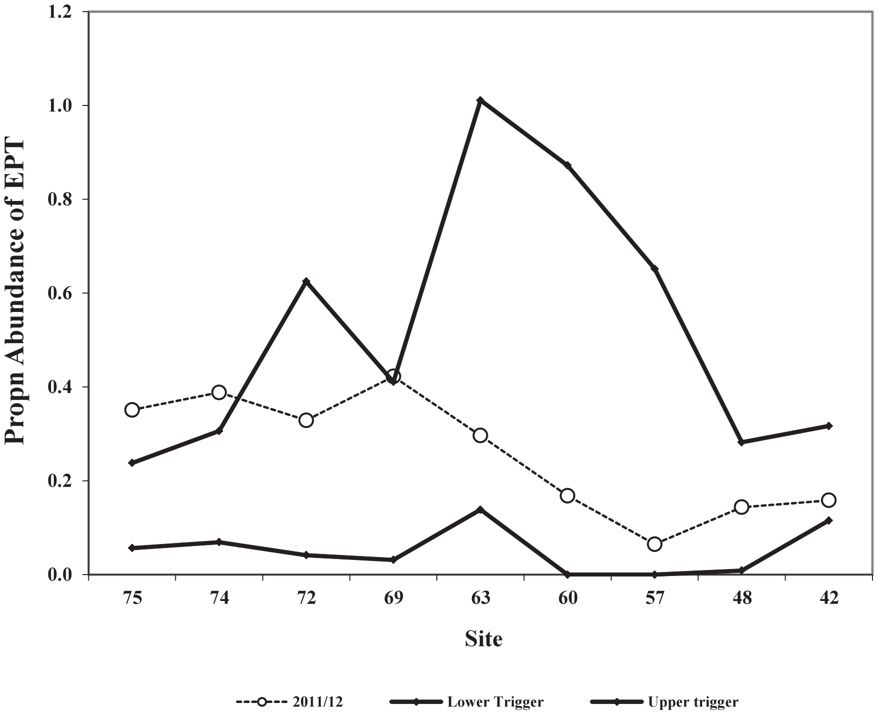


Figure 7-13 Taxonomic Richness metric values for 2011–12 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



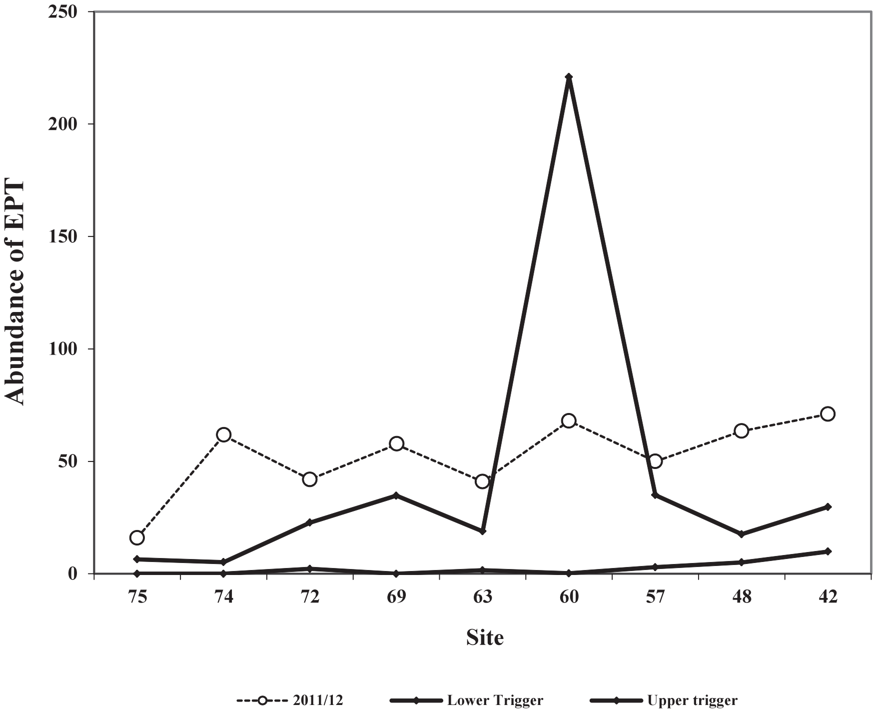


Figure 7-14 Ecologically Signicant Species metric values for 2011–12 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data

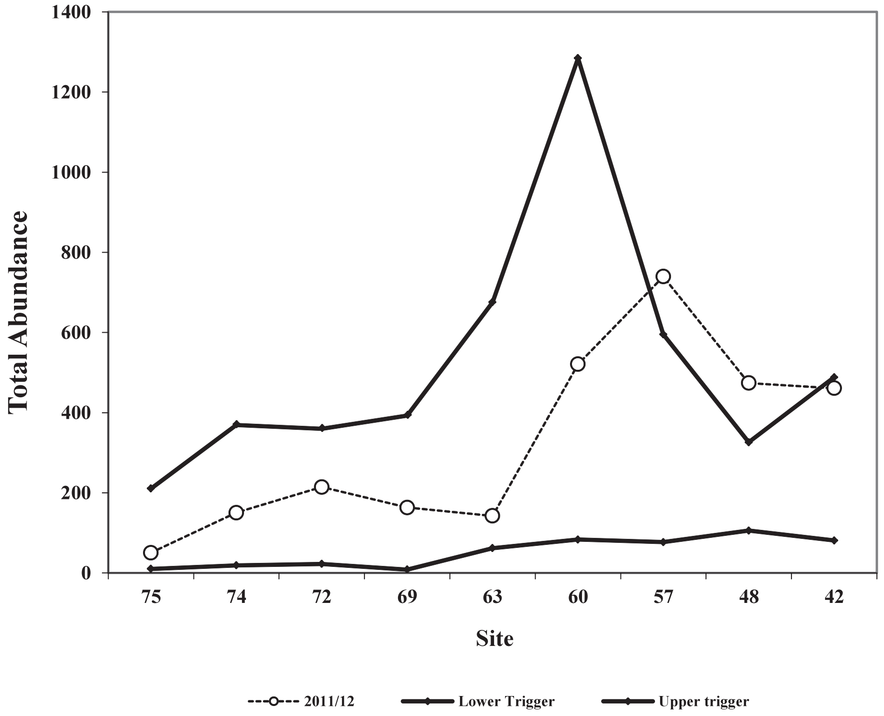
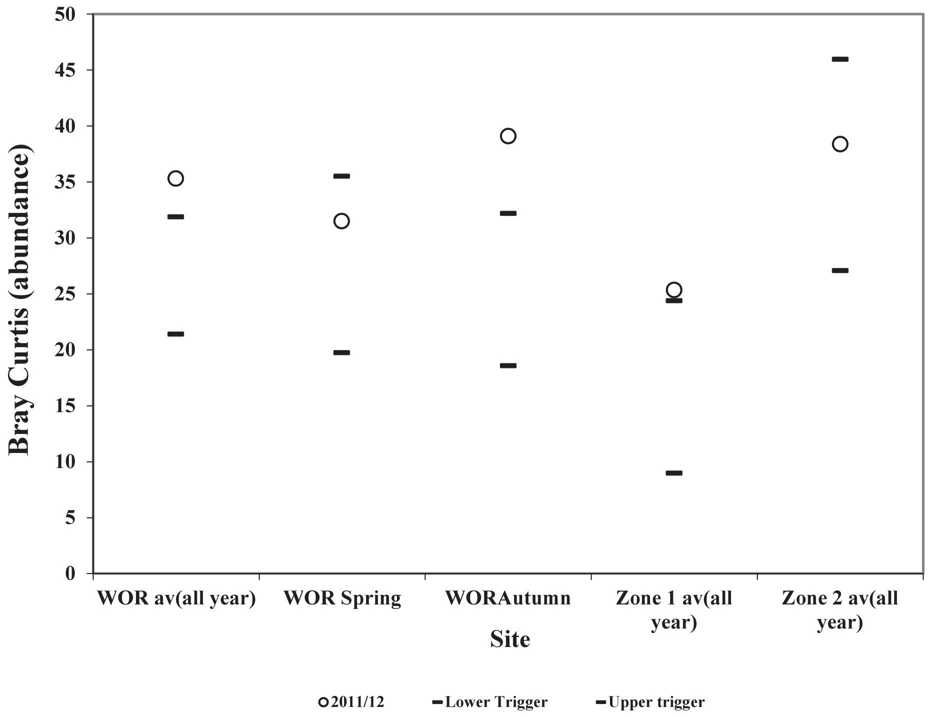


Figure 7-15 Biomass/Productivity metric values for 2011–12 compared with upper and lower LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



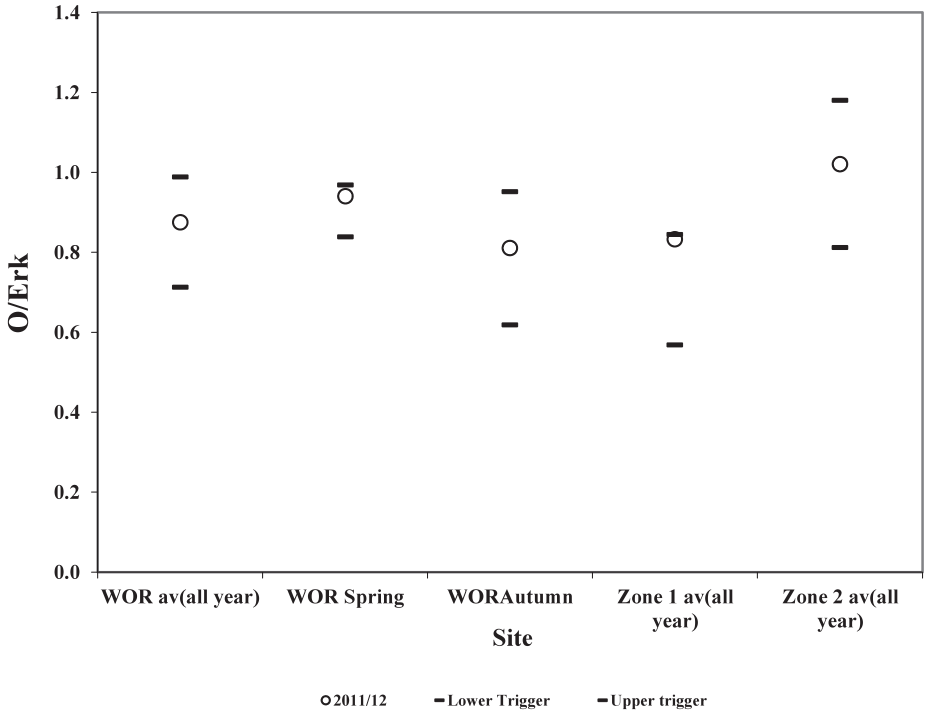
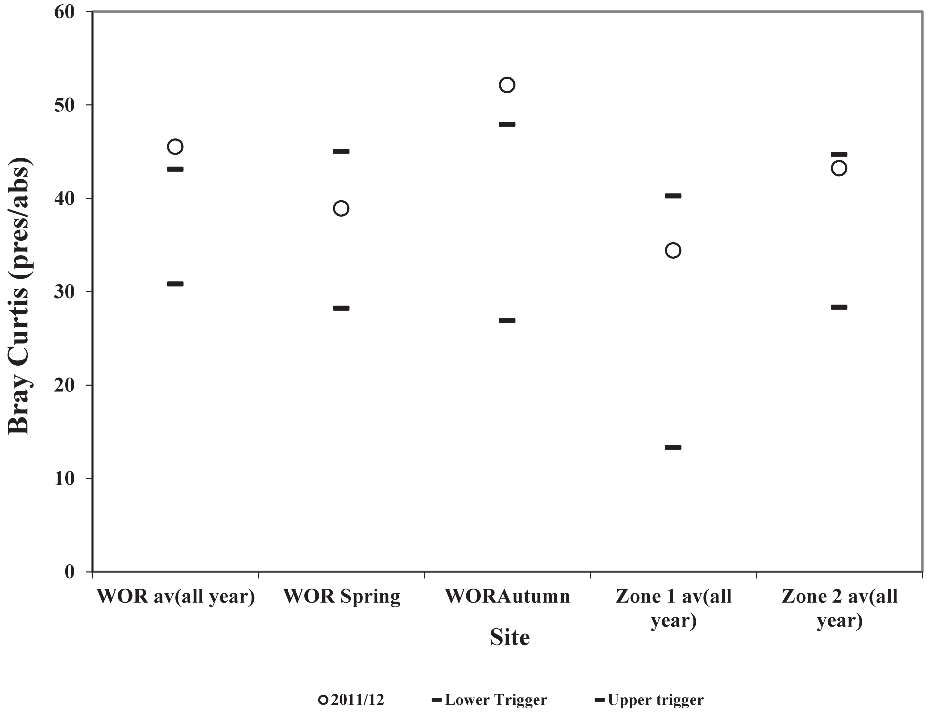


Figure 7-16 Community Structure metric values for 2011–12 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: WOR = Whole-of-river (by year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data



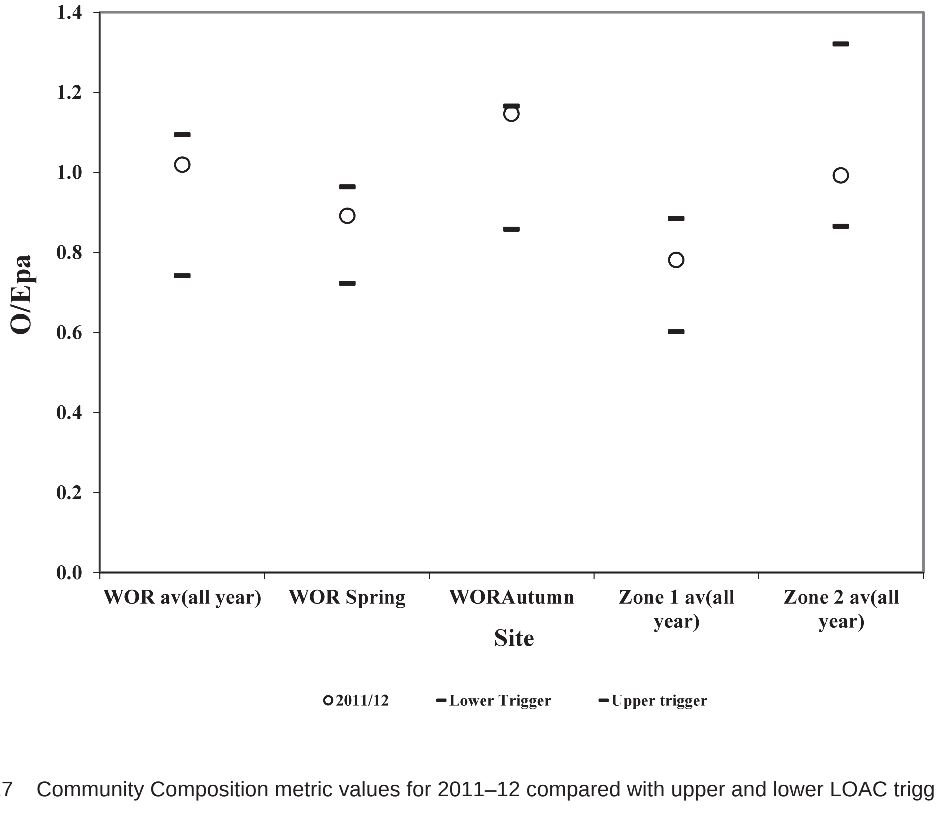
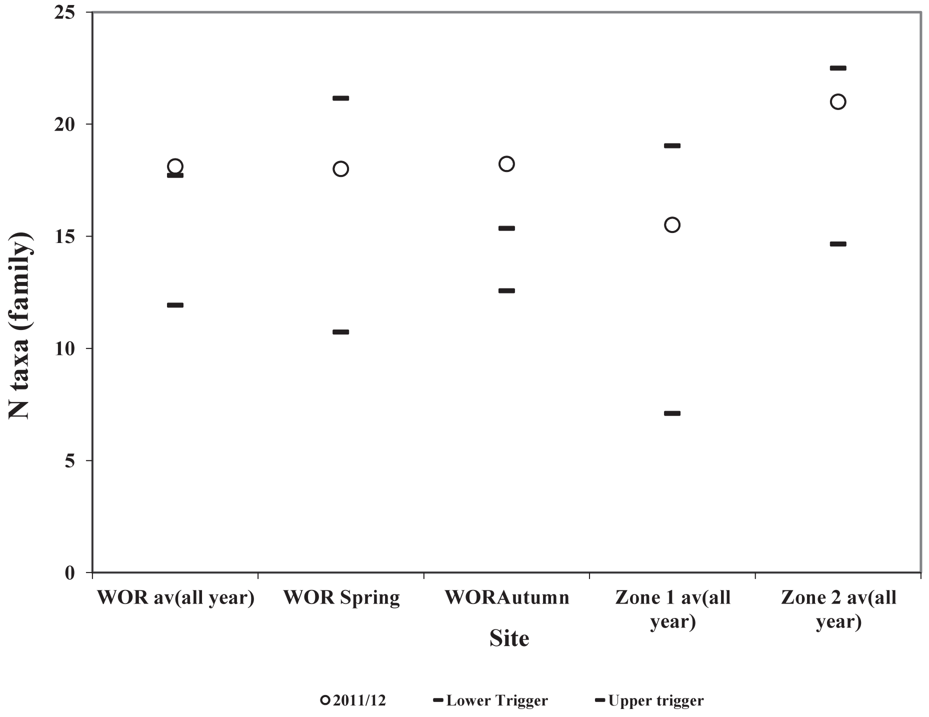


Figure 7-17 Community Composition metric values for 2011–12 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data



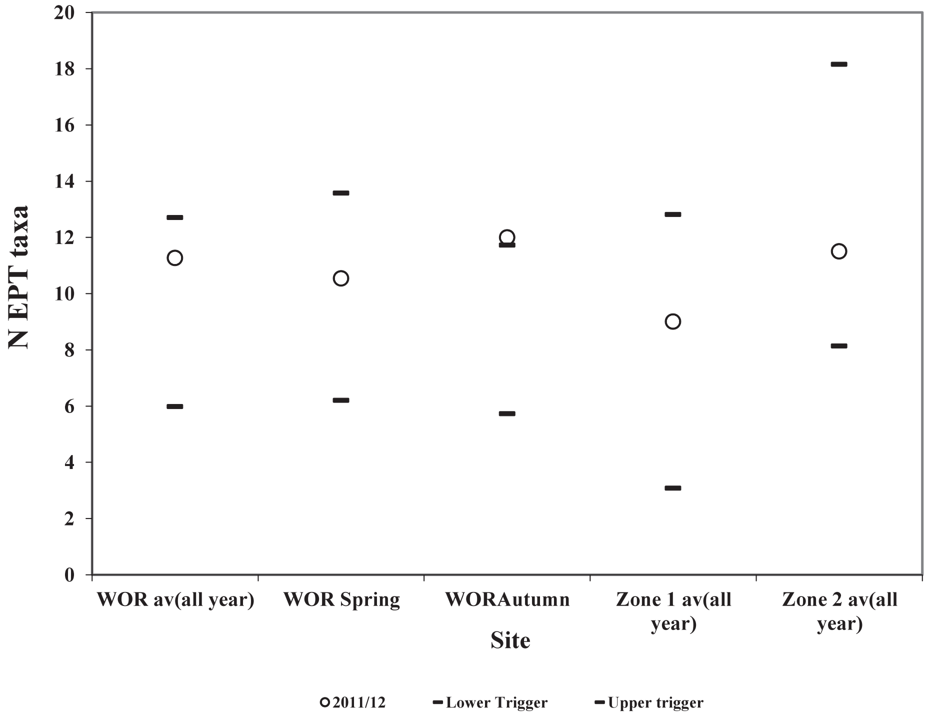
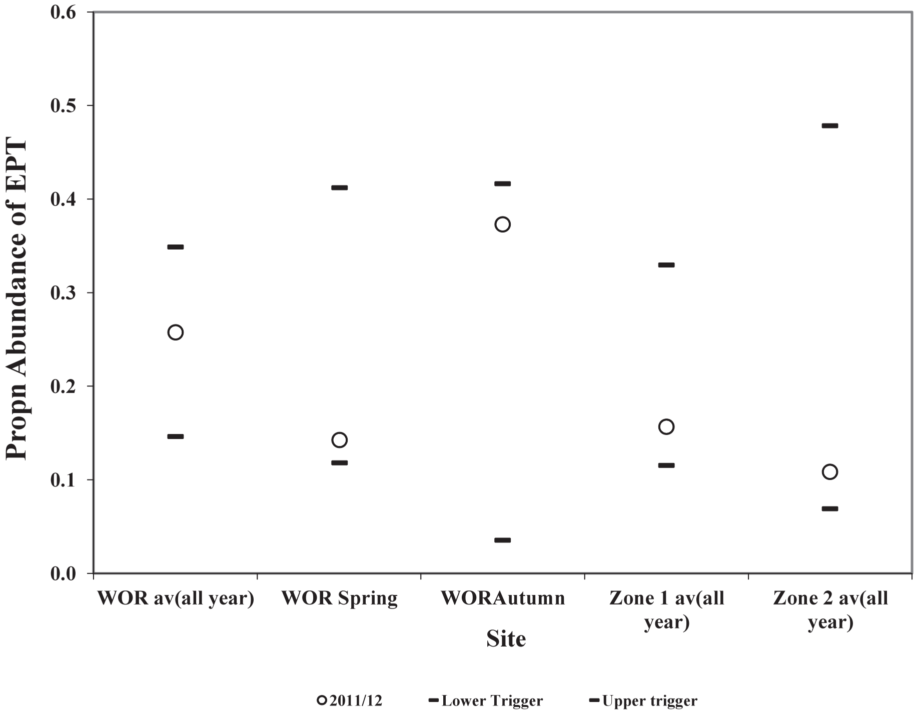


Figure 7-18 Taxonomic Richness metric values for 2011–12 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data



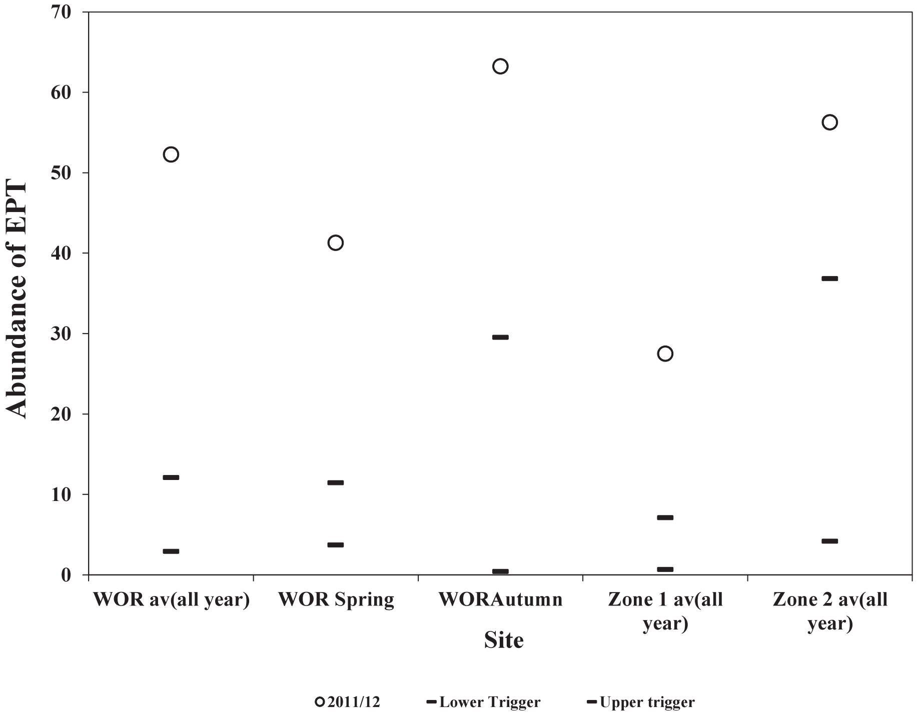


Figure 7-19 Ecologically Signicant Species metric values for 2011–12 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

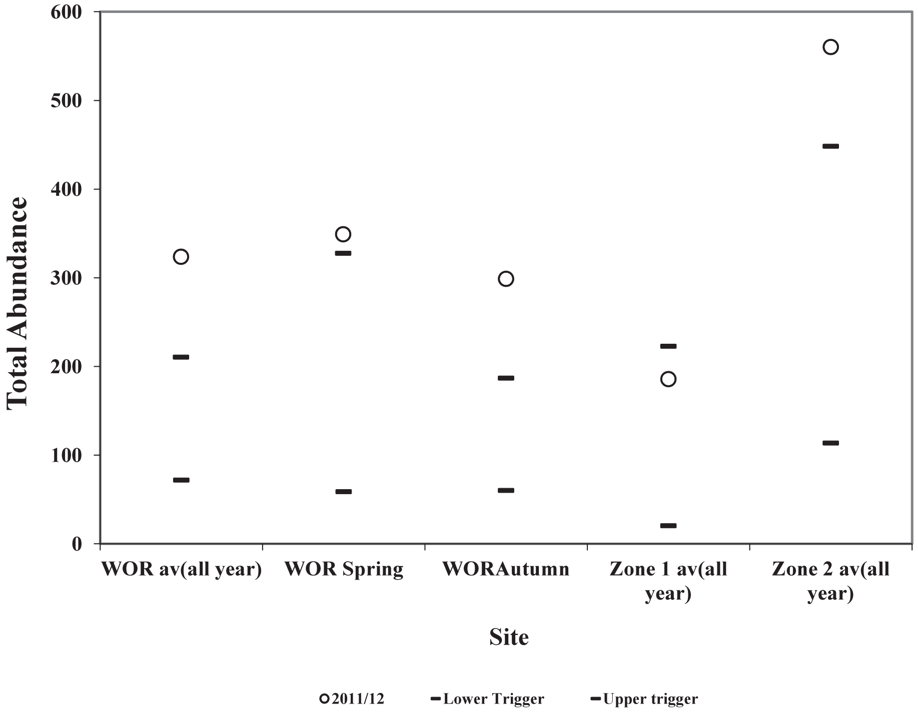


Figure 7-20 Biomass/Productivity metric values for 2011–12 compared with upper and lower LOAC trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

### 7.4.3 Trigger status: six-year—2006–07 to 2011–12

The following section summarises and comments on the mean observations for 2006–07 to 2011–12 in comparison with the six-year trigger values (see Figure 7-21 to Figure 7-30 and Table 7-3).

#### *7.4.3.1 Community structure*

*Bray Curtis (abundance):* All sites within trigger bounds and close to upper bound Figure 7-21). Zone 1 falls above upper bound, reflecting an improvement in community composition, and whole-of-river value lies just above the upper trigger value (Figure 7-26).

*Comment*—Generally consistent with pre-Basslink conditions, with improvement in zone 1.

*O/Erk:* All sites within trigger bounds (Figure 7-21). Zone 1 falls above upper bound, reflecting an improvement in community composition (Figure 7-26).

*Comment*—Generally consistent with pre-Basslink conditions, with improvement in zone 1.

#### *7.4.3.2 Community composition*

*Bray Curtis (pres/abs data):* All sites within trigger bounds (Figure 7-22), with site 75 value falling on upper bound. Zone 1 falls above upper bound, reflecting an improvement in community composition (Figure 7-27).

*Comment*—Generally consistent with pre-Basslink conditions, with improvement in zone 1.

*O/Epa:* All sites compliant, with site 75 exceeding upper bound (Figure 7-22). Whole-of-river values falling within bounds (all year) with some seasonal variation (Figure 7-27). Zone 1 values fall above the upper bound, and zone 2 values fell just below lower bound.

*Comment*—Generally consistent with pre-Basslink conditions, with improvement in zone 1, but a decline in zone 2.

#### *7.4.3.3 Taxonomic richness*

*N Taxa (fam):* All sites (Figure 7-23 and Figure 7-28), with site 48 falling on the upper bound. Both zone 2 and whole-of-river values compliant, with latter showing minor exceedance of upper trigger bound in autumn. Zone 1 also shows a light exceedance.

*Comment*—Generally consistent with pre-Basslink conditions, with slight improvement.

*N EPT Species:* All sites compliant (Figure 7-23). Values for whole-of-river and zone 1 compliant, with zone 2 value falling just below the lower bound (Figure 7-28).

*Comment*—Generally consistent with pre-Basslink conditions.

#### *7.4.3.4 Ecologically significant species*

*Proportion of total abundance as EPT:* Most sites, both zones and whole-of-river values compliant (Figure 7-24 and Figure 7-29), with exceedances at sites 69, 74 and 75 and minor excursion below lower trigger bound for site 42.

*Comment*—Raised relative densities of *Asmicridea* caddis and mayflies in zone 1 sites over several years have contributed to this metric. This represents a sustained improvement in community composition in zone 1—otherwise consistent with pre-Basslink conditions. Enhanced zone 1 values are highly likely to be a result of sustained environmental baseflows post-Basslink interacting with food input from tributaries.

*Abundance EPT:* High at most zone 1 sites, with exceedances at sites 74 and 48 (Figure 7-24). Values show exceedances for whole-of-river and zone 1, all year and in both seasons (Figure 7-29). Value is compliant for zone 2.

*Comment*—Enhanced zone 1 densities are a product of baseflow constancy from power station release combined with food input from tributaries. Highly likely to be a result of sustained environmental baseflows post-Basslink.

#### *7.4.3.5 Biomass/productivity*

*Total abundance:* All sites compliant with exception of exceedance of upper trigger bound at site 48 (Figure 7-25). Exceedance for whole-of-river (all year and in autumn) and in zone 1 (Figure 7-30), mainly driven by raised EPT group densities.

*Comment*—Represents an improvement in the macroinvertebrate community (in biomass and productivity).

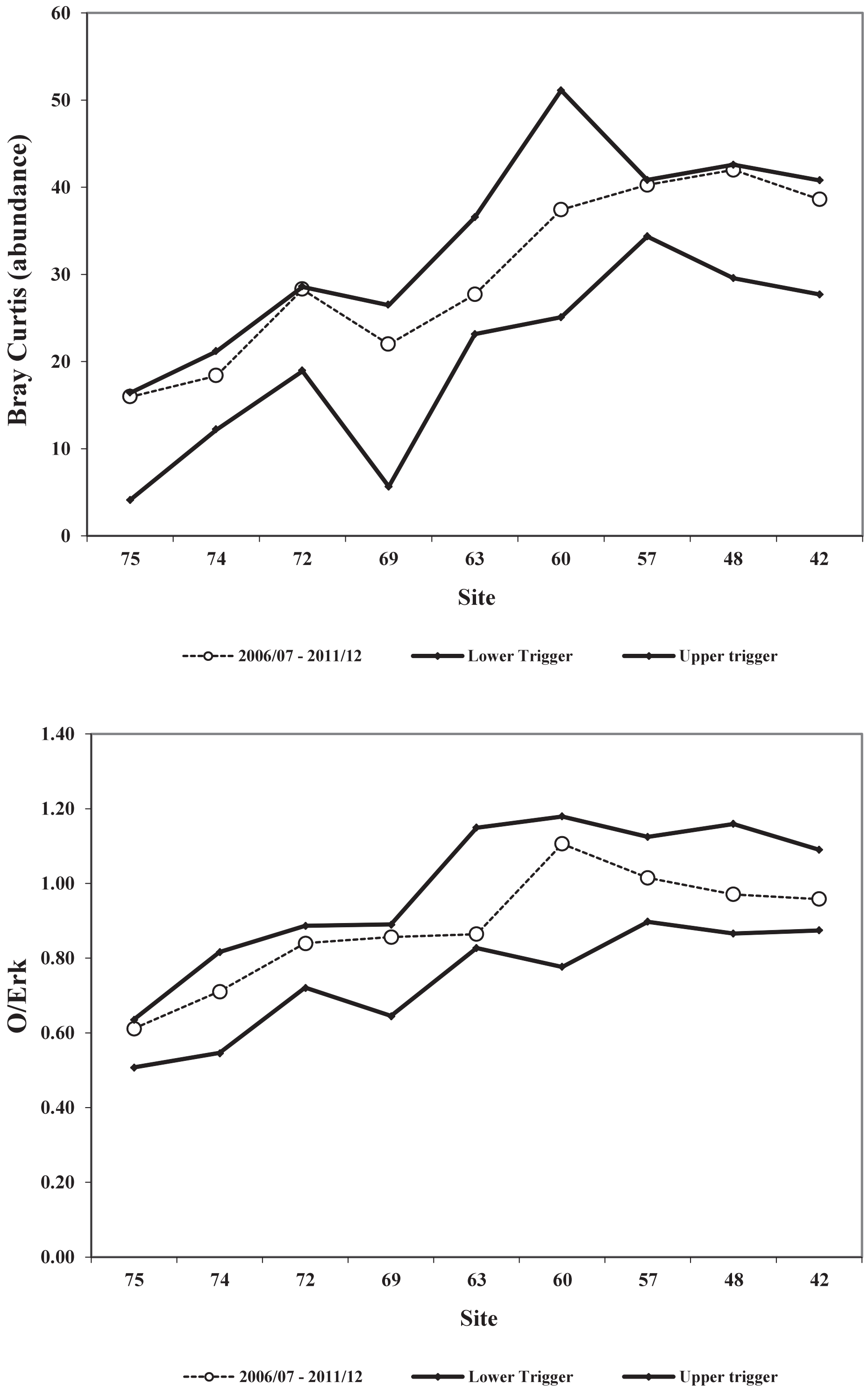
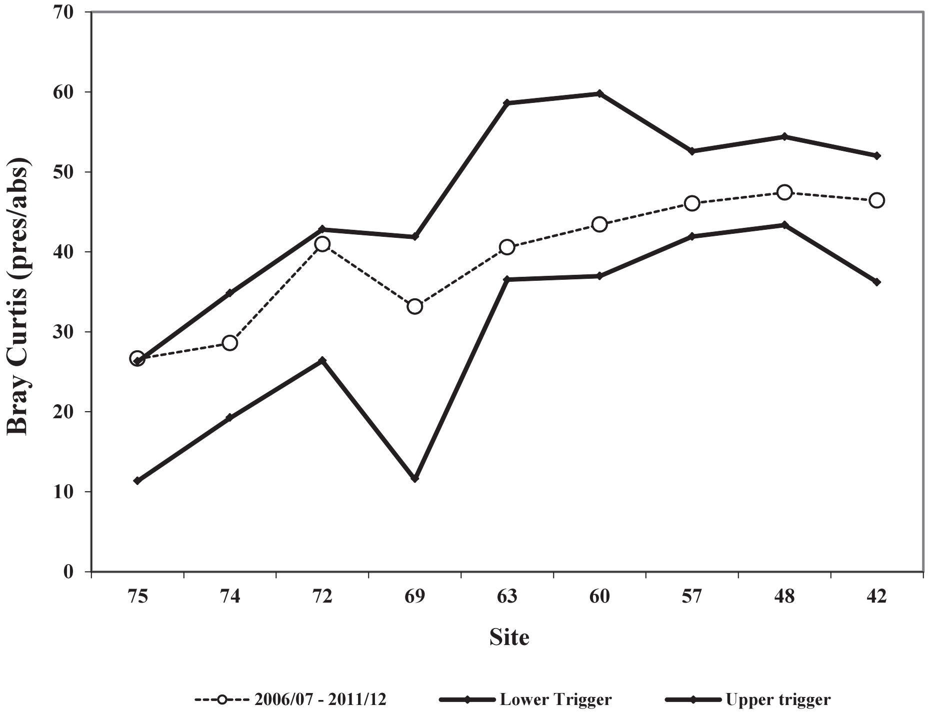


Figure 7-21 Community Structure metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



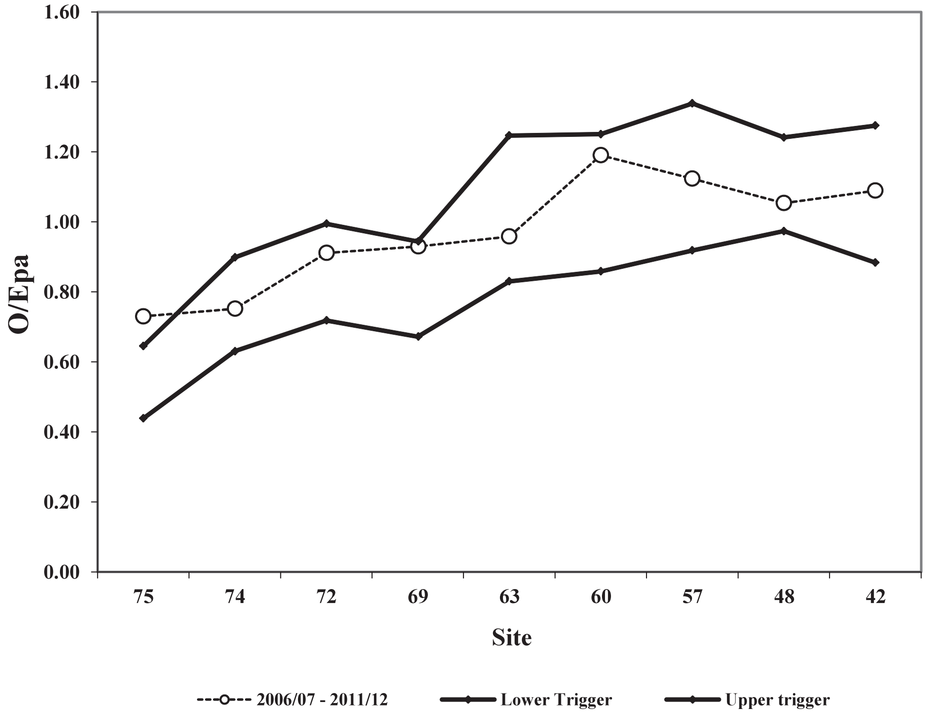
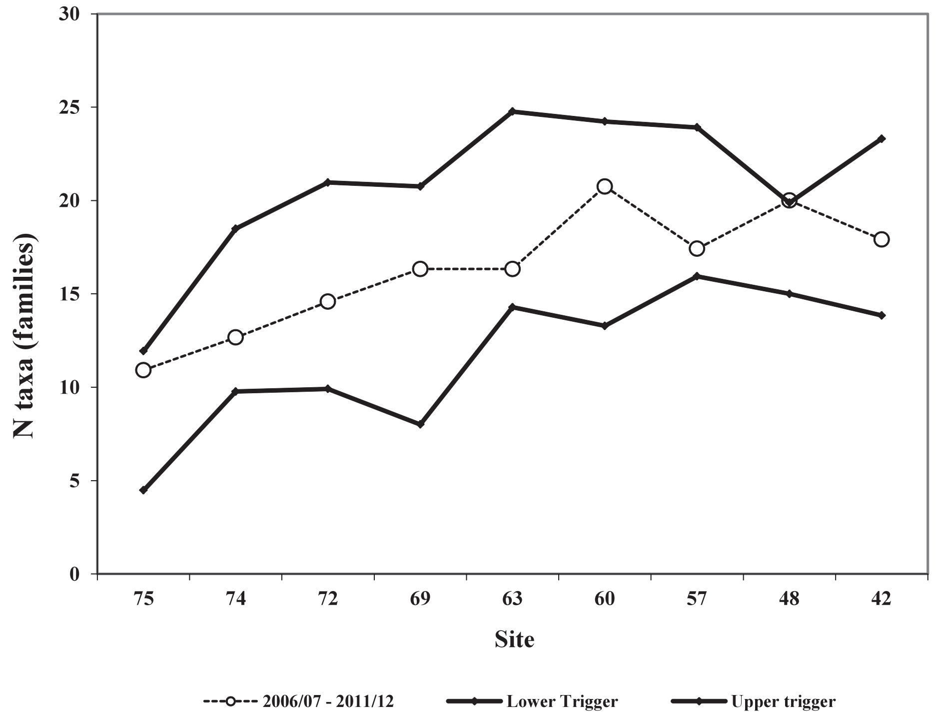


Figure 7-22 Community Composition metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



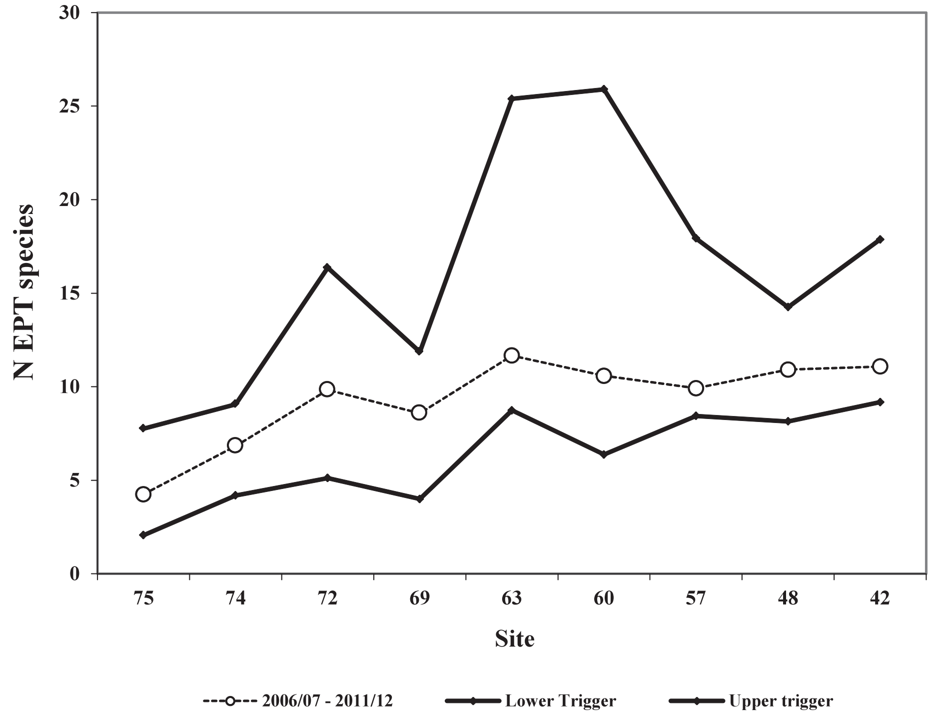
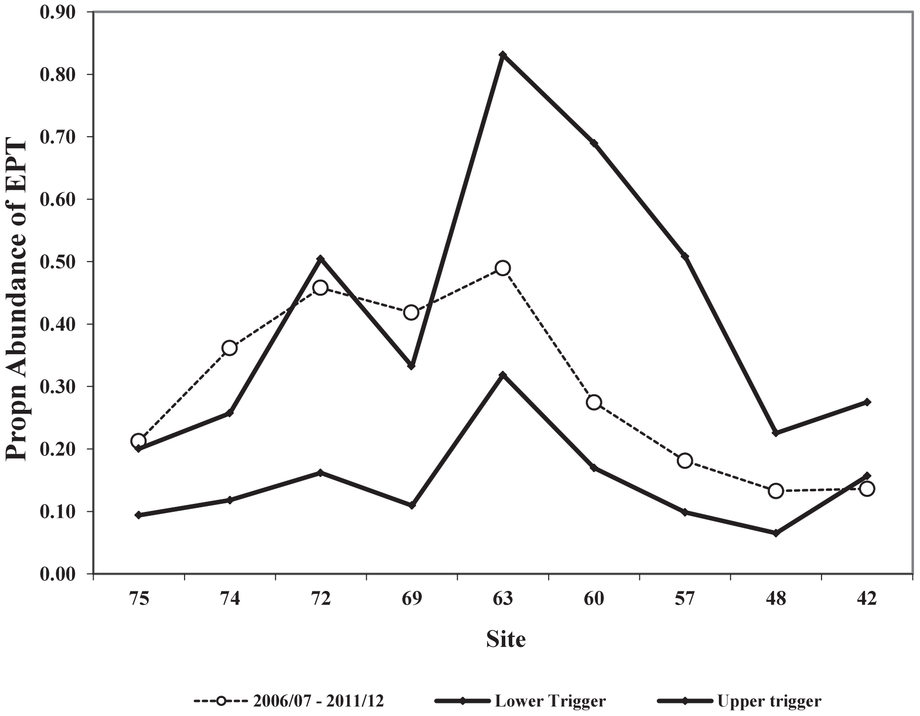


Figure 7-23 Taxonomic Richness metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



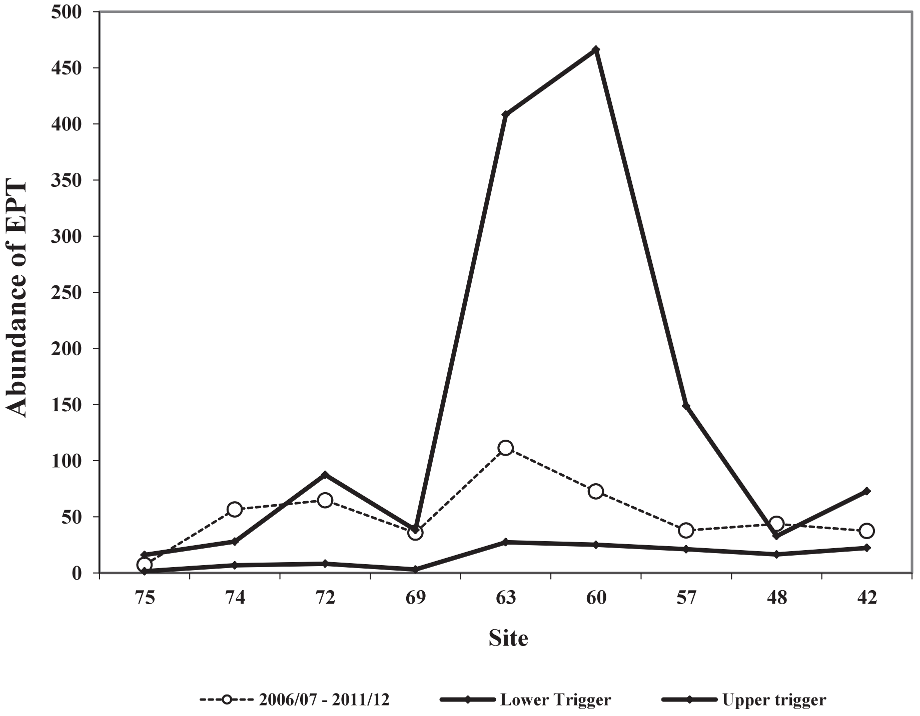


Figure 7-24 Ecologically Signicant Species metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values for each site in the Gordon River Trigger values based on the 95th percentile of pre-Basslink data

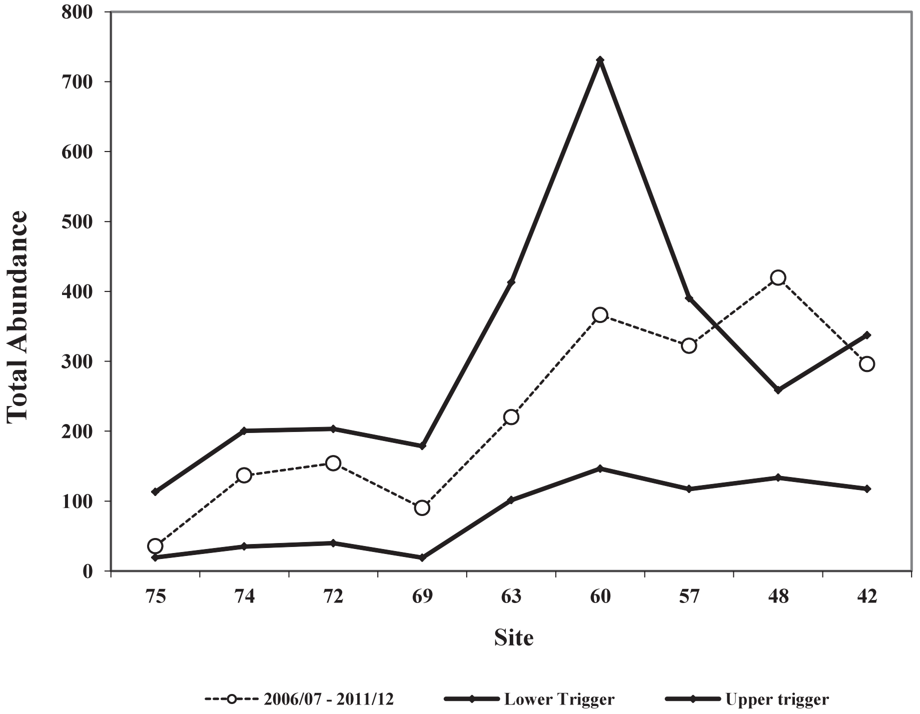
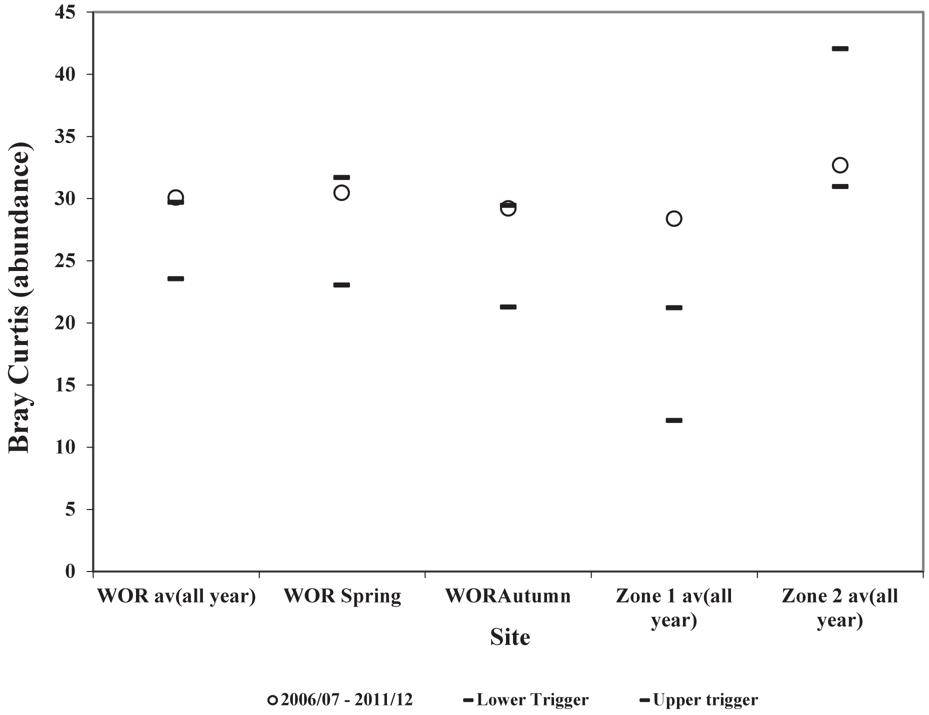


Figure 7-25 Biomass/Productivity metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



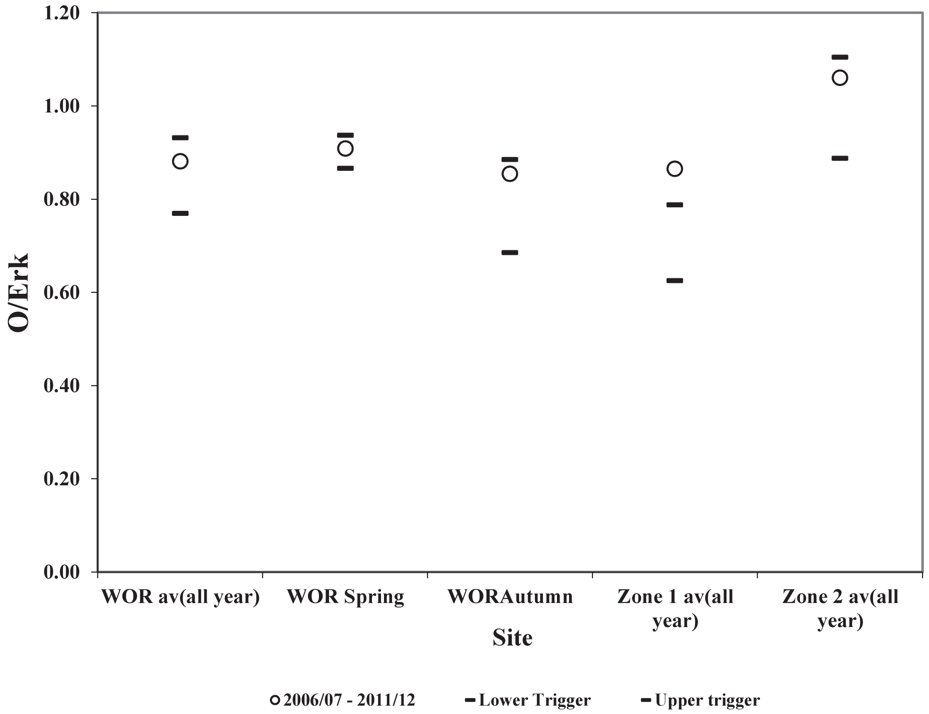
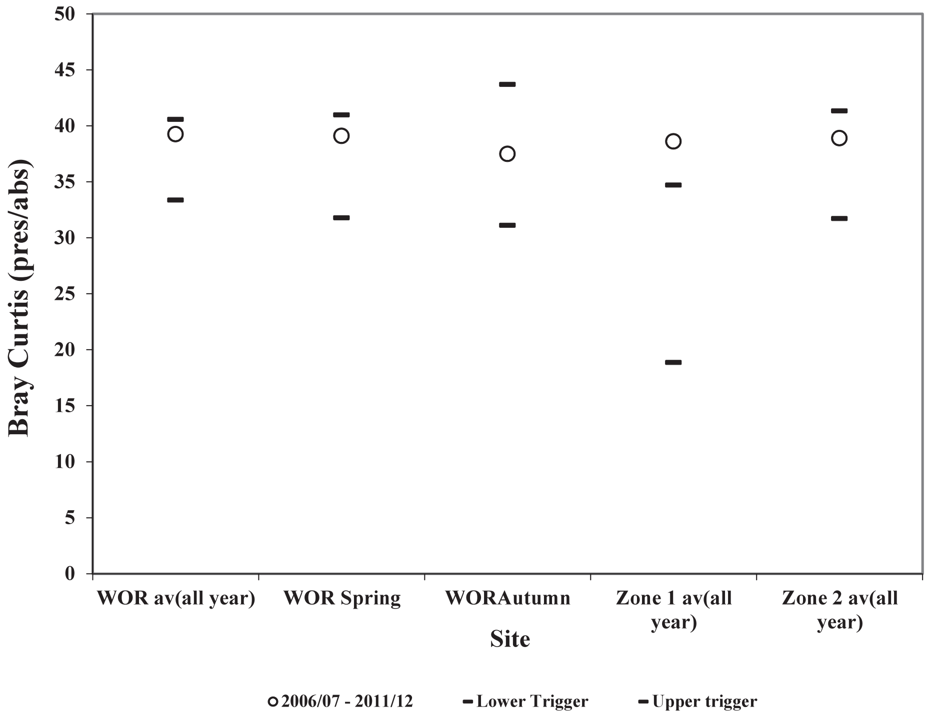


Figure 7-26 Community Structure metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values in the Gordon River for the following cases: WOR = Whole-of-river (by year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data



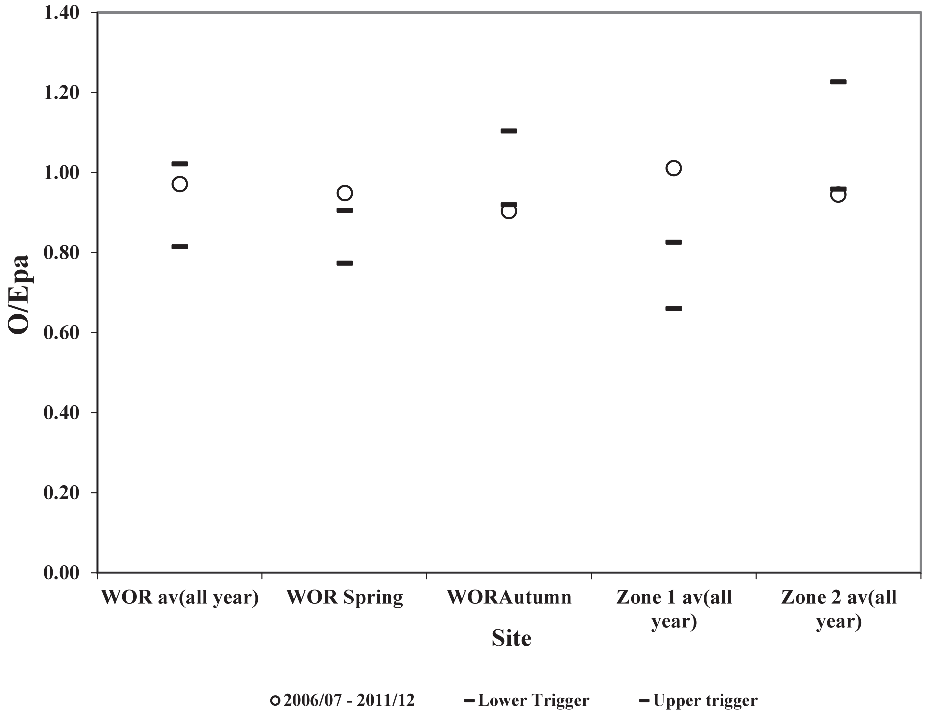
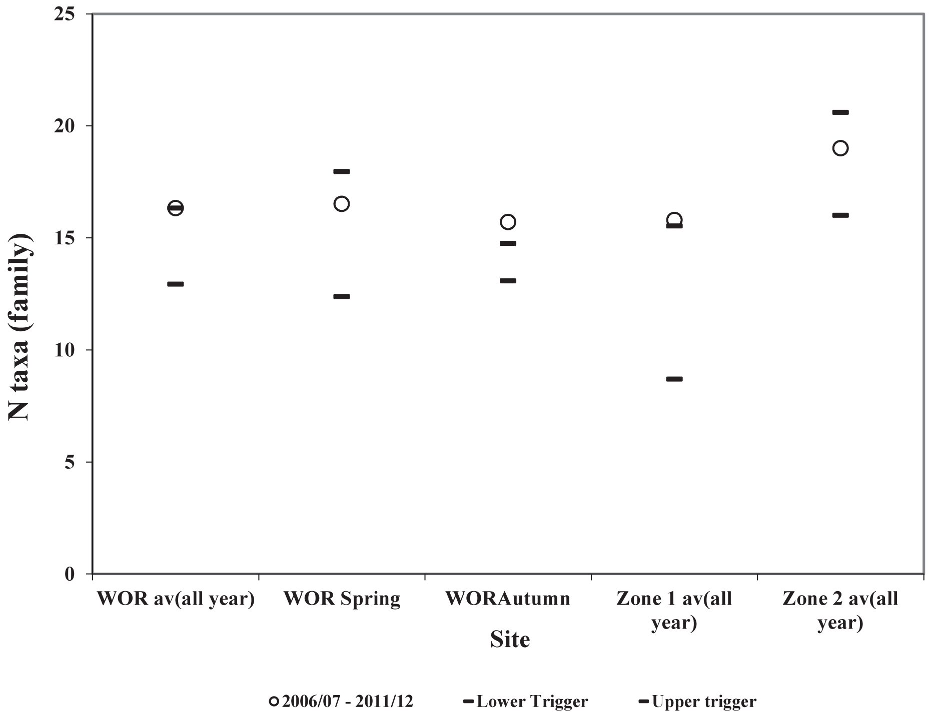


Figure 7-27 Community Composition metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data



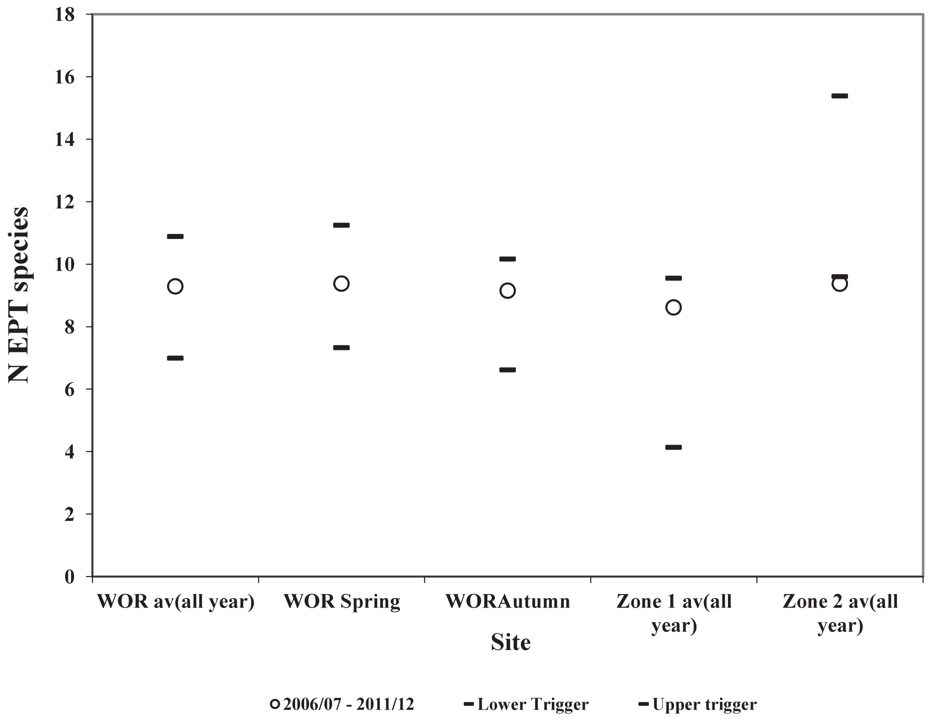
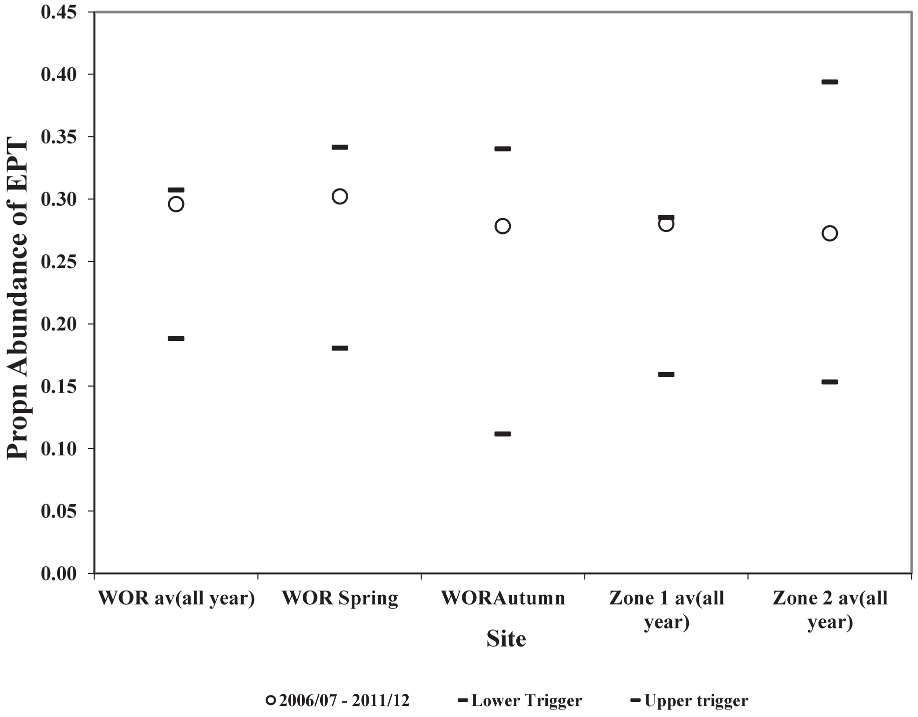


Figure 7-28 Taxonomic Richness metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data



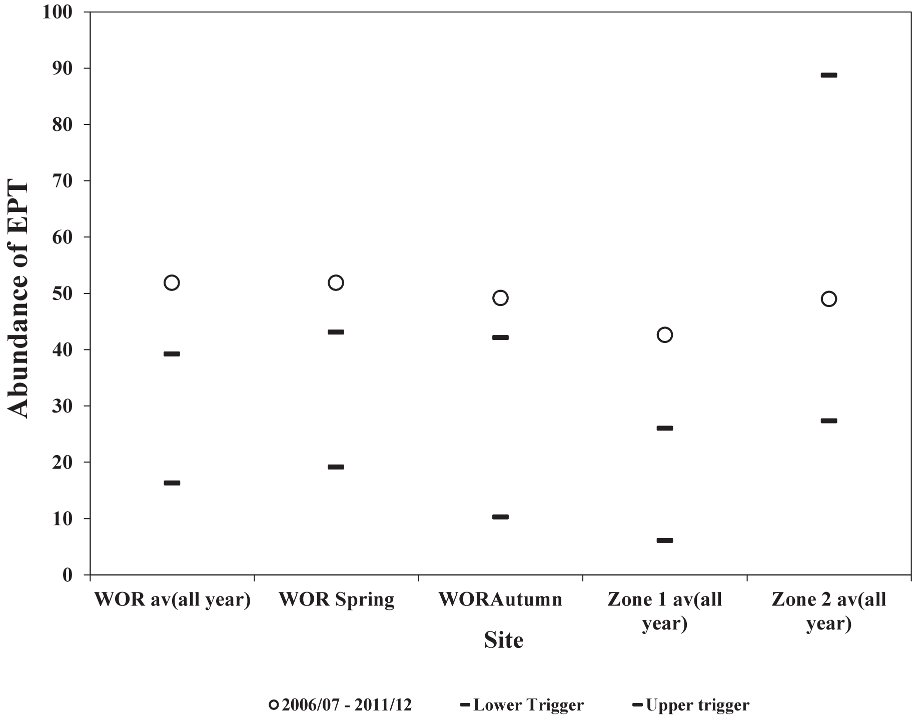


Figure 7-29 Ecologically Signicant Species metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data

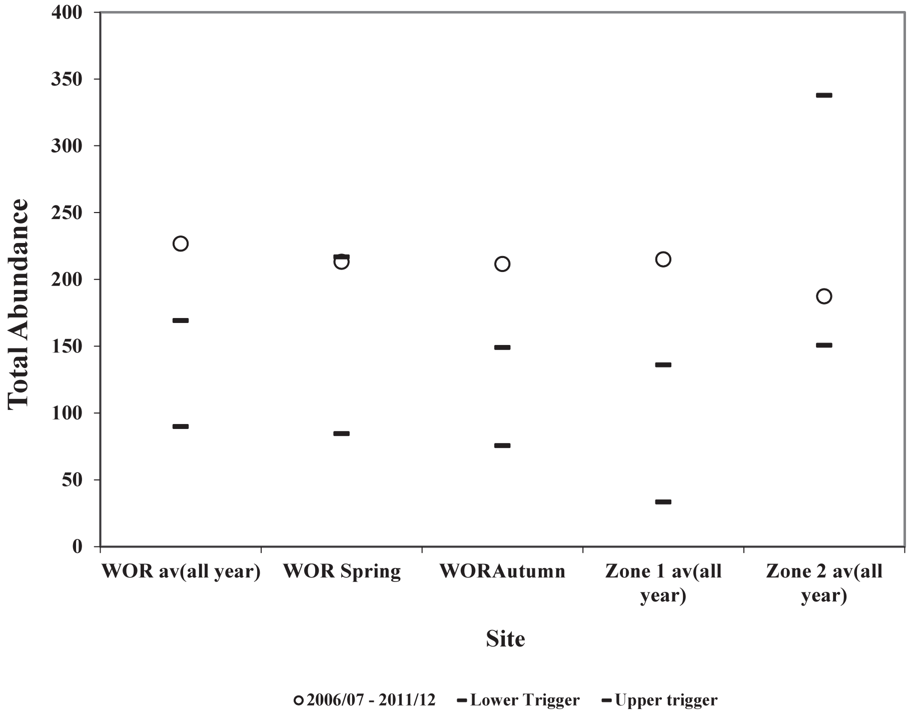


Figure 7-30 Biomass/Productivity metric values, as means for 2006–07 to 2011–12, compared with upper and lower LOAC six-year trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (all year). Trigger values based on the 95th percentile of pre-Basslink data

## 7.5 Long-term trends

### 7.5.1 Univariate indicators

Trends in all metrics are shown in Figure 7-31 to Figure 7-35. As expected, 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 generally consistent in values with time.

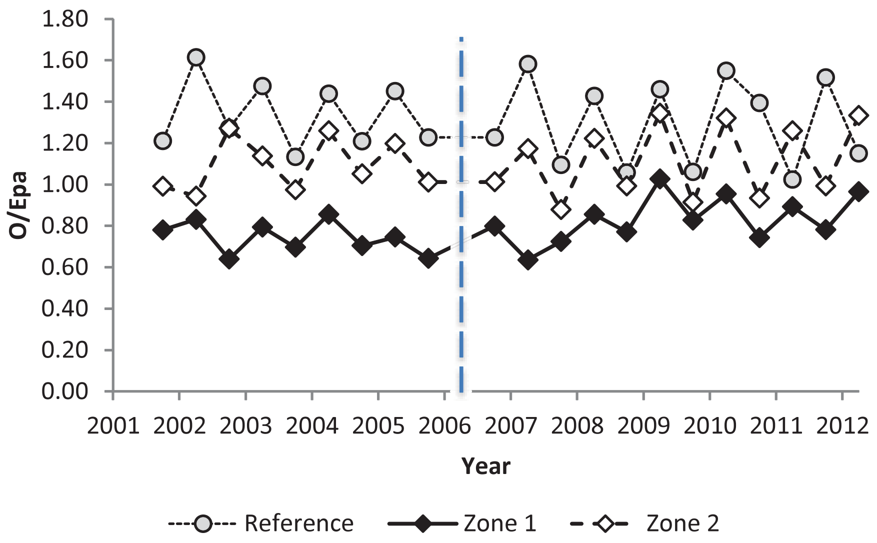
However, some metrics have shown a post-Basslink rise in value for zone 1 over the period 2007–08 to 2011–12. These include O/Epa, the proportional and total abundance of EPT species, the number of EPT species, the number of macroinvertebrate families and the Bray Curtis similarity to reference (based on both abundance and presence/absence data) (Figure 7-32 to Figure 7-34). Most zone 1 metrics declined markedly in 2010–11 compared to the immediately preceding years, reversing any rising post-Basslink trends. Several metrics fell into the lower end of the pre-Basslink range.

Most of these metrics recovered or continued to increase in value in 2011–12.

No substantive overall post-Basslink increases in metric values have been observed in zone 2. Two zone 2 metrics have been observed to decline in value post-Basslink—the proportional and total abundance of EPT species—but the former rose in value in 2010–11 and the latter in 2011–12 (Figure 7-34). Overall in zone 2, both the trends in metric values and the temporal variation in abundance of several dominant taxa (see section 7.5.2) have tended to follow those of the reference rivers. Zone 2 appears to be biologically intermediate between zone 1 and the reference rivers in its composition and temporal dynamics, which is unsurprising as it receives substantial inflows from the Denison and other tributary rivers. This is reflected in its Bray Curtis similarity values which are generally higher than for zone 1. It is also worth noting that the abundance-based value of this metric has sustained higher values than for the pre-Basslink period since early (autumn) 2009 (Figure 7-32).

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 7-33 to Figure 7-35). This was also accompanied by a decline of around 0.2 units in both O/Epa and O/Erk, mainly in spring (Figure 7-31). This is believed to have been be related to the dry conditions experienced during much of the program which led to lower than normal flows in reference rivers. Several metrics rose substantially in spring 2011–12 in reference river sites.

Several metrics showed a lagged response to post-Basslink conditions, with a number of metrics showing increases between 2007–08 and 2011–12. This may have been an artefact of the flow conditions post-Basslink, which were more stable than anticipated. Changed flow conditions now more closely resemble the originally expected Basslink flow regime.



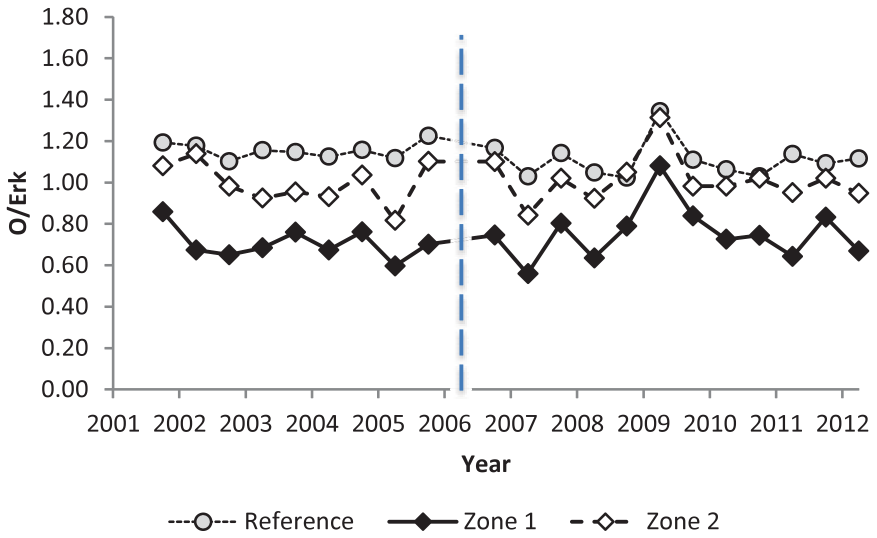


Figure 7-31 Mean O/Epa and O/Erk indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations

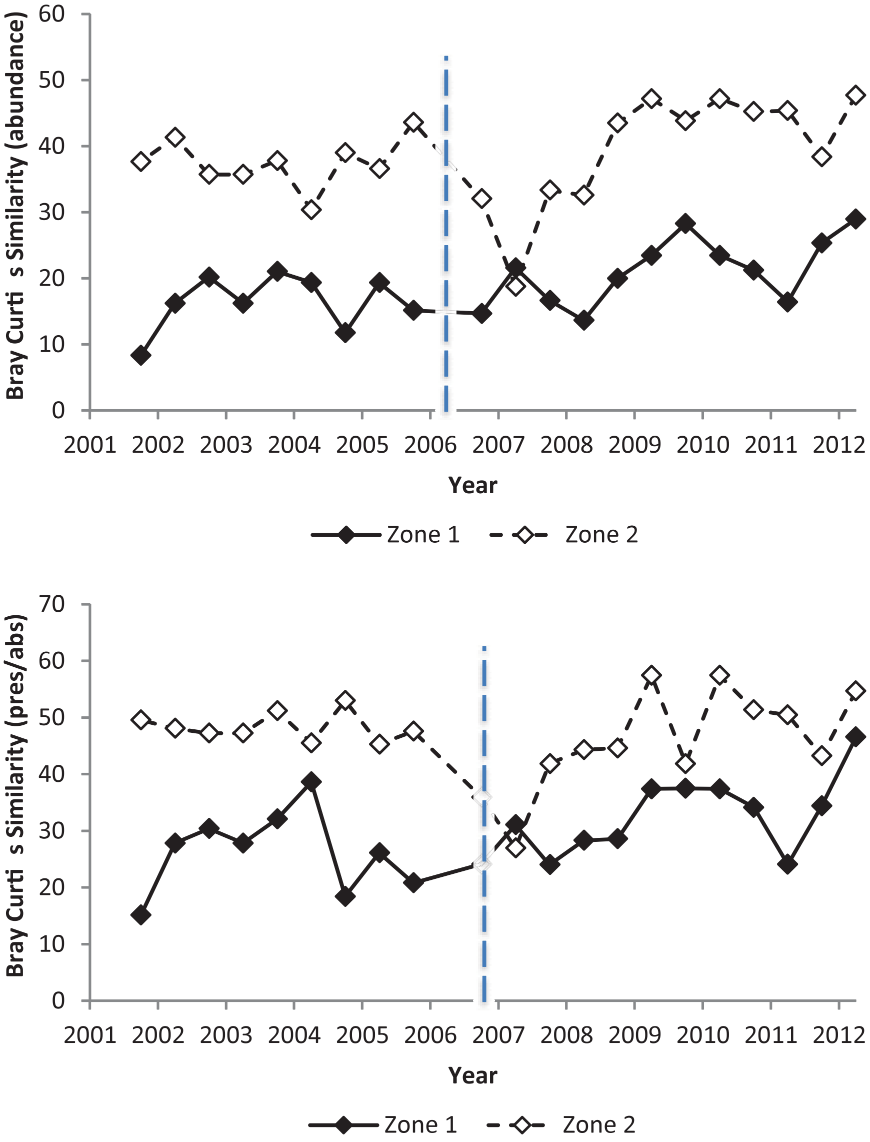
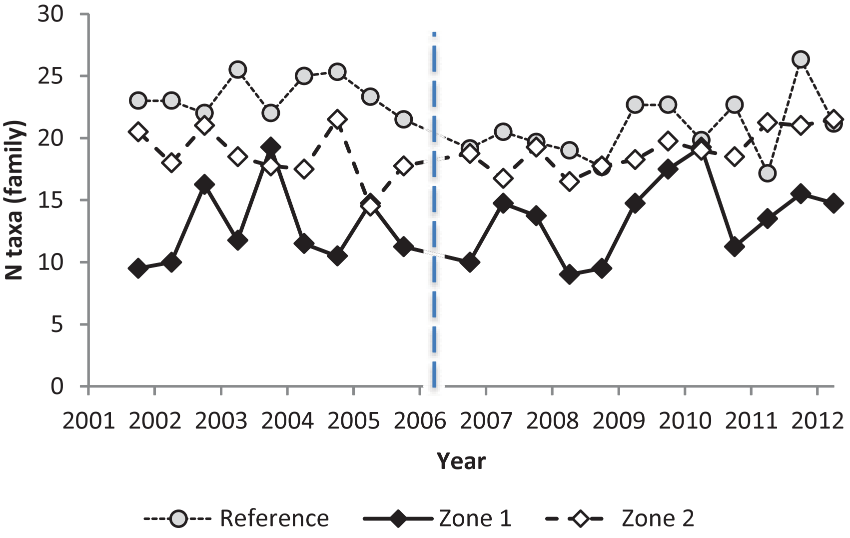


Figure 7-32 Mean Bray Curtis Similarity indicator values between each zone in the Gordon and the reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations



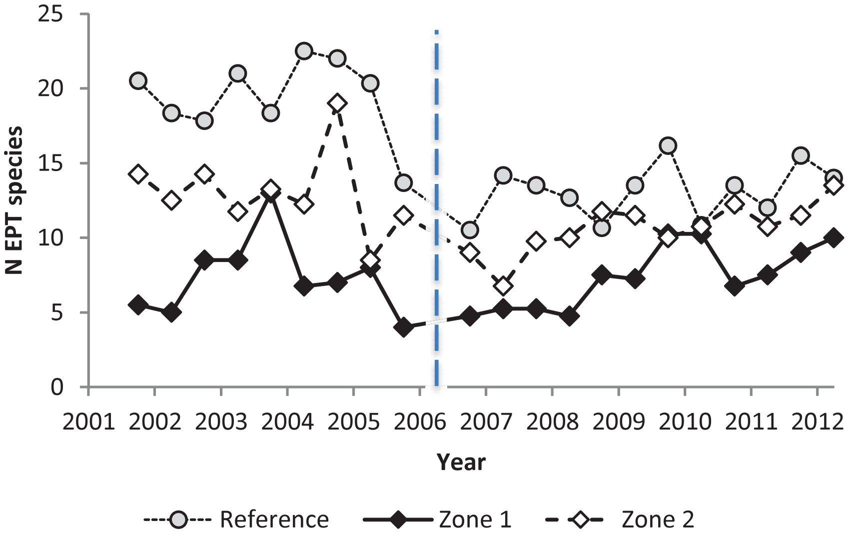
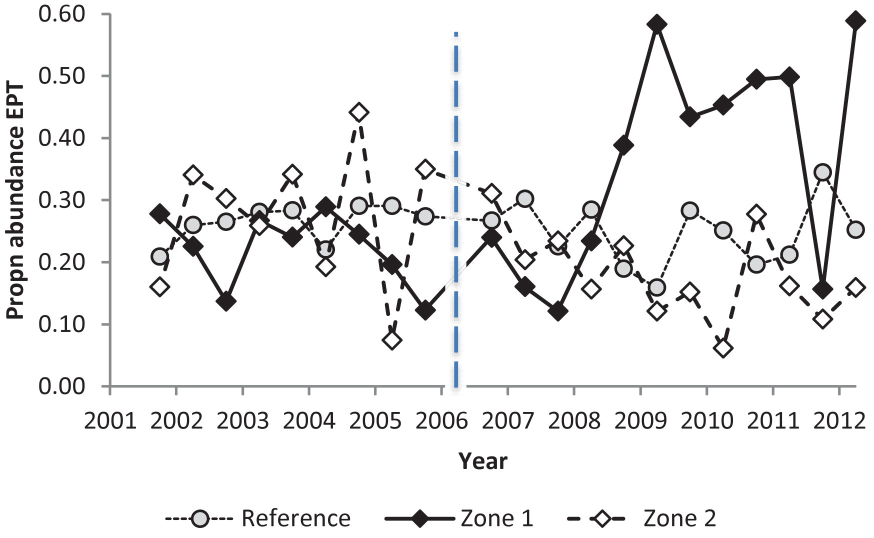


Figure 7-33 Mean N taxa (family) and N EPT species indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations



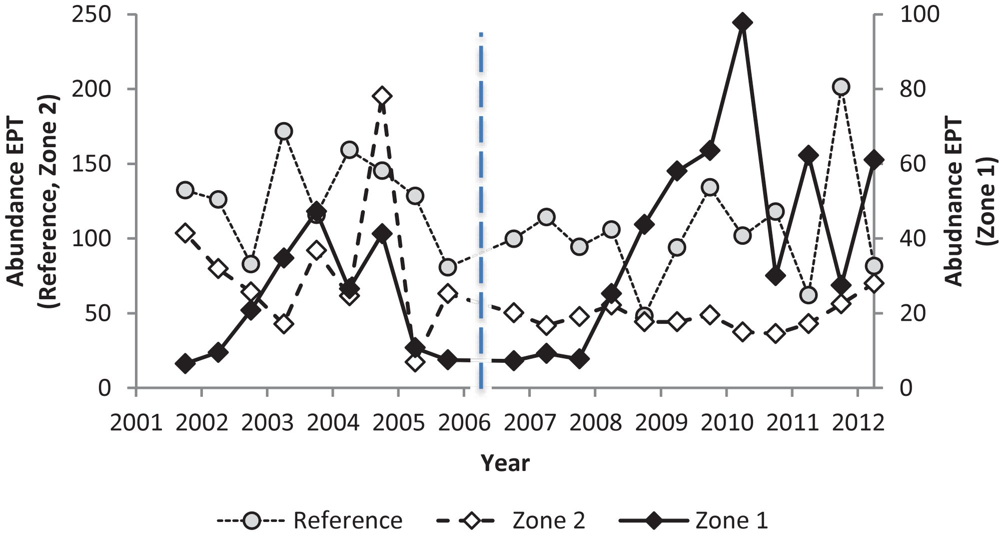


Figure 7-34 Mean proportional abundance and absolute abundance of EPT taxa indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations

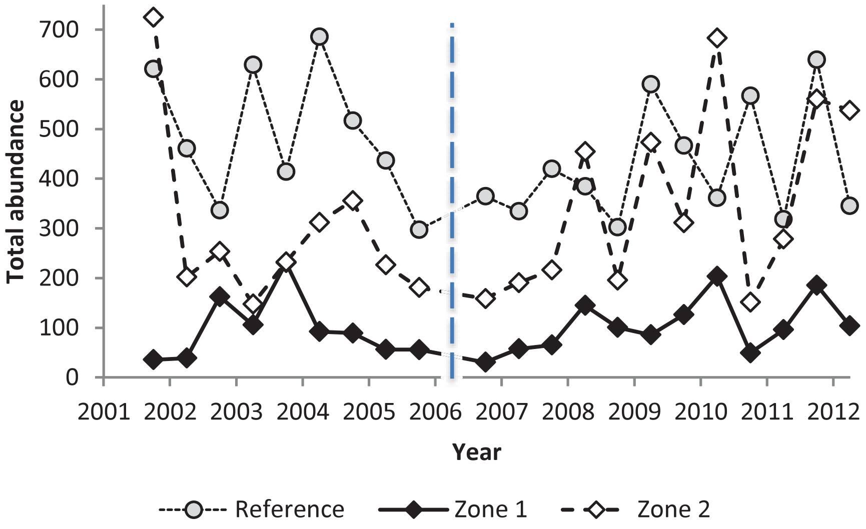


Figure 7-35 Mean total benthic macroinvertebrate abundance indicator values for each zone in the Gordon and reference rivers on each sampling occasion. Vertical dashed line indicates initiation of Basslink operations

## 7.5.2 Individual taxon abundances

Both marked variation and trends have been evident over the monitoring period in several of the numerically dominant macroinvertebrate taxa in the Gordon River (Figure 7-36 to Figure 7-37).

The taxon primarily responsible for the change in the absolute and proportional abundance of EPT taxa indicators in zone 1 is the caddis family Hydropsychidae (especially *Asmicridea*, the snowflake caddis), for which an increasing abundance was observed between spring 2008 and autumn 2010 in zone 1 (Figure 7-36). A decline occurred in zone 2 between 2008 and 2010—*Asmicridea* abundances have remained low in that zone since that time. Numbers have reduced in zone 1 since 2010 but remain higher than observed during the pre-Basslink period.

Both Gripopterygidae and Hydrobiosidae also increased in abundance in zone 1 (though with considerable inter-annual variation) and continue to contribute to the observed increase in proportional EPT representation and to community compositional similarity to reference sites (Figure 7-36 and Figure 7-37). 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*. After Basslink operations commenced, these conditions were increasingly being met upstream of the Denison confluence 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.

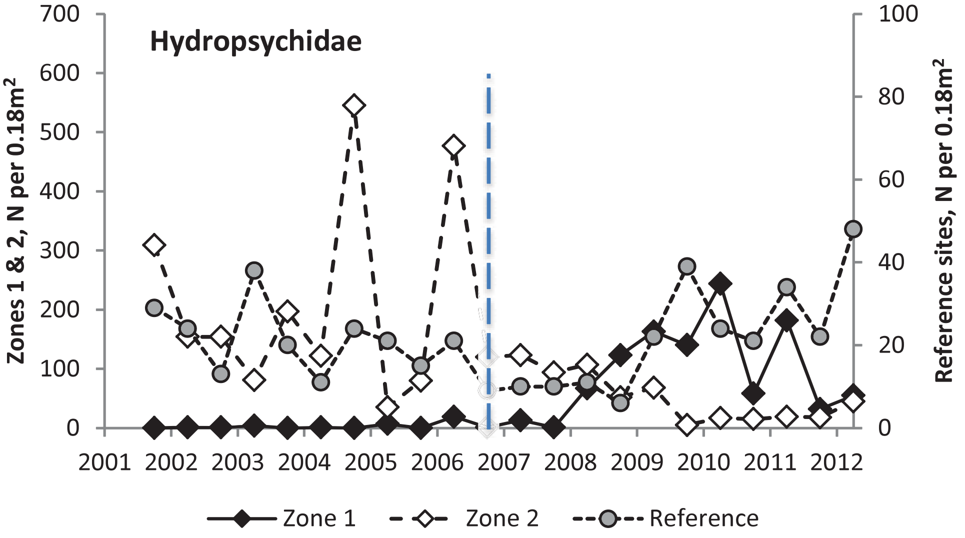
Abundances of all these groups declined in 2010–11, particularly for the Hydrobiosidae (Figure 7-36 and Figure 7-37). This decline is highly likely due to the changed nature of the flow regime in that year, which more closely approximated the hydro-peaking pattern expected for Basslink operations, and which is likely to particularly affect these flow-sensitive taxa. Abundances increased again in 2011–12.

By contrast, numbers have been more stable or declining slightly during that period in zone 2 and this has continued in 2011–12.

An increase in simuliid (blackfly) larval densities post-Basslink was evident for zone 2 from spring 2007 to autumn 2012, with a marked inter-seasonal swing (Figure 7-37). A decline in 2010–11 was reversed in 2011–12.

It is also noteworthy that Hydrobiid snails (which generally consist of the species *Beddomeia franklinensis*) appear to have increased in abundance in zone 1 during the post-Basslink period (Figure 7-38). More detailed analysis of the species composition of this group will be conducted for the final Basslink review report, in order to assess the presence of any listed species (e.g. *Phrantela richardsoni*).

Overall, there was a post-Basslink increase in abundance of the aquatic insect families Hydropsychidae, Gripopterygidae and Hydrobiosidae in zone 1, with indications of other taxa showing a lagged increase in zone 2. The general declines that were observed in 2010–11, which is likely to be due to a change in power station operations, appear to have partially reversed in 2011–12. No similar declines were observed in reference sites in 2010–11, discounting any effect of background changes in catchment conditions.



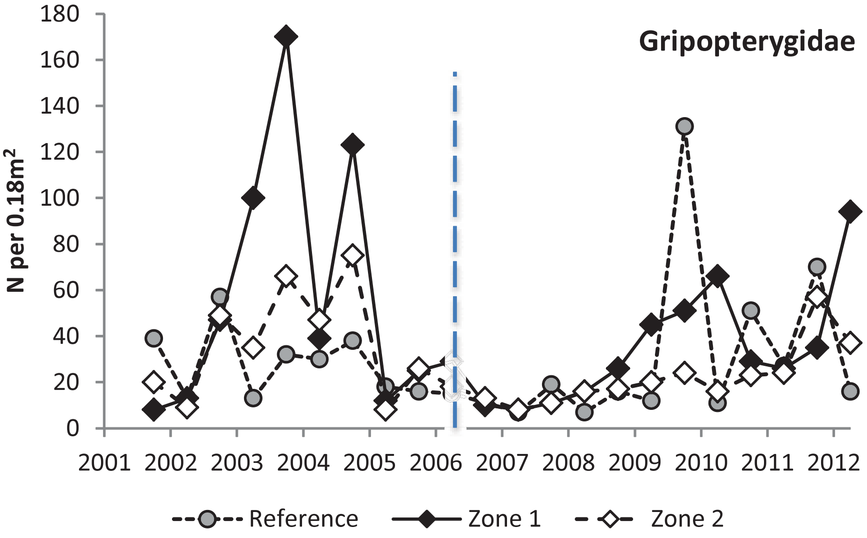
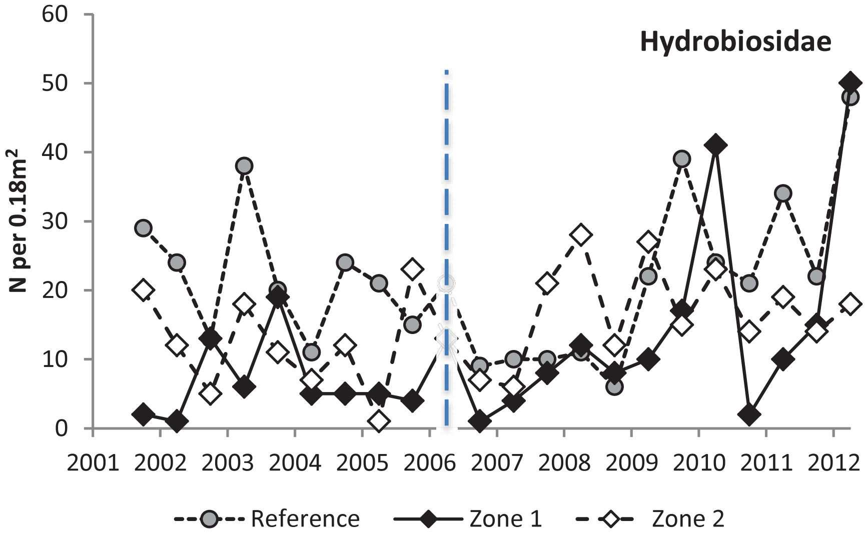


Figure 7-36 Mean abundance (n per 0.18 $m^2$) of two key taxa for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations



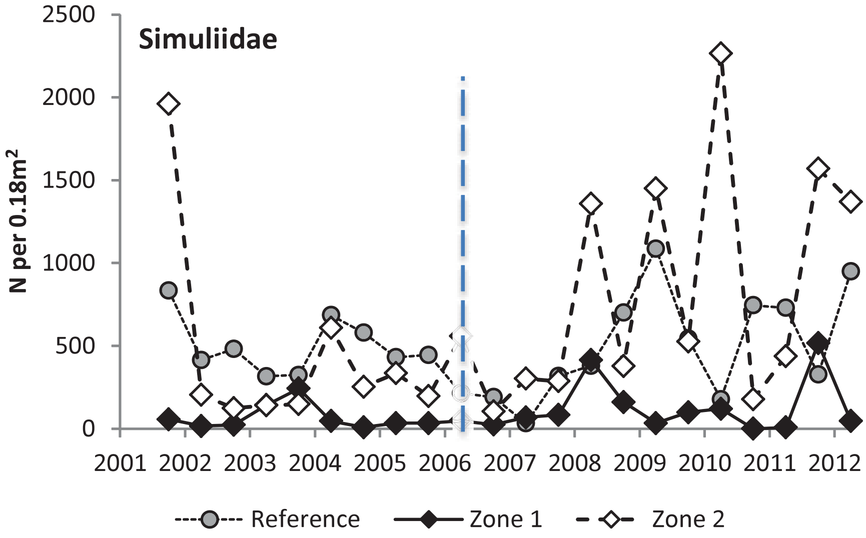


Figure 7-37 Mean abundance (n per 0.18 $m^2$) of two key taxa for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations

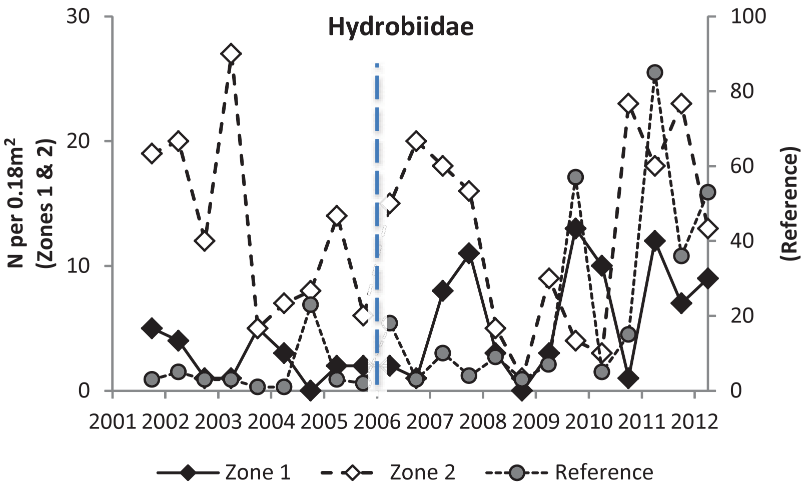


Figure 7-38 Mean abundance (n per 0.18 m$^2$) of Hydrobbid snails for zones 1 and 2 in the Gordon River and for the reference river sites against time. Dashed vertical line indicates initiation of Basslink operations

### 7.5.3 Conclusions

Spring 2011 and autumn 2012 constitute the sixth full year of the post-Basslink monitoring period.

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

Overall, trigger compliance was high. Some upper trigger exceedances reflect substantive, lagged post-Basslink increases in abundance and diversity of aquatic insects. These changes have been particularly strong in zone 1, and increasingly extended upstream with time until 2010–11, accompanied by a substantive increase in macroinvertebrate community compositional similarity to reference sites. Changed flow conditions in 2010–11, consisting of greater degree of flow peaking, partially reversed these trends, but they appear to have been restored in part during 2011–12. The current status for the six-year post-Basslink period is:

- trigger exceedances for the total and proportional abundance of EPT species and Bray Curtis similarity to reference sites, especially in zone 1;
- values falling just below the six-year lower trigger bounds for the number of EPT species and O/Epa;
- general trigger compliance for all other metrics.

The exceedances represent improvement in biological condition relative to pre-Basslink conditions. Most of this improvement occurred prior to 2010–11, followed by a reversal. Some of the indicators have risen again in 2011–12. The environmental flow continues to mitigate post-Basslink operation effects on instream biota for zone 1.

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# 8 Algae and moss

## 8.1 Introduction

Aquatic benthic algae and moss were surveyed in spring (November) 2011 and autumn (February) 2012 in accordance with the requirements of the Basslink Monitoring Program for the Gordon River. Fixed-transect, quantitative (quadrat-based) assessment of aquatic benthic algal and moss cover was conducted at nine monitoring sites in the Gordon River between the power station and the Franklin confluence. Three reference sites were also sampled.

## 8.2 Methods

### 8.2.1 Sample sites

Survey sites were the same as for the Basslink monitoring benthic macroinvertebrate sampling being conducted in the Gordon River, as shown in Map 8-1 and Table 8-1.

### 8.2.2 Benthic algal survey

#### *8.2.2.1 Gordon River*

Sampling was conducted in spring (5–6 November 2011) and in autumn (25 February 2012). All aquatic benthic algal and moss assessment at Gordon River sites was conducted by measuring per cent area of cover at fixed distances along existing transects across the river, with one transect assessed at each site.

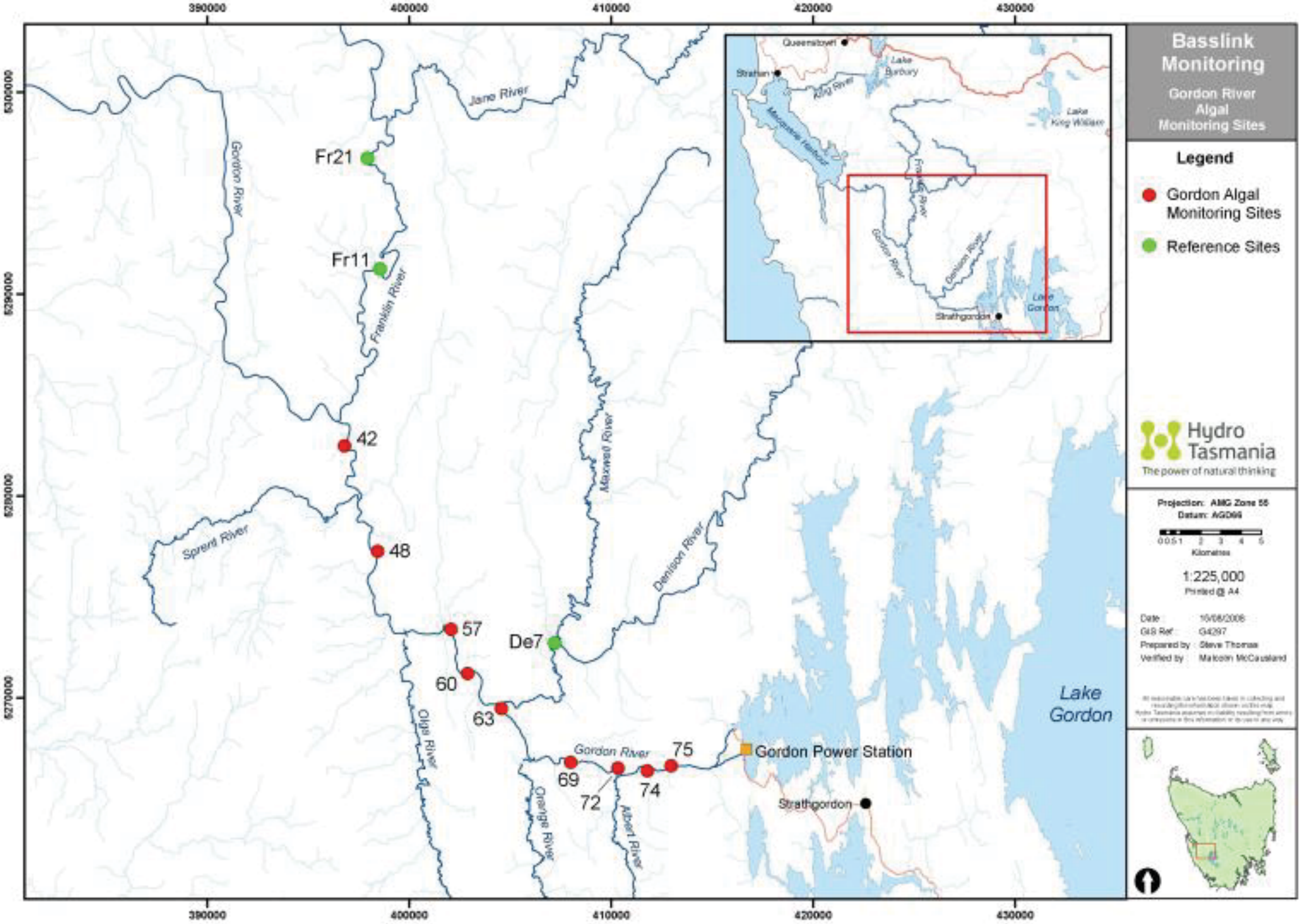
All Gordon River data was collected as follows:

- transects were re-established, at existing locations perpendicular to the direction of river flow, by running a measuring tape across the river from the existing transect head-peg (which was designated as the zero distance offset) to a fixed peg on the opposite bank;
- algal and moss density, as per cent cover, was recorded using a 30 cm x 30 cm quadrat at 2.5 m intervals in three locations—1 m upstream of the transect line, on the transect line, and 1 m downstream of the transect lines; and
- within each quadrat, density was reported for four broad floristic groups—filamentous algae, characeous algae, moss and macrophytes.

Each transect was also divided into broadly similar ‘zones’, characterised by consistency of benthic substrate composition. Zones were defined following visual inspection of the channel substrate, and defined in terms of their dominant substrate composition, e.g. cobble/gravel, sand/silt, sand/snags, bedrock etc.

#### *8.2.2.2 Reference sites*

Reference site sampling was conducted on the same dates as for the Gordon River sites. Plant cover was assessed at 30 randomly chosen locations across the channel on the dominant substrate (typically cobbles and boulders) using the same quadrat procedure described above. It should be noted that bedrock substrate and backwater features were not sampled, due to high variability in the nature of these substrates at reference sites and their frequent morphological dissimilarity from those observed in the Gordon River. This was not the case for the dominant river bed substrate of cobbles and boulders. Data comparability between these sample sets and those for the Gordon River is therefore restricted to filamentous algae only, as mosses favour bedrock habitats.



Map 8-1 Sites sampled in 2011–12 for aquatic benthic algae, moss and macrophytes

Table 8-1 Sites sampled in 2011–12 for aquatic benthic algae, moss and macrophytes

| River | Site code | Site name (old code) | Easting | Northing |
|---|---|---|---|---|
| Gordon | 75 | Gordon R d/s Albert Gorge (G4) | 412980 | 5266630 |
| | 74 | Gordon R d/s Piguenit R (G4A) | 412311 | 5266383 |
| | 72 | Gordon R in Albert Gorge (G5) | 410355 | 5266524 |
| | 69 | Gordon R u/s Second Split (G6) | 408005 | 5266815 |
| | 63 | Gordon R u/s Denison R (G7) | 404584 | 5269469 |
| | 60 | Gordon R d/s Denison R (G9) | 402896 | 5271211 |
| | 57 | Gordon R u/s Smith R (G10) | 402083 | 5273405 |
| | 48 | Gordon R d/s Olga R (G11b) | 398450 | 5277275 |
| | 42 | Gordon R @ Devil's Teapot (G15) | 396804 | 5282486 |
| Franklin | Fr11 | Franklin R d/s Blackman's bend (G19) | 398562 | 5291239 |
| | Fr21 | Franklin R @ Flat Is (G20) | 397939 | 5296733 |
| Denison | De7 | Denison d/s Maxwell R (G21) | 407206 | 5272718 |

## 8.2.3 Analysis

Mean plant cover scores were derived for the main channel bed (bank toe to bank toe). These were plotted and compared to trigger levels to assess any exceedances.

## 8.2.4 Results

### *8.2.4.1 Spring 2011*

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69 and 63. The presence of deep, fast water once again prevented survey across the entire channel for sites 57, 48 and 42. An average 69 m of river bed was surveyed across all sites, ranging between 40 to 88 m.

Data from surveys are summarised in Table 8-2. Aquatic flora in the Gordon River had a consistently low to moderate cover across all sites. Moss and filamentous algae were again the dominant forms, and had low to moderate overall mean per cent cover across all sites, with means of 1.8 and 0.2% in zones 1 and 2 respectively. Macrophytes were only observed at site 72 and with very low cover.

Observable filamentous algal cover was again very low in the reference river samples.

Table 8-2 Summary cover data for algae, moss and macrophytes surveyed in spring 2011 for Gordon River sites

| **Site** | | **Mean% cover** | | | | **Width surveyed (m)** |
|---|---|---|---|---|---|---|
| | | **Moss** | **Filamentous algae** | ***Nitella/Chara*** | **Macrophytes** | |
| **Gordon** | | | | | | |
| 75 | G4 | 5.25 | 1.63 | 0 | 0 | 67.5 |
| 74 | G4A | 1.14 | 8.05 | 0 | 0 | 62.5 |
| 72 | G5 | 0.01 | 4.77 | 3.78 | 1.15 | 85.0 |
| 69 | G6 | 0.87 | 0.17 | 0 | 0 | 77.5 |
| 63 | G7 | 0.45 | 0.60 | 0.39 | 0 | 75.0 |
| 60 | G9 | 0.72 | 0.27 | 0 | 0 | 87.5 |
| 57* | G10 | 0.05 | 0.02 | 0 | 0 | 55.0 |
| 48* | G11B | 0.02 | 1.97 | 0 | 0 | 72.5 |
| 42* | G15 | 0.10 | 1.38 | 0 | 0 | 40.0 |
| **Reference** | | | | | | |
| Fr11 | G19 | 0 | 0.37 | 0 | 0 | |
| Fr21 | G20 | 0 | 0.01 | 0 | 0 | |
| De7 | G21 | 0 | 0.02 | 0 | 0 | |

* indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated

### 8.2.5 Autumn 2012

Surveys were successfully completed across the entire river channel for sites 60 to 75. The presence of deep, fast flowing water prevented survey across the entire channel for sites 42 to 57. An average 67 m of river bed was surveyed across all sites, ranging between 43 to 88 m.

Data from surveys are summarised in Table 8-3. Aquatic flora in the Gordon River had a consistently low cover across all sites. Moss and filamentous algae were again the dominant forms, and had low to moderate overall mean per cent cover across all sites, with means of 11.8 and 0.41% in zones 1 and 2 respectively. Macrophytes were again observed at site 72 with very low cover.

Table 8-3 Summary cover data for algae, moss and macrophytes surveyed in autumn 2012 for Gordon River sites

| **Site** | | **Mean% cover** | | | | **Width surveyed (m)** |
|---|---|---|---|---|---|---|
| | | **Moss** | **Filamentous algae** | ***Nitella/Chara*** | **Macrophytes** | |
| **Gordon** | | | | | | |
| 75 | G4 | 7.19 | 0.59 | 0 | 0 | 67.5 |
| 74 | G4A | 10.55 | 8.10 | 4 | 0 | 65.0 |
| 72 | G5 | 4.01 | 25.87 | 0.25 | 0.01 | 77.5 |
| 69 | G6 | 0.21 | 12.63 | 0 | 0 | 76.0 |
| 63 | G7 | 0.14 | 20.45 | 0.01 | 0 | 72.5 |
| 60 | G9 | 0.12 | 0.74 | 0 | 0 | 87.5 |
| 57* | G10 | 0.09 | 0.02 | 0 | 0 | 50.0 |
| 48* | G11B | 0.38 | 0.51 | 0 | 0 | 67.5 |
| 42* | G15 | 0.21 | 0.39 | 0 | 0 | 42.5 |
| **Reference** | | | | | | |
| Fr11 | G19 | 0 | 2.62 | 0 | 0 | |
| Fr21 | G20 | 0.04 | 0.04 | 0 | 0 | |
| De7 | G21 | 0 | 0 | 0 | 0 | |

* indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated

### 8.2.6 Comparison with previous years

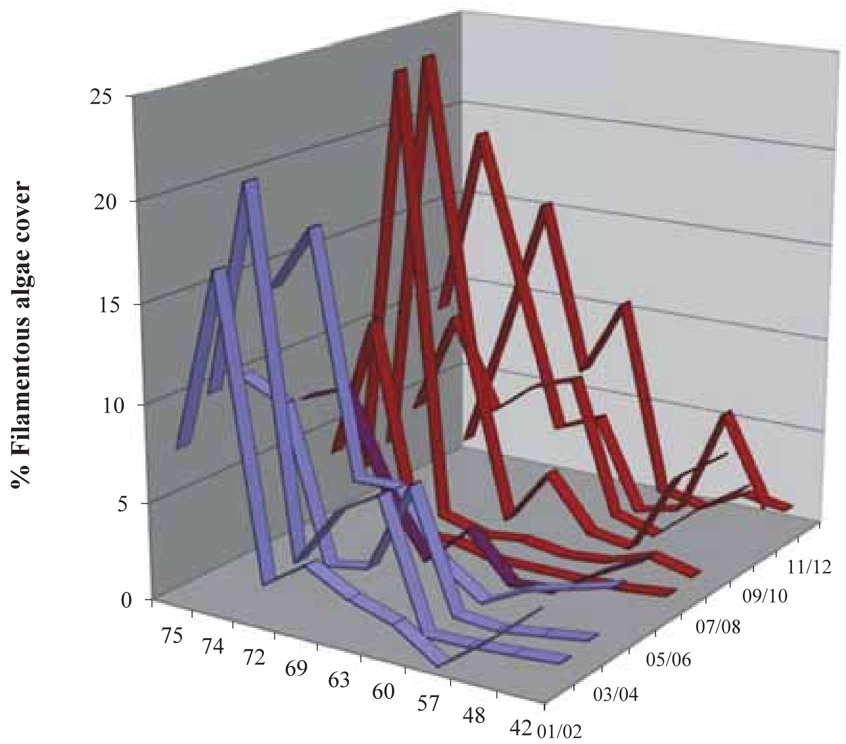
Overall mean per cent cover for moss and filamentous algae are shown for all sites for each year (as means across each transect over the two seasonal sampling occasions), in Table 8-4. There was no significant difference in per cent cover of either moss or filamentous algae between 2011–12 and pre-Basslink years for whole-of-river or at either zone.

Plots of the downstream trends in annual mean of moss and filamentous algae for all six years from 2001–02 to 2011–12 are shown in Figure 8-1. Inter-annual variation in cover, and its relationship to changes in flow and other environmental conditions, will be evaluated in detail in the final Basslink Review Report.

The pattern and mean per cent cover for both moss and filamentous algae in 2011–12 were broadly similar to previous years. Reduced algal levels are an anticipated effect of sustained minimum environmental flows post-Basslink (see Basslink Baseline Report conceptual model, Hydro Tasmania 2005a). There were, however, no statistically significant differences between 2011–12 data and the mean of all previous or pre-Basslink years (by paired t-test, with pairing by site, all p >0.2).

Table 8-4 Annual mean per cent cover for moss and filamentous algae at all transects in 2001–02 to 2011–12 in the lower Gordon River

| | **Period** | **Mean for** | **Site** | | | | | | | | | **Whole-of-river** | **Zone 1 (u/s) Denison)** | **Zone 2 (d/s) Denison)** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **75** | **74** | **72** | **69** | **63** | **60** | **57** | **48** | **42** | | | |
| Algae | Pre-Basslink | 2001–02 | 7.79 | 17.00 | 1.86 | 3.35 | 2.19 | 1.51 | 0.01 | 1.72 | 3.72 | 4.35 | 6.44 | 1.74 |
| | | 2002–03 | 9.88 | 20.73 | 2.18 | 5.28 | 6.59 | 0.03 | 0.09 | 0.26 | 0.44 | 5.05 | 8.93 | 0.21 |
| | | 2003–04 | 10.10 | 9.08 | 1.18 | 1.56 | 6.31 | 0.18 | 0.00 | 0.32 | 0.67 | 3.27 | 5.65 | 0.29 |
| | | 2004–05 | 13.99 | 17.43 | 4.87 | 4.95 | 1.55 | 0.00 | 1.20 | 1.84 | 2.50 | 5.37 | 8.56 | 1.38 |
| | Transition | 2005–06 | 7.61 | 8.49 | 3.52 | 0.33 | 2.48 | 0.09 | 0.26 | 1.76 | 2.96 | 3.06 | 4.49 | 1.27 |
| | Post-Basslink | 2006–07 | 3.96 | 11.43 | 0.38 | 0.50 | 0.00 | 0.00 | 0.00 | 0.11 | 0.37 | 1.86 | 3.25 | 0.12 |
| | | 2007–08 | 2.31 | 24.00 | 0.70 | 0.07 | 0.33 | 0.00 | 0.21 | 1.02 | 0.49 | 3.24 | 6.77 | 0.43 |
| | | 2008–09 | 3.11 | 24.34 | 9.40 | 0.18 | 3.22 | 0.46 | 0.13 | 4.39 | 5.98 | 5.69 | 8.05 | 2.74 |
| | | 2009–10 | 4.35 | 9.85 | 5.05 | 6.84 | 7.64 | 0.68 | 0.04 | 1.97 | 3.54 | 4.44 | 6.75 | 1.56 |
| | | 2010–11 | 9.36 | 19.35 | 11.61 | 3.85 | 4.83 | 0.12 | 0.69 | 6.40 | 1.79 | 6.44 | 9.80 | 2.25 |
| Moss | Pre-Basslink | 2001–02 | 6.09 | 10.63 | 0.14 | 8.50 | 1.05 | 0.33 | 0.80 | 2.84 | 3.10 | 3.72 | 5.28 | 1.77 |
| | | 2002–03 | 2.07 | 8.16 | 1.06 | 3.42 | 2.46 | 0.13 | 0.25 | 0.54 | 0.06 | 2.01 | 3.43 | 0.24 |
| | | 2003–04 | 2.09 | 6.18 | 0.07 | 1.64 | 2.15 | 0.98 | 0.75 | 0.87 | 0.62 | 1.71 | 2.43 | 0.81 |
| | | 2004–05 | 4.91 | 12.62 | 0.54 | 0.76 | 2.14 | 1.98 | 0.25 | 1.59 | 0.41 | 2.80 | 4.19 | 1.06 |
| | Transition | 2005–06 | 1.94 | 8.63 | 0.06 | 1.54 | 0.50 | 1.63 | 0.64 | 0.25 | 2.08 | 1.92 | 2.53 | 1.15 |
| | Post-Basslink | 2006–07 | 2.73 | 8.07 | 0.41 | 2.82 | 2.73 | 1.12 | 0.28 | 1.45 | 0.64 | 2.25 | 3.35 | 0.87 |
| | | 2007–08 | 4.32 | 6.70 | 0.28 | 5.34 | 3.42 | 0.66 | 0.26 | 0.81 | 0.95 | 2.53 | 4.21 | 0.67 |
| | | 2008–09 | 9.18 | 0.89 | 0.04 | 0.88 | 0.41 | 0.18 | 0.06 | 0.48 | 3.32 | 1.71 | 2.28 | 1.01 |
| | | 2009–10 | 3.80 | 16.21 | 0.04 | 1.45 | 1.15 | 0.62 | 0.28 | 1.58 | 0.56 | 2.85 | 4.53 | 0.76 |
| | | 2010–11 | 4.82 | 4.54 | 0.17 | 0.52 | 1.10 | 0.47 | 0.10 | 1.17 | 0.41 | 1.48 | 2.23 | 0.54 |
| | | 2011–12 | 6.22 | 5.85 | 2.01 | 0.54 | 0.29 | 0.42 | 0.07 | 0.20 | 0.16 | 1.75 | 2.98 | 0.21 |



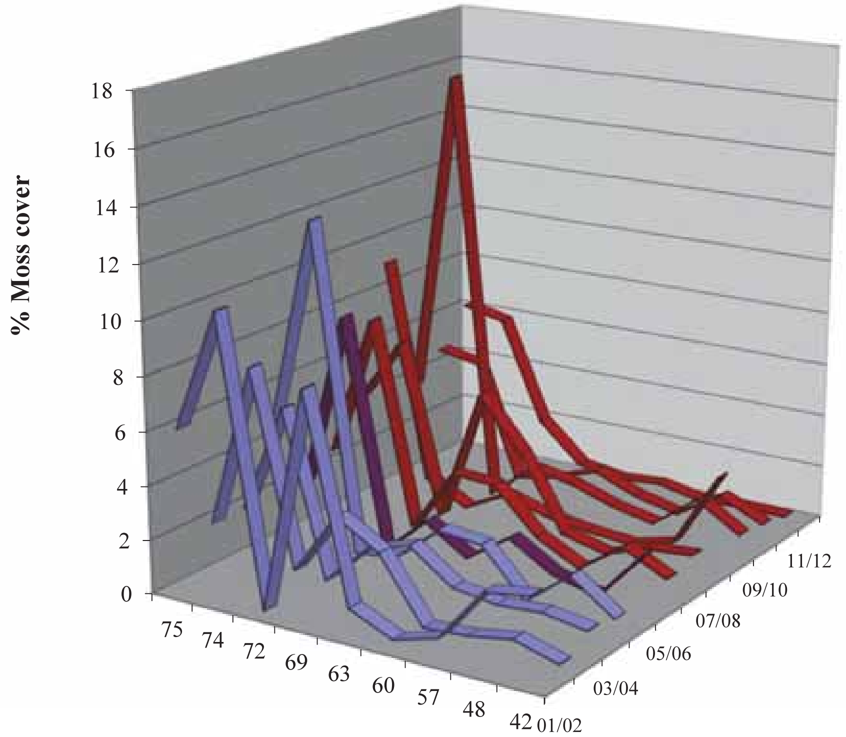


Figure 8-1 Downstream trends in mean per cent moss cover and mean per cent filamentous algal cover in the Gordon River during the pre-Basslink period (2001–02 to 2004–05—blue lines), the transitional period (2005–06—deep purple) and the six years of the post-Basslink period (2006–07 to 2011–12—red)

## 8.3 Comparisons with triggers

### 8.3.1 Results

Two metrics have been identified for assessing the degree of any changes in benthic plants in the Gordon River due to Basslink operations:

- per cent cover of filamentous algae; and
- per cent cover of moss.

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 or not post-Basslink. Upper and lower triggers have been determined. Triggers have been developed for each individual site in the Gordon River, as well as for the entire river (‘whole-of-river’) and zones within the river. Seasonal differences are also taken into account for the whole-of-river case. Two zones have been described for algae and moss—zone 1, upstream of the Denison confluence (incorporating sites 69 to 75), and zone 2, downstream of the Denison confluence (incorporating sites 42 to 60).

### 8.3.2 Trigger status—one-year (2011–12)

The following section summarises and comments on the observations for 2011–12 in comparison with the one-year trigger values.

Triggers have been established for one year of observations, and are compared against the data for 2011–12 (as in the 2006–07 to 2010–11 reports), in order to assess the post-Basslink effect for this year only.

Plots of the one-year trigger levels for each metric are shown below compared with the value for the metric recorded in 2011–12, at individual site level (Figure 8-2) and at whole-of-river and zone level (Figure 8-3).

#### *8.3.2.1 Filamentous algal cover*

Cover values in 2011–12 fell within trigger bounds at all sites except for minor exceedances at site 72 (Figure 8-2). No exceedances were observed for whole-of-river, for all year or either season, or for the two zones (Figure 8-3).

*Comment*—generally consistent with pre-Basslink conditions, with one minor exceedance which is not of ecological significance.

### *8.3.2.2 Moss cover*

All site cover values fell within trigger bounds (Figure 8-2), as did whole-of-river and zone values (Figure 8-3).

*Comment*—Consistent with pre-Basslink conditions.

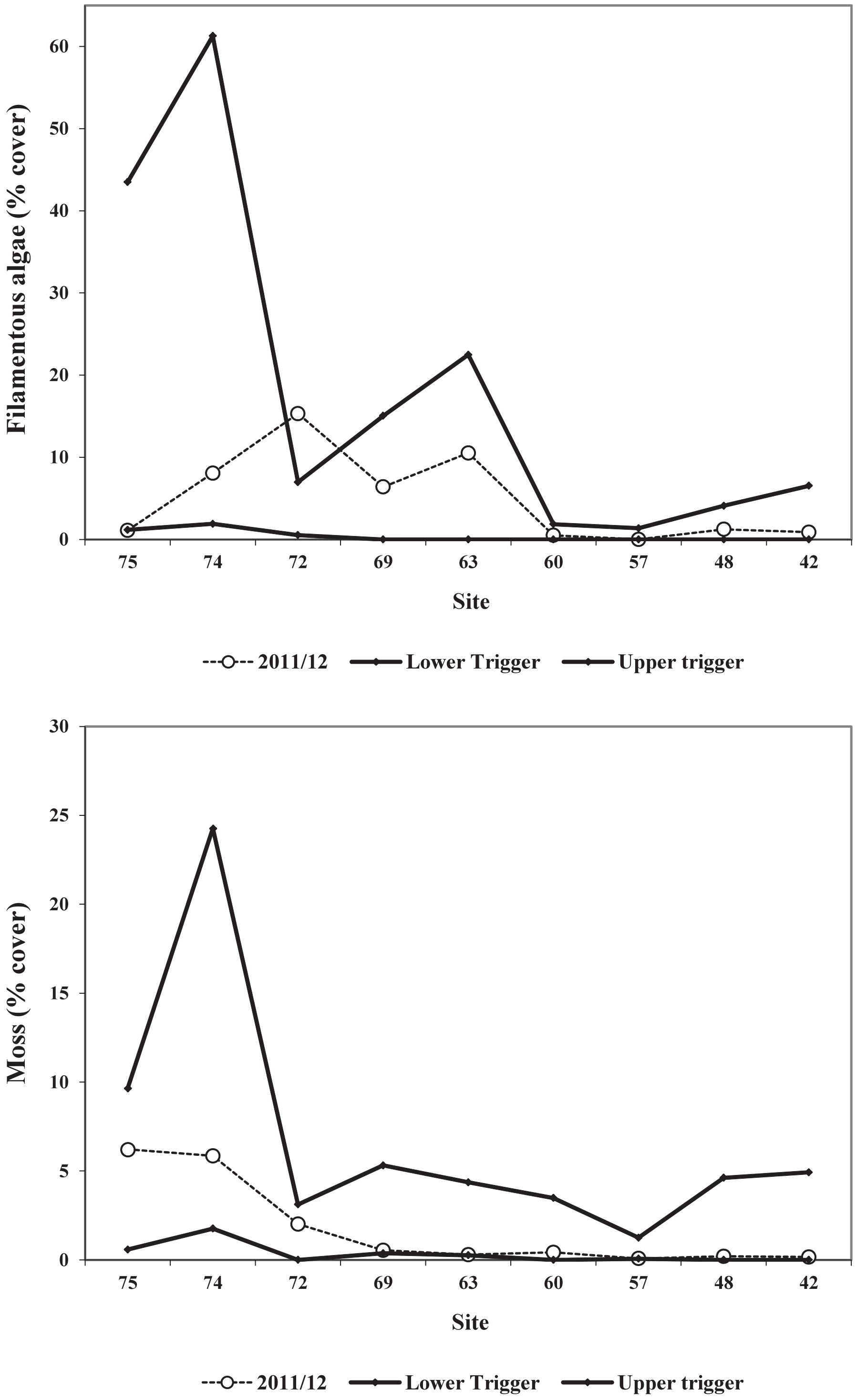
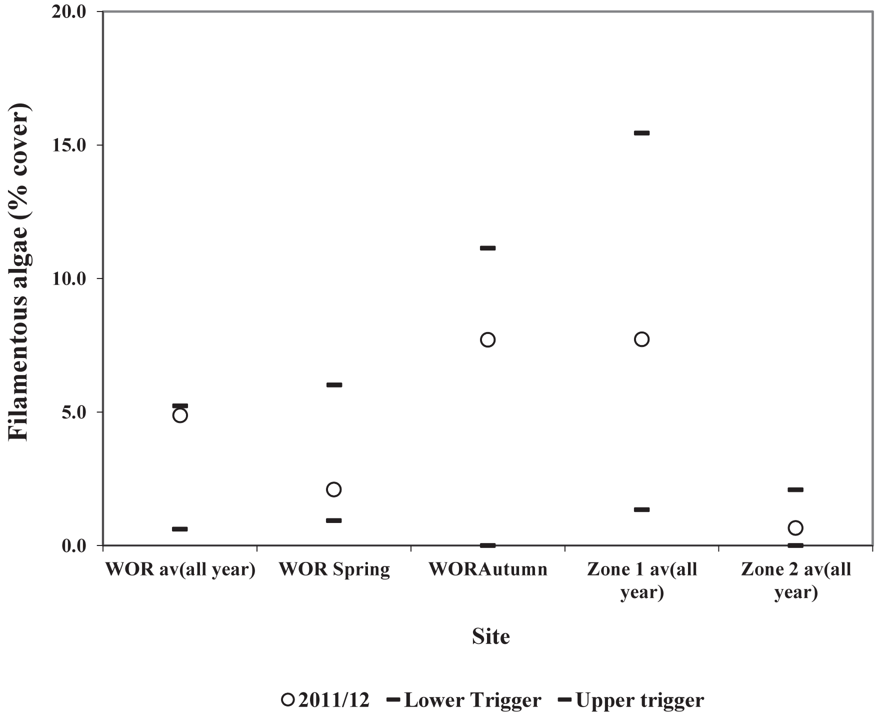


Figure 8-2 Per cent cover of benthic filamentous algae and moss for 2011–12 compared with upper and lower one-year LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



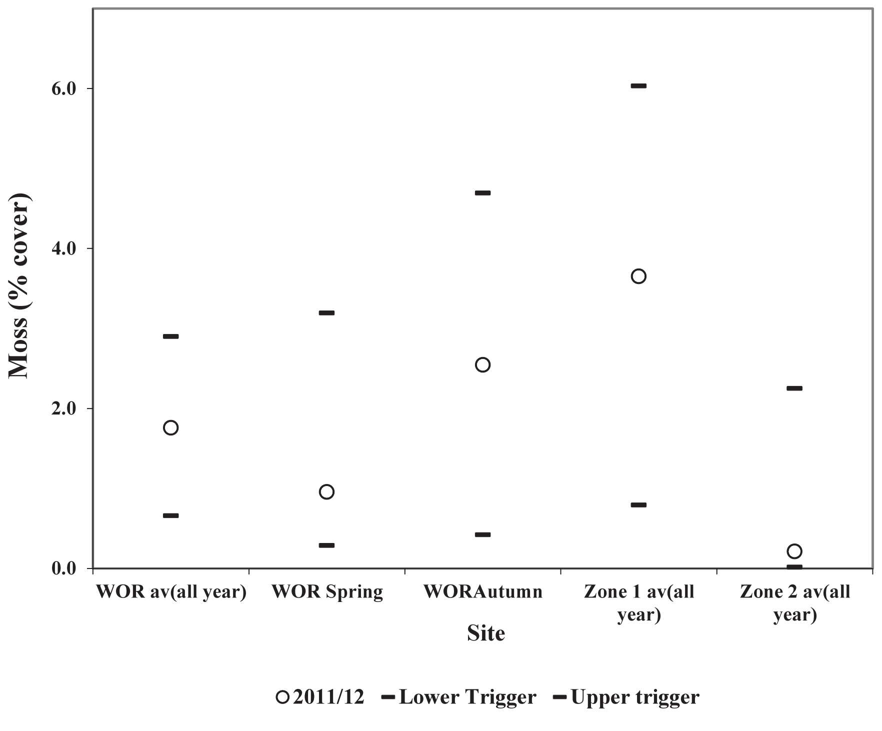


Figure 8-3 Per cent cover of benthic filamentous algae and moss for 2011–12 compared with upper and lower one-year LOAC trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

### 8.3.3 Trigger status—six-year (2006–07 to 2011–12)

The following section summarises and comments on the mean observations for 2006–07 to 2011–12 in comparison with the six-year trigger values.

#### *8.3.3.1 Filamentous algal cover*

Cover values in 2006–07 to 2011–12 at all sites, for whole-of-river and both zones, fall within their trigger bounds (Figure 8-4 and Figure 8-5) with the following exceptions:

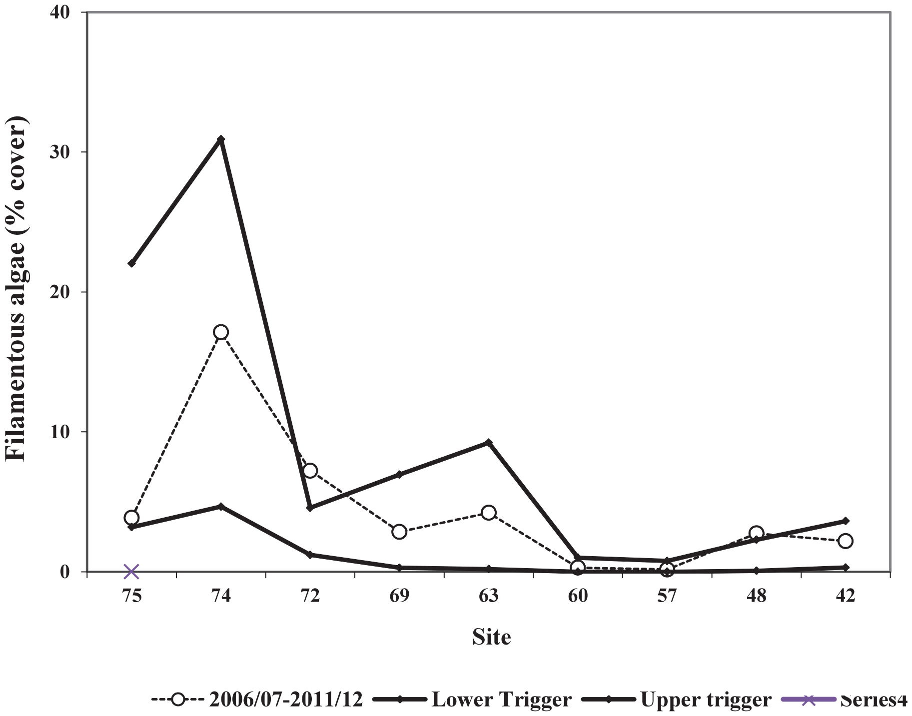
- sites 48 and 72 which have minor algal cover exceedances above their upper trigger bounds; and
- whole-of-river all year and zone 2 also show minor exceedances.

Mean cover appears to be trending upward over the six years post-Basslink in zone1 and for the whole-of-river (Figure 8-6), now resulting in minor trigger exceedances (Figure 8-5). The trend is slow, and considerable inter-site and seasonal variation still exists in cover values.

*Comment*—the pattern between sites and zones is consistent with pre-Basslink conditions. Site values have been broadly consistent with pre-Basslink ranges but now show minor exceedances for selected sites, and at whole-of-river and zone 2 scales.

Moss cover—Cover values fall within or close to trigger bounds at all sites (Figure 8-4). The mean value for whole-of-river falls just below the upper trigger bound (Figure 8-5). Cover exceeds the upper trigger bound in spring for the whole-of-river mean, but not by an ecologically significant amount. A post-Basslink decline in mean moss cover is apparent in zone 2 (Figure 8-6), but not for zone 1 or at whole-of-river scale.

*Comment*—generally consistent with pre-Basslink conditions, with minor exceedance in spring.



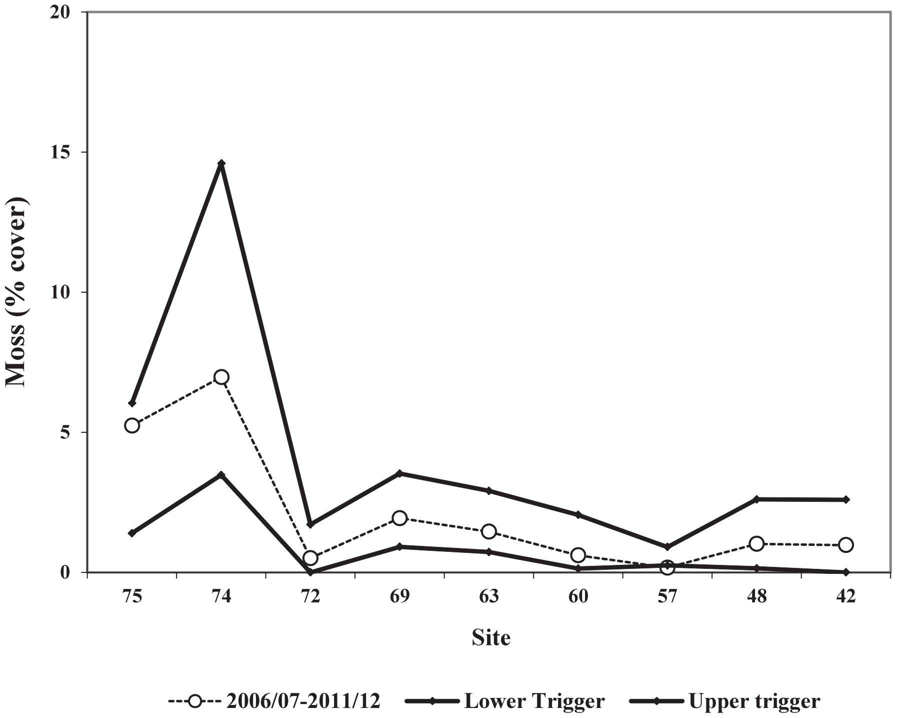
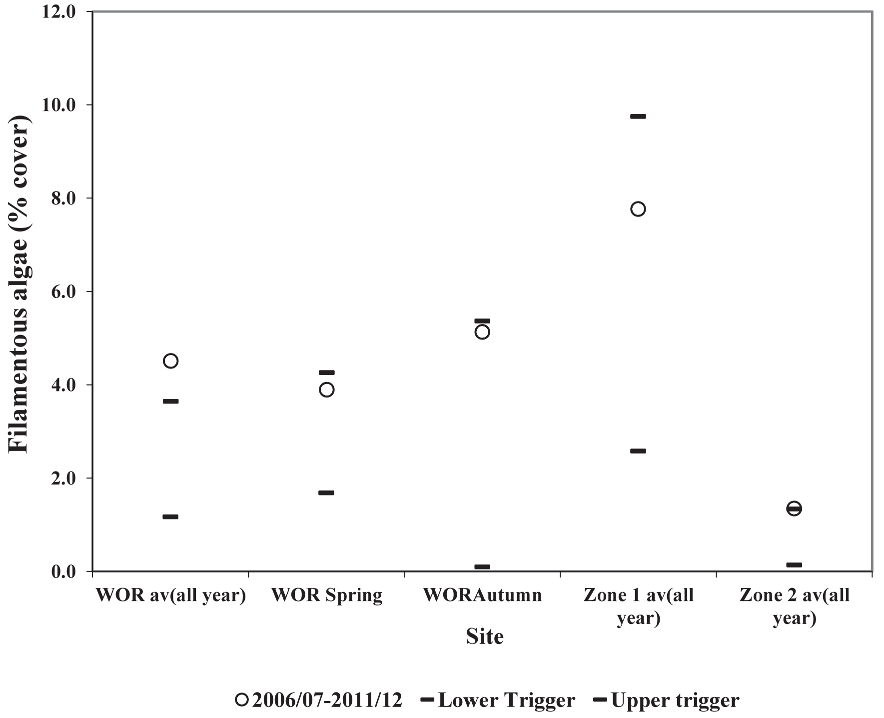


Figure 8-4 Mean per cent cover of benthic filamentous algae and moss for 2006–07 to 2011–12 compared with upper and lower six-year LOAC trigger values for each site in the Gordon River. Trigger values based on the 95th percentile of pre-Basslink data



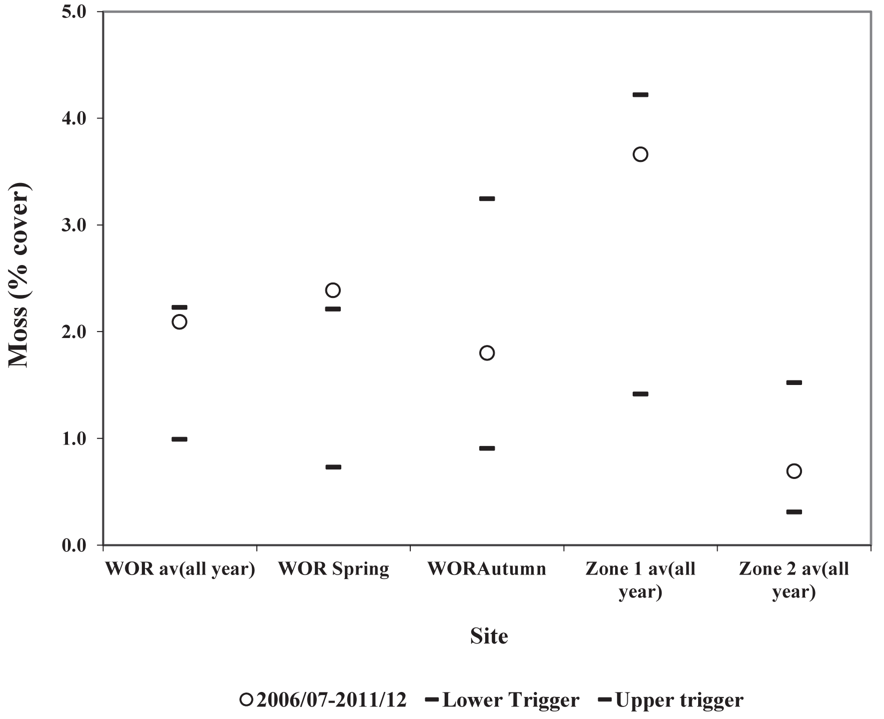


Figure 8-5 Mean per cent cover of benthic filamentous algae and moss for 2006–07 to 2011–12 compared with upper and lower six-year LOAC trigger values in the Gordon River for the following cases: whole-of-river (year = seasons combined, spring and autumn), zones 1 and 2 (year). Trigger values based on the 95th percentile of pre-Basslink data

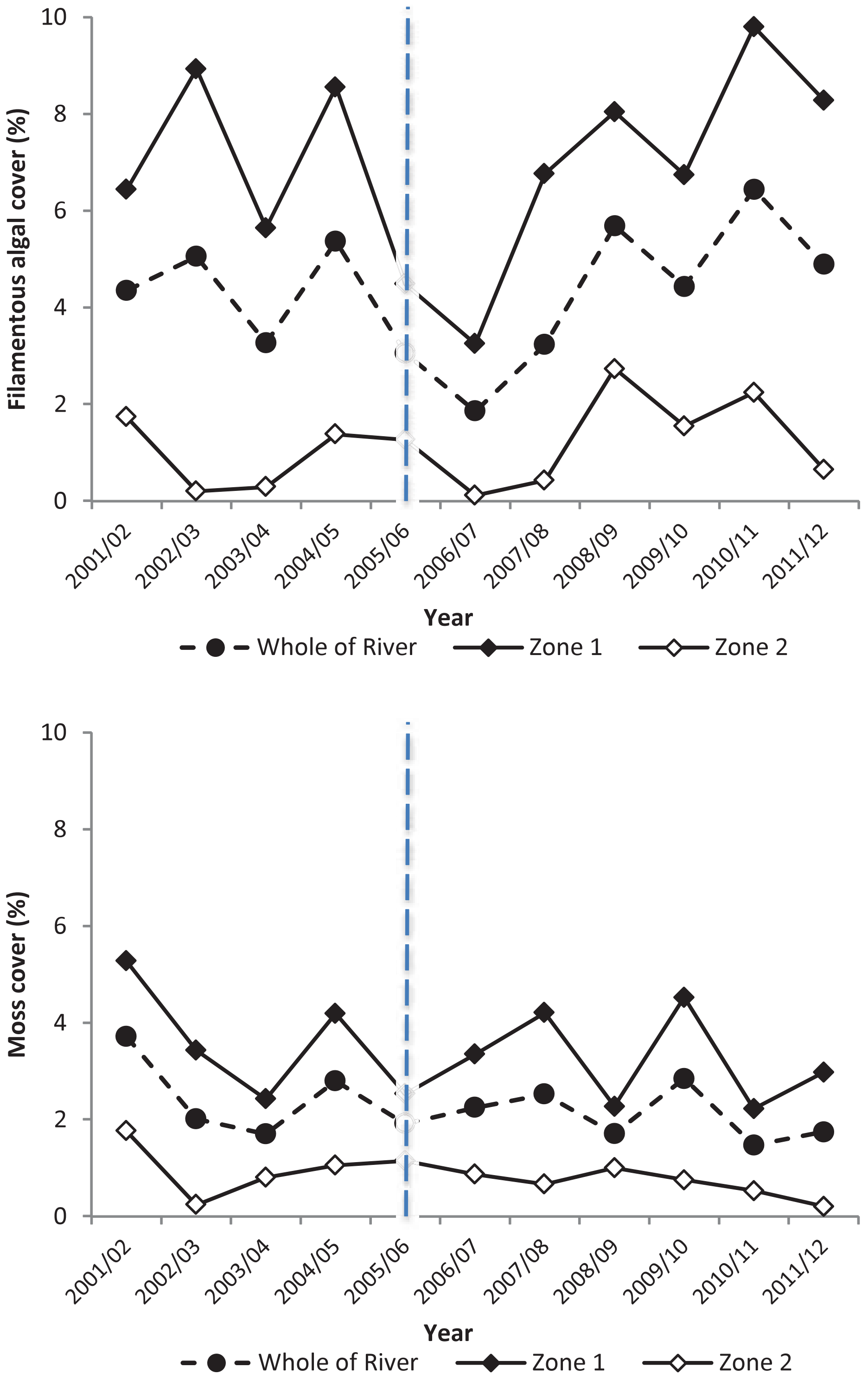


Figure 8-6 Long-term trends in per cent cover of benthic filamentous algae and moss in the two zones of the Gordon and for the whole-of-river from 2001–02 to 2011–12. Vertical dashed line indicates commencement of Basslink operations

## 8.4 Conclusions

Spring 2011 and autumn 2012 constitute the sixth full year of the post-Basslink monitoring period.

As in the pre-Basslink period, overall aquatic plant cover was low in the Gordon River.

Filamentous cover was generally low, peaking in the upper reaches of zone 1, and was very low downstream of the Denison confluence, as observed previously. A minor exceedance was noted for whole-of-river and zone 2, but were otherwise consistent in overall magnitudes and trends of cover with pre-Basslink years. The long-term (six-year) post-Basslink mean cover shows some minor exceedances for filamentous algae, and also for moss. Moss cover was very low downstream of the Denison confluence, as observed previously. Values fell within trigger level bounds and were consistent in overall magnitudes and trends of cover with pre-Basslink years.

The observed algal and moss exceedances do not constitute a substantive ecological change.

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# 9 Fish

## 9.1 Introduction

The aims of the fish monitoring program are to:

- monitor the relative abundance of fish in the middle Gordon River and assess whether there is a significant change due to Basslink-related alterations to hydrological conditions;
- assess potential changes in the longitudinal fish community structure of the Gordon River with the aim of identifying any changes in the zone of influence; and
- determine any changes to the fish populations of affected tributaries, particularly if recruitment success for juvenile galaxiids has changed under Basslink.

This report summarises the results of the 2011–12 Basslink fish monitoring surveys, which were undertaken in December 2011 and March 2012.

## 9.2 Methods

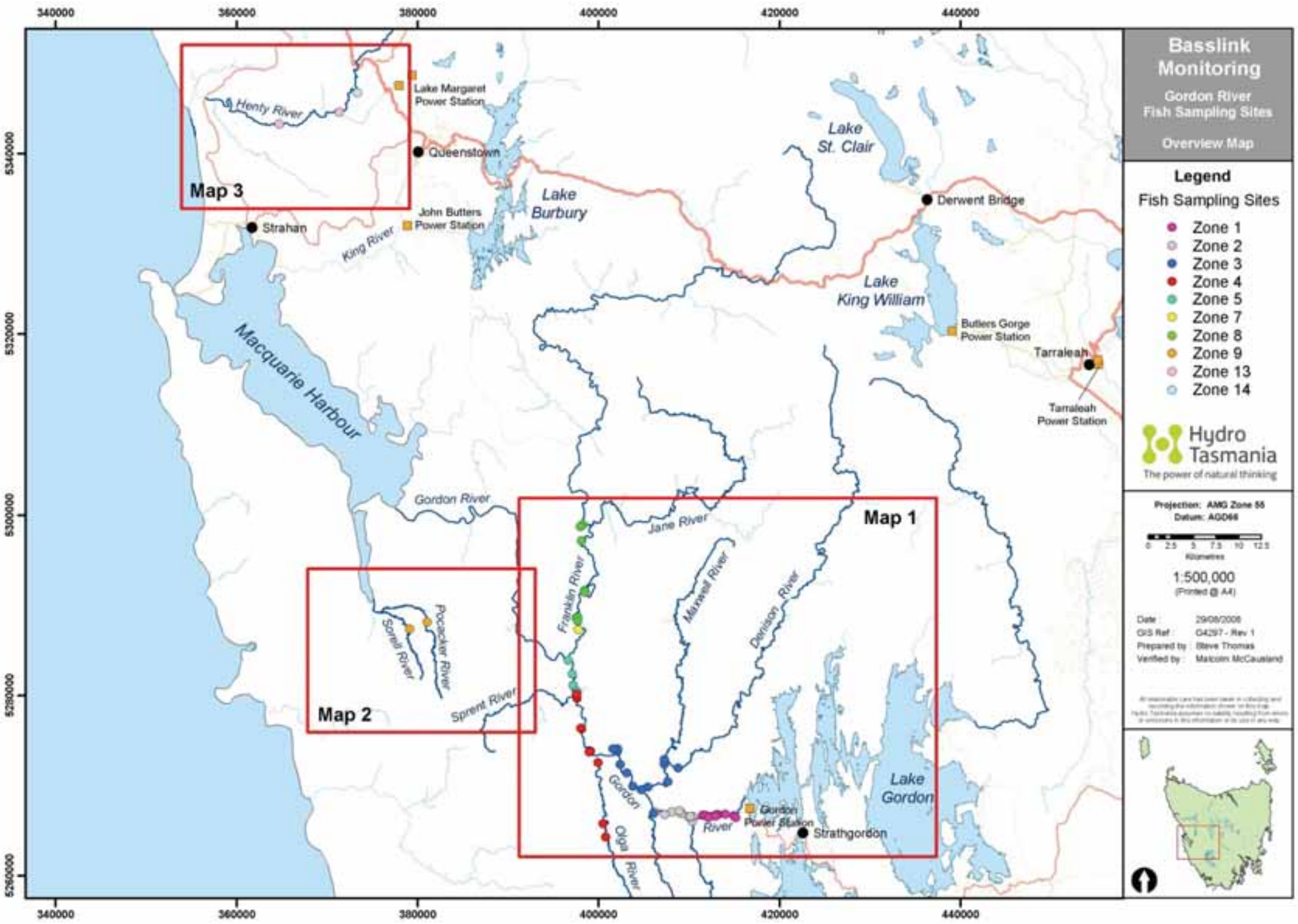
The summer 2011 monitoring surveys were conducted on 3–4, 8 and 15 December. Autumn fish sampling was undertaken on 29 March to 1 April 2012. The summer sampling was spread over three trips due to elevated flows in the reference sites.

Thirty-one monitoring sites in the Gordon catchment were scheduled for sampling in each monitoring season. These sites are listed in Table 9-1 and are located in the main channel of the Gordon River, or in tributaries of the Gordon River, with fish populations at these sites either directly or indirectly affected by power station operation. The monitoring sites are distributed through a series of Gordon catchment monitoring zones—Maps 9-1 to 9-4 show the location of these zones. The rationale behind the zone allocations is discussed in Howland *et al.* (2001). Seven river and four tributary reference sites were scheduled for sampling in conjunction with the monitoring sites, and these reference sites are listed in Table 9-2.

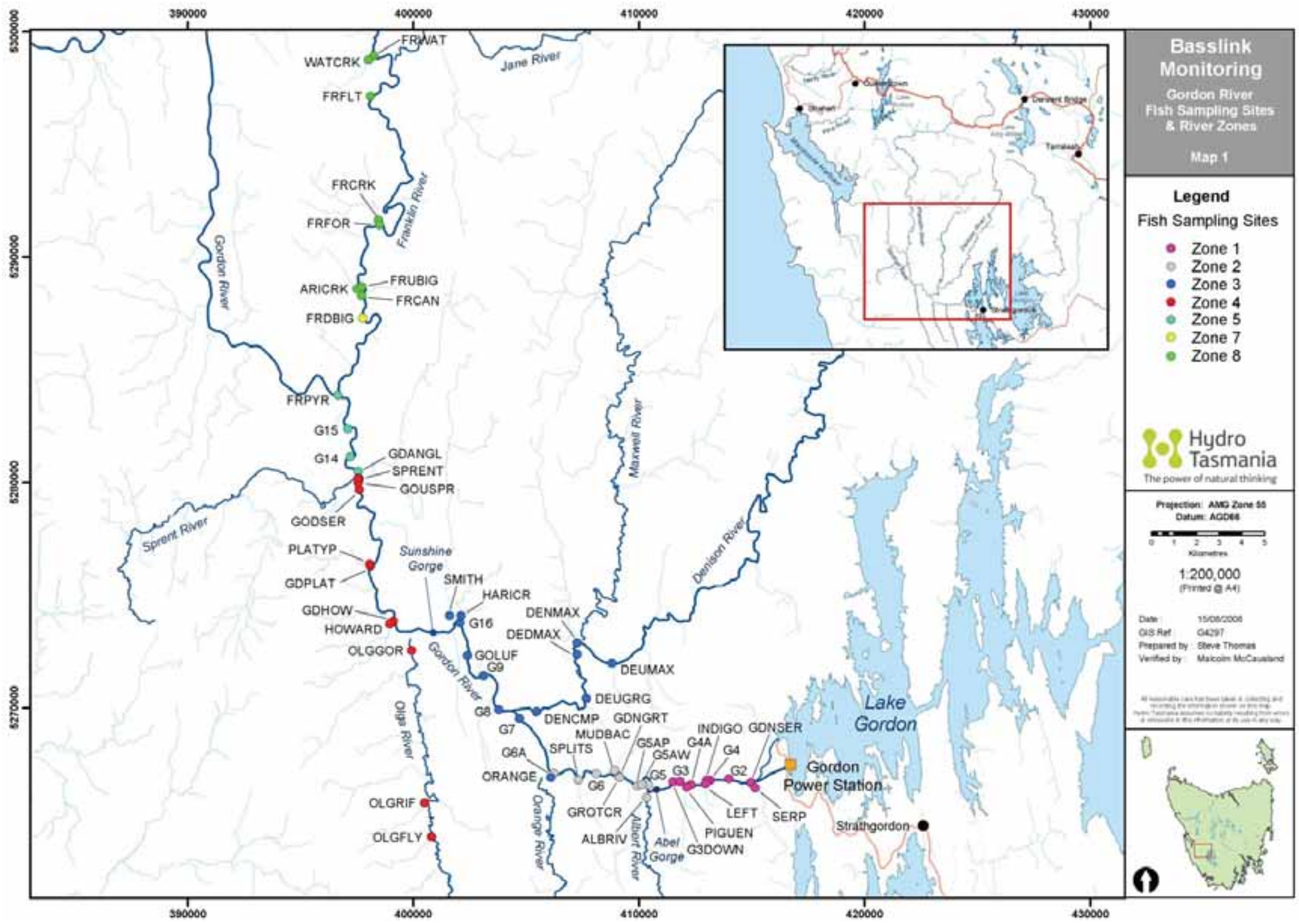
The fish monitoring zones are defined as follows:

- zone 1: Gordon River and tributaries from Gordon Dam downstream to, and inclusive of, Abel Gorge;
- zone 2: Gordon River and tributaries from Albert River downstream to, and inclusive of, the First Split;
- zone 3: Gordon River and tributaries from Orange River downstream to Sunshine Falls;
- zone 4: Gordon River and tributaries from Sunshine Falls to the Sprent River;

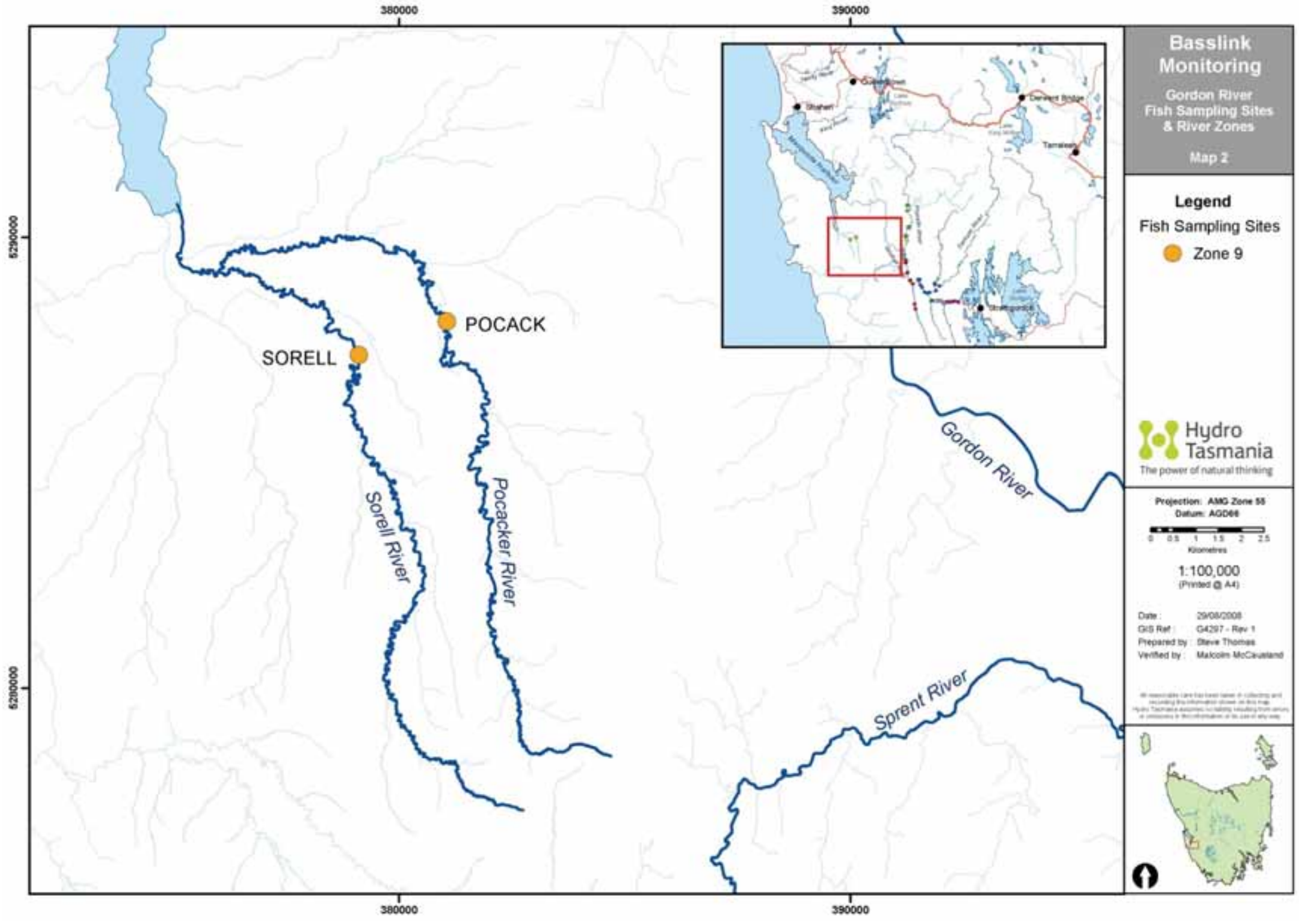
- zone 5: Gordon River from Angel Cliffs downstream to Big Eddy;
- zone 7: Franklin River between Pyramid Island and Big Fall;
- zone 8: Franklin River and tributaries upstream of Big Fall;
- zone 9: Birches Inlet catchment;
- zone 13: Henty River at and downstream of the Yolande River; and
- zone 14: Henty River upstream of the Yolande River.



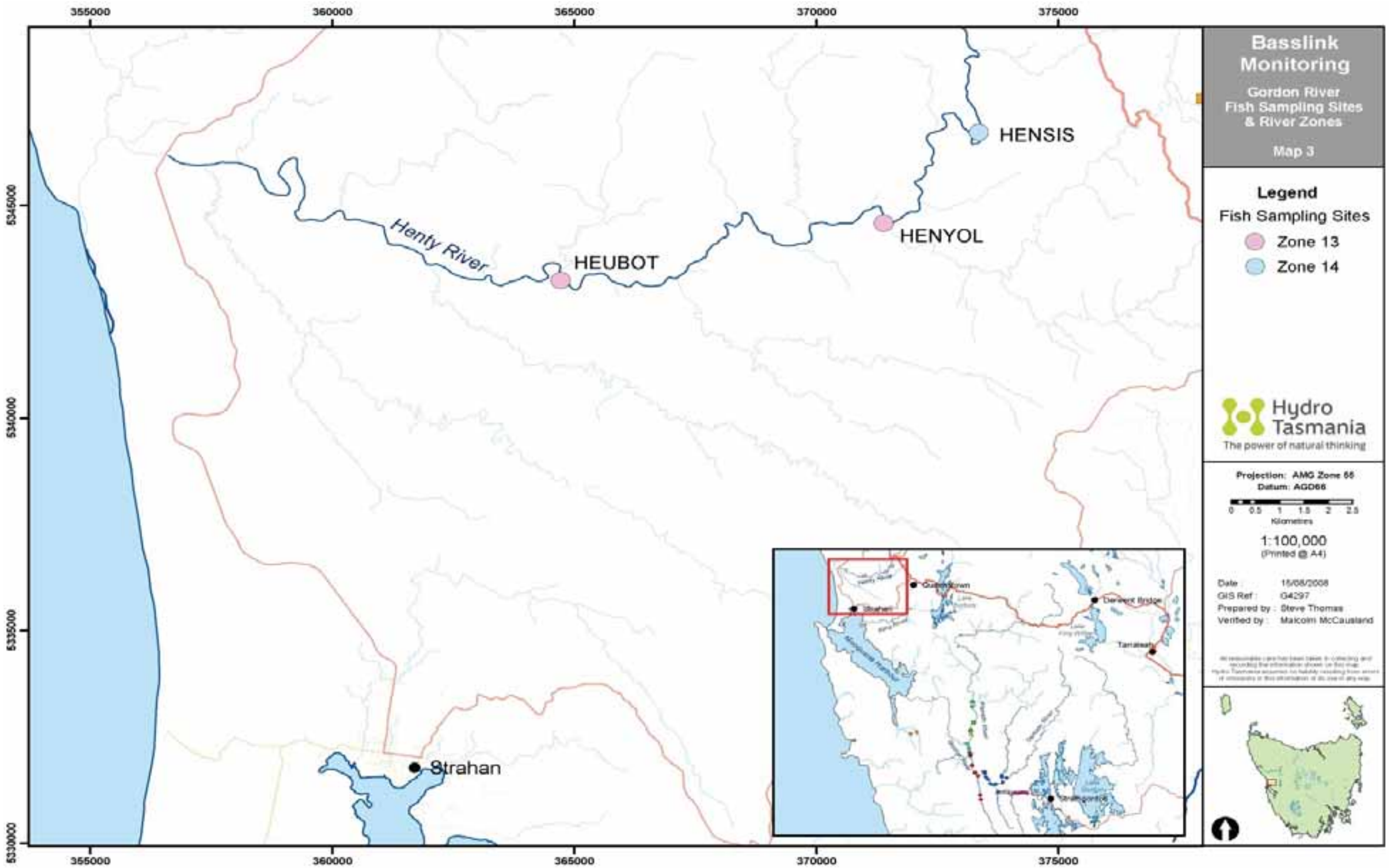
Map 9-1 Fish monitoring sites and zones in the Gordon River (zones 1–5), Franklin River (zones 7–8), Birches Inlet (zone 9) and Henty River (zones 13–14)



Map 9-2 Gordon River fish sampling sites and river zones, zones 1–8



Map 9-3 Sampling sites at Birches Inlet (zone 9)



Map 9-4 Fish sampling sites on the Henty River (zone 13-14)

Table 9-1 Gordon catchment monitoring sites. Alternative site names are shown in parenthesis

| Zone | River sites | Tributary sites |
|---|---|---|
| 1 | 75 (G4), 74 (G4a), 73 (G3 u/s and d/s) | Left bank Creek@site 75*, Indigo Creek, Piguenit Rivulet |
| 2 | 72 (G5 upper and lower), 71 (G5a pipe and water meter) and 69 (G6) | Albert River, Splits Creek and Mudback Creek |
| 3 | 68 (G6a), 63 (G7) and 57 (G16) | Smith River and Harrison Creek, Denison River u/s Gorge, Denison River@Maxwell, Orange River* |
| 4 | 54 (Howards Creek), 51 (Platypus Creek), 46 (Gordon u/s Sprent) | Howards Creek, Olga River, Platypus Creek and Sprent River |
| 5 | 45 (Gordon d/s Sprent), 44 (G14), 42 (G15) | Franklin@Pyramid Island |
| * indicates a change to the original site list, see text for explanation | | |

Table 9-2 Reference sites

| Zone (catchment) | River sites | Tributary sites |
|---|---|---|
| 7 (Franklin) | Franklin d/s Big Fall | none |
| 8 (Franklin) | Franklin u/s Big Fall<br>Franklin@Canoe Bar | Forester Creek, Ari Creek,<br>Wattle Camp Creek |
| 9 (Birches Inlet) | Sorell River | Pocacker River |
| 13 (Henty) | Henty u/s Bottle Creek<br>Henty@Yolande River | None recommended |
| 14 (Henty) | Henty@Sisters | None recommended |

‘Optional’ sites, listed in Table 9-3, are included in the monitoring program design and consist of 11 monitoring and four reference sites that are located in both Gordon River tributaries and out-of-catchment rivers. These sites were included to provide additional data for the monitoring program in the event of failure to sample some of the core/essential sites. ‘Optional’ sites are sampled if time and logistics permit, however essential sites take priority in the sampling regime.

The majority of the essential monitoring sites were sampled in 2011–12. High water level meant that Gordon at Platypus Creek could not be sampled in December 2012. In circumstances similar to the 2010-11 monitoring program, high flows limited the number of optional sites that could be sampled in summer to six, but favourable conditions in autumn allowed nine optional sites to be sampled.

Several changes have been made to the monitoring site classifications since the inception of the monitoring program in 2001. The Orange River monitoring site was originally classified as optional, but was reclassified as essential to replace the Denison u/s Maxwell site, which had to be abandoned due to ongoing access difficulties. The Serpentine River site was removed from the sampling program and replaced by Left Bank Creek@G4 due to ongoing safety concerns. Franklin@Flat Island was added in March 2011, due to ongoing access difficulties at Franklin@Wattle Camp Creek, as the small size of the cobble bar at this site makes it susceptible to inundation at moderate flows.

Table 9-3 Optional survey sites. Alternative site names are shown in parenthesis

| | Zone | River sites | Tributary sites |
|---|---|---|---|
| Monitoring | 1 | 76 (G2) | none |
| | 2 | Gordon@Grotto Creek | Grotto Creek |
| | 3 | site 60 (G9), Gordon@G8, Gordon@Fluffies | *Denison@Denison Camp |
| | 4 | none | Howards Creek inundation, Olga@riffles |
| | 5 | Gordon@Angel Cliffs | none |
| Reference | 8 (Franklin) | Franklin@Forester Creek,<br>Franklin@Wattle Camp Creek,<br>*Franklin@Flat Island | none |
| | 14 (Henty) | Henty@West Sister | None |
| * indicates a change to the original site list, see text for explanation | | | |

Fish surveys were undertaken by backpack electrofishing, following the methods detailed in Howland *et al.* (2001). Surveys of the Gordon monitoring sites were conducted by three two-person teams, with a target electrofishing effort of 1200 seconds shocking time for each site. Gordon catchment tributary sites situated outside the power station zone of influence were sampled by two teams, and a single team sampled the out-of-catchment reference sites.

Fish teams sampled a range of representative habitats at each site. After capture, fish were anaesthetised, identified and counted, and fork lengths were recorded to the nearest millimetre. Fish were then released to a suitable backwater area to recover from anaesthesia. Qualitative assessments of general aquatic habitat descriptors were recorded for each site.

# 9.3 Results and discussion

## 9.3.1 Exotic species

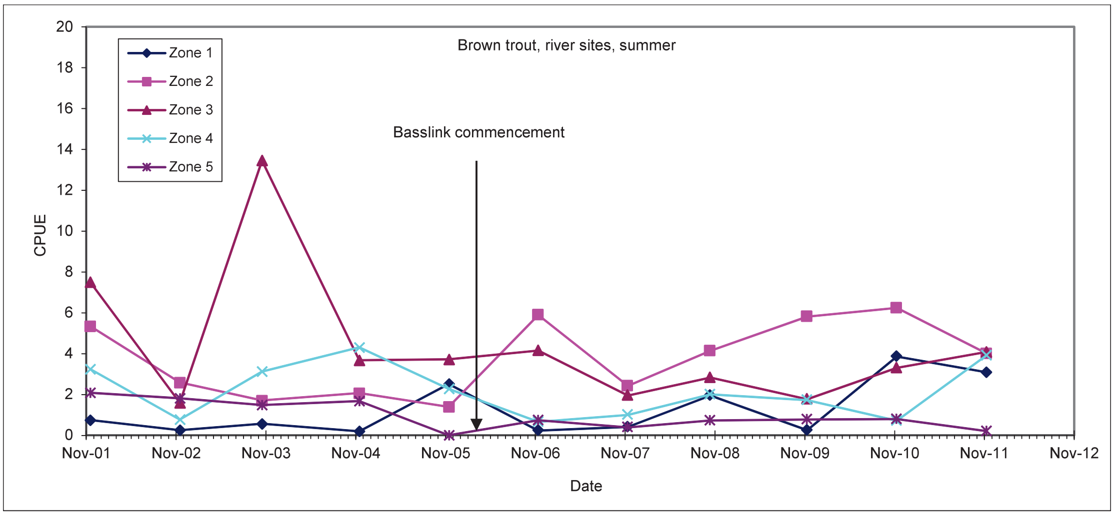
### *9.3.1.1 Brown trout (Salmoniidae)*

Figure 9-1 shows brown trout catches in the Gordon River between the start of the monitoring program in December 2001 and the last survey, which was completed in March 2012. As previously reported in 2011, the relative abundance of brown trout in the zone 1 and zone 2 river sites continues to be equal to, or above, mean pre-Basslink levels for both summer and autumn.

Tributary monitoring zone catches are shown in Figure 9-2. Autumn zone 2 catches were the highest recorded for this zone over the duration of the monitoring program, and were above the pre-Basslink autumn mean. As reported in Hydro Tasmania (2011), brown trout catches from zone 3 have consistently been the highest of all monitoring zones for the duration of the monitoring program in both seasons, however 2011–12 relative abundances were not significantly different to the pre-Basslink mean.

Data from the reference sites is shown in Figure 9-3. Catches were generally similar to historical levels in most zones. As previously reported, brown trout catches from Birches Inlet sites were usually low and inconsistent, however in the last three years of the monitoring program zone 9 trout catches have been well above pre-Basslink means for both seasons.

Brown trout relative abundances in the upper Gordon River and tributary zones have generally shown a post Basslink increase. Relative abundances from most of the reference sites do not show consistent trends. Catches from Birches Inlet may be marginally higher than pre-Basslink, but pre-Basslink means from these sites were very low. As discussed in section 9.5.2, increases recorded from the Gordon River monitoring sites have not been consistent across all zones and so have not resulted in upper exceedences of any exotic species trigger categories.



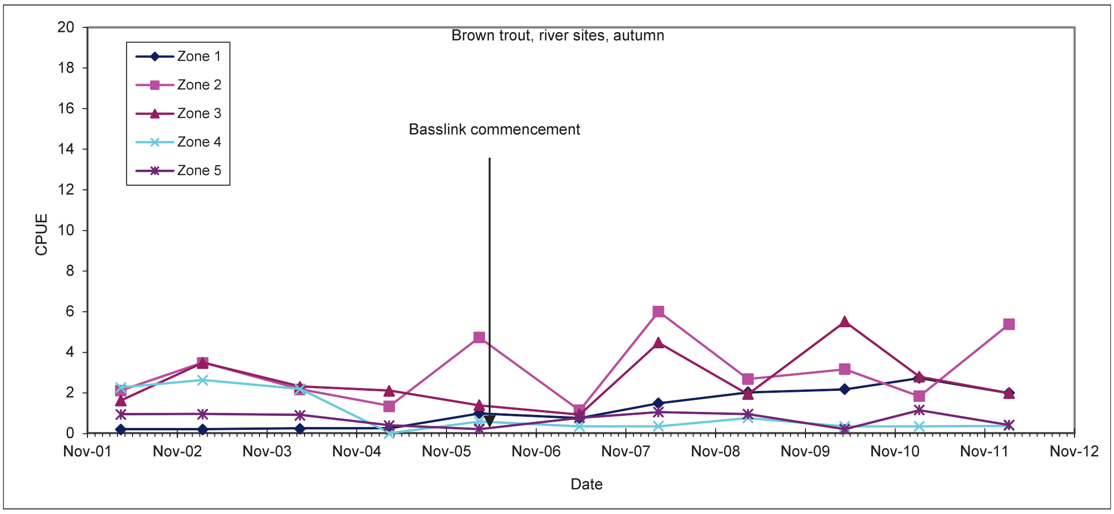
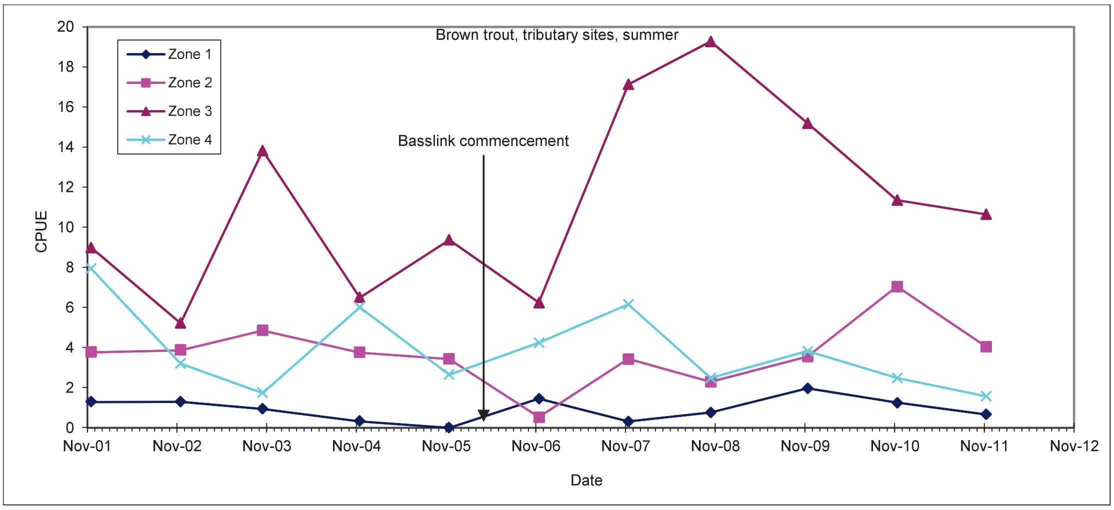


Figure 9-1 Seasonal (summer and autumn) CPUE for brown trout caught in the Gordon River monitoring zones between December 2001 and March 2012



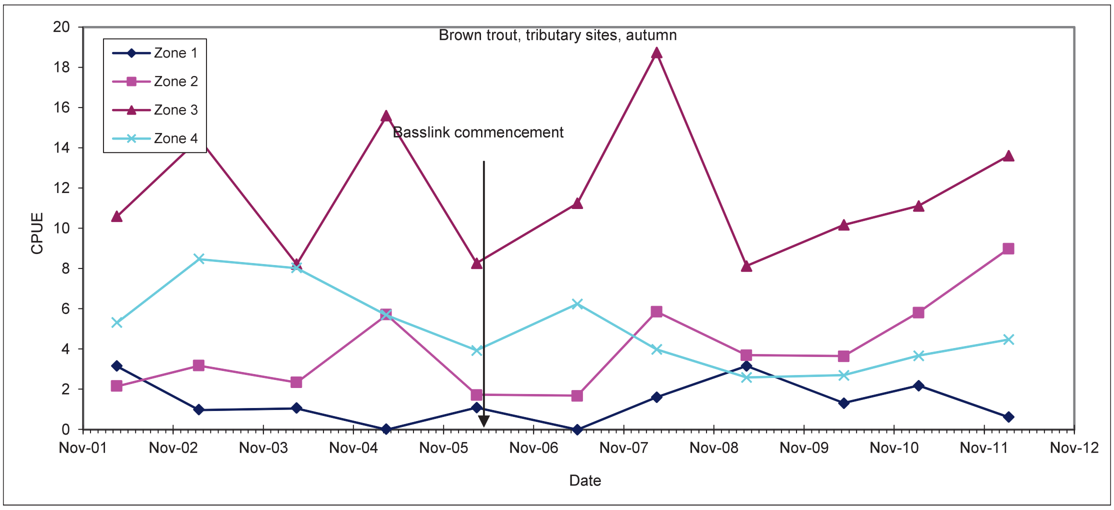


Figure 9-2 Seasonal (summer and autumn) CPUE for brown trout caught in the Gordon tributary monitoring zones between December 2001 and March 2012

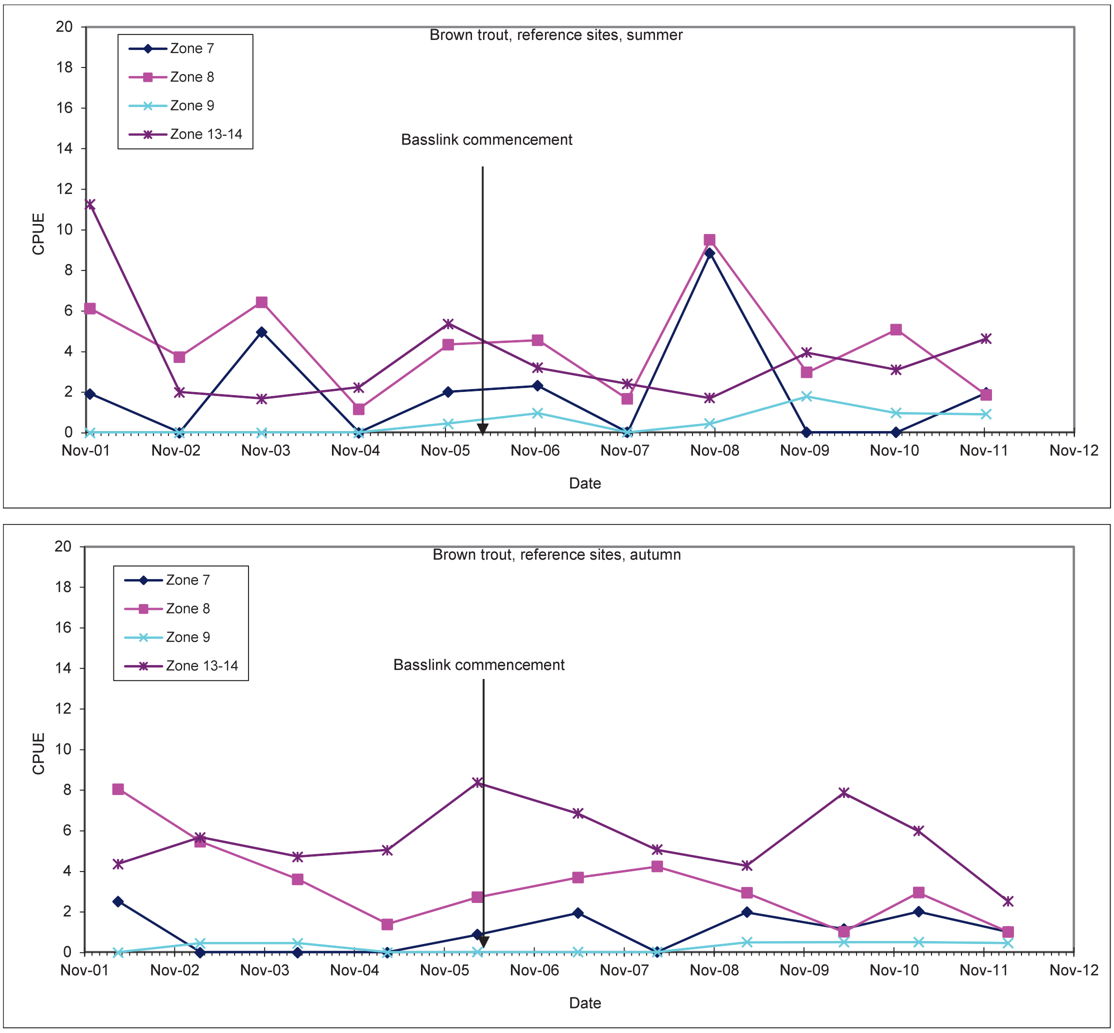


Figure 9-3 Seasonal (summer and autumn) CPUE for brown trout caught in the Reference zones between December 2001 and March 2012

### *9.3.1.2 Rainbow trout and Atlantic salmon (Salmoniidae)*

No rainbow trout or Atlantic salmon were captured during 2011–12, however these species have rarely been caught during the monitoring program and are very uncommon at any of the monitoring sites.

### *9.3.1.3 Perch (Percidae)*

Figure 9-4 shows the relative abundance of redfin perch in the Gordon River between the start of the monitoring program and the latest monitoring trip in 2012. Two fish were caught in summer at Gordon@G5 in zone 2, but none were observed or captured during autumn 2012.

Despite low catches in recent years, redfin perch continue to persist in the Gordon River below the dam, but their abundance and range is very restricted.

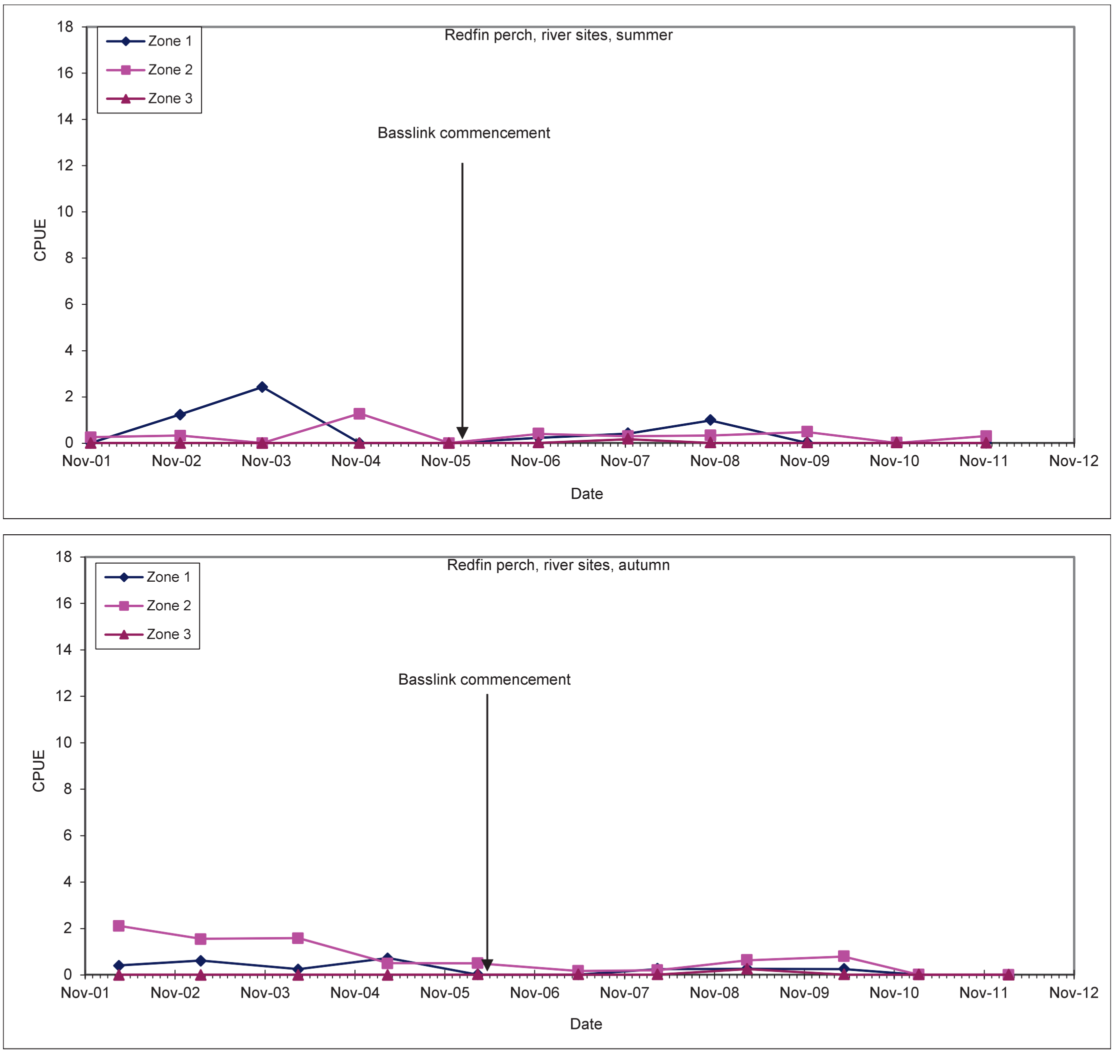


Figure 9-4 Seasonal (summer and autumn) CPUE for redfin perch caught in the Gordon River monitoring zones 1, 2 and 3 between December 2001 and March 2012

## 9.3.2 Native species

### *9.3.2.1 Lampreys (Mordaciidae and Geotriidae)*

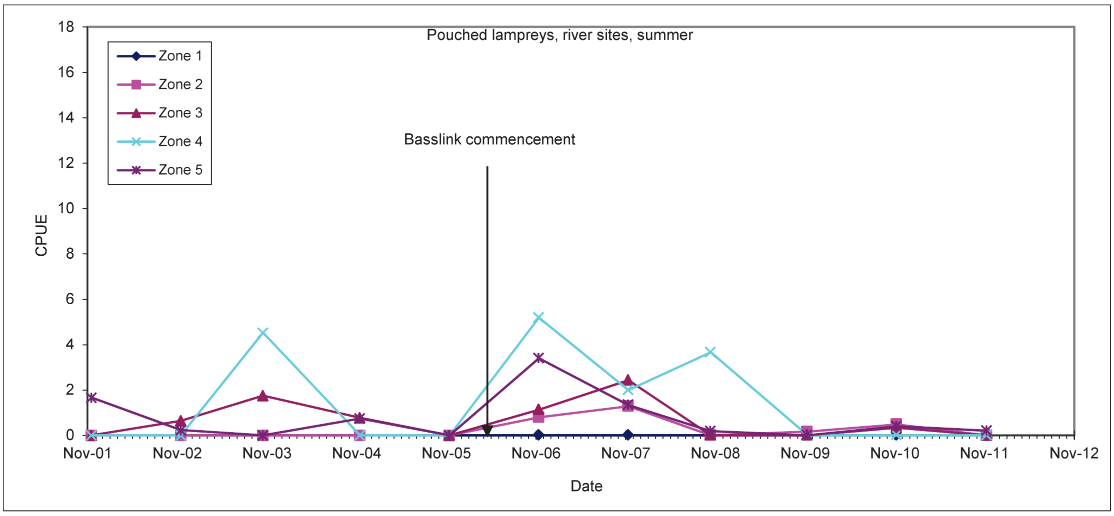
#### 9.3.2.1.1 Short headed lamprey (*Mordacia mordax*)

One short headed lamprey ammocete was caught from the lower reaches of the Olga River during the summer 2011 monitoring trip, and two ammocetes were captured from a zone 3 river and zone 4 tributary site in the 2012 autumn sample. This result is within their expected abundance levels and distribution range derived from baseline data.

#### 9.3.2.1.2 Pouched lamprey (*Geotria australis*)

Figure 9-5 shows the relative abundance of pouched lampreys in the Gordon River zones, and Figure 9-6 shows relative abundance data from the reference sites.

With the exception of zone 3, summer catches across all test and reference zones were similar to pre-Basslink means. Pouched lamprey abundances in zone 3 were lower than the pre-Basslink mean. Autumn results were more variable, as zone 2 catches were higher whilst zone 5 catches were lower than pre-Basslink means. Results from the references sites were also variable, with zone 7 results below and zone 8, 12–14 results above pre-Basslink means.



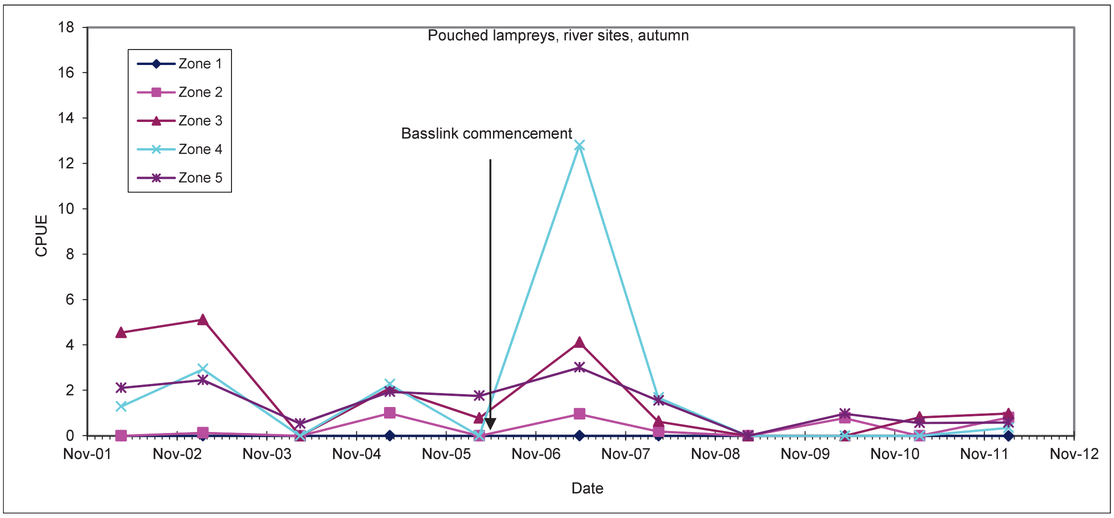


Figure 9-5 Seasonal (summer and autumn) CPUE for pouched lampreys caught in the Gordon River zones between December 2001 and March 2012

Previous Basslink Monitoring Reports (Hydro Tasmania 2010, Hydro Tasmania 2011) discussed the low and variable catches for these monitoring years. There has been no consistent abundance trend differentiating test from reference sites over the post Basslink period.

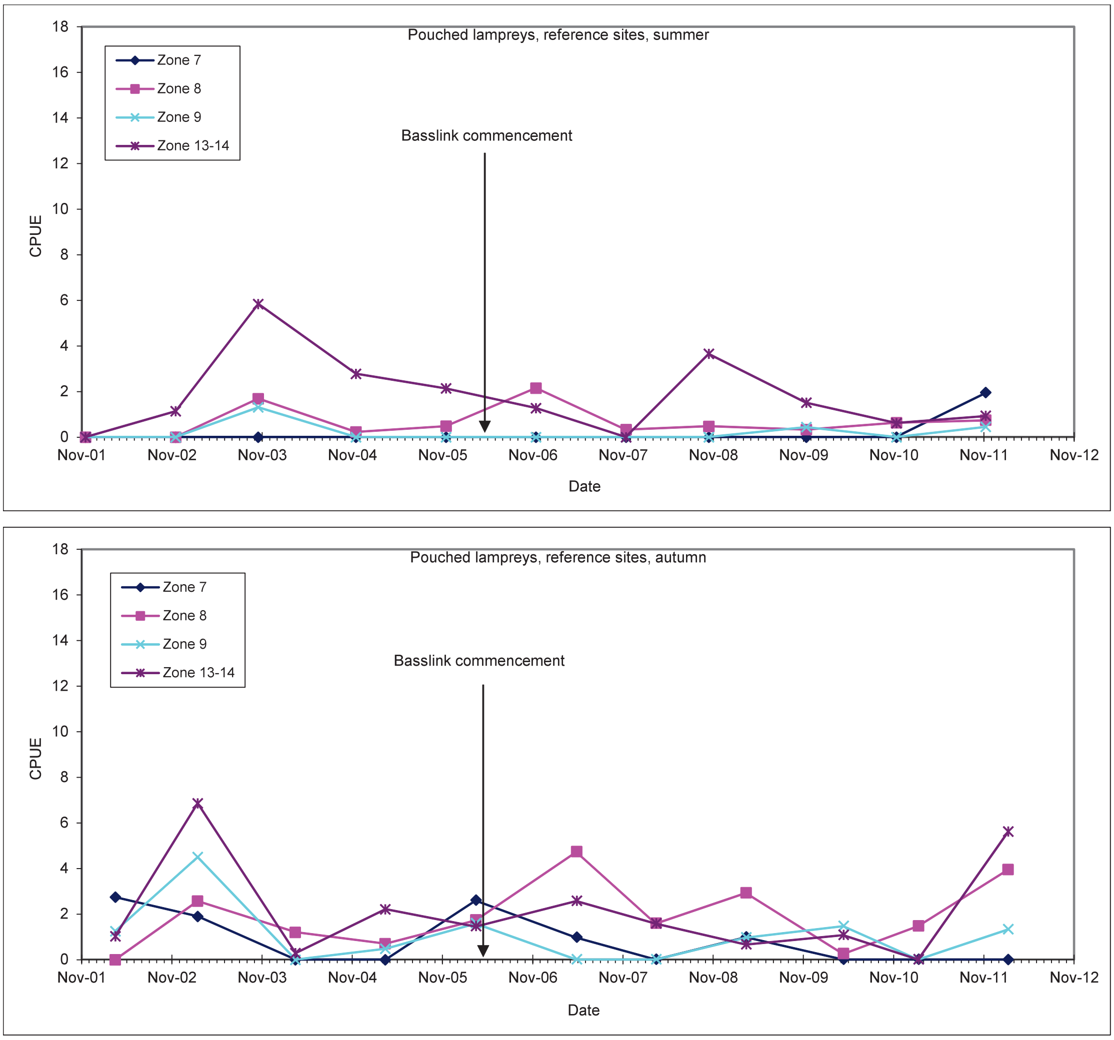


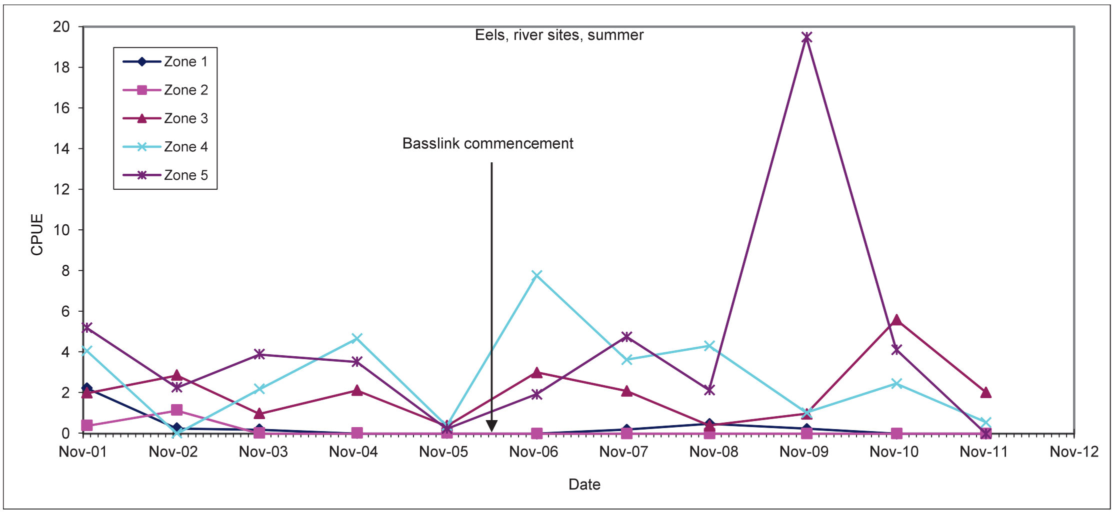
Figure 9-6 Seasonal (summer and autumn) CPUE for pouched lampreys caught in the Gordon River zones between December 2001 and March 2012

### 9.3.2.2 *Eels (Anguillidae)*

#### 9.3.2.2.1 Short-finned eels (*Anguilla australis*)

The relative abundance of short-finned eels over the duration of the monitoring period is shown in Figure 9-7. Summer catches were generally similar to pre-Basslink means across all monitoring sites (test and reference), and only zone 5 returned catches that were below pre-Basslink means.

Autumn catches from the reference sites were also similar to pre-Basslink relative abundances, but zones 2–4 returned catches that significantly exceeded pre-Basslink means. This observation is probably an artefact of the exceptionally strong recruitment that was observed in summer 2009.



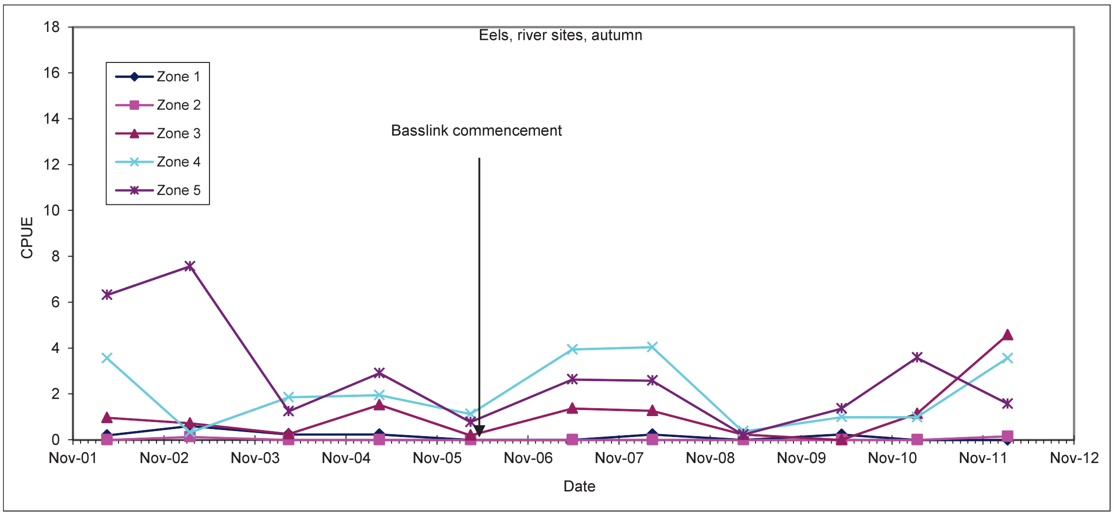


Figure 9-7 Seasonal (summer and autumn) CPUE for short finned eels caught in the Gordon River monitorng zones between December 2001 and March 2012

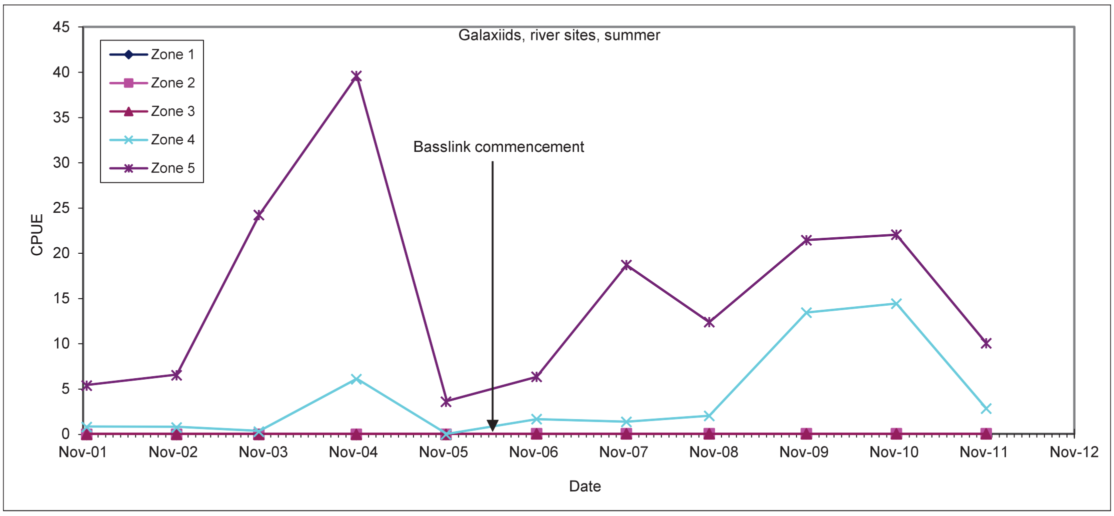
### *9.3.2.3 Galaxiids (Galaxiidae)*

Figure 9-8 and Figure 9-9 show the relative abundance of galaxiids in the Gordon River and tributary sites over the monitoring program. Relative abundance data for *G. truttaceus*, *G. brevipinnis*, *G. maculatus* and *N. cleaveri* have been used to derive these plots.

Galaxiid relative abundance in summer was similar to pre-Basslink levels in the Gordon River and tributary monitoring sites. This was generally the case for the reference sites, as zone 7 was the only reference zone to show results that exceeded the pre-Basslink mean.

Galaxiid relative abundances measured in autumn in river zones 3, 5, 7 and 8 exceeded pre-Basslink means, and tributary catches from zones 3 and 4 were also well in excess of pre-Basslink means. The zone 3 tributary results are noteworthy, as it appears as though galaxiid numbers have shown a small but notable increase in total numbers caught in the recent surveys in comparison to pre-Basslink abundances. However, the relatively small increases in catch per unit effort make it difficult to determine from Figure 9-9.

Previous annual reports (Hydro Tasmania 2010, Hydro Tasmania 2011) described strong recruitment of *G. truttaceus* in the catchment resulting in catch rates that were among the highest for all species sampled in the Gordon River, and once again this species was second only to brown trout in relative abundance. The six-year review will explore the significance of this result and possible factors that may be driving it, such as strong recruitment in previous years complimenting a possible environmental flow effect.



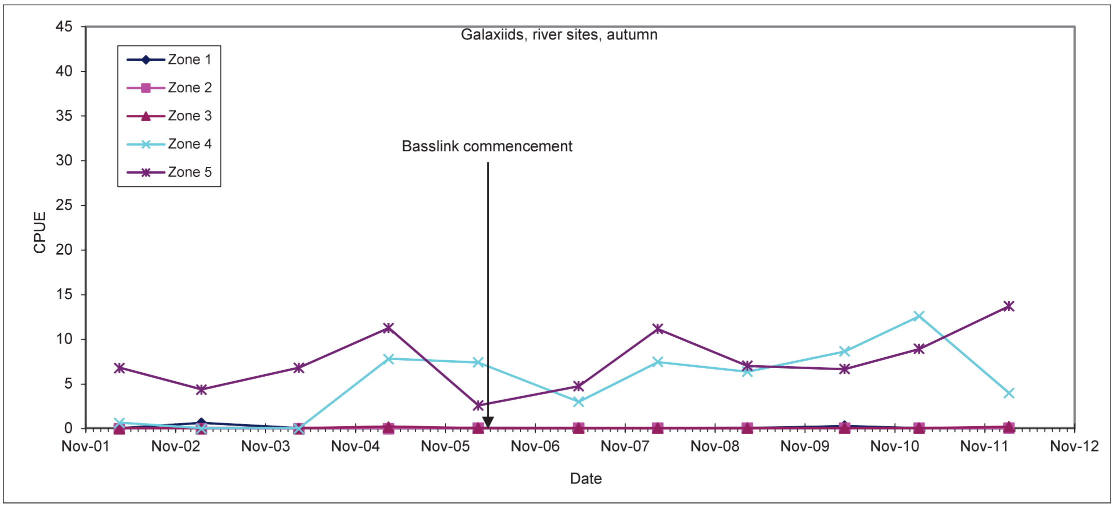
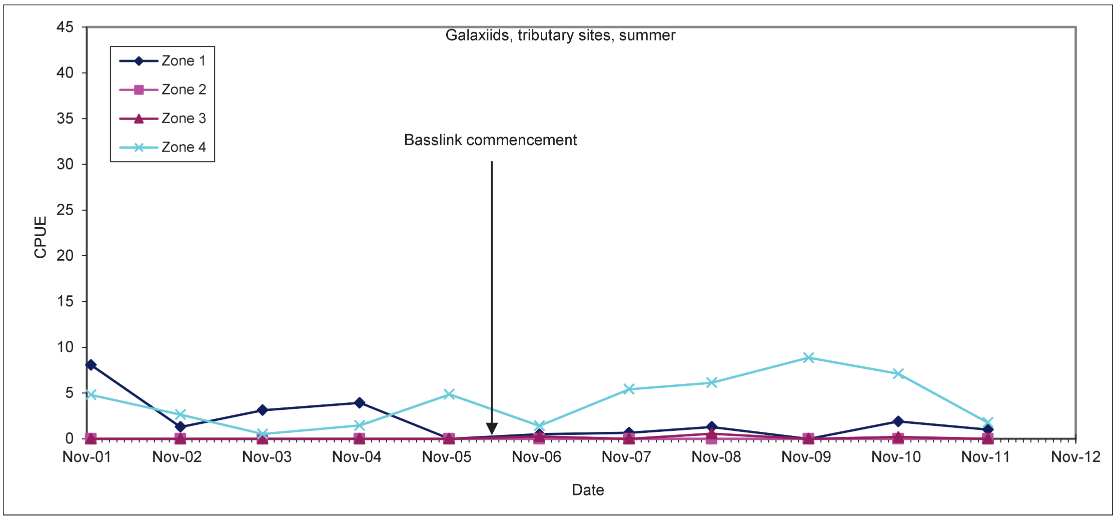


Figure 9-8 Seasonal (summer and autumn) CPUE for galaxiids caught in the Gordon River zones between December 2001 and March 2012

Climbing galaxias were present in low abundances in summer and autumn catches from zone 1 tributaries, which is consistent with previous years, and small numbers of fish were captured from zones 3 and 5. Once again recruitment to the test zones appears to have been limited in summer 2011, and there was no evidence of juvenile recruitment to zone 1. Catches of jollytails in the Gordon River were relatively low in summer, with small numbers caught in zone 5, which is consistent with previous results. Autumn catches in the monitoring zone were also restricted to zone 5, but catches were similar to the pre-Basslink mean.



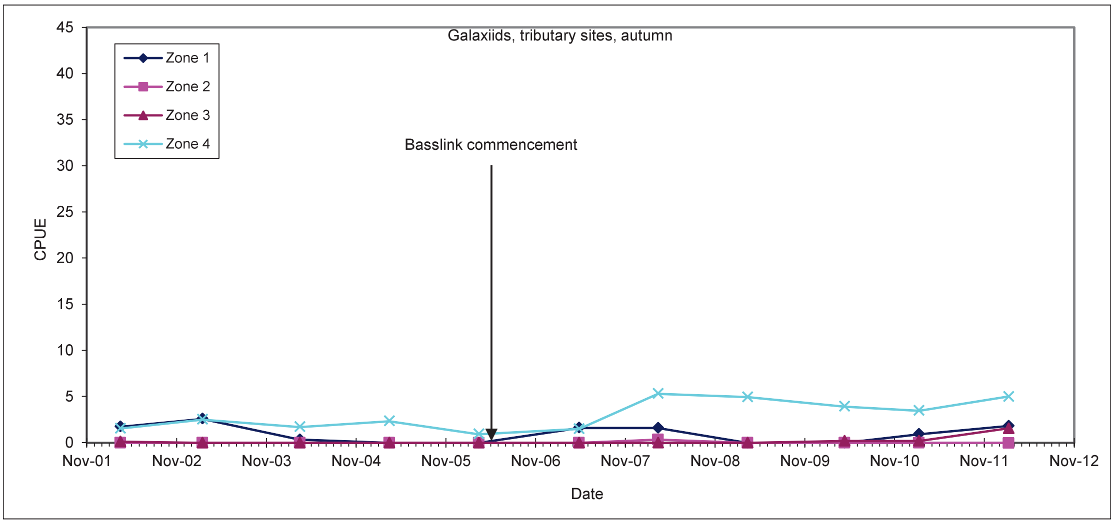


Figure 9-9 Seasonal (summer and autumn) CPUE for galaxiids caught in the Gordon tributary zones between December 2001 and March 2012

### *9.3.2.4 Bovichthyidae*

#### 9.3.2.4.1 Sandys (*Pseudaphritis urvillii*)

Figure 9-10 shows the relative abundance of sandys in zones 3 to 5 over the duration of the monitoring program (2001–12). As pointed out in previous annual reports, zones 1 and 2 are not included in this figure as the distribution of this species appears to be restricted to sites downstream of the Splits (zone 3). Zone 4 river and tributary catches exceeded pre-Basslink summer means, and autumn zone 4–5 river and zone 3–4 tributary catches also exceeded pre-Basslink means. Catches from the reference sites were variable and showed no consistent trend in abundance when compared to pre-Basslink means.

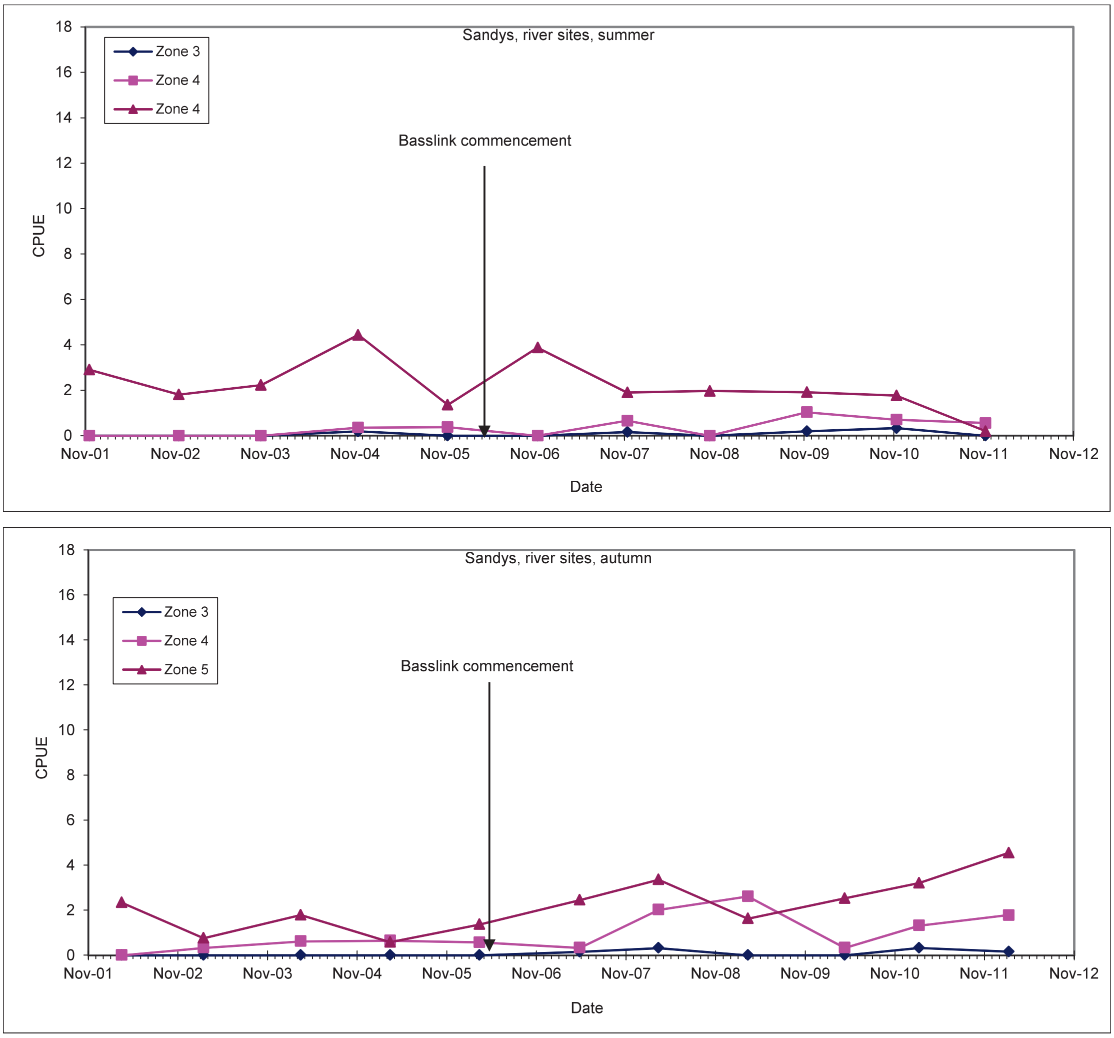


Figure 9-10 Seasonal (summer and autumn) CPUE for sandys caught in the Gordon river zones between December 2001 and March 2012

### 9.3.2.5 *Prototroctidae*

#### 9.3.2.5.1 Australian grayling (*Prototroctes maraena*)

Grayling have previously been caught on only one occasion during the monitoring program—one fish was caught at the Henty u/s Bottle Creek reference site in December 2004. No Australian grayling were caught during the 2011–12 survey, which is consistent with most of the previous monitoring years.

## 9.4 Fish stranding

No fish strandings were recorded during the 2011–12 monitoring surveys.

## 9.5 Trigger levels

Ten trigger levels have been developed for the Basslink fish monitoring program. Data was pooled from river and tributary sites and zones for assessment against trigger levels. Five triggers have been derived using autumn data, and the remaining five triggers were derived using annual data. Triggers are calculated for individual years, and there are also cumulative triggers based on pooled data over all post-Basslink years. Each trigger category has both upper and lower bounds. Exceedence of the lower bound may indicate a deterioration of the river's fish community relative to the Basslink period. With the exception of the exotic fish trigger, exceedence of the upper bound may indicate an improvement in the status of the river's fish community. However potential exceedences, regardless of direction, have been used as an indicative tool.

Performance against these triggers during the 2011–12 monitoring year and cumulative 2006–12 monitoring years is shown in Figure 9-11 to Figure 9-14.

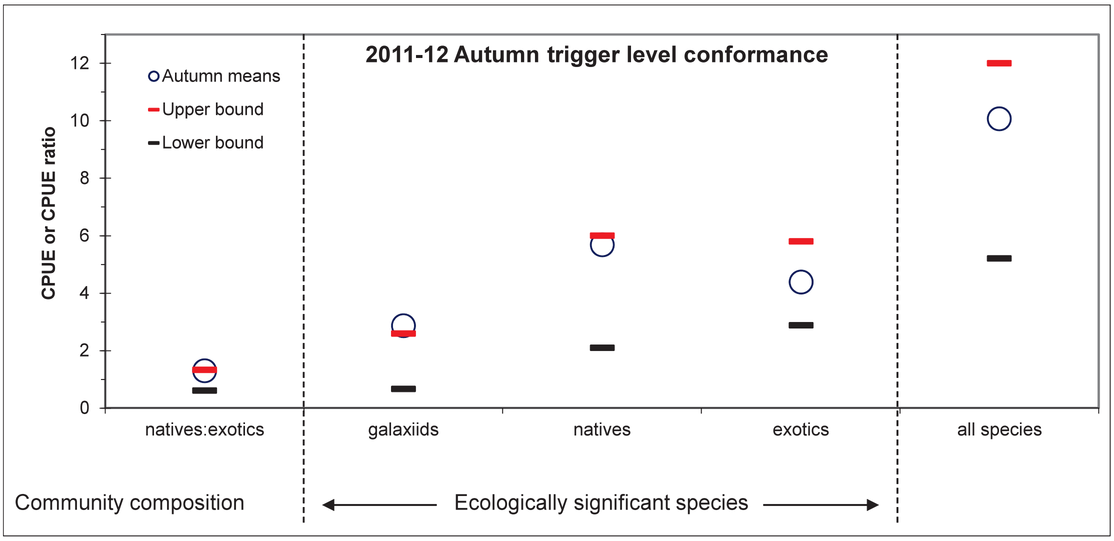


Figure 9-11 Summary of 2011–12 autumn trigger level conformance

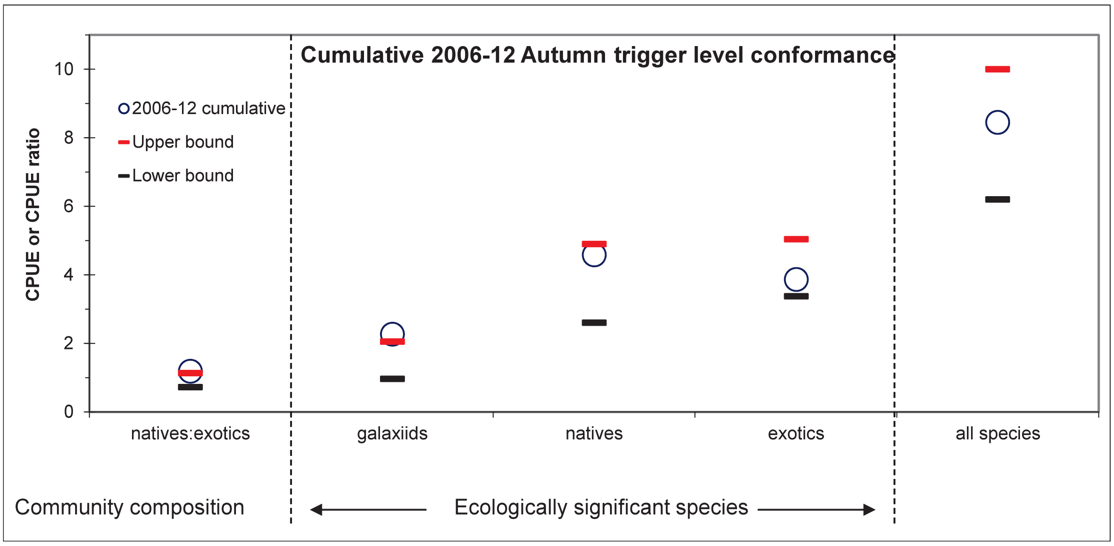


Figure 9-12 Summary of cumulative (pooled) 2006–12 autumn data trigger level conformance

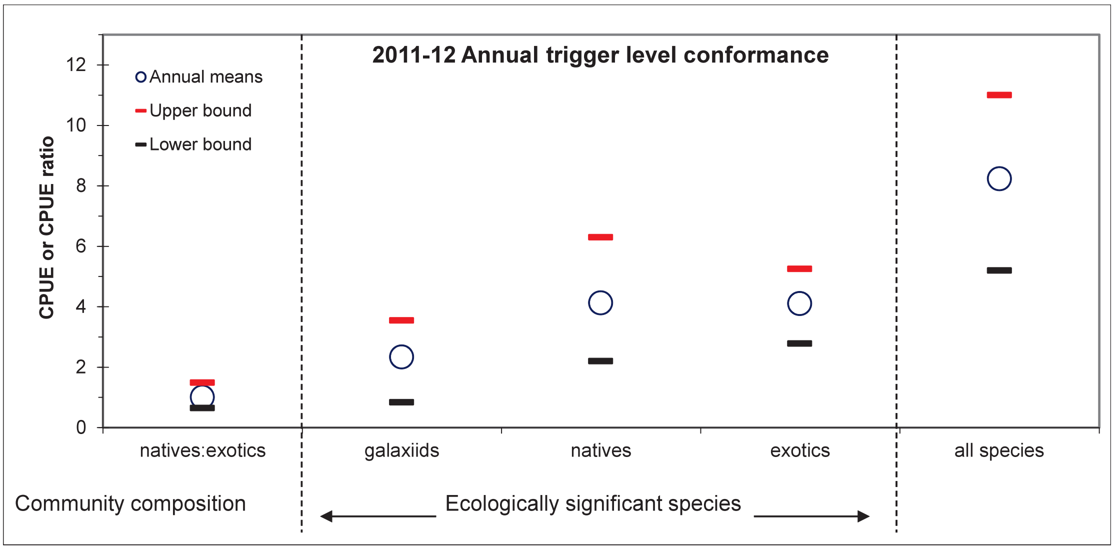


Figure 9-13 Summary of 2011–12 annual trigger level conformance

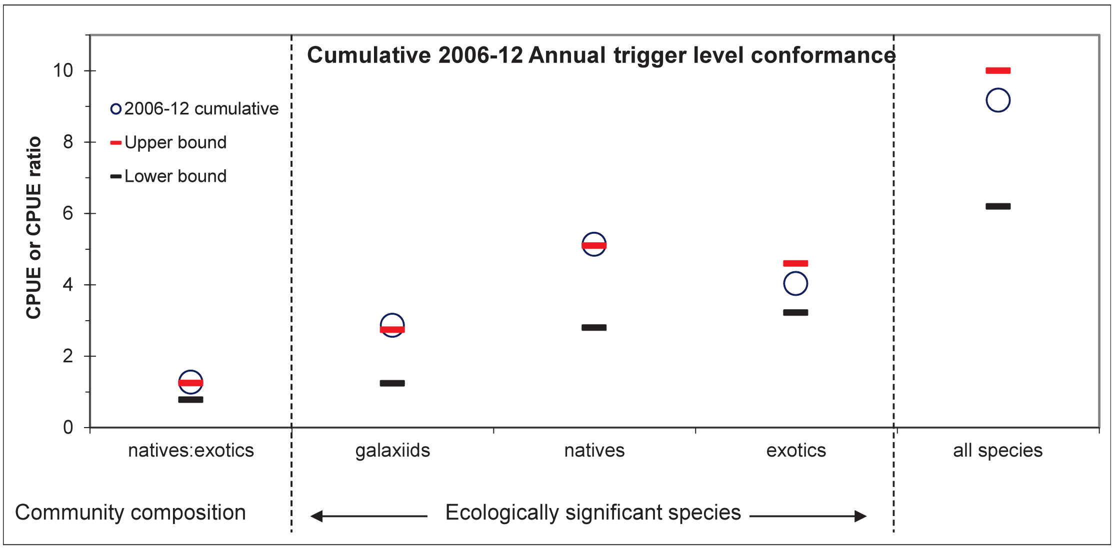


Figure 9-14 Summary of cumulative (pooled) 2006–12 annual data trigger level conformance

### 9.5.1 Community composition

Two trigger levels, derived from the ratio of native to exotic fish, have been developed to assess potential changes to community composition following the commencement of Basslink operations. Single season (autumn) and annual (summer and autumn) trigger values are shown in Appendix 10. Figure 9-11 and Figure 9-12 show a graphical representation of the 2011–12 autumn and cumulative 2006–12 autumn means in comparison to their respective triggers levels. Figure 9-13 and Figure 9-14 show the 2011–12 annual and cumulative 2006–12 annual means in comparison to their trigger levels.

The autumn and annual community composition indicators were within or above bounds of their respective triggers in 2011–12. The CPUE ratio in the autumn 2011 indicator and 2011–12 annual community composition indicator were within the upper and lower trigger bounds. The cumulative 2006–12 autumn and cumulative 2006–12 annual results exceeded the upper trigger bound. These results are similar to the last two monitoring years and were again driven by elevated native fish abundances relative to exotic (primarily trout) abundance. Trout abundances were generally comparable to pre-Basslink levels across the Gordon monitoring sites. This result indicates that the river's native fish relative abundance has increased comparative to pre-Basslink levels.

### 9.5.2 Ecologically significant species

Six trigger levels have been developed to assess the potential impact of Basslink operations on ecologically significant species. Seasonal trigger levels derived for native fish relative abundance, exotic species relative abundance and galaxiid relative abundance are shown in Appendix 10. Figure 9-11 and Figure 9-13 show performance against the triggers during 2011–12. Performance against the cumulative autumn and annual 2006–12 triggers is shown in Figure 9-12 and Figure 9-14.

All of the ecologically significant species categories were above their respective lower trigger bounds. Galaxiid relative abundance exceeded the upper 2011–12 autumn trigger level, the cumulative 2006–12 autumn and cumulative 2006–12 annual trigger levels.

High relative abundance of galaxiids leads to high relative abundance of native fish in comparison to pre-Basslink levels. The 2011–12 autumn, cumulative 2006–12 autumn and 2011–12 annual native fish abundances were within the trigger bounds, while the cumulative 2006–12 annual trigger for this category was in excess of the upper trigger bound. The 2011–12 annual trigger was the only category that was not approaching the upper bound. These results reflect good post Basslink native fish abundances, particularly in the later years of the monitoring program, which are primarily driven by strong spotted galaxias relative abundances.

The exotic fish category was within the pre-Basslink bounds of the autumn and annual 2011–12 and cumulative 2006–12 trigger levels, and as such has remained within the trigger bounds during the post Basslink period to date, indicating that there has not been a significant change relative to the pre-Basslink period.

### 9.5.3 Biomass/productivity

Two trigger levels have been developed to assess potential changes to biomass or productivity due to changed hydrological conditions following the commencement of Basslink operation. Trigger levels for this category were derived from autumn and annual relative abundance data for all fish species present in the Gordon River monitoring zones. Results for the 'all species' biomass/productivity trigger has been calculated for the 2011–12 monitoring year and the pooled 2006–12 monitoring years. The 2011–12 results are shown in Figure 9-11 and Figure 9-13. The cumulative 2006–12 results are shown in Figure 9-12 and Figure 9-14.

All species relative abundance reflected pre-Basslink conditions, sitting midway between the lower and upper bound for most categories, and there have been no exceedences of the lower bound throughout the post Basslink monitoring period. The cumulative 2006–12 annual result continues to be well above its lower trigger bound. These results indicate that the relative abundance/biomass of the Gordon River's fish assemblage is comparable to the pre-Basslink period, and is buoyed by strong native fish abundance.

## 9.6 Conclusions

Spotted galaxias were the most abundant native fish in the river over summer, second only to brown trout in autumn, reflecting strong recruitment in previous years. Climbing galaxias and jollytails were caught in relatively small numbers which is consistent with previous years.

Brown trout were the most abundant of all species, native or exotic, captured in the river during the 2011–12 monitoring surveys. Redfin perch were the only other exotic captured, and they were present in small numbers in the upper monitoring zones (1 and 2), and no increase in their distribution was detected. These results are consistent with previous surveys.

Brown trout catches in the upper Gordon River and its tributaries appear to have increased in the post Basslink period. These increases have not resulted in exceedences of the upper exotic trigger which is calculated across pooled zones.

Pouched lampreys abundances were variable, with summer relative abundances across all zones similar to pre-Basslink levels. Autumn results were variable within the test and reference sites and showed no consistent trends relative to pre-Basslink abundances. Short headed lampreys are uncommon at the test and reference sites, and the low catches recorded during the year were consistent with the results from previous years. Rapid fluctuations in stream water levels and power hydropeaking can strand ammocoetes in the substrate and isolate them from flowing water (Columbia River Basin Lamprey Technical Workgroup, 2012), and so hydropeaking operation has the potential to impact upon lamprey population. The Basslink Six Year Review Report will assess the data more rigorously and determine whether there are any detectable linkages between lamprey abundance and a range of pre-/post Basslink flow components, particularly those related to hydropeaking.

Short finned eel abundances were generally similar to pre-Basslink means, with elevated catches in autumn probably reflecting strong recruitment in previous years.

Trigger results were above the lower bound for all categories. Out of the 10 triggers for the 2011–12 autumn and annual categories, one upper bound exceedence occurred in autumn galaxiid relative abundance (ecologically significant species). Five exceedences of the upper bound occurred in the cumulative 2006–12 autumn and annual triggers in the following categories:

- the ratio of native to exotic fish;
- galaxiid relative abundance; and
- native fish relative abundance.

Exceedences were driven by elevated *G. truttaceus* abundance and reflect strong recruitment of this species in the Gordon River over the post Basslink period. As per the previous annual report (Hydro Tasmania 2011) exotic species and all species triggers were the only triggers not to exhibit exeedence(s) of the upper bound in any of the trigger categories (autumn, annual, single year or cumulative year).

# 10 Discussion of trigger results

## 10.1 Introduction

The decision tree framework developed in 2007–08 (Hydro Tasmania, 2008), and revised as part of the three-year review (Hydro Tasmania 2010a), has been used to assess trigger exceedances for individual disciplines and to identify linkages between disciplines. The updated decision tree, shown in Figure 10-1, provides a broad framework for the interpretation of results. It should be considered a guide for interpreting results only, as scenarios may arise that fall outside of the framework.

## 10.2 Application of decision tree to individual disciplines

The decision tree technique is applied to the disciplines of fluvial geology, macro-invertebrates, algae and moss, riparian vegetation and fish. Hydrology, water quality and karst geomorphology are not assessed as these disciplines are not associated with any formal triggers.

Results for the 2011–12 monitoring year have been assessed against triggers derived for a single year comparison as well as for the 2006–12 time period.

The following discussion for individual disciplines focuses on results and trigger exceedances for the 2011–12 monitoring year. The discussion in each discipline provides brief synopsis of the relationship between the trigger value results and the decision tree. 'Steps' mentioned in the discussions refer to the decision tree in Figure 10-1. Additional discussions of trigger results are contained in the individual discipline sections.

### 10.2.1 Fluvial geomorphology

Using the Basslink decision tree to evaluate the Gordon River geomorphology results is difficult because the decision tree is based on the interpretation of trigger value results, and the geomorphology trigger values, in isolation, have been found to be an unsatisfactory way to identify post-Basslink changes. The Basslink Review Report 2006–09 (Hydro Tasmania, 2010a) recommended, and the Gordon River Scientific Reference Committee agreed, that a multiple-lines-of-evidence approach should be used to evaluate the geomorphology results, with the triggers constituting one of the lines of evidence. Other information to be considered includes field observations, photo-monitoring, piezometer results and the analysis of hydrologic parameters. In line with this approach, the following analysis uses all results to evaluate the 2011–12 findings with respect to the conceptual model, rather than limiting the analysis to the trigger values alone.

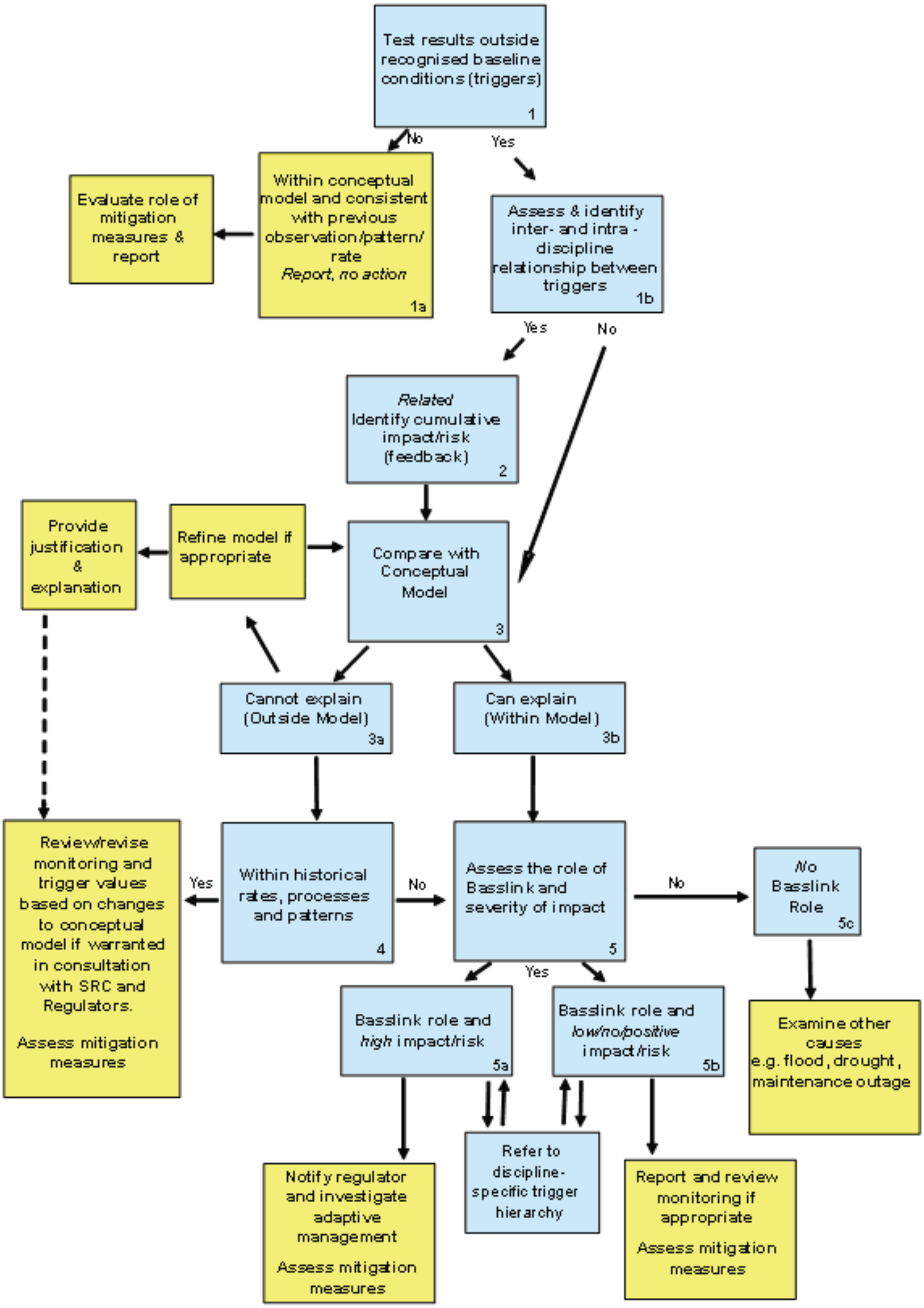


Figure 10-1 Decision tree for interpreting Basslink trigger results. Yellow boxes show outcomes and actions, numbers refer to ‘streams’ referred to in discussion

At a broad scale, equivalent to 'step 1' in the decision tree, the 2011–12 results are outside of the pre-Basslink baseline condition upon which the triggers were based, but consistent with the conceptual model and previous observations and patterns (step 1b). For the past three monitoring years the hydrology of the river has differed considerably from the pre-Basslink monitoring years and the first three post-Basslink monitoring years due to the low total volume of flow discharged from the power station. These flow patterns have resulted in conditions which are outside of previous observations, but consistent with the conceptual model of the river under low flow. The predominant features of the 2011–12 monitoring year include:

- the continued presence and increased growth of vegetation in the 1–2 and 2–3 turbine bank levels under low power station discharge conditions;
- the 2–3 turbine bank level has remained unsaturated with the exception of some limited periods in May 2011. The photo-cam cameras captured features associated with seepage processes during the high saturation period at sites known to be highly active, but evidence of seepage erosion was not widespread through the river; and
- erosion pins have shown low levels of change, with the <1-turbine pins generally showing deposition, and the upper banks erosion or no change. This is consistent with the overall flattening of bank toes and steepening of the bank which has been observed throughout the Basslink monitoring period.

These observed characteristics were not common during the pre-Basslink monitoring period, but are consistent with the conceptual model and understanding of the relationship between power station operation, bank saturation, seepage erosion and scour.

The 2011–12 monitoring year has been consistent with the understanding of how power station operation affects bank saturation and draining. The short-duration high flow events which predominated during the winter only resulted in high levels of bank saturation when the power station continued discharging at ~two turbines between maximum peaks. This is consistent with the conceptual model, and is reflected in the requirements of the 'new' ramp-rule which aims to prevent bank saturation, rather than only regulating draw-down rates.

The erosion pin trigger values for geomorphology remain outside of the pre-Basslink predictions due to a combination of an extreme flood event in August 2007, which led to widespread alterations to the river, combined with little change over the past few years. The low rates of change observed in the Gordon River over the past three post-Basslink years are likely attributable to the low flow volumes released by the power station over this period, combined with a lack of major flooding, rather than power station operations associated with Basslink.

Overall the monitoring results for the 2011–12 monitoring year are consistent with the understanding of the river and conceptual model. The deviation of the results from the derived trigger values owes more to the assumptions that are the basis of trigger values (i.e. that erosion rates will remain uniform over time), rather than post-Basslink changes.

The impact of the mitigation measures on the geomorphology results is assessed as follows:

- **Minimum flow**—the minimum flow has minimal direct effect on the banks of the Gordon River. Some rilling has been observed on bank toes following power station shutdown associated with Basslink monitoring, which is attributable to the toe being saturated under the environmental flow, however similar features were observed pre-Basslink following power station shutdown in the absence of a minimum flow. Theoretically, the higher minimum water level following a decrease in power station discharge will reduce scour rates, as scour is related to the surface slope of the river, and a higher minimum level will reduce the surface slope of the river following power station shutdown.
- **Ramp-down rule**—The risk of seepage erosion remained low throughout the year, except for some limited periods during winter, when power station discharge did not decrease substantially between power station peaks. These conditions are less likely to occur in the future as the ramp-rule has been revised and is now aimed at preventing the occurrence of bank saturation, as well as requiring ramped power station discharges when saturation levels are high. The 'new' rule aligns operational and environmental considerations.

### 10.2.2 Riparian vegetation

The analysis of the trigger values for riparian vegetation showed that 21 of the 37 vegetation values were outside trigger bands in the 2011–12 monitoring year (Table 10-1). Trigger responses are grouped into two main ecological variables that can be used to assess the health, or otherwise, of riparian vegetation:

- community composition, assessed at the zone level; and
- plant abundance by life form, assessed at the whole-of-river scale.

Where triggers for the whole-of-river have shown deviations outside trigger bands, data has been explored at the zone scale to determine if the response is occurring in all areas, if particular areas are driving the changes, or if other areas are masking real effects (step 1).

Community composition triggers for similarity indices were outside pre-Basslink trigger ranges generally by only a small margin. The Bray Curtis similarity indices used are highly sensitive to small changes in the number of species present. This is particularly the case where the quadrat size is small (1 $m^2$) and species diversity is low. The pre-Basslink trigger ranges were calculated from only three years of data, which is unlikely to have captured all of the species variation present in the system. Therefore the community composition metric is now including the additional variation that has been recorded when measurements have been made over a longer timeframe.

Higher quadrats tended to be comparatively stable while lower quadrats were becoming less similar. Species in lower quadrats establish, persist for a period and then are lost or replaced by others. There appears to be a number of species which occur in these plots and due to the small sample size it is stochastically determined which species are present in any given plot at any given time. No species were recorded this year that had not previously been observed, however particular herb and graminoid species are becoming more prevalent in the lower quadrats due to the low flows.

Values for species richness were above trigger range in five instances and these were generally in the lower quadrats. This is consistent with the increased recruitment of species in periods of low flow. This metric measures the total number of species present and the sample size is small, so the recording of one or two additional species in quadrats is sufficient to exceed the trigger range and this is readily explained in years of enhanced recruitment.

Species evenness triggers were marginally below the pre-Basslink ranges for one quadrat type in zone 4 and is the result of the increased dominance of some shrub species, particularly at one site on a cobble bar in the middle of the river. This site is being inundated and eroded, resulting in the removal of smaller herb species, however the larger shrub species persist and continue to dominate resulting in a reduction in species evenness.

Trigger values based on the presence of life forms were variable. Bryophyte measures were within trigger value ranges and responses between zones were variable. The cover of bryophytes either increased slightly or remained stable compared to the previous year.

Trigger values for the comparison of ratios of ‘above’/‘low’ for percentage ferns was within trigger ranges. However, trigger values were outside the trigger ranges for ‘above’/‘high’ ratios. This is likely to be the result of the continued expansion of ferns in the ‘above’ quadrats rather than any significant losses of ferns from the ‘high’ quadrats. Ferns tend to be more common on upper banks and a largely absent from ‘low’ quadrats.

Ratios for ‘above’/‘high and ‘above’/‘low’ for percentage shrubs were within trigger ranges for one-year means but fell outside the upper margins for the six-year means, indicating higher measures over the last six years rather than particularly elevated values this year.

The ratio of ‘above’/‘high for percentage bare ground was within trigger value ranges. However, trigger values were below the lower trigger ranges for ‘above’/’low’ comparisons. This was a result of a relatively greater reduction in bare ground in ‘above’ quadrats rather than an expansion of bare ground in low quadrats.

Trigger values ratios of total vegetation were marginally outside the range for the one-year and six-year cumulative ratio comparisons for the ‘above’/‘low’ ratios and outside the six-year cumulative ratio for the ‘above’/’high’ ratios.

The lower than expected result for the ‘above/’low’ ratios for the one-year result is likely to be due to the recovery of vegetation in ‘low’ quadrats in 2011–12, while the exceedance of the upper trigger for the six-year cumulative measure is the result of a number of high ratio values over the past six years. This again is likely to be caused by continued vegetation expansion in the ‘above’ quadrats in comparison to the relative abundance of total vegetation cover found in the ‘high’ and ‘low’ quadrats impacted by water flows.

Interpretation of changes in these cover ratios should be treated with caution and highlights the quite different processes that are occurring in these quadrat types. The trigger ranges can be exceeded due to changes in the impacted quadrats but also due to changes to the ‘above’ quadrats.

When assessed within the decision tree framework, these deviations from trigger values proved to be outside baseline conditions (hence the triggers being exceeded) but did show interdisciplinary relationships (step 1b). Declines in bare ground and the associated increase in vegetation cover in quadrat types was reflected in the geomorphological studies which recorded another year where overall rates of change remained low and similar to the past few years based on the results of the erosion pin measurements.

Following the decision tree process, these results are within conceptual model processes (steps 3 to 3b). The model identifies the recovery of vegetation during periods of low flows. The role of Basslink in this process (step 5) is considered to be minimal (5b) because the establishment of vegetation on the river banks is part of a response to low power station discharges during this year and preceding years. Therefore, the navigation through the decision tree for the values outside triggers ends with a combination of a low Basslink impact and no Basslink effect.

These results reflect the relationship between the vegetation and flow patterns on the river identified in pre-Basslink monitoring and in the conceptual model, with the lower total power station discharges in 2009–12 leading to the subsequent recovery of vegetation which has continued into 2012. Linkages to geomorphological processes are summarised in section 10.3.

### 10.2.3 Macroinvertebrates

Nine measures incorporating 126 individual triggers (see Appendix 8.3) were assessed for macroinvertebrates under the five following components:

- community structure—Bray Curtis (abundance) and O/Erk;
- community composition—Bray Curtis (presence/absence) and O/Epa;
- taxonomic richness—N taxa (family) and N EPT species;
- ecologically significant species—abundance EPT and proportional abundance EPT; and
- biomass/productivity—total abundance.

Performance against triggers is assessed for each site for the 2011–12 monitoring year. Results are also combined and assessed at the whole-of-river (WOR) scale for the whole year and both seasons (spring and autumn), as well as at the zone scale (zone 1 and 2).

Three of the nine measures (O/Epa, O/Erk and total abundance) did not have any significant trigger exceedances when analysed across all sites, both zones and whole-of-river year and seasons (spring/autumn) scales (Table 10-1). These results are consistent with the pre-Basslink conceptual models, as well as with previous observations and patterns (steps 1 and 1a).

Eight indicators exhibited local exceedances when reported at site level as well as frequently recording exceedances at the whole-of-river or zone level. These were as follows:

- **Bray Curtis (abundance)**—minor exceedances were recorded above the upper trigger bound at sites 72 and 57; also minor exceedances were observed of the upper trigger bounds for whole-of-river, all year and for the autumn season, and for zone 1;
- **Bray Curtis (presence/absence)**—minor exceedances were recorded above the upper trigger bound at sites 72 and 75; also minor exceedances were observed of the upper trigger bounds for whole-of-river, all year and for the autumn season;
- **O/Epa**—minor exceedances were recorded above the upper trigger bound at sites 69 and 75;
- **N Taxa (family)**—exhibited an exceedance for the whole-of-river both in the autumn season and all year, and a minor exceedance at site 48;
- **NEPT species**—exhibited a minor exceedance for the whole-of-river in the autumn season;
- **Proportional abundance EPT**—all values above upper trigger levels for sites 69, 74 and 75; no exceedances at WOR or zone scales, though values fall just above the lower trigger bound in spring and zone 2;

- **Abundance EPT**—greatly exceeded upper trigger bound at all sites except site 60 (zone 1); greatly exceeds for WOR (all year and both seasons) and for both zones; and
- **Total abundance**—all sites compliant, though with exceedances above the upper trigger values for sites 48 and 57; exceedances above upper bounds for whole-of-river (all year and both seasons) and zone 2.

None of these trigger bound exceedances constitute a negative Basslink effect (i.e. a decline in biodiversity or community structure relative to reference streams). All represent either minor or substantial improvements in biological condition—which, though often small, are statistically and, especially for zone 1, ecologically significant.

Raised aquatic insect abundances, especially snowflake caddis (*Asmicridea*), Gripopterygid stoneflies and Hydrobiosid caddis at sites above the vicinity of the Denison confluence, are (again) the primary cause of the trigger bound exceedances recorded in zone 1 in 2011–12. This phenomenon is consistent with the conceptual model (step 1a) as these abundances are expected to be highly responsive to changes in (minimum) flow stability as well as in tributary inputs in food resources.

Introduction of the minimum environmental flow was expected to promote the abundance of filter feeding EPT species, especially *Asmicridea*, as this flow provides protection from bed dewatering and/or extreme low water velocities at low flows and between power station releases (absent under pre-Basslink conditions). This is not seen as a negative ecosystem response, although it is sensitive to the post-Basslink flow regime in combination with natural catchment inputs.

A decline in relative abundance of *Asmicridea* at sites in the immediate vicinity of the Denison confluence (sites 57 to 63) was also observed, particularly in spring 2011, part of a longer term decline in zone 2 observed since 2008. Provision of the minimum flow by control of releases from the power station will tend to shift the response (and hence peak abundance) of this genus to upstream of the Denison confluence.

A rise in overall diversity and abundance of aquatic insects, especially in zone 1, is driving an increase in community compositional similarity towards that recorded in the reference rivers. This change is reflected in changes in Bray Curtis index values, which now fall close to (and just below) the upper trigger bound. Bray Curtis (pres/abs) values are also high in zone 2, though still mainly below upper trigger bounds.

None of the trigger exceedances were inconsistent with the conceptual model.

The primary mitigation measure affecting macroinvertebrates is the minimum environmental flow. Consistent results for indicators within or above the upper trigger bounds at a range of scales indicates that this measure is protecting the fauna from post-Basslink changes in the flow regime that might otherwise cause declines in abundance and/or diversity. The minimum environmental flow is also leading to abundances of key flow-obligate species, such as *Asmicridea*, exceeding those observed pre-Basslink and thus exceeding the upper trigger bounds (step 6). Community compositional similarity to reference rivers has therefore risen slightly, indicating an overall improvement in ecological condition, especially in zone 1 above the Denison River.

With regard to the decision tree (Table 10-1), the macroinvertebrate indicators are either consistent with the conceptual model and within pre-Basslink ranges (step 1a) or are experiencing small changes driven by Basslink flow changes, but with a neutral or positive impact (step 5b). No changes to mitigation actions are required at this stage.

### 10.2.4 Algae and moss

The following is a description of the trigger behaviour within the context of the decision tree framework, for the algae and moss triggers (see Appendix 10) for 2011–12. Two measures were examined for algae and moss, with performance against a total of 28 triggers assessed at the site, zone (1 and 2) and whole-of-river (WOR) scales (all year, spring and autumn):

- **Filamentous algae cover**—values in 2011–12 fell within trigger bounds at all sites except for minor exceedances at site 72. No exceedances were observed for whole-of-river, for all year or either season, or for the two zones. These observations are therefore consistent with pre-Basslink conditions and the conceptual model (step 1a); and
- **Moss cover**—values in 2011–12 fell within trigger bounds for all sites, as did whole-of-river and zone values (step 1). The observations remain consistent with the conceptual model (step 1a).

The algal and benthic moss cover indicators are consistent with the conceptual model and within or very close to pre-Basslink ranges (step 1a, Figure 10-1). No changes to mitigation actions are required at this stage.

### 10.2.5 Fish

Trigger levels are grouped into three principal categories—community composition, ecologically significant species and biomass/productivity—and five indicator variables are nested within these groups. The derivation of these categories is discussed in Hydro Tasmania (2006).

The fish 2011–12 trigger levels results were within or above trigger bounds.

No lower trigger level exceedances were reported (step 1), with all fish measures including galaxiid, native fish, exotic, native to exotic ratio, and all species relative abundances above lower indicator levels. However, the cumulative 2006–12 autumn and annual community composition indicators were marginally in excess of their respective trigger level, which was a result of the elevated ratio of native fish abundance to exotic species abundance over several monitoring years. Upper trigger levels were also exceeded for the autumn, cumulative autumn, and cumulative annual galaxiid abundance. The cumulative annual native fish abundance was also in excess of the trigger bounds. These upper trigger level exceedances do not represent a negative Basslink effect, but reflect an increase in post-Basslink native fish abundances, particularly in the later years of the monitoring program.

The results were consistent with the conceptual model, as proposed in the Basslink Baseline Report (Hydro Tasmania 2005), and were generally consistent with previous observations, including the minor community composition upper trigger exceedences in recent years. As was noted in the 2010–11 Annual Report (Hydro Tasmania 2011), it is difficult to determine whether these small, positive exceedences are linked to the effect of the environmental flow (5b), natural processes (5c) or a combination of both. No follow-up actions or changes to mitigation measures are recommended, as there is a low risk of negative Basslink impact.

## 10.3 Links between disciplines

As in 2010–11, the exceedances of the various disciplines in 2011–12 were again principally influenced by hydrology. The only disciplines that appear to show related responses to hydrology are geomorphology and riparian vegetation. A summary of the links between disciplines, and the influence of hydrology is as follows:

- as was found in the 2010–11 monitoring, the 2–3 turbine bank level has remained unsaturated. The geomorphological field observations found that there was no evidence of widespread seepage erosion throughout the river, although there were seepage processes features recorded during the high saturation period at sites known to be highly active;
- geomorphological field observations have shown low levels of change, with the below one-turbine pins generally recording deposition, and the upper banks showing erosion features or no change. These observations reflect the overall flattening of bank toes and steepening of the bank, which has been observed throughout the Basslink monitoring period, and are consistent with the results of the vegetation quadrat analysis;
- the results of the geomorphological and vegetation monitoring reflect the relationship between the vegetation and flow patterns on the river identified in pre-Basslink monitoring and in the conceptual model, with the lower total power station discharges since 2009 leading to the recovery of vegetation, which has continued into 2012;

- the primary mitigation measure affecting macroinvertebrates is the minimum environmental flow. Consistent results for indicators within or above the upper trigger bounds at a range of scales indicates that this measure is protecting the fauna from post-Basslink changes in the flow regime that might otherwise cause declines in abundance and/or diversity. Community compositional similarity to reference rivers has therefore risen slightly, indicating an overall improvement in ecological condition, especially in zone 1 above the Denison River; and
- there are no clear links that can currently be drawn between positive fish trigger exceedances and other disciplines.

Table 10-1 Summary of trigger value exceedances across all disciplines for 2011–12

| **Discipline** | **Trigger** | **Zone/Site/Season** | **Trigger exceeded** | **No. and proportion of triggers of exceeded (2011–12)** | **Trigger response** |
|---|---|---|---|---|---|
| Geomorphology<br>5 trigger values | *4 triggers exceeded out of total 5 (80%)* | | | | |
| | Erosion pins | zone 1 | - | 0 out of 1 | - |
| | Erosion pins | zone 2 | Below trigger bands | 1 out of 1 | Note and explain with multiple lines of evidence |
| | Erosion pins | zone 3 | Below trigger bands | 1 out of 1 | Note and explain with multiple lines of evidence |
| | Erosion pins | zone 4 | Below trigger bands | 1 out of 1 | Note and explain with multiple lines of evidence |
| | Erosion pins | zone 5 | Above trigger bands | 1 out of 1 | Note and explain with multiple lines of evidence |
| Macroinvertebrates<br>126 trigger values | *37 triggers exceeded out of total 126 (29%)* | | | | |
| Community structure | Bray Curtis (abundance) | sites 57, 72, WOR (all year, autumn), zone 1 | Above trigger bands | 5 out of 14 | Note and explain |
| | O/Erk | - | - | 0 out of 14 | - |
| Community composition | Bray Curtis (pres/abs) | Sites 75, 72, WOR (all year, autumn) | Above trigger bands | 4 out of 14 | Note and explain |
| | O/Epa | Sites 69 and 75 | Above trigger bands | 2 out of 14 | Note and explain |
| Taxonomic richness | N taxa (families) | Site 48, WOR (all year, autumn) | Above trigger bands | 3 out of 14 | Note and explain |
| | N EPT taxa | WOR (autumn) | Above trigger bands | 1 out of 14 | Note and explain |
| Ecologically significant species | Proportion abundance EPT | Sites 69, 74 and 75 | Above trigger bands | 3 out of 14 | Note and explain |
| | Abundance EPT | Sites 42, 48, 57, 63, 69, 72, 74 and 75<br>WOR (all year, autumn, spring, zones 1 and 2) | Above trigger bands | 13 out of 14 | Note and explain |

| Discipline | Trigger | Zone/Site/Season | Trigger exceeded | No. and proportion of triggers of exceeded (2011–12) | Trigger response |
|---|---|---|---|---|---|
| Biomass/productivity | Total abundance | sites 57 and 48, WOR (all year, spring, autumn), zone 2 | Above trigger bands | 6 out of 14 | Note and explain |
| Benthic algae and moss cover<br>28 trigger values | *0 triggers exceeded out of total 28 (0%)* | | | | |
| | % filamentous algae cover | - | - | 0 out of 14 | - |
| | % moss cover | - | - | 0 out of 14 | - |
| Riparian vegetation<br>37 trigger values | *21 triggers exceeded out of total 37 (57%)* | | | | |
| Community composition | Bray Curtis similarity | all trigger values exceeded | Above and below trigger bands | 9 out of 9 | Note and explain |
| | Species/taxa richness | zone 3 'high' and 'low', zone 4 'low', zone 5 'high' and 'low' | Above trigger values- | 5 out of 9 | Note and explain |
| | Species/taxa evenness | zone 4 'high' | Below trigger band | 1 out of 9 | Note and explain |
| Plant abundance by life form | Bare ground cover | 'above'/'low' | Below trigger band | 1 out of 2 | Note and explain |
| | Total vegetation cover | 'above'/'high' and 'above'/'low' | Above trigger bands | 2 out of 2 | Note and explain |
| | % non-vascular (bryophytes) | | | 0 out of 2 | |
| | % ferns | 'above'/'high' | Above trigger bands | 1 out of 2 | Note and explain |
| | % shrubs | 'above'/'high' and 'above'/'low' | Above trigger bands - | 2 out of 2 | Note and explain |
| Fish<br>10 trigger values | *1 triggers exceeded out of total 10 (10%)* | | | | |
| Community composition | ratio of native : exotics | - | - | 0 out of 2 | - |
| Ecologically significant species | native fish relative abundance | - | - | 0 out of 2 | - |
| | exotic species relative abundance | - | - | 0 out of 2 | - |
| | galaxiid relative abundance | autumn | Above trigger band | 1 out of 2 | Note and explain |
| Biomass/productivity | All species | - | - | 0 out of 2 | |
| | | | **TOTAL** | **63 out of 206 (31%)** | |

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