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Basslink Monitoring Program

Gordon River

Basslink Monitoring

Annual Report

2005–06

Prepared by

Hydro Tasmania

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Executive summary

The Gordon River Basslink Monitoring Annual Report a key output from Hydro Tasmania's Gordon River Basslink Monitoring Program. The principal objective of the report is to present the consolidated results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program during the 2005–06 reporting year.

2005–06 was the fifth and final year of pre–Basslink monitoring. Basslink was commissioned in April 2006. The program extends the knowledge gained during the 1999–2000 investigative years and the 2001–05 monitoring on the present condition, trends, and spatial and temporal variability of the middle Gordon River environment. This information will assist in the future management of the river.

The results from the 2005–06 monitoring are reported in eight sections covering each of the disciplines being monitored. Where appropriate, comparisons have been made with the data from earlier years. The information presented in this document is extracted from field reports produced by the various contributors who completed the monitoring.

An additional two sections provide:

- a comparative analysis of aerial photos over the pre–Basslink period (1999 and 2004); and
- the derivation of trigger values from pre–Basslink data for each discipline. These will be used as indicators of change post–Basslink. Interim trigger values were derived in the Basslink Baseline Report, which was published in December 2005.

Hydrology

The rainfall in 2005–06 at Strathgordon was higher than usual, with August, December and April recording 146 %, 212 % and 155 % respectively, of the average rainfall for each month. The Gordon Power Station rarely operated at full capacity during 2005–06, which resulted in greater 1– and 2–turbine operation and less 3–turbine operation than in 2004–05. Basslink operation commenced on 28 April 2006, resulting in a more varied discharge pattern for the power station from this date onwards. Basslink testing was also performed during the period December 2005 to April 2006.

The power station operating pattern throughout the year, and hence the downstream hydrological regime, can be summarised as follows:

July–October 2005
The power station operated at intermediate discharges (indicative of 1– and 2–turbine operations) during this period. July saw mostly 2–turbine operation, resulting in higher than

average flows. This was due to dry conditions elsewhere in the State (despite higher than average rainfall in the Gordon catchment) resulting in increased power station usage.

November 2005–January 2006
The power station operated only intermittently during these months, mainly due to refurbishment of turbines resulting in a number of outages and limiting the power station to 2-turbine discharge.

February–April 2006
Although the power station was limited to 2-turbine operation during this period, there was still significant discharge in February and March during Basslink testing. April experienced significantly lower discharge than usual.

May–June 2006
Basslink operation commenced on 28 April 2006 and power station discharge during May was of a stop/start nature, resulting in lower than average discharge. June saw almost constant 2-turbine operation, resulting in higher than average discharge.

On a monthly flow basis, July, September and June exceeded the long-term median discharge values.

Analysis of the duration and frequency of station shut-down events indicated that there were 17 % less of these events than in 2004–05, but with a similar modal range. One long-duration shut-down was recorded in late December for seven days. In terms of operating events, the power station recorded fewer short- and long-duration start-ups than in 2004–05. The modal range was 16–24 hours, similar to previous years.

The compliance monitoring site (site 65) was established in January 2004 on the Gordon River, upstream of the Denison confluence. Its flow pattern and median monthly flow values were similar to those of the tailrace during 2005–06, with additional flow from tributaries. The duration curve for this site was similar to that of the tailrace, but with increased flows for the entire flow range. At least some of this difference may be attributable to backwater from high Denison River flows.

As part of the 2005–06 Basslink operations water license requirements, minimum environmental flow targets at site 65 were confirmed. These minimum flows were 10 $m^3 s^{-1}$ for the period December through May, and 20 $m^3 s^{-1}$ for the period June through November. Basslink operation began on 28 April 2006, and a duration analysis of hourly flows at site 65 shows that the minimum flow target of 10 $m^3 s^{-1}$ was met 98.6% of the time in May 2006. The minimum flow target of 20 $m^3 s^{-1}$ was met 100% of the time during June 2006.

The Gordon above Franklin (site 44) recorded a flow pattern which included the power station discharge plus some peak flow events produced by rainfall and tributary runoff. The data from this site showed that the flow pattern matched the power station tailrace discharge pattern closely from early January to late March. Natural high volume flow events originating in tributary streams were recorded in each of the other months. The median discharge values at the tailrace, site 65 and site 44 for 2005–06 were 63, 91, and 164 $m^3 s^{-1}$ respectively, showing the downstream increase due to inflows from tributary streams.

Water quality

Surveys of water quality were undertaken on Lake Gordon and Lake Pedder during July and October 2005, as well as January and April 2006. The physico-chemical conditions of surface waters of Lakes Gordon and Pedder were considered normal for lakes in the region and water quality was high.

The thermal structure of Lakes Gordon and Pedder were generally similar to those recorded in previous years. The main difference between previous years was the persistence of a significant oxicline throughout the year at the intake site. In the previous two years, only the April and July profiles have anoxic conditions at depth.

Monitoring in the Gordon River included water temperature at three sites (75, 65, 62) and dissolved oxygen at the tailrace site. Water temperatures displayed a broad seasonal pattern which was related to the temperature of Lake Gordon. During periods of intermittent and low power station discharge, daily temperature oscillated more widely at site 62 compared to 75. The greater variation at site 62 is a function of distance downstream, and the greater influence of the temperature regime of major tributaries.

Dissolved oxygen concentrations were monitored at the tailrace and there were few periods when levels fell below 6 mg L^{-1}. The annual trend in dissolved oxygen levels in the tailrace was related to the dissolved oxygen levels corresponding to the level of the power station intake. Dissolved oxygen levels measured at site 65 from April 2006, are mostly high, often exceeding 12 mg L^{-1}. This high concentration is likely to be the result of oxygenation in the 12 km between the tailrace and site 65. Further analysis of this data will be required to confirm this in the 2006–07 Gordon Basslink Monitoring Annual Report.

Fluvial geomorphology

Geomorphology monitoring in the 2005–2006 monitoring year consisted of two scheduled Basslink monitoring trips.

Piezometer results reflected the prevailing flow conditions, with periods of high risk of seepage erosion limited to the first few months, when all three turbines were in operation. Field observations were also consistent with the operation of two turbines; there was no evidence of seepage erosion in the 2–3 turbine zone, and there was increased vegetation and deposition of organic debris at this bank level.

In spite of the lack of 3-turbine discharge, erosion rates in the 2–3 turbine level of the banks in the river as a whole and in zones 2 and 3 in particular did not show a decrease, indicating that seepage erosion and scour are not the only important erosion processes in the 2–3 turbine zone. Based on observations during rain events, the direct impact of rain on the denuded exposed banks is hypothesised to also be an important process in the river.

Erosion rates in the <1-turbine bank level in zones 4 and 5 were lower than previous trends, which may be due to reduced shear stress on bank toes due to reduced 3-turbine operation, and/or deposition from the high natural inflows which occurred in November and December 2005.

Long-term erosion results at a site in zone 2 have provided an estimate of scour rates in this reach. A muddy root-mat has been progressively eroding since December 1999 at a horizontal recession rate of ~0.7 m/yr. This is the first estimate of erosion rates associated with scour on low lying banks not affected by seepage processes.

Surveyed cross-sections showed the channel has been relatively stable over the pre-Basslink monitoring period, and photo-monitoring results showed few changes, except those associated with increased vegetation in the 2–3 turbine bank level, due to the reduction in high flows.

Karst geomorphology

Karst monitoring was conducted and water level data loggers were downloaded in three trips in October 2005, March 2006 and April 2006.

In Bill Neilson Cave, the pattern of change at the wet sediment banks over the 12-month period was similar to that which has occurred in other years, i.e winter erosion and summer deposition at the lower levels in the cave due to the action of the cave stream; minor net erosion at mid levels; and minor net deposition at higher levels due to the backflooding by the Gordon River. Consistent with other years, there was zero net change at the dry sediment bank over the 2005–2006 monitoring season.

In Kayak Kavern, over the 12-month period, there has been very minor net erosion on top of the sediment mound, and both minor net erosion or relatively large net deposition on various parts of the active slope. During summer, the pins on the extremities of the slope recorded relatively large deposition but there is some evidence of disturbance of the pins and the data must be treated with caution. As observed for 2004–05, there are no consistent seasonal trends in deposition/erosion patterns evident in Kayak Kavern.

In cave GA-X1, the overall trend measured in October was for the progressive depletion of sediment. While little sediment change occurred at the upper levels, fluctuations in water level in the cave during single turbine operations were related to the erosion of 8 mm of sediment from the lower erosion pin. There was little sediment change in GA-X1 measured in March 2006 due mainly to the relatively low Gordon River levels and the lack of inundation in the cave over summer. As in October, the majority of water level fluctuation activity was at the lower levels in the cave and was responsible for net erosion measured at the lowest pin over the 12-month monitoring period. The highest pin was, for the most part, outside the inundation zone and is accumulating sediment, most likely from the influx of material with rainfall through the second cave entrance located above the pin.

Changes in depth of leaf litter in the dolines were variable. A long-term trend of negligible change on the steeper sides of the dolines and accumulation at the base is evident. As noted previously, the changes in the lengths of the erosion pins are not determined by the inundation regime of the Gordon River and are of less consequence than any changes in the distances between the tops of the pins. There were no significant changes in the measurements of distances between the tops of the pins at either doline, within the precision of the method. This suggests that the morphology of the dolines remains stable.

The two erosion pins at Channel Cam recorded aggradation over the winter period and slight erosion over summer. This continues the annual trend although there has been net deposition in contrast to the net erosion which occurred in 2004-05. As the channel was above the level of inundation for the majority of the year, it is probable that the accumulation of sediment in winter is related to surface runoff. This is supported by the photo-monitoring that shows significant ponding of surface water in the channel despite the lack of inundation. The slight erosion over summer is likely to have occurred with rainfall pooling and draining from the channel.

Riparian vegetation

Riparian vegetation surveys were conducted in December 2005 and April 2006. The autumn period did have some transitory 'Basslink' flow patterns as a result of the pre-Basslink testing phases, so the results presented have not been formally analysed or compared.

Patterns of vegetation cover, species richness and seedling recruitment recorded in the spring 2005 and autumn 2006 monitoring events generally continued to follow the established patterns reported in the Basslink Baseline Report (BBR). These patterns included the predominant influence of bank stratification on vegetation abundance, fluctuating patterns of seedling recruitment and high mortality of seedlings.

Macroinvertebrates

Macroinvertebrates were sampled in October 2005 and March 2006 at nine sites in the Gordon River between the Gordon Power Station and the Franklin confluence. Six reference sites were also sampled in the Franklin, Denison, Maxwell and Jane Rivers. All sites were sampled using quantitative surber samplers and on-site rapid bio-assessment. The former samples were used to generate data on abundances of individual taxa, total abundances and diversity (as number of taxa). The latter samples were used to derived O/E values for each site, using the combined RIVPACS models developed for Hydro Tasmania catchments.

Patterns and trends in diversity and O/E values were mostly similar to those observed in all previous pre-Basslink years. The number of taxa increased substantially with distance downstream of the power station. O/E values also increased with distance from the power station, with values upstream of the Denison River falling significantly below reference values. The one change to previous values was seen in March 2006, when the O/Epa values were significantly higher upstream of the Denison relative to all previous sampling trips. This is suggestive of an increase in the diversity of common (expected) families over the summer.

Analysis of all macroinvertebrate monitoring data to date indicates no statistically significant or substantial change in the overall pattern of diversity or total macroinvertebrate abundance between years one and five of monitoring.

Instream algae and moss

Benthic algae were surveyed in spring (October-November) 2005 and autumn (March) 2006 at nine sites in the Gordon River between the Gordon Power Station and the Franklin confluence, and three reference sites. All sites were assessed by surveys across the river channel, estimating % algal cover in zones across river transects, and the collection of dominant algae from each transect zone.

Patterns and trends in algal cover were broadly similar to those observed in previous years.

- Aquatic flora had a consistently low to moderate cover across all sites;
- moss and filamentous algae had similar, low overall mean % cover across all sites;
- filamentous algae were more abundant at sites 69 and upstream;
- mean moss cover was highly variable; and
- macrophytes occurred at site 72 at low densities.

In March 2006, filamentous algal cover was low throughout, as expected in autumn, with slightly raised levels at sites 48 and 42, which suggested sustained moderate pre-Basslink trial flows permitting algal growth on the upper bars within the channel.

Data was also collected at three reference sites (Fr11, Fr21 and De7), for future interpretation and benchmarking. Sampling at these sites was conducted by random placement of quadrats on the dominant channel substrate at 30 locations. Filamentous algal cover was low. Cover at Gordon sites 69 and upstream was substantially higher than at reference sites, consistent with current understanding.

Fish

Catches were low in both summer and autumn. A total of 342 fish were captured, representing eight species in summer and nine species in autumn.

Catch rates for brown trout in summer was consistent with those recorded for previous surveys, and catches in autumn were lower than in previous surveys. It is likely that catch declines are linked to high rainfall in the catchment and sequential freshes proceeding both sampling periods resulting in decreasing fish abundance around channel margins, and also decreased electrofishing efficiency at sites with elevated flows. The presence of brown trout fry in zone 1 had not been observed previously and indicates that successful trout spawning is possible in this zone under suitable conditions.

Redfin perch were absent from the summer catches, and three fish were captured from zone 2 in autumn. While the reason for their summer absence is not clear, the general decline in redfin abundance supports the hypothesis that this species has probably occurred previously in the river via introduction from the power station but failed to establish a self sustaining population due to lack of suitable habitat, due to unsuitable hydrological conditions and spawning areas.

Short-finned eels were below average for the summer surveys, particularly in the test zones. This is not likely to be associated with recruitment failure but more likely an artefact of flow-related behavioural changes, reduced fishing efficiency, and localised habitat sampling inaccessibility due to elevated flows.

Unseasonably high rainfall and high flow variability in the Gordon River and its tributaries inhibited upstream galaxiid migration in summer. This is evident in low galaxiid catch rates and lack of juveniles in the population structure in summer catches. Small schools of juvenile galaxiids were observed in Lake Fidler, and Gordon River adjacent to Fidler in mid January 2006 following several weeks of low rainfall, and so migration appears to have been reduced in size and delayed until flows stabilised in the catchment.

In summary, unseasonably high baseflows and sequential flow events preceding and during sampling reduced catch rates in both test and reference sites. Reduced catch rates were recorded for most species, and reductions in electrofishing efficiency due to elevated sampling flows probably contributed to catch reductions.

Pre–Basslink aerial photo analysis

A qualitative aerial photography comparison was completed using 1999 and 2004 photos obtained at a scale of 1:5,000. Both photo sets were acquired during summer with no discharge from the power station, however the water level during the 1999 photo run was higher than the 2004 run. The water level difference was small in the upstream zones, and did not affect the ability to detect changes. With distance downstream, the difference in flow levels increased, reaching a maximum in zone 5 where water levels differed by ~0.5m (1999 higher). In places this hindered the ability to identify 'new' logs in the river as opposed to existing logs which were present, but not visible in 1999. Water level differences did not hinder a comparison of major features in the middle Gordon, and no changes to channel form were observed between the two sets of photos in any of the geomorphic zones. Drip lines, the Plimsoll line, cobble bar location and form and the extent of vegetation all remained largely unchanged within the limits of detection of the qualitative assessment. The aerial photos did not allow detection of bank changes known to occur during the 1999–2004 period due to the very small scale of bank erosion (mm), and the screening of banks by overhanging vegetation.

Changes which were noted include additional tree fall in tributaries affected by back–water effects in zones 1–3. These include the Albert River, Orange River and numerous smaller tributaries. The Gordon and Denison confluence also experienced change over the past five years, with additional tree falls and bank slumping noted in 2004 as compared to 1999.

Changes to existing tree falls was generally limited to the loss of leaves and small branches, and re–alignment of woody debris with respect to current directions. Additional tree falls were identified in all zones. In zones 1 and 3–5, new tree fall 'rates' are approximately one new tree fall per km of zone length over the six–year period. Zone 2 has a much higher rate of tree fall, with 15 new falls identified over the 3 km reach. In all of the zones, these additional tree falls have generally occurred as single tree events distributed throughout the zone, with little impact on the surrounding bank evident in the aerial photos. Only four of the tree falls appear to have had a discernible impact on the bank.

Cobble bars showed very few changes through the middle Gordon River. In zone 1, the 'construction bar' has undergone some loss of material, and in lower zone 2, a tree fall has altered flow across one bar. No evidence of erosion of cemented cobble bars was found in the aerial photos.

Most changes identified in the aerial photography comparison have been documented by the ground–based photo–monitoring component of the Basslink monitoring program, and future changes at these sites will continue to be documented on an annual basis.

Summary of trigger values

Background

The Gordon River Basslink Monitoring Program was set up in order to document the pre- and post-Basslink condition of the Gordon River such that changes to the state of the river and associated biota in response to Basslink operations could be detected and, if necessary, be acted upon. Part of the framework for the ongoing management of the river includes establishing trigger levels for each of the scientific disciplines represented in the monitoring program. Any post-Basslink monitoring results that fall outside these limits would be considered a potential change in the state of the river and would be cause for further investigation. The level of investigation required is dependent on the variable(s) being exceeded and the interpretation of those results in the context of the sensitivity, environmental importance and temporal variance of those indicator variables. The process for investigation and the interpretation of trigger exceedences is explained in detail in the Gordon River Basslink Baseline Report as well as the individual trigger level reports (see section 11) provided for each of the Gordon River Basslink Monitoring Program disciplines.

General approach

For each of the disciplines where formal trigger levels have been required, these triggers have been set by compiling the pre-Basslink data sets for the nominated indicator variables, and defining confidence levels around the mean. The studies have either adopted 95 % as the confidence level or set other values as appropriate for the indicator variable in question.

In order to compare post-Basslink data to the trigger levels, it is intended in some disciplines to utilise the average of all post-Basslink data to date to obtain increasing levels of accuracy around the post-Basslink mean as the monitoring program progresses. When these mean values are to be assessed against the trigger levels, the range of the trigger levels are contracted from one year to the next in order to compensate for the increasingly less variable post-Basslink mean. When simple annual averages are compared against the trigger levels, no adjustment to the trigger levels from year to year will be made.

Although it varies between disciplines, there is generally a three stage response to a breach of a trigger level. Initially there is a 'note and explain' response where the exceedence is investigated in the context of other supplementary information. If no suitable explanation for the exceedence can be made or there are consistent breaches of the trigger value, then additional investigation is required to determine the cause. The third level of response dictates that the need for management intervention should be investigated and appropriate mitigation actions implemented. Such actions would be triggered when there was consistent decline in the health of the Gordon River and the change in condition could be attributed to Basslink-related hydrological changes.

The following sections summarises the approaches taken to setting trigger levels for the various Basslink Monitoring Program disciplines.

Water quality

The main water quality variables considered relevant to the condition of the Gordon River were dissolved oxygen and water temperature. The mix of lake water drawn into the intake will vary according to the hydraulic conditions at the intake which is principally dominated by the flow rate, the strength of stratification and position of the thermocline in relation to the intake level.

Dissolved oxygen is significantly affected by the power station. As water passes through the power station it is subject to varying degrees of air injection, which is governed by both operational requirements and environmental rules. The environmental rules seek to minimise the incidence of both high and low levels of dissolved oxygen in water discharged through the power station. These operating rules will reduce the variability of dissolved oxygen in the water, similarly, the rapids downstream of the tailrace will tend to 'de-gas' super-saturated waters and will aerate water that is low in dissolved oxygen, therefore there is unlikely to be any significant dissolved oxygen signal that can be attributed to Basslink.

As the main water quality factors are largely Basslink independent, no trigger levels are proposed as part of the Basslink Monitoring Program. It has however been recognised that there is a benefit in monitoring dissolved oxygen and temperature levels in order to assist in the interpretation of the biological monitoring data. So whilst no trigger level comparisons will be undertaken for these parameters, water quality monitoring will remain as part of the Basslink Monitoring Program.

Fluvial geomorphology

The geomorphology of the Gordon River is dynamic and is continuing to adjust to the regulation of the river and the staged commissioning of the three Gordon Power Station turbines between 1977 and 1988. There is uncertainty regarding the eventual geomorphological 'end state' of the river with or without Basslink, and given the complexity of the linkages between changed hydrology and the geomorphological response, the focus of monitoring has been on key geomorphological processes. This is supplemented by other indicators of the condition of the river. It has also been clear that the various zones have different susceptibilities to erosion, and that the processes operating in these zones are showing a slow progression downstream as sediment supply and other factors approach equilibrium in the upper zones.

In terms of trigger levels, the geomorphological discipline is unique in that it has to account for the continuing long-term change in the state of the river irrespective of Basslink. As such, attempts have been made to quantify both the trend and expected variability in these processes for each of the five river zones. Given the uncertain, and potentially cyclical nature of the geomorphology, the pre-Basslink data can only be used as a valid baseline whilst the underlying trends and processes remain unchanged. In order to assess this, the results for erosion and deposition is determined for each zone at three different elevations on the banks corresponding to the different turbine operating heights and compared to the pre-Basslink comparison.

The formal trigger levels for fluvial geomorphology are based on the net level of erosion as measured in March each year and are compared to the pre-Basslink trend on both a cumulative and year-by-year basis. The confidence limits in both cases are set at 95 %.

Aside from the quantifiable indicator variables, there are also a number of qualitative measures that are used in the interpretation of the fluvial geomorphology data. These measures do not have formal trigger levels applied to them however they may hold important future information in the event that the quantitative triggers are exceeded and additional investigation is required.

Karst geomorphology

Changes in sediment movement have been identified as the most likely karst related impacts associated with Basslink. The Gordon River Basslink Baseline Report determined that the setting of formal triggers for karst related variables was not feasible, primarily due to the low number (19) of installed erosion pins and the lack of any replication on which to base statistical analyses. Nonetheless it was determined that consideration of possible changes in erosion and depositional processes be completed on an informal basis to flag possible changes in the karst geomorphology. Consequently there have been a number of informal triggers proposed which relate to rates of sediment movement and frequency of inundation.

There are three sets of informal triggers:

- changes in the rate of sediment deposition or erosion with reference to the maximum and average rates observed during the pre-Basslink period;
- the amount of dry sediment bank inundation as measured by both the percentage of time that the bank is inundated as well as the peak height of inundation compared to the pre-Basslink record; and
- the sum of the distances between erosion pins in the dolines compared to the average distance pre-Basslink.

It is likely that these triggers will be exceeded regularly due to the lack of a statistical confidence level around the pre-Basslink data, however, the interpretation of any exceedences is appropriately conservative and relies on a number of lines of evidence before further investigation or re-analysis of the data is triggered. Additional data from general field observations, photo-monitoring and surveying will assist in the interpretation of such data.

Riparian vegetation

Given the large number of variables it is likely that some exceedences will be apparent through the duration of the Basslink Monitoring Program through type 1 error. Recognising this, the approach has been taken whereby individual exceedences result in a 'note and explain' response and more substantial investigation is only recommended where trigger exceedence cannot readily be explained in the context of the pre–Basslink data set, outlier occurrences (e.g tree fall) or with reference to other disciplines (e.g fluvial geomorphology).

The quantitative variables for monitoring change in the riparian vegetation community are focussed on the density or abundance of flora species, seedlings or ground cover conditions and are considered to provide a suitable basis for comparison of the pre– and post–Basslink condition of the river. The priority group of indicator variables are those that measure characteristics such as community composition, species richness and species evenness. Quantitative measures of community structure, ecologically significant species, and population dynamics are also given.

In addition to these measures qualitative variables such as vegetation condition and photo–monitoring are also utilised to assist in interpretation and to flag broader issues that may not be captured by the quantitative monitoring.

Macroinvertebrates

Benthic macroinvertebrates are seen as one of the key indicators of the biological health of the Gordon River. Five components are considered key to the ecological integrity of the benthic macroinvertebrate population. These components, in priority order, along with the derived indicator variables are:

Community Structure	– Bray Curtis similarity to Reference (abundance data)
	– O/Erk
Community Composition	– Bray Curtis similarity to Reference (presence/absence data)
	– O/Epa
Taxonomic Richness	– Taxon Richness (number of families)
	– No. of EPT species
Ecologically significant species	– Proportional abundance of EPT species
	– Density of Ephemeroptera
Biomass/productivity	– Total density (n per unity area)
	– Total abundance (n per unit stream length)

For the purposes of setting trigger levels, the macroinvertebrate data have been grouped into two broad zones corresponding to sites upstream of the Denison confluence (zone group 1) and those downstream of the Denison (zone group 2). Trigger levels have been set for the lower bound of either the 90 % or 95 % confidence limits of the pre–Basslink commissioning data set.

Means of post-Basslink commissioning data that fall below these lower bounds will be considered to have exceeded the trigger levels.

Exceeding the lower bound trigger values will provide either an 'early warning' signal or 'supplementary evidence' to assist in interpretation of other results of concern. In the case of an exceedence of a 'management intervention' variable this would indicate a decline of significant concern and would trigger an investigation as to whether an appropriate course of mitigation action should be undertaken.

Instream algae and moss

Only two variables are recommended for trigger level reporting for instream algae and moss, however, there are both upper and lower bound trigger levels which have been set based on the 90 % confidence limits of the pre-Basslink data. The nominated lower bounds and upper bounds are asymmetric around the pre-Basslink mean due to differing assumptions on the significance of +ve and -ve changes.

Persistent exceedence of the trigger levels should be investigated to evaluate the underlying cause of those changes, whether this could be interpreted as a Basslink effect and what influence such changes are having on the aquatic ecology of the river.

Fish

There are three key components of the fish community of the Gordon River that are considered to require trigger values. The theory around their derivation is similar to that for macroinvertebrates and algae, although it is complicated by the presence of introduced species such as brown trout and redfin perch. Monitoring the fish population is also restricted due to the depauperate nature of the fish community in the Gordon River. The low fish numbers limit the sample size that can be logistically achieved within the constraints of the Basslink Monitoring Program and this limits the range of statistical comparisons that can be undertaken for pre- versus post-Basslink. As a result of this the fish data for the river are pooled between zones in order to allow a reasonable level of statistical validity.

There have been five different indicator variables identified for the key components for which lower bounds have been set based on a range of confidence levels between 80 % and 90 %. The abundance of exotic fish also has a trigger level set at the upper bound recognising that a large increase in the relative abundance of exotic species is likely to be deleterious to the ecology of the river. There are different limits associated with the annual and autumn data. No summer data are considered in isolation due to the high variability in catches associated with summer fish migration activity.

The response to trigger exceedences follows the three general categories of response with additional investigations being triggered when exceedences persist for two or more pooled samples.

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1 Introduction and background

The purpose of the Gordon River Basslink Monitoring Annual Report (GRBMAR) is to present the results of all monitoring undertaken pursuant to the Gordon River Basslink Monitoring Program (BMP) during 2005-06.

1.1 Context

The core of the Gordon Basslink Monitoring Program (BMP) was established as an outcome of the Basslink approvals process. The aims of the Gordon River Basslink Monitoring Program are:

- to undertake pre-Basslink monitoring 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;
- to undertake six years of post-Basslink monitoring in order to determine the effects of Basslink operations and to assess the effectiveness of mitigation measures; and
- to obtain long-term datasets for potentially Basslink-affected aspects of the middle Gordon River ecosystem, which 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 has been to measure conditions and identify trends under the existing 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 which presently exist due to the presence of, and the flow regulation resulting from, the Gordon Power Scheme.

In terms of World Heritage values, the modified conditions in the Gordon River have been explicitly recognised throughout the World Heritage nomination and management activities and the Basslink approvals process. Kriwoken (2001) documented the specific points that:

- the production of hydro-electricity significantly and extensively impacted south-west Tasmania, and in particular the Gordon River, four years before the region was first nominated as a World Heritage Area. The Gordon River was therefore a regulated, highly modified river environment and not representative of a pristine ecosystem when listed under the World Heritage Convention;
- the 1982 and 1989 World Heritage Area nominations expressly acknowledge existing hydro-electric schemes and the direct impact those schemes have on natural waterways in the Tasmanian Wilderness World Heritage Area (TWWHA). Implicit in this acknowledgement is that downstream ecosystems are modified by flow regulation; and

- Lake Gordon, the Gordon River Power Station and the tailrace were not included in the TWWHA.

The independent investigative studies produced for the Basslink IIAS (see Locher 2001) led, via the comprehensive approvals process, to the formulation of the BMP. These were included in the Special Licence which Hydro Tasmania holds under the *Water Management Act* 1999. The scope of the BMP are appropriate for the task at hand (as defined in the Special Licence) given the physical limitations of the area, the climate and the resource constraints of the Basslink project.

1.2 Basslink Baseline Report

One of the requirements of Hydro Tasmania's Special Licence is to produce a Basslink Baseline Report (BBR) prior to Basslink commissioning. The BBR was completed in December 2005 and provided a comprehensive statement of pre-Basslink conditions in the middle Gordon River. This involved the analysis of all of the BMP data collected to date, and the application of the results of these analyses to the consideration of how post-Basslink conditions will be compared with the pre-Basslink ranges of variability and trends.

1.3 The 2005-06 monitoring

The Gordon River Basslink Monitoring Program for 2005-06 completed the fifth and final year of pre-Basslink monitoring; as such this is the last of the pre-Basslink Gordon River Monitoring Annual Reports. Monitoring took place in November and December 2005 and in March and April 2006. Poor weather and high tributary flows in November and December 2005 meant that work had to be undertaken over several weekends. Originally it had been anticipated that the pre-Basslink monitoring would only run for three years. However, delays in commissioning meant additional data could be collected.

Basslink began transmission trials in early December 2005, and was fully commissioned and operating in late April 2006.

1.4 Logistical considerations

As indicated in the 2001-02 GRBMAR, 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 and the absence of other access infrastructure.

Power station outages are needed because the majority of viable helicopter landing sites are on cobble bars in the river bed which are exposed only when there is little or no discharge from the power station. They are also required 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 high flow conditions.

To complete the required monitoring work, the Gordon River Basslink Monitoring Program has a schedule of four visits per year, each involving two consecutive days of assessment.

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. Site references using the AGD will be approximately 200m different from those using the GDA. These will be updated as new maps become available.

1.6 Document structure

This document is the fifth of the Gordon River Basslink Monitoring Annual Reports to be produced, and is organised into eleven sections plus an executive summary.

This first section discusses the requirements, context, operational considerations and constraints of the program. Sections 2–9 report on the monitoring work which was undertaken during 2005–06, and present the consolidated results of each of the individual monitoring elements. These include:

- Hydrology (section 2);
- Water quality (section 3);
- Fluvial geomorphology (section 4);
- Karst geomorphology (section 5);
- Riparian vegetation (section 6);
- Macroinvertebrates (section 7);
- Instream algae and moss (section 8); and
- Fish (section 9).

The results from the 2005–06 monitoring are reported in each of these sections. Some between-year analyses were undertaken, where sufficient data were available to make such analyses meaningful. A more complete analysis of variability and time-related trends within the Gordon River ecosystems under study is reported in the Basslink Baseline Report.

As this is the last of the pre-Basslink Annual Reports, there are a further two sections included this year:

- section 10 (Pre-Basslink aerial photo analysis) provides a comparative analysis of aerial photographs taken of the Gordon River in 1999 and 2004, to assist in the assessment of changes to the river channel under pre-Basslink conditions; and

- section 11 (Trigger value reports) provides full trigger value reports for each discipline. A set of interim trigger values was presented in the Basslink Baseline Report in December 2005. However, the final values presented here incorporate the most recent data into the statistical models, and explore a broader range of statistical approaches. This additional statistical treatment has provided the most appropriate trigger values for each discipline.

Two appendices are included as follows:

- Erosion pin graphs (appendix 1);
- Annotated aerial photography maps (appendix 2);

1.7 Authorship of sections

The information presented in sections sections 2–9 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 prepared by Malcolm McCausland, with considerable assistance from the researchers and internal reviewers. Donna Porter assisted with editing and production.

Table 1.1. Section numbers, section titles and original authors from whose reports the information in sections 2–11 was extracted.

Section	Section title	Author(s)
2	Hydrology	Rowan Murray (Hydro Tasmania)
3	Water quality	Malcolm McCausland (Hydro Tasmania)
4	Fluvial geomorphology	Lois Koehnken (Technical Advice on Water)
5	Karst geomorphology	Jenny Deakin and Rolan Eberhard (consultants)
6	Riparian vegetation	Anita Wild (Hydro Tasmania)
7	Macroinvertebrates	Peter Davies and Laurie Cook (Freshwater Systems)
8	Instream algae and moss	Peter Davies and Laurie Cook (Freshwater Systems)
9	Fish	David Ikedife (Hydro Tasmania)
10	Pre–Basslink aerial photo analysis	Lois Koehnken (Technical Advice on Water)
11	Trigger value reports	Lois Koehnken (Water quality); Corresponding authors for sections 4–9

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.

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2 Hydrology

This section of the Gordon River Basslink Monitoring Annual Report summarises the hydrological data from the Gordon River downstream of the Gordon Power Station for the 2005–06 period.

2.1 Site locations

The gauging stations used to record river levels during 2005–06 are shown in Figure 2.1. These were sites 39, 44, 62, 65, 69, 71, 75 and the Gordon Power Station tailrace (site 77).

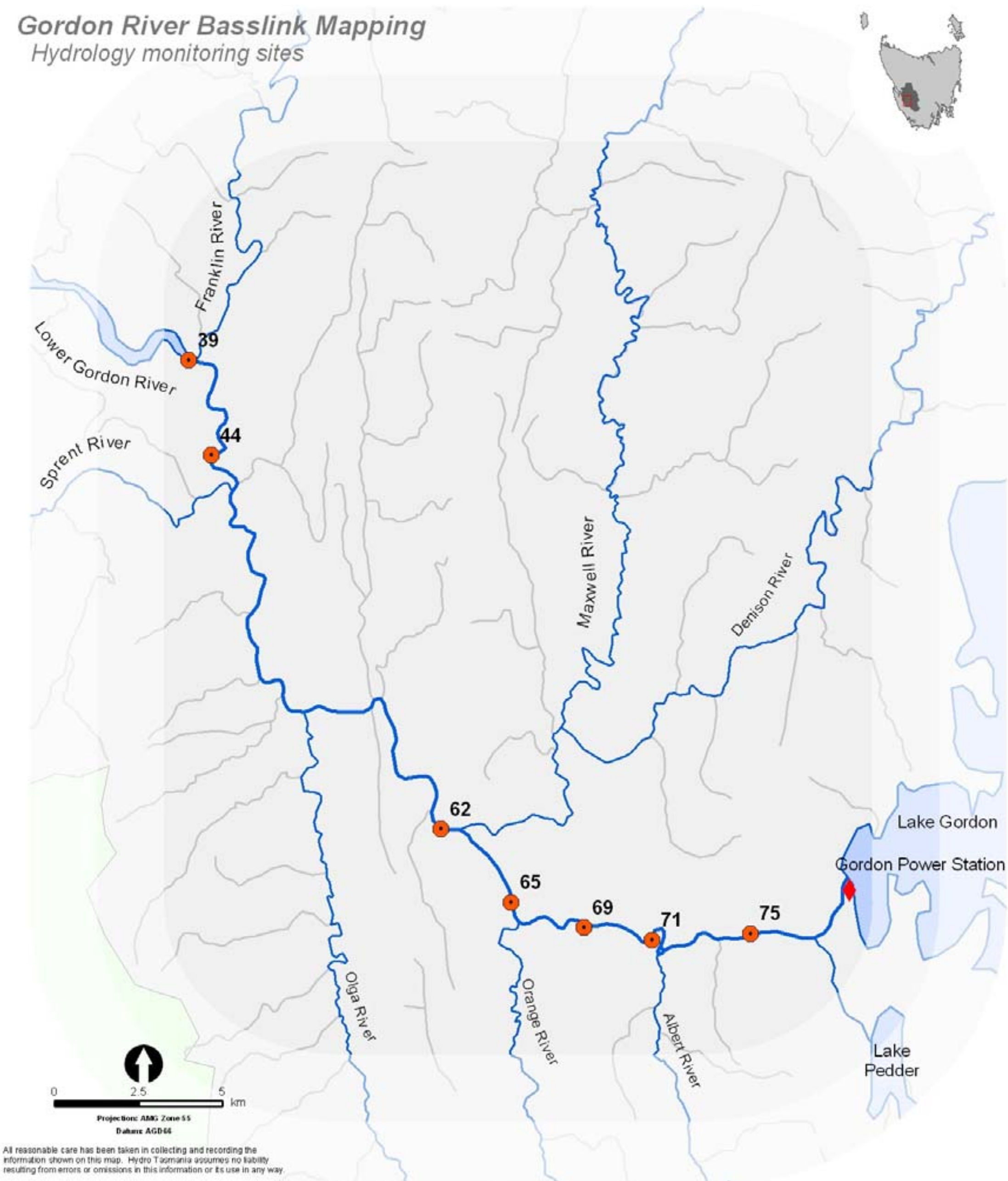

Figure 2.1. Location of the water level recorders in the Gordon River.

2.2 Strathgordon rainfall

The Strathgordon meteorological station has rainfall records dating back to 1970. These allow the development of long-term mean monthly values and comparisons with the monthly rainfall totals recorded for 2005-06. Figure 2.2 shows the total monthly and long-term average rainfall values. These indicated that 2005-06 was a slightly above average year in terms of total rainfall (2628mm compared to 2458mm); however there were some particularly dry months and also some very wet months when compared to average. September 2005 and January 2006 were very dry months, with values lower than the 20th percentile of the long-term values for those months, while August 2005, December 2005 and April 2006 were wet months with values greater than the 80th percentile of the long-term values.

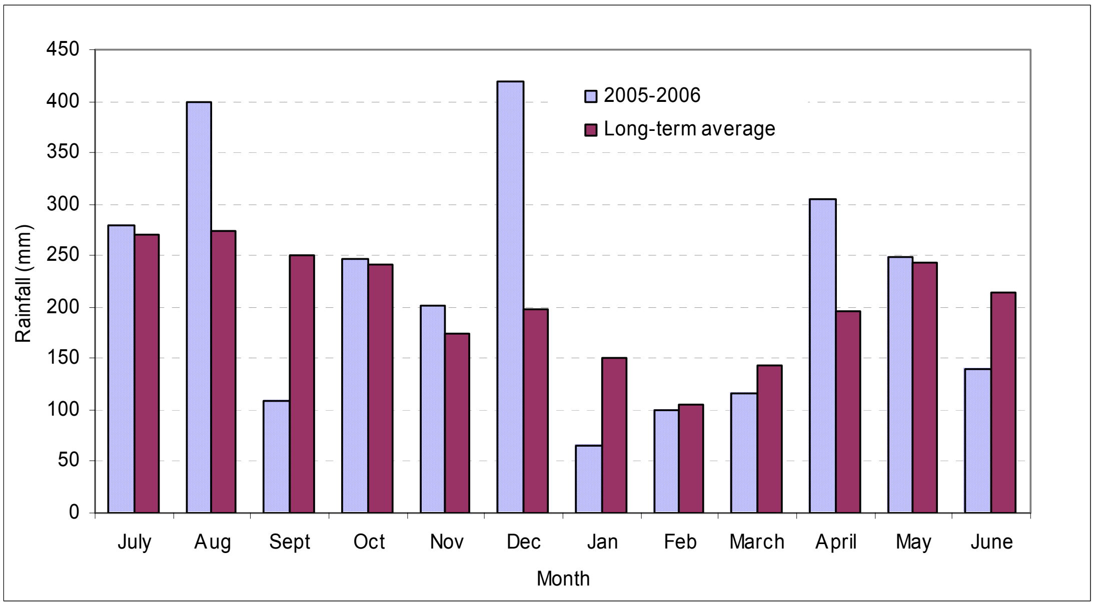

Figure 2.2. Total monthly rainfall values recorded at Strathgordon for 2005–06 compared with mean monthly values from 1970–2006.

2.3 Gordon Power Station discharge

The discharge pattern for the Gordon Power Station is driven by factors other than local rainfall. With the catchment yields being relatively low State-wide, the Gordon Power Station was utilised more often than under average rainfall conditions. Basslink operation also commenced in late April 2006, resulting in a more varied discharge pattern for the power station from this date onwards. Basslink testing was performed during the period December 2005 to April 2006.

2.3.1 Discharge

Figure 2.3 shows the discharge from the power station for 2005-06. It indicates intermittent power station operation for most of the year. The power station operated under high discharge conditions in July 2005, from mid January to early April 2006, and again in June 2006.

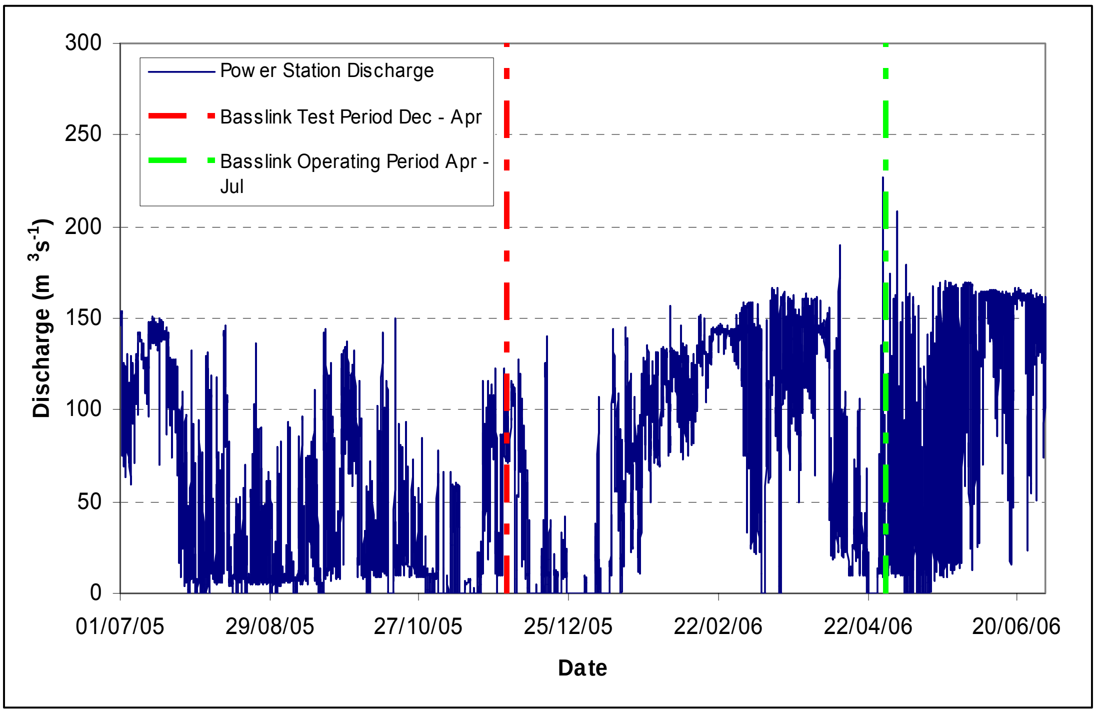

Figure 2.3. Gordon Power Station discharge (hourly data) from July 2005 to June 2006.

During 2005–06, the power station operated two turbines more than 50 % of the time (Table 2.1). Three turbines were in operation only 1 % of the time, as one turbine (G2) was being rebuilt from May 2005–April 2006, which was a substantial decrease from the 2004–05 and historical operations.

Table 2.1. Percentage of time that each configuration of turbines was in operation during 2005–06 and historically.

Configuration	Percentage of time operating 05–06	Percentage of time operating 04–05	Percentage of time operating 96–05	Approximate tailrace discharge (m^3 s^{-1})
0–turbine	14.8 %	14.7 %	18.3 %	0–10
1–turbine	31.0 %	24.8 %	18.2 %	70–80
2–turbine	53.2 %	22.5 %	29.5 %	140–150
3–turbine	1.0 %	37.9 %	34.0 %	>210

The power station operating pattern throughout the year, and hence the downstream hydrological regime, can be summarised as follows:

July–October 2005

The power station operated at intermediate discharges (indicative of 1– and 2–turbine operations) during this period. July saw mostly 2–turbine operation, resulting in higher than average flows. This was due to dry conditions elsewhere in the State (despite higher than average rainfall in the Gordon catchment) resulting in increased power station usage.

November 2005–January 2006

The power station operated only intermittently during these months, mainly due to refurbishment of turbines resulting in a number of outages and limiting the power station to 2-turbine discharge.

February–April 2006

Although the power station was limited to 2-turbine operation during this period, there was still significant discharge in February and March during Basslink testing. April experienced significantly lower discharge than usual.

May–June 2006

Basslink operation commenced on 28 April 2006 and power station discharge during May was of a stop/start nature, resulting in lower than average discharge. June saw almost constant 2-turbine operation, resulting in higher than average discharge.

2.3.2 Median monthly discharge

Figure 2.4 shows the median monthly discharge from the power station for 2005–06 compared with long-term values (since August 1996). This figure illustrates that discharge was lower than usual for the majority of the year. It was higher than usual in July and September–October 2005 and in June 2006.

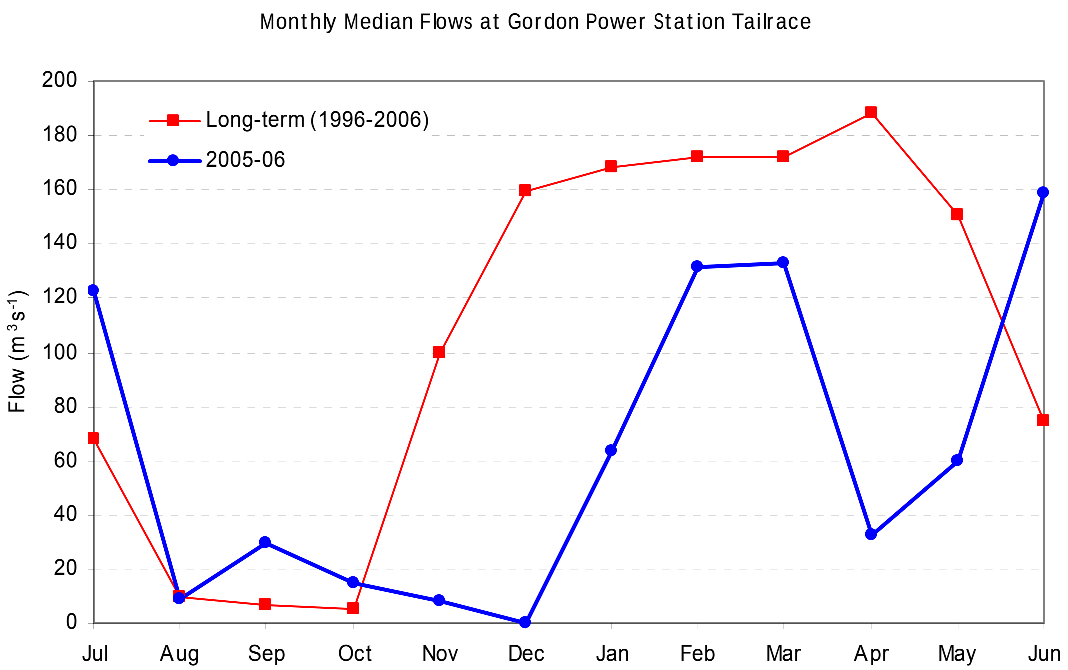

Figure 2.4. Median monthly discharge from the tailrace of the Gordon Power Station for 2005–06 compared with long–term median values.

2.3.3 Duration curves

Figure 2.5 shows the duration curve for the power station tailrace discharge for 2005-06, as well as the long-term (since 1996) duration curve. The 2005-06 curve shows that there was less discharge than usual to the 75th percentile, with the greatest difference occurring around the 10th percentile. The long-term median value is approximately 124 m^3 s-1, while the 2005-06 median value was 63 m^3 s^{-1}. This pattern differs slightly from the previous year, particularly for the higher volume discharges (1st to 30th percentiles), which were less than in 2004-05.

As described in Section 2.3, the Gordon Power Station rarely operated at full capacity during 2005-06, due to greater 1- and 2-turbine operation and less 3-turbine operation than in previous years. This also resulted in the lower than normal flows in the 0 to 70th percentile range.

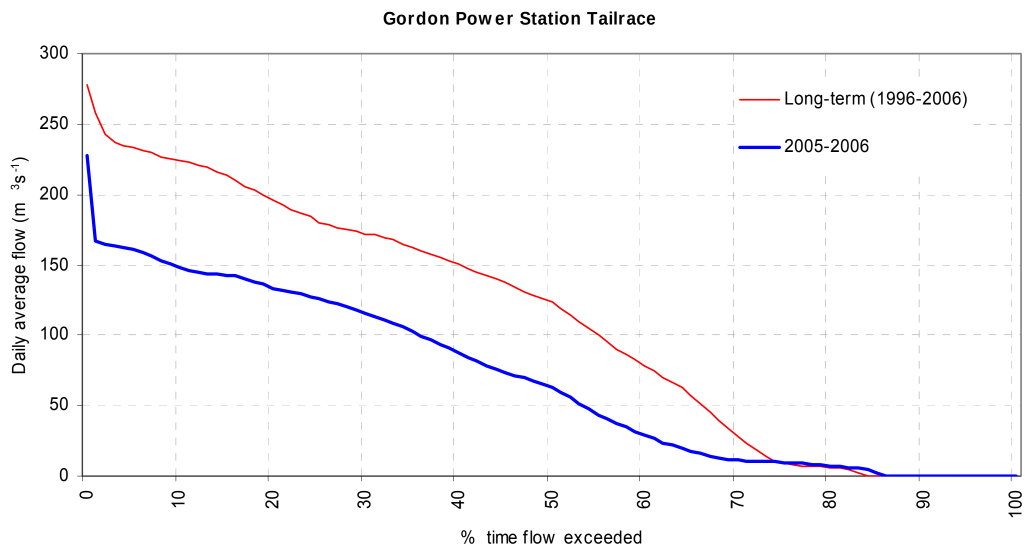

Figure 2.5. Duration curve for discharge from the power station tailrace for 2005–06.

2.3.4 Event analyses

One of the methods for analysing power station operations and their effect on discharge into the Gordon River is to examine the number and duration of shut-down (zero discharge) and operating (>zero discharge) events.

In 2005-06, the shut-down events had a similar modal range to previous years, although the frequency of six-hour outages was much less (five events vs. 24 in 2004-05). Figure 2.6 shows the frequency and duration of the shut-down events. In total, 83 shut-down events were recorded during the year, a decrease from the 100 events of 2004-05. One long-term outage (>144 hours) was recorded in late December 2005.

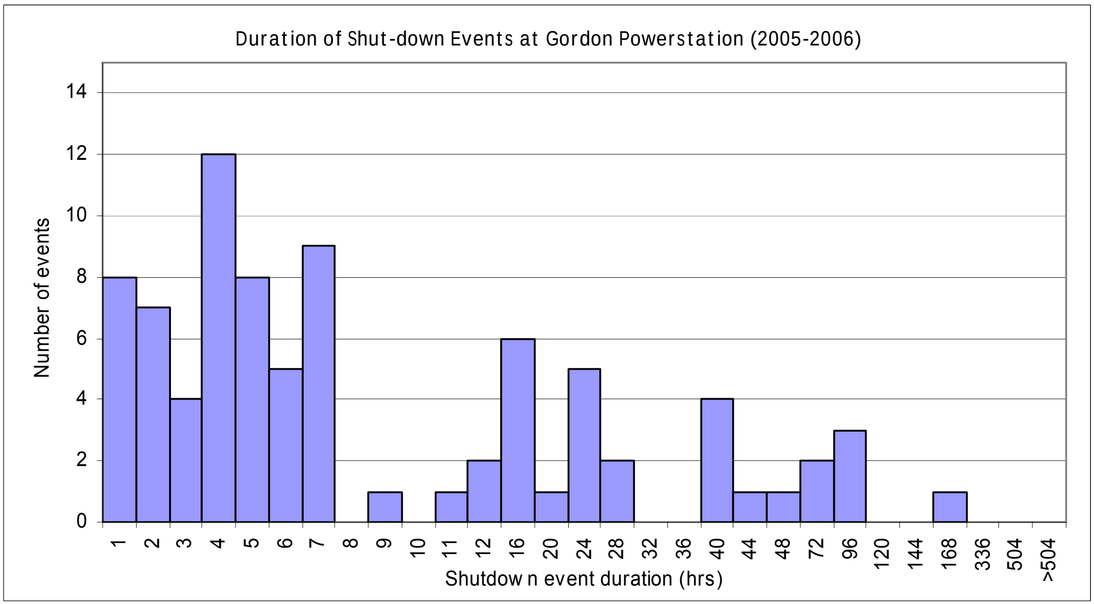

Figure 2.6. Frequency and duration of zero discharge (shut–down) events recorded for the Gordon Power Station during 2005–06.

The number of operating events, indicated by discharges greater than 3 $m^3 s^{-1}$, is shown in Figure 2.7. This figure indicates that there were a comparatively large number of 16–24 hour operating events, a similar modal value to previous years.

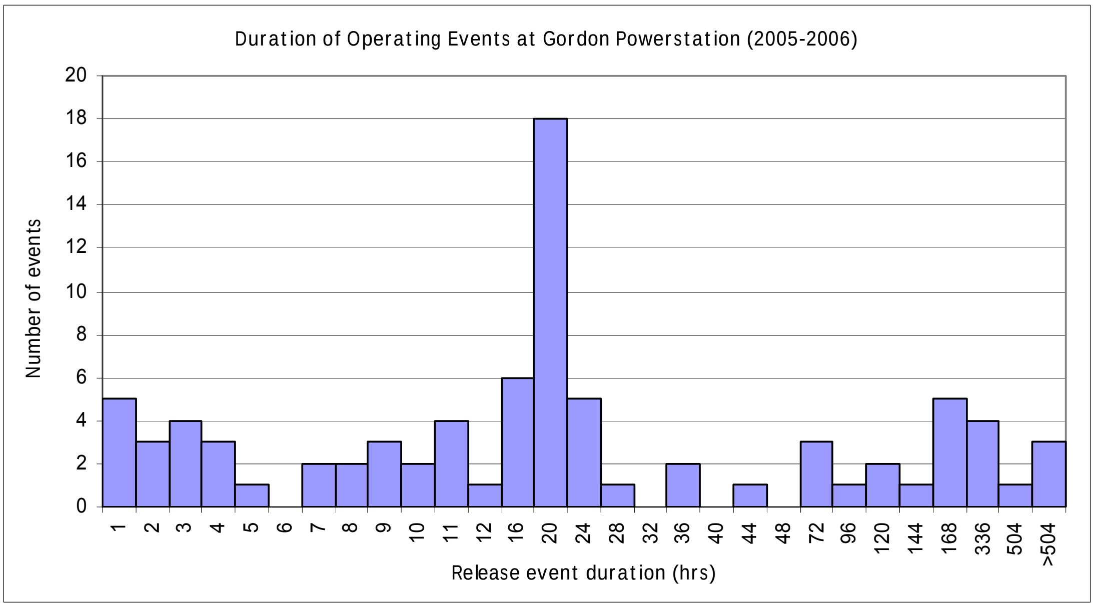

Figure 2.7. Frequency and duration of operating events (discharge > 3 $m^3 s^{-1}$) recorded for the Gordon Power Station during 2004–05.

2.4 Gordon above Denison (site 65)

Site 65, about 2 km upstream of the Denison confluence, was installed in late 2003. This site monitors the minimum environmental flow required post-Basslink commissioning.

2.4.1 Discharge

Figure 2.8 shows the discharge recorded at site 65 for 2005–06. This data indicates a close concordance with power station discharge (Figure 2.3), to which peak values, the result of high flows from tributary streams (such as the Albert and Orange Rivers), are added.

A backwater effect has been observed at this site. When the Denison floods and Gordon discharge is low, the Denison water may backflow up past site 65. The result of this effect would be an overestimation of the high flows at site 65. 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).

As part of the Basslink water license amendments, minimum environmental flow targets at site 65 were recommended. Two levels of minimum environmental flow were approved on a three year trial basis. For the period December through May, the minimum flows required are 10 $m^3 s^{-1}$, for the period June through November the minimum flow required is 20 $m^3 s^{-1}$. Basslink operation began on 28 April 2006. The duration analysis of hourly flows at site 65 shows that the minimum flow target of 10 $m^3 s^{-1}$ was achieved 98.6 % of the time in May 2006. The minimum flow target of 20 $m^3 s^{-1}$ in June 2006 was fulfilled 100 % of the time.

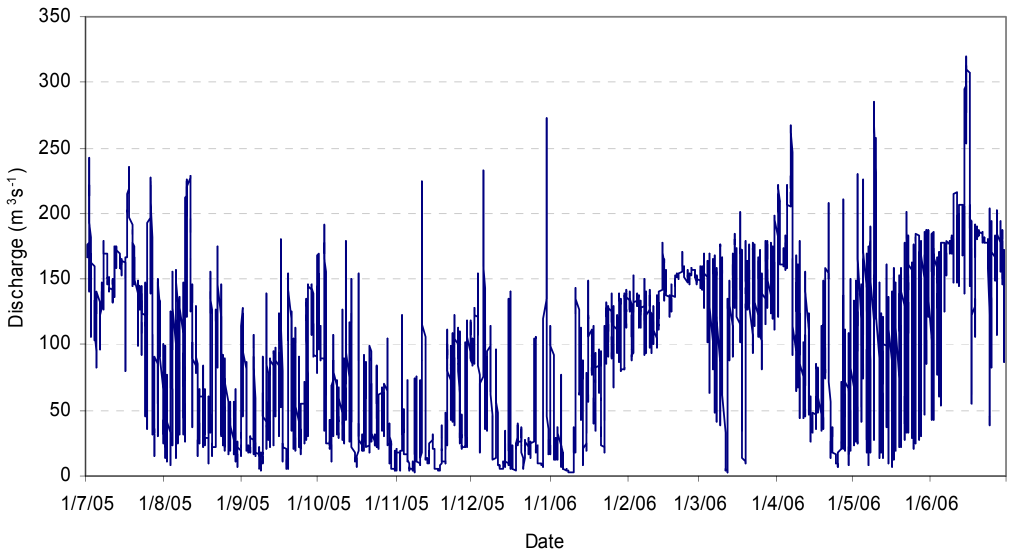

Figure 2.8. Flow recorded (hourly data) at site 65 (Gordon above Denison), from July 2005 to June 2006.

2.4.2 Median monthly flows

The median monthly flow for site 65 is shown in Figure 2.9. Comparison with long-term patterns shows almost identical median flows for the first half of 2005–06, however lower than long-term median flows were recorded in January and April 2006, while a higher than long-term median flow was evident in June 2006.

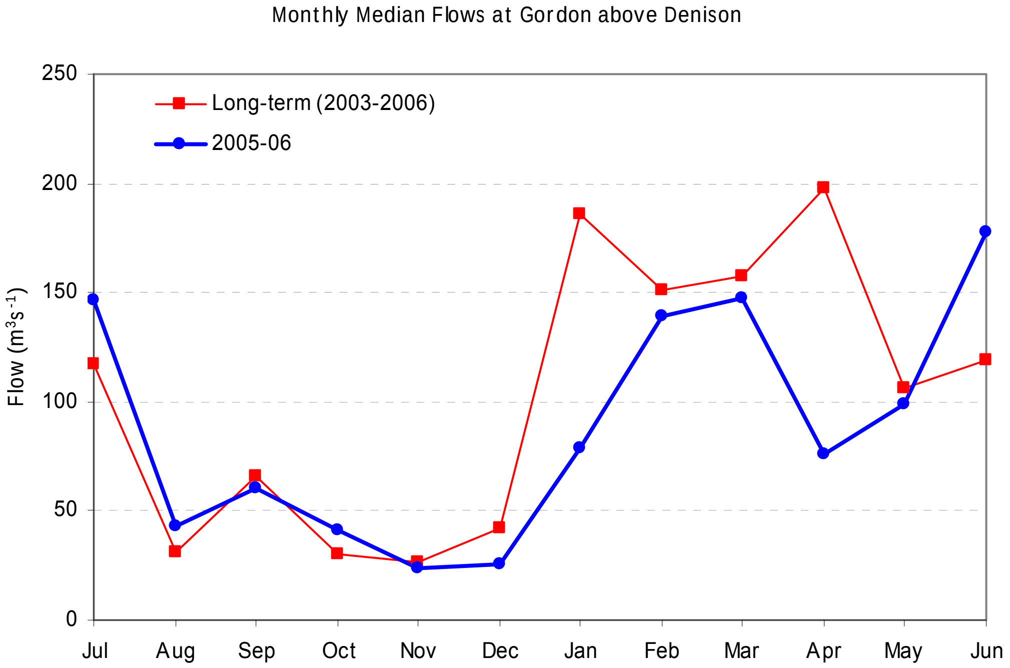

Figure 2.9. Median monthly flow at site 65 for 2005–06 compared with long-term median values.

2.4.3 Duration curves

The duration curve for site 65 is shown in Figure 2.10. Comparison with the long-term average shows a decrease in flow during 2005-06 for flows exceeding the 70th percentile (39 $m^3 s^{-1}$).

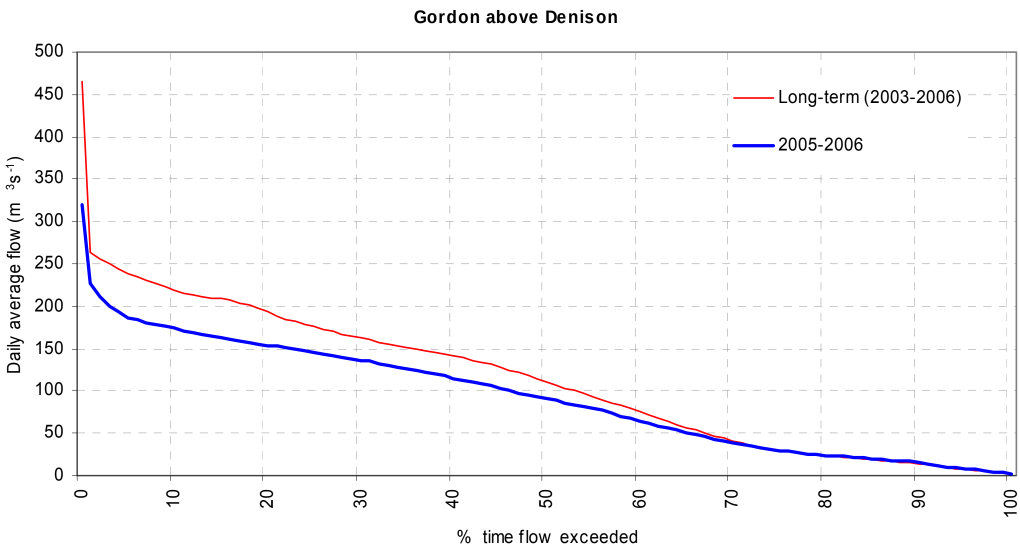

Figure 2.10. Duration curve for flow at site 65.

2.5 Gordon above Franklin (site 44)

The Gordon above Franklin site (site 44) is the furthest downstream site unaffected by tidal influences. Site 44 records the power station discharge after 33 km of flow in the river channel. This is combined with the discharge from a number of significant tributaries, including the Albert, Orange, Denison, Maxwell, Olga and Sprent Rivers. It does not include flows in the Franklin River. Data from site 44 were used to indicate the effects of tributary streams on the discharge pattern from the power station.

2.5.1 Flow

Figure 2.11 shows the time series plot for flow at site 44 for 2005-06. The power station discharge is superimposed. For January to April 2006, the power station discharge is the major component of the site 44 flows, while for the remainder of the year it is the flow from tributary streams, such as the Denison River, that results in the high peak discharges evident in Figure 2.11. Peak flows for the site this year were recorded in late December 2005.

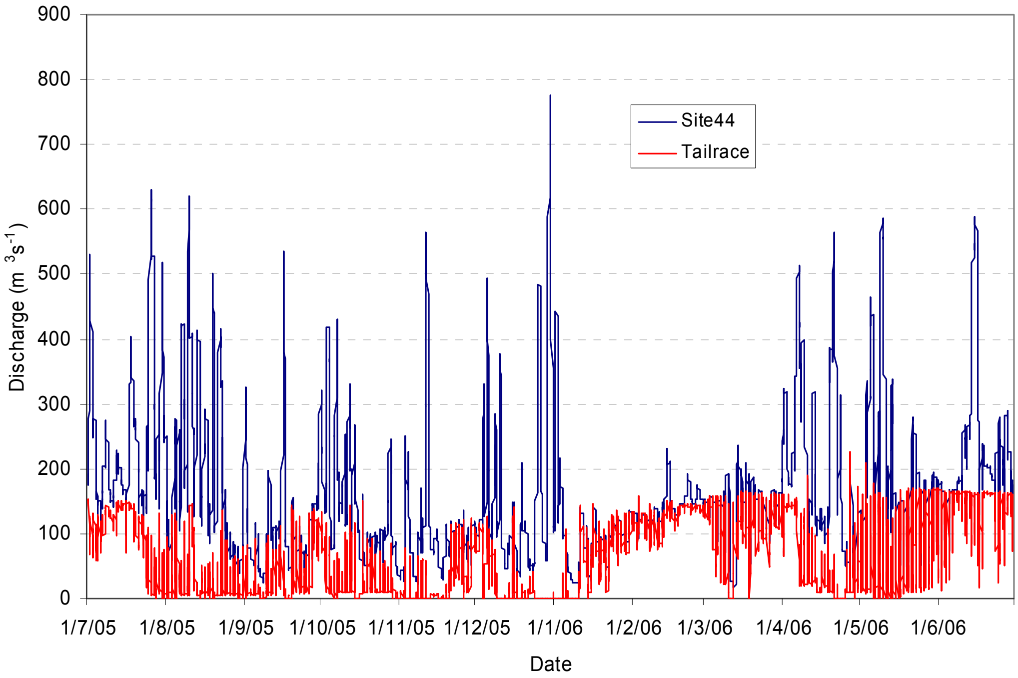

Figure 2.11. Flow recorded (hourly data) at site 44 (Gordon above Franklin) and the tailrace during 2005–06.

2.5.2 Median monthly flows

Figure 2.12 shows the median monthly discharge for this site over 2005-06, compared with the long-term (since December 1999) pattern. It indicates that the discharge at the downstream end of the study area had reduced flows in the summer and autumn months (December 2005 through May 2006).

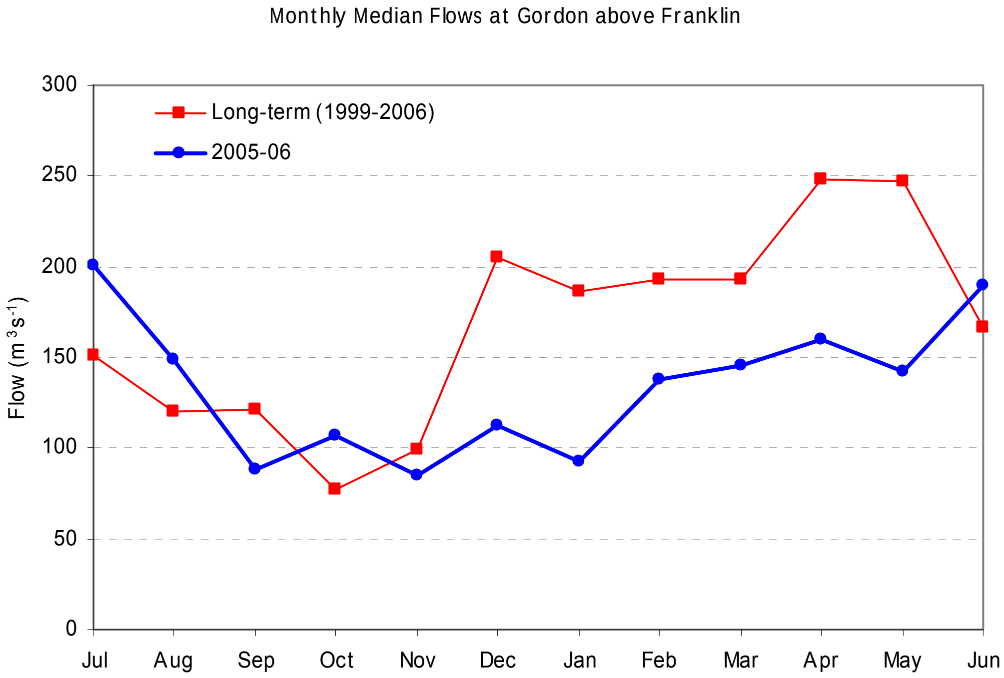

Figure 2.12. Median monthly flow at site 44 (Gordon above Franklin) for 2005–06 and the long–term monthly median values.

2.5.3 Duration curves

Figure 2.13 shows the duration curve for Gordon River site 44 (upstream of the Franklin River) for 2005–06 and compares it with the long–term (since December 1999) record.

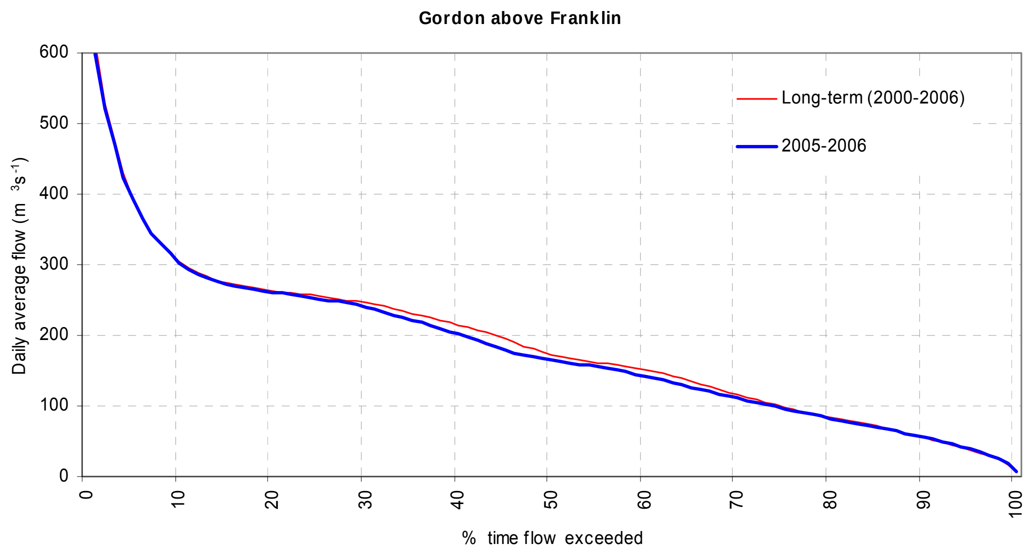

Figure 2.13. Duration curves for the Gordon above Franklin site (site 44) for 2005–06 and historic (since 2000).

Figure 2.14 shows the duration curves for sites 44, 65 and the tailrace with the Y axis scaled to match that of the tailrace duration curve (Figure 2.5). This allows a more accurate comparison between the three sites, and shows that the pattern of low discharges evident at the tailrace and, to a lesser extent, site 65 was not apparent at site 44. This indicates that the tributary streams were making a substantial contribution throughout the year at this site. Site 44 also recorded much greater flood discharges than the upstream sites, as would be expected.

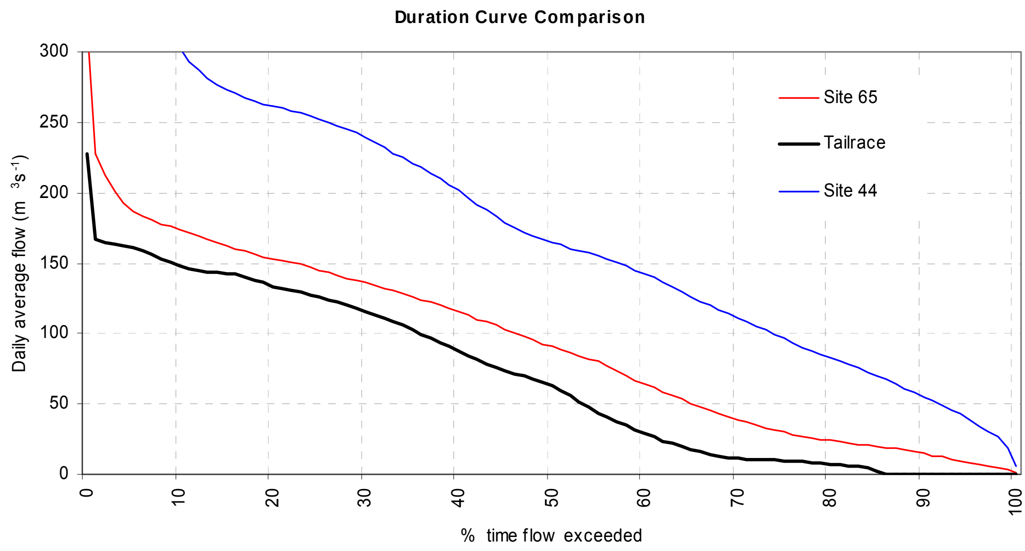

Figure 2.14. Duration curves for site 44 (Gordon above Franklin), site 65 (Gordon above Denison) and the Tailrace (site 77) for 2005–06.

2.6 Conclusion

Total rainfall at Strathgordon in 2005-06 was higher than usual, with August, December and April recording 146 %, 212 % and 155 % respectively, of the average rainfall for each month. The Gordon Power Station rarely operated at full capacity during 2005-06, but had greater 1- and 2-turbine operation. Basslink operation commenced on 28 April 2006, resulting in a more varied discharge pattern for the power station from this date onwards. Basslink testing was also performed during the period December 2005 to April 2006.

The power station operating pattern, and hence the downstream hydrological regime, fell into three categories:

- intermittent operation, for August 2005 to mid-January 2006, and mid-April 2006 to late May 2006;
- operation at intermediate discharges (indicative of 1-2 turbine operations), for July 2005, mid-January 2006 to mid-April 2006 and most of June 2006; and
- operation essentially at full-gate for a very brief period in late April/early May 2006.

On a monthly basis, July, September and June exceeded the long-term median discharge values. Overall, the power station discharge pattern was less than usual to the 75th percentile, with a median value of 63 $m^3 s^{-1}$ compared with the long-term median of 124 $m^3 s^{-1}$.

There were 17 % less shut-downs than in 2004-05, but with a similar modal range. One long-duration shut-down was recorded in late December 2005. In terms of operating events, the power station recorded fewer short- and long-duration start-ups than in 2004-05. The modal range was 16-24 hours, similar to previous years.

Flow pattern at the compliance monitoring site (site 65) and median monthly flow values were similar to those of the tailrace, with additional flow from upstream tributaries. The duration curve for this site was similar to that of the tailrace, but with increased flows for the entire flow range. At least some of this difference may be attributable to backwater from high Denison River flows.

A duration analysis of hourly flows at site 65 post-Basslink operation shows that the minimum flow target of 10 $m^3 s^{-1}$ was met 98.6 % of the time in May 2005. The minimum flow target of 20 $m^3 s^{-1}$ was met 100 % of the time during June 2006.

The Gordon above Franklin (site 44) recorded a flow pattern which included the power station discharge plus some peak flow events produced by rainfall and tributary runoff. The data from this site showed that the flow pattern matched the power station tailrace discharge pattern closely from early January to late March. Natural high volume flow events originating in tributary streams were recorded in each of the other months. The duration curve for site 44 shows the overall effect of the natural inflows.

The median discharge values at the tailrace, site 65 and site 44 for 2005-06 were 63, 91, and 164 $m^3 s^{-1}$, respectively, showing the downstream increase due to inflows from tributary streams.

The flow regime at the downstream sites post-Basslink commissioning is influenced by the power station operation. During May operation was of a stop/start nature, resulting in lower than average discharge. June saw almost constant 2-turbine operation, resulting in higher than average discharge. Site 65 is most affected by the power station operation while site 44 has more natural inflow and is less influenced by power station operations.

2.7 Hydrological interactions

The hydrological regime influences all sites downstream of the power station. Power station-driven flow regulation tends to dominate the flow regime of the downstream sites with a pattern which is often substantially different from the natural flow regime. Seasonal tributary inflows mitigate this effect to an extent proportional to their flow volume and location in the catchment. In general, when there are major natural inflows, the Gordon Power Station operates less.

The hydrological regime is the primary driver of geomorphic processes. The interaction between hydrologic and geomorphic processes impacts on riparian vegetation through erosion (substrate stability), deposition (burying, light interception), inundation (for too long, or in the wrong season) and direct physical disturbance (shear, abrasion). Benthic algae would be subject to a similar range of impacts.

The hydrological regime directly impacts on benthic macroinvertebrates through habitat area, flow velocities, and stranding. Combined with water temperature, it influences the physiological responses of individual species.

The hydrological regime combined with topography and physical barriers may impede the movement of migratory fish species.

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3 Water quality

Water quality parameters were measured in Lake Gordon and Lake Pedder and in the Gordon River downstream of the power station during 2005–06. The water quality monitoring sites are shown in Figure 3.1.

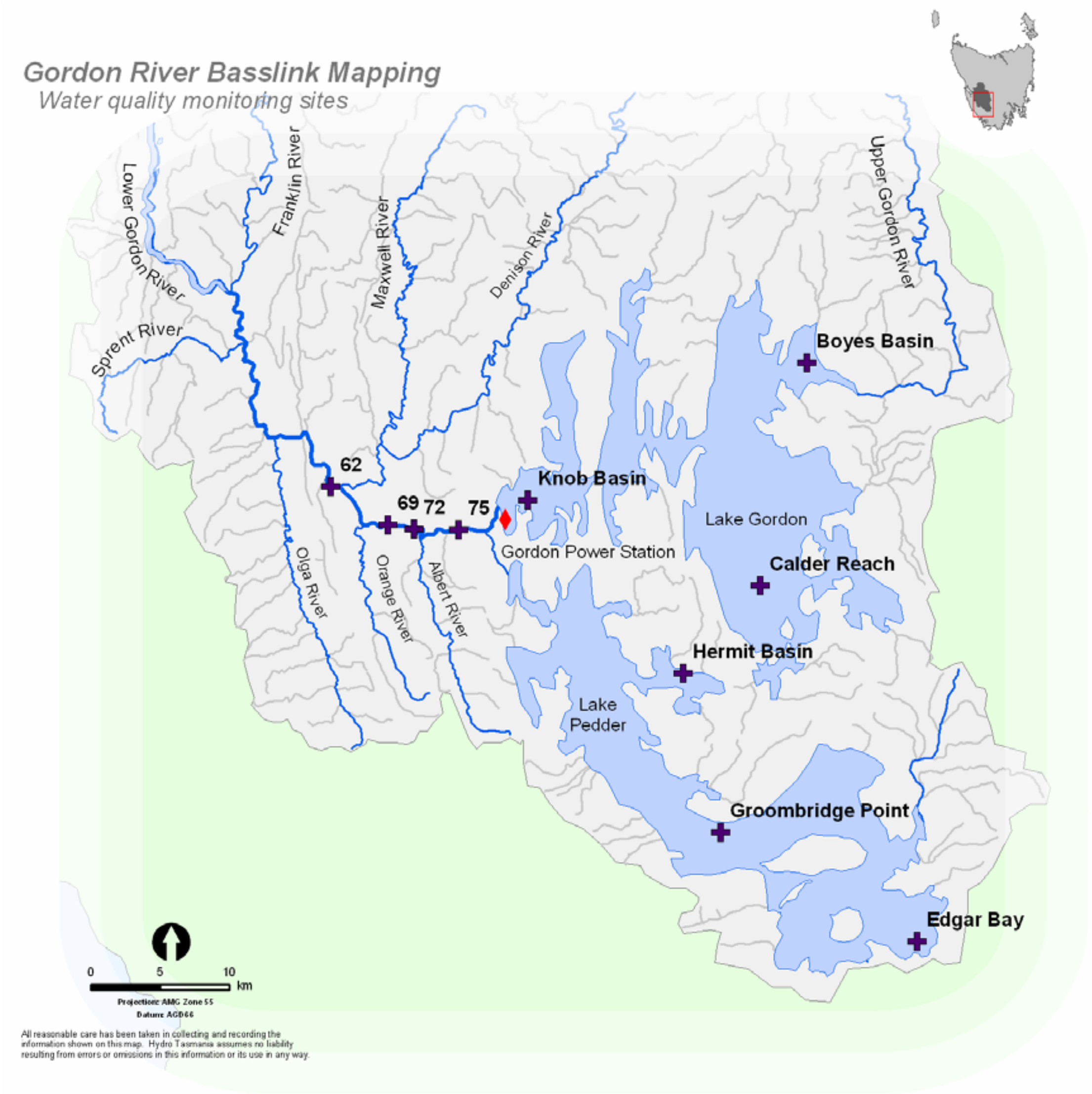

Figure 3.1. Map of the locations of water quality monitoring sites in Lakes Pedder and Gordon, and the Gordon River.

3.1 Field methods

In Lakes Gordon and Pedder, chemical analyses were carried out on surface water samples. The following parameters were analysed for each water sample:

- total phosphorus and dissolved reactive phosphorus (DRP);
- nitrite, nitrate, total Kjeldahl nitrogen (TKN) and ammonia;

- chlorophyll–*a*;
- metals (Fe, Mn, Zn, Cd, Cu, Al, Co, Cr, Ni and Pb);
- sulphate;
- alkalinity; and
- dissolved organic carbon.

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

3.1.1 Lake Gordon

During 2005–06, quarterly water quality monitoring was conducted in Lake Gordon at the power station intake, at Calder Basin and at Boyes Basin adjacent to the upper Gordon River inflow. Depth profiles of water temperature, dissolved oxygen, pH, and conductivity were taken to monitor the status of the water column at these sites. Surface water chlorophyll–a, water temperature, pH, conductivity, turbidity and dissolved oxygen concentrations were also recorded at these locations and surface samples for laboratory measurement of nutrients and metals were collected. On one sampling occasion in April 2006, poor weather conditions prevented the completion of a full profile for all parameters at Calder Basin. In addition, the July 2005 sampling was unable to provide a full depth profile for the measurement of pH.

3.1.2 Lake Pedder

Depth profiles were measured off Groombridge Point in Lake Pedder, which is the deepest point of the main body of the lake. Surface water samples measuring chlorophyll–*a*, water temperature, pH, conductivity, turbidity and dissolved oxygen were collected at Groombridge Point, Hermit Basin and Edgar Bay, while surface samples for laboratory measurement of nutrients and metals were collected from Groombridge Point.

3.1.3 Gordon River

Water quality monitoring data was collected from four sites on the Gordon River, downstream from the Gordon Power Station. These are:

- Gordon Power Station tailrace (site 77);
- Gordon River at site 75 (G4 – Albert Rapids);
- Gordon River at site 62 (downstream of the Denison confluence); and
- Gordon River at site 65 (upstream of the Denison confluence)

Water temperature was logged at the first three sites for the full year, with dissolved oxygen only being recorded at the tailrace site. Of these, only the tailrace has the capacity to have the data retrieved by telemetry, while sites 75 and 62 must be downloaded manually during field visits. For this reason, the data record for these sites is analysed outside the normal reporting year cycle from April 2005–April 2006. This corresponds with field visits when manual retrieval of data was undertaken. Compliance site 65 first began measurements in April 2006, providing temperature readings by telemetry. Dissolved oxygen readings at site 65 are not presented here, as they require review, and will be presented in the 2006–07 annual report.

3.2 Results

3.2.1 Lake Gordon water quality

Temporal changes in water temperature, pH and dissolved oxygen for Boyes Basin, Calder Basin and at the intake site are shown in Figure 3.2 and Figure 3.3 respectively. Depth profiles of each of the parameters varied with location, inflows and season.

3.2.1.1 Boyes Basin

Boyes Basin is the shallowest of the three sampling sites, with depths ranging between 19 and 28m during the sampling periods. It is also located closest to the upper Gordon River which is one of the major inflows to the lake. In July, temperatures were almost isothermal with depth ranging between 8.4 °C at the surface to 5.7 °C at 22m. Temperatures were higher in October and January. In October, substantial early season stratification was evident, with temperatures that ranged between 16 °C at the surface and 8 °C in the hypolimnion. In January, stratification was slightly more pronounced, with a temperatures range of 20 °C at the surface to 12 °C in the hypolimnion. Interestingly, January temperatures decreased relatively constantly between 5 and 10m which may be attributable to a significant inflow event. April temperatures were significantly lower than January, with temperatures approximating 13 °C in the surface and 10 °C in the hypolimnion.

The pH values were lower at greater depth, with values ranging between 5.8 and 7 for all sampling trips. In January, the difference between surface and bottom was most pronounced, with the higher pH at the surface probably attributable to increased algal production.

Dissolved oxygen levels were highest in July, ranging between 9–11 mg L^{-1} (79–90 % saturation). October dissolved oxygen levels were also high, and ranged from 8–9 mg L^{-1} (74–83 % saturation) throughout the depth of the water column. In January, levels were above 8 mg L^{-1} (83 % saturation), in the upper 24m but decreased between 24–28m to a minimum 7 mg L^{-1} (61 % saturation) as a result of thermal stratification. Dissolved oxygen levels increased again in April reaching 9 mg L^{-1} (88 % saturation) at the in the upper 15m, while the lower 4m had greater concentration of dissolved oxygen at 11 mg L^{-1} (96 % saturation). This high dissolved oxygen at depth is probably due to the significant input of cool, oxygenated water from the upper Gordon River that may have occurred at this time.

Conductivity at Boyes Basin was low, and ranged between 27–50 µS cm^{-1} over the full depth range for each of the sampling days, while turbidity was low within the range of 1.7–4.1 NTU (Table 3.1). Chlorophyll–*a* was also low with a range of 0.74–2.78 µg L^{-1} , that is typical for oligotrophic lakes. (Table 3.1).

3.2.1.2 Calder Reach

The temperature profile for Calder Reach demonstrates the gradual warming of the water column from isothermal conditions in July to stratification in January. The limited depth profile in April indicating isothermal conditions for the first 17m shows that a deepening of the surface mixing occurred. In January, surface and hypolimentic (45m depth) temperatures were 17 and 10 °C, respectively. In April, water temperatures approximated 13 °C through the 17m that was able to be measured. Below 30m depth, temperature remained relatively constant throughout the year ranging from 8.9–10.3 °C. The pH profiles were similar to those measured at Boyes Basin ranging from 5.7–6.8 (Figure 3.2). Between July and January, pH tended to decrease with depth. Dissolved oxygen levels were high in July and October ranging between 8.8–9.7 mg L^{-1} (77–88 % saturation) (Figure 3.3). In January levels were above 8.6 mg L^{-1} (81 % saturation), in the upper 25m but decreased between 20m and 42m as a result of thermal stratification to a minimum of. 5.9 mg L^{-1} (52 % saturation). In April, dissolved oxygen between the surface and 17m depth was high at 9.1 mg L^{-1} (89 % saturation). Conductivity, turbidity and chlorophyll–*a* were all low ranging between 35–50 µS cm^{-1}, 1.9–4.3 NTU and 0.21–1.21 µg L^{-1}, respectively (Table 3.1).

3.2.1.3 Intake site

The temperature profiles at the power station intake displayed near isothermal conditions in July, pronounced shallow stratification in October and strong stratification in January. In April there was a deep surface mixed layer (Figure 3.2).

In July, temperatures approximated 9 °C to a depth of 30m, at which point the temperature declined with depth to an approximate minimum of 8 °C. Also in July, the dissolved oxygen was greater than 7.2 mg L^{-1} (62 % saturation) to a depth of 20m. An oxycline was evident at this depth with anoxia evident over the depth range of 52–64m. A strong oxycline, with anoxia in bottom waters was also evident on all other sampling days (Figure 3.3). In October, temperature ranged between 8 and 16 °C, while dissolved oxygen ranged between 0 and 9.4 mg L^{-1}. In January, the temperature range was very similar from 8 °C at 81m depth to an unseasonably cool 15 °C at the surface. Dissolved oxygen displayed a constant decrease from 9.7 to 5 mg L^{-1} over a depth range of 0 to 40m. An increasing rate of decline was apparent below this depth, with anoxic conditions apparent between the depths of 60m and 81m.

In April, water temperature ranged from 13 °C at the surface to 8 °C at 54m. Dissolved oxygen was 9.1 mg L^{-1} at the surface, with an oxycline at 30m. Dissolved oxygen declined to anoxic conditions between the depths of 60m and 69m.

The pH values at the intake displayed variability with time and depth (Figure 3.2). Values were higher at the surface ranging from 5.6 to 6.8 and 5.3 to 5.9 in the hypolimnion between July 2005 and April 2006. Surface conductivity at the intake location was low and ranged from 37 to 48 µS cm^{-1} over depth for each of the sampling days, while turbidity was low within the range of 0.9–1.9 NTU (Table 3.1). Chlorophyll–*a* was also very low with a range of 0.08–1.35 µg L^{-1} and is typical for oligotrophic lakes (Table 3.1).

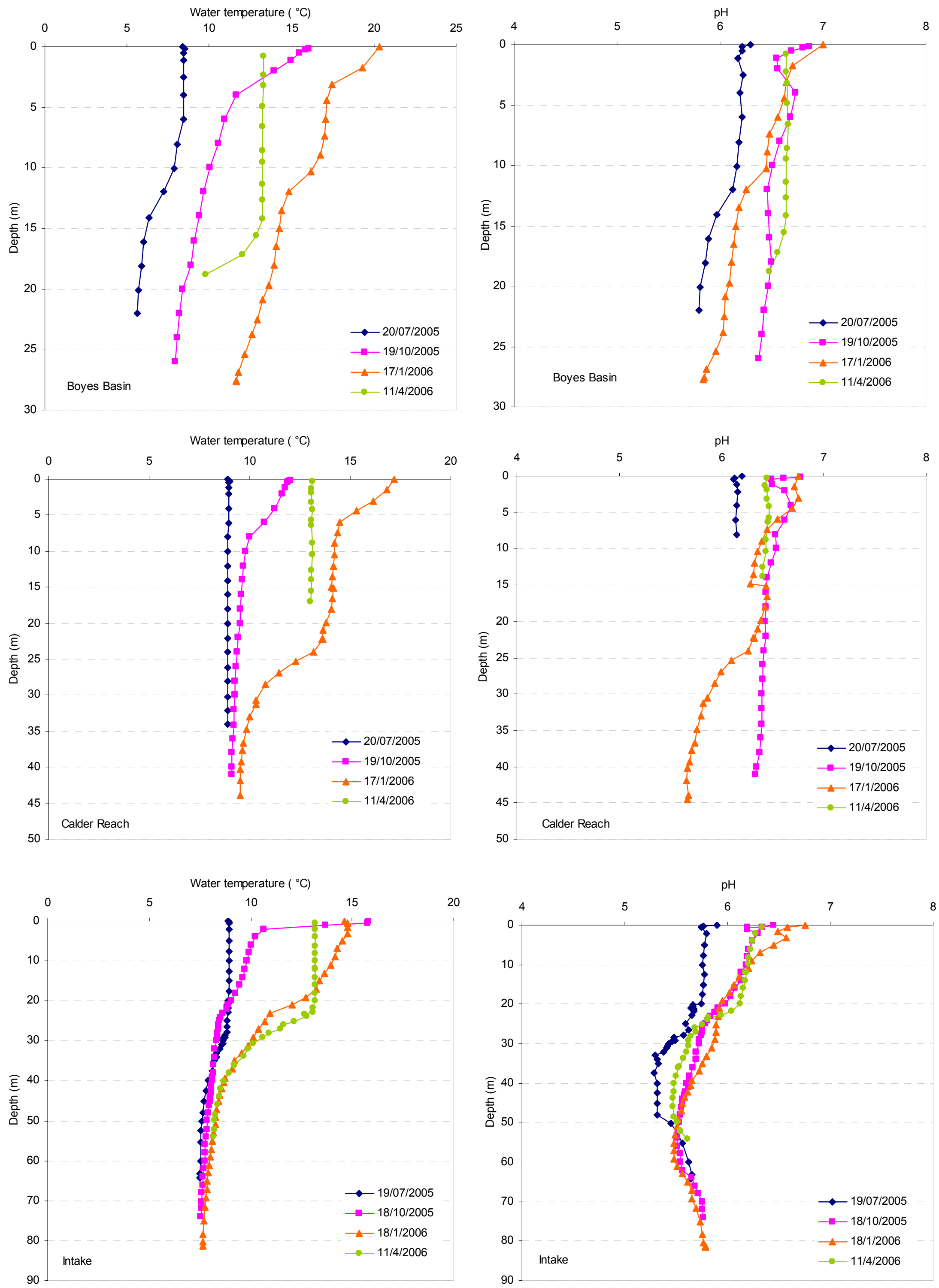

Figure 3.2. Depth profiles of water temperature (left) and pH (right) in Lake Gordon at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) for 2005–06. Note that the intake gate level is at 254m ASL, and the intake depths were 22.1m (19 July 2005), 26.3m (18 October 2005), 29.6m (18 January 2006) and 27.2m (11 April 2006).

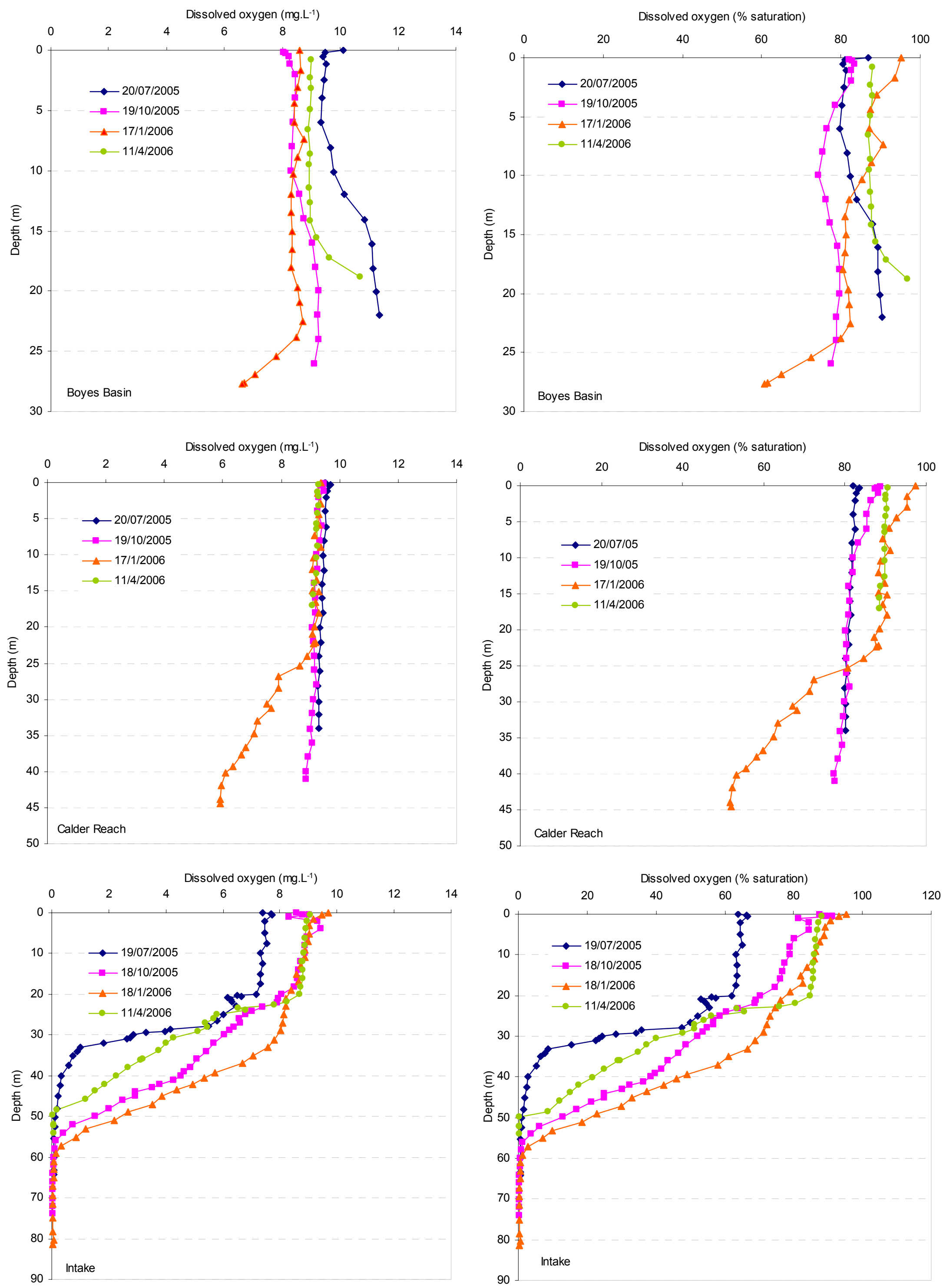

Figure 3.3. Depth profiles of dissolved oxygen concentration (left) and % saturation (right) in Lake Gordon at Boyes Basin (top), Calder Reach (middle) and the power station intake (bottom) for 2005–06. . Note that the intake gate level is at 254m ASL, which corresponds to intake depths of 22.1m (19 July 2005), 26.3m (18 October 2005), 29.6m (18 January 2006) and 27.2m (11 April 2006).

3.2.1.4 Summary of surface water results

Surface water samples were analysed in the laboratory for the parameters listed in section 3.1 and results are presented in Table 3.1. The results are representative of Tasmanian fresh waters in the

Tasmania's south-western region with low nutrient and metal concentrations, relatively high dissolved organic carbon and slightly acidic pH values. Unlike previous years, elevated chlorophyll-*a* levels were not recorded at Boyes Basin. Sulphate concentrations were within the range reported in previous years, while alkalinity measures were lower or at the lower end of the reported range previous years.

Table 3.1. Nutrients, metals, sulphate, alkalinity, dissolved organic carbon and chlorophyll–*a* levels recorded from three monitoring sites in Lake Gordon during 2005–06.

Parameter	Boyes Basin	Calder Basin	Intake
Specific conductivity ($\mu S\ cm^{-1}$)	27–45	35–50	37–48
Turbidity (NTU)	1.7–4.1	1.9–4.3	0.9–1.9
Chlorophyll–*a* ($\mu g\ l^{-1}$)	0.74–2.78	0.21–1.01	0.08–1.35
Dissolved organic carbon ($mg\ L^{-1}$)	6.3–8.5	5.1–8.0	5.5–7.1
Total phosphorus ($mg\ L^{-1}$)	<0.005–0.007	<0.005–0.012	<0.005–0.005
Dissolved reactive phosphorus ($mg\ L^{-1}$)	<0.002–0.003	<0.002–0.003	<0.002–0.004
Nitrite ($mg\ L^{-1}$)	0.003–0.004	0.003	0.003–0.004
Nitrate ($mg\ L^{-1}$)	0.039–0.064	0.053–0.065	0.049–0.072
Total Kjeldahl nitrogen ($mg\ L^{-1}$)	0.205–0.243	0.167–0.269	0.136–0.210
Ammonia ($mg\ L^{-1}$)	0.015–0.030	0.022–0.031	0.016–0.026
Iron ($mg\ L^{-1}$)	0.458–0.598	0.468–0.639	0.433–0.650
Manganese ($mg\ L^{-1}$)	0.007–0.010	0.006–0.012	0.007–0.018
Zinc ($mg\ L^{-1}$)	<0.001–0.002	<0.001–0.006	<0.001–0.005
Cadmium ($mg\ L^{-1}$)	<0.001	<0.001	<0.001
Copper ($mg\ L^{-1}$)	<0.001	<0.001–0.002	<0.001
Aluminium ($mg\ L^{-1}$)	0.160–0.206	0.146–0.242	0.146–0.157
Cobalt ($mg\ L^{-1}$)	<0.001	<0.001	<0.001
Chromium ($mg\ L^{-1}$)	<0.002	<0.002	<0.002
Nickel ($mg\ L^{-1}$)	<0.002	<0.002	<0.002
Lead ($mg\ L^{-1}$)	<0.005–0.003	<0.005–0.003	<0.005
Sulphate ($mg\ L^{-1}$)	1.1–1.2	1.1–1.4	1.1–1.4
Alkalinity ($mg\ L^{-1}$)	4–5	3	2–3

3.2.2 Lake Pedder water quality

Lake Pedder is relatively shallow (15-16m depth) and well mixed with depth profiles of temperature displaying isothermal conditions in July, January and April with some surface warming in October (Figure 3.4). The temperature profiles also demonstrate a gradual warming of the water body from winter at 7-8 °C to 15 °C in summer. The resulting effect was that water quality parameters did not change with depth (Table 3.2, Table 3.3) which is consistent with the 2004-05 monitoring results. Water samples from the surface were analysed for a range of parameters as outlined in section 3.1. As in previous years water quality was good in Lake Pedder. Conductivity, turbidity, chlorophyll, nutrient and metal concentrations were all low, while dissolved oxygen was high in surface waters and pH was slightly acidic. Dissolved organic carbon concentrations were similar to those measured in Lake Gordon.

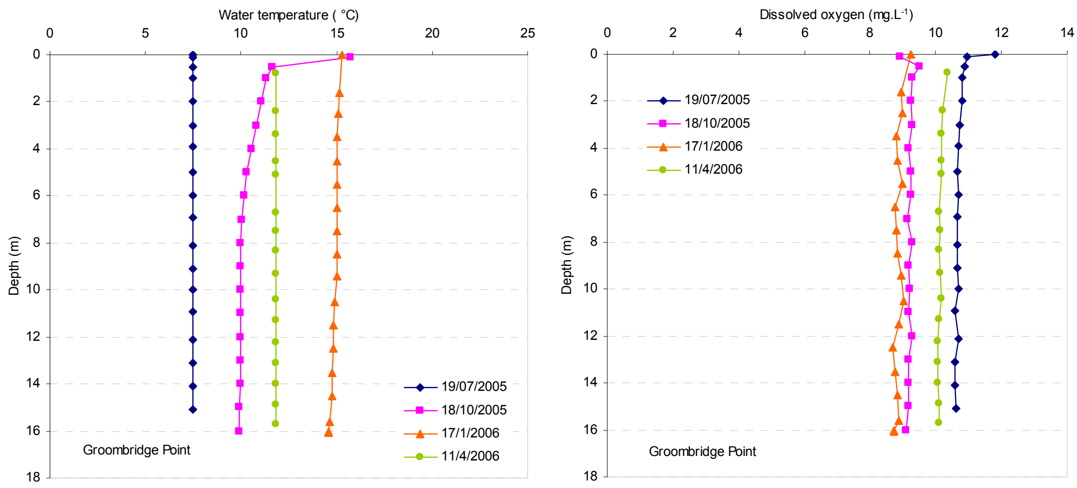

Figure 3.4. Depth profiles of water temperature in Lake Pedder for 2005–06.

Table 3.2. Water quality parameter ranges measured at the three monitoring sites in Lake Pedder during 2005–06.

Parameter	Edgar Bay (surface)	Hermit Basin (surface)	Groombridge Point (surface)	Groombridge Point (15 m)
Chlorophyll–*a* (μg l^{-1})	0.53–1.17	0.32–1.47	0.57–1.16	–
Dissolved oxygen (mg L^{-1})	9.0–12.0	9.1–11.1	8.9–11.8	8.7–10.6
Dissolved oxygen (% saturation)	89–100	90–94	90–99	81–95
pH	6.2–6.7	5.8–6.0	6.2–6.9	6.0–6.4
Turbidity (NTU)	0.62–0.95	0.56–0.65	0.58–0.86	–
Conductivity (μS cm^{-1})	39–47	37–44	38–46	38–46
Water temperature (°C)	7.4–15.8	7.4–16.3	7.5–15.7	7.5–14.6

Table 3.3. Nutrients, metals, sulphate, alkalinity, and dissolved organic carbon levels at Groombridge Point, Lake Pedder during 2005–06.

Parameter	Range (mg L^{-1})
Total phosphorus	<0.005–0.012
Dissolved reactive phosphorus	<0.002–0.003
Nitrite	0.003–0.004
Nitrate	0.050–0.058
Total Kjeldahl nitrogen	0.199–0.212
Ammonia	0.022–0.029
Iron	0.232–0.300
Manganese	<0.005
Zinc	<0.001–0.002
Cadmium	<0.001–0.001
Copper	<0.001–0.001
Aluminium	0.116–0.122
Cobalt	<0.001
Chromium	<0.001
Nickel	<0.002
Lead	<0.005
Sulphate	1.2–1.4
Alkalinity	<2–2
Dissolved organic carbon	5.2–6.4

3.2.3 Water quality in the Gordon River

The hydrological regime and conditions in Lake Gordon tend to govern water temperature and dissolved oxygen in the Gordon River at and immediately below the power station (Figure 3.2 and Figure 3.3). The dissolved oxygen concentration and temperature of outflow water is influenced by lake level, degree of thermal stratification and power station operating conditions (i.e number of turbines, flow).

The Gordon River water temperatures were measured at the tailrace (site 77), site 75 (Gordon @ G4) and site 62 (Gordon @ Denison confluence), while dissolved oxygen was measured at the tailrace. More recent installation of water quality monitoring equipment at site 65 (Gordon upstream of the Denison confluence) is presented for the two months since its installation in April 2006.

3.2.3.1 Data quality and duration

Temperature (Figure 3.5) and dissolved oxygen (Figure 3.7) data is missing for short periods during the 2005–06 monitoring period at the tailrace as a result of equipment failures. The break downs were generally short at less than a week. The second issue with the tailrace data set is that of large diurnal temperature variation between October 2005 and March 2006. The daily peaks in water temperature are attributable to heating of holding chambers during the sampling process. Water is drawn from the tailrace to a chamber, temperature measured and then water is released. During summer, the holding chamber heats up, causing a misleading increase in water temperature. Consequently, the high variability in water temperatures in the tailrace are not consistent with the temperature of the hypolimnetic water released. Given the errors in the tailrace temperature data, it is not presented or discussed further.

3.2.3.2 Water temperature

Water temperature was monitored at the tailrace (site 77), site 75 (G4), and site 62 (Figure 3.5). Data are not presented for the tailrace as a result of the erroneous measurements. Site 75 is located 2 km downstream of the power station tailrace and is below the Albert confluence but above the Orange confluence, while site 62 is a further 10 km downstream below the Denison and Maxwell confluences.

A similar seasonal pattern at sites 75 and 62 was observed, which ranged from a mean maximum temperature of 13 °C in April 2005 to a mean minimum of around 7–8 °C in August 2005. This temperature regime is primarily influenced by the temperature of water at the Lake Gordon intake to the power station, which can be seen to correspond very closely on the days in which lake water quality profiles were undertaken (Figure 3.5). Differences between these sites are most obvious from September 2005 to March 2006, when water temperature is generally higher further downstream at site 62. In addition to the higher temperature at site 62, there is a significant degree of diurnal water temperature variation (Figure 3.6), influenced by changes in ambient air temperature. The greater distance downstream provides an opportunity for water to better reflect the daily fluctuations in air temperature at site 62. Furthermore, this site is significantly influenced by inflows from the Denison, where waters also have the opportunity to warm up during the day and cool at night.

To assess the influence of power station discharge on downstream temperatures, discharge from the tailrace (site 77) was plotted against temperature at sites 75 and 62 (Figure 3.6). Three scenarios are plotted representing a range of seasonal and discharge conditions. These scenarios are from mid May–mid July 2005, October–November 2005 and January–February 2006. A series of significant peaks and troughs with an amplitude of up to 6 °C from the seasonal temperature baseline coincided at sites 62 and 75 (Figure 3.6). From April 2005 to October 2005, the temperature variation was cooler than the baseline, while from October 2005 to February 2006 the temperature variation was warmer than the baseline. For site 65, the telemetered data from April to June 2006 indicates cool temperature variations. These short, significant variations are related to the discharge from the power station and the ambient air temperature. This is evident in all of the seasonal scenarios presented in which the most significant variations in temperature, in both positive and negative directions, coincide with periods of minimal power station discharge (Figure 3.6).

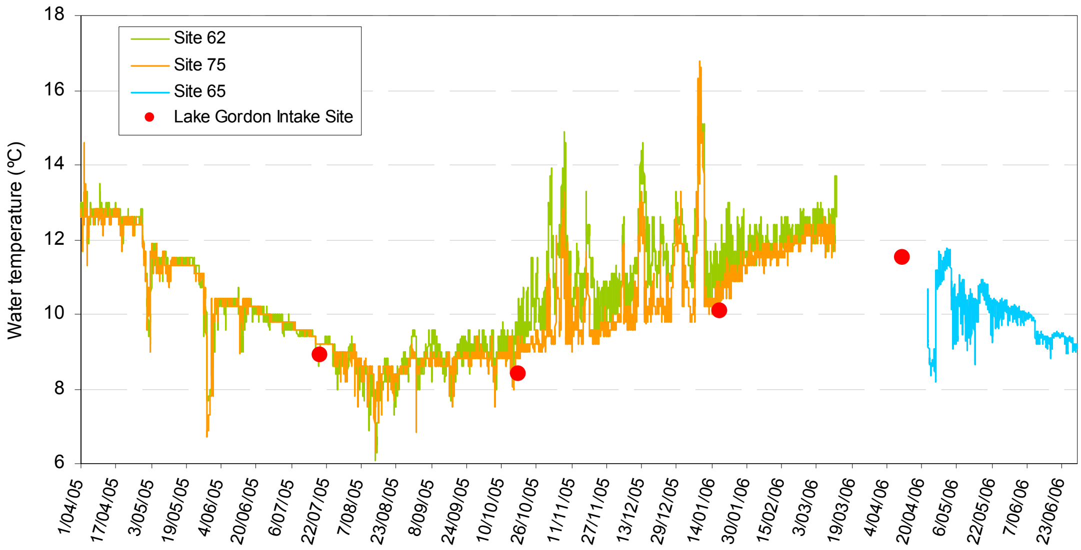

Figure 3.5. Water temperature data recorded for sites 75 (2km downstream of the tailrace), 65 (12km downstream of the tailrace) and 62 (15km downstream of the tailrace) from April 2005–June 2006. Note data from site 65 temperature data has been telemetred since its installation in April 2006, while sites 75 and 62 are downloaded manually from the datalogger and are only available until March.

Discharge from the power station for April 2005 to June 2006 ranged from of 0–270 $m^3 s^{-1}$. Discharge in May–July 2005 was high for most of this period with flow rates mostly >100 $m^3 s^{-1}$. For these high flow periods, water temperatures at both sites are very similar, and showed the gradual seasonal decline in water temperature from around 11.5 °C–9.5 °C over this period, typical of the source water at Lake Gordon intake. Two decreases in flow rate to in late May and mid June coincided with decreases in temperature of between 1–4 °C for sites 75 and 62. Cooler air temperatures at this time of year are responsible for rapid cooling of the water at theses sites in the absence of significant flow.

In October–November 2005, the flows were more variable, with a large amount of time spent at a baseflow of around 20 $m^3 s^{-1}$, with peaks in flow up to around 100 $m^3 s^{-1}$. There were also a number of periods where flow at the tailrace was <3 $m^3 s^{-1}$. Over this period the temperature at site 62 was usually higher than that at site 75, and showed significantly greater variation in temperature in response to changes in flow rate. This is most apparent on 29 October–22 November when a series of flow reductions saw temperature increase at site 62 at times from 10 to 14 °C and at site 75 from 9 to 11 °C.

In January–February 2006, a period of low or no flow in early January was followed by a gradual increasing trend in flow. All discharges from 21 January 2006 until the end of February were greater than 100 $m^3 s^{-1}$. As with the other scenarios, the very low flow at the beginning of January demonstrated the sensitivity of temperature at both sites 75 and 62 to discharge from the power station. Increases in temperature of between 5 and 6 °C were seen for both sites in response to the reduced discharge and the response of the water in the river to ambient air temperature. As discharge from the power station increased, the amplitude of the diurnal variations decreased in response.

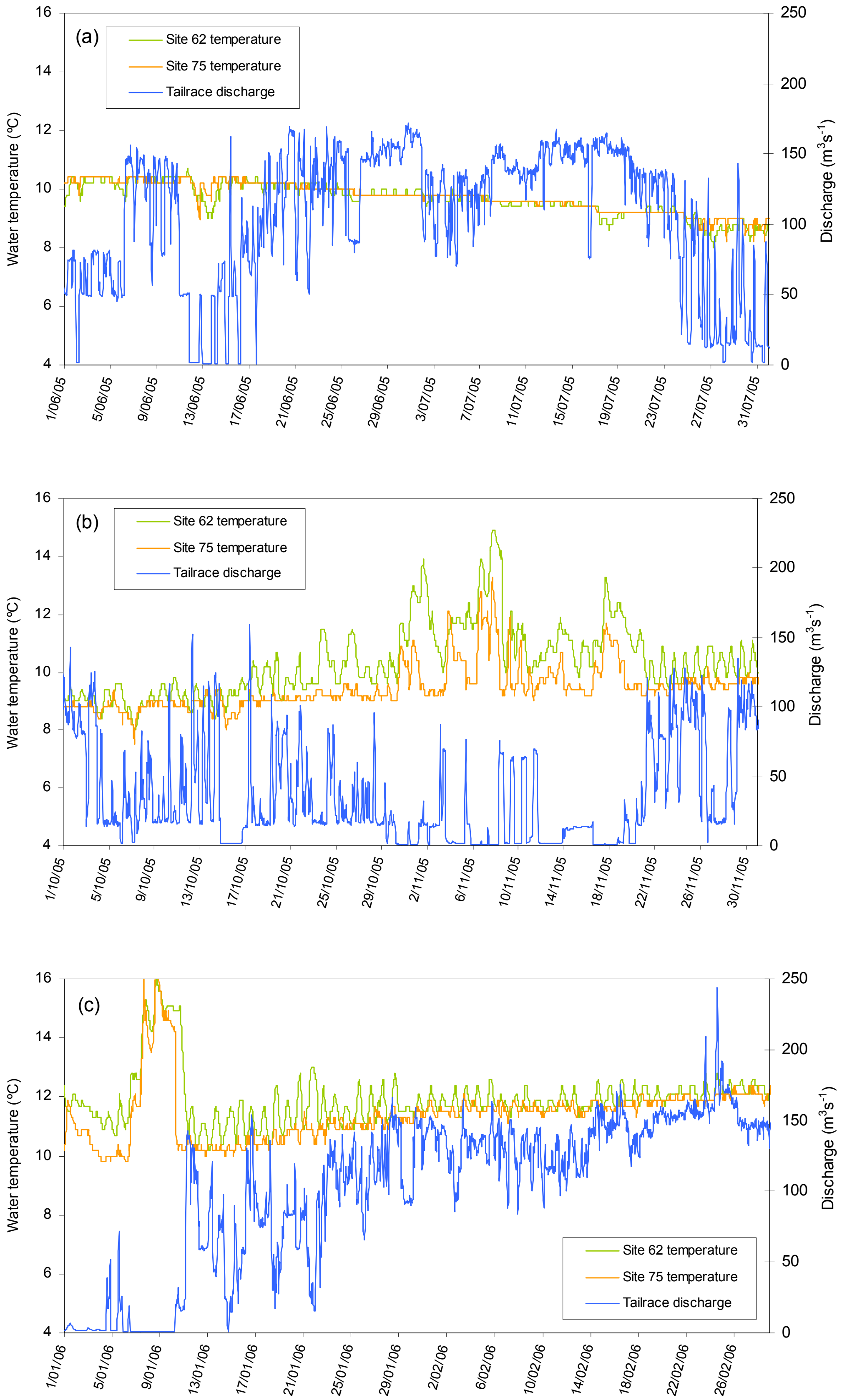

Figure 3.6. Water temperatures at sites 75 (2 km downstream) and 62 (15 km downstream) and corresponding tailrace discharge for (a) June–July 2005, (b) October–November 2005 and (c) January–February 2006.

3.2.3.3 Dissolved oxygen

Dissolved oxygen levels at the power station tailrace (site 77) for the period of July 2005 to June 2006 are shown in Figure 3.7. Similarly to the temperature data from site 77, there are short periods of equipment malfunction.

Dissolved oxygen levels in the tailrace were generally medium-high with a median of 8.0 mg L^{-1} and a range between 5.3 mg L^{-1} on 23 October 2005 to 12.1 mg L^{-1} on 2 November 2005. Concentrations of oxygen at the tailrace were indicative of those in Lake Gordon (Figure 3.7), having a very similar annual trend. Dissolved oxygen was relatively low in July 2005, with values in the range of 6 to 8 mg L^{-1}. Towards the end of July, there was an increase that remained consistent until early October with in the range 7-9 mg L^{-1}. A subsequent decline was seen for most of October 2005, which was then followed by an increase in dissolved oxygen levels to between 7 and 12 mg L^{-1} until mid January. A gradual decrease in dissolved oxygen levels was apparent from January to April 2006 when the lowest dissolved oxygen levels were logged, in conjunction with the effects of stratification in Lake Gordon. From April to June 2006, the dissolved oxygen concentrations in the tailrace showed a significant increase to between 8 and 11 mg L^{-1}.

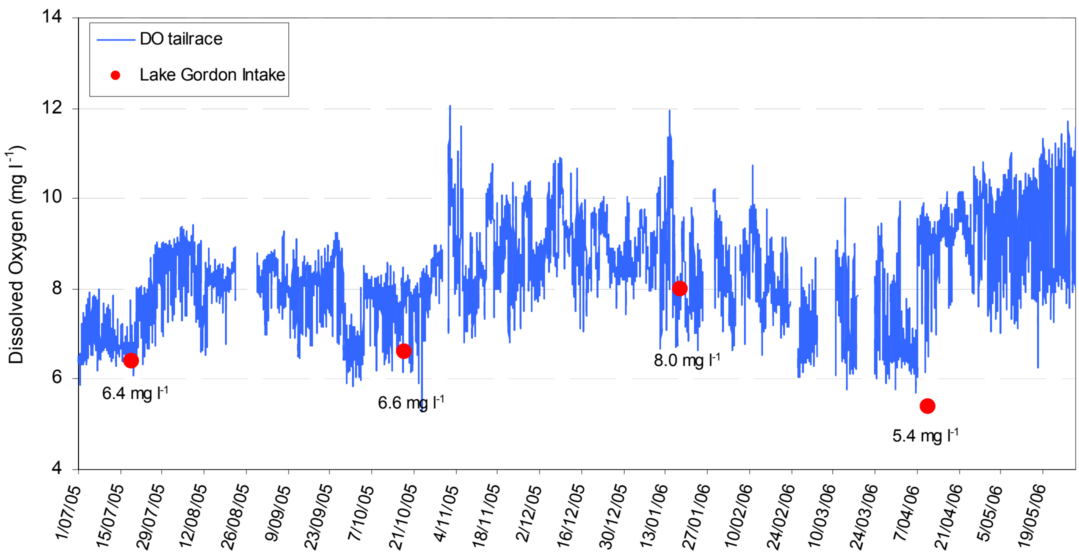

Figure 3.7. Dissolved oxygen values recorded at the power station tailrace from July 2004–June 2005. Spot values represent the measurement of dissolved oxygen at the Lake Gordon intake site that correspond to the level of the power station intake.

3.3 Conclusion

The physico-chemical conditions for Lakes Gordon and Pedder were considered normal for lakes in the south-west Tasmanian region. Water quality was good in both lakes and was characterised by low nutrient concentrations, low turbidity levels and low chlorophyll-a levels. Metal concentrations were also low.

The thermal structure of Lakes Gordon and Pedder were also similar to previous years. Parameter values recorded in the depth profiles varied with location and between monitoring trips. Dissolved oxygen levels generally remained high and above 5.5 mg L^{-1} at Boyes Basin and Calder Reach. Anoxia was evident on all occasions it was sampled, but this was below the level of the intake structure. Lake Pedder remained evenly mixed during 2005–06. No stratification in any of the water quality parameters was evident.

In the Gordon River, water temperatures displayed a broad seasonal pattern related to the thermal pattern of Lake Gordon. Periods of low discharge resulted in approximately 1–2 °C higher temperature at site 62 compared to 75. Conversely, high discharge conditions resulted in similar temperature values at sites 75 and 62. Temperature at both sites was sensitive to reductions in discharge, with significant increases or decreases in temperature observed under the influence of ambient air temperatures. Dissolved oxygen concentrations within the tailrace were generally at medium to high concentrations.

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4 Fluvial geomorphology

4.1 Introduction

This report summarises the Basslink fluvial geomorphology monitoring results for the period March 2005–March 2006. The Monitoring Program aims 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 here as the middle Gordon River), and relate these changes to power station operations or other factors where appropriate. This monitoring year incorporates the last pre-Basslink monitoring period (March 2004–October 2005). The autumn 2006 results are not included as pre-Basslink results, because the cable was being tested, but are not considered post-Basslink either, as the cable was not operational for the entire period.

This report is being prepared after the production of the Basslink Baseline Report (BBR) which was published in December 2005 and summarises and integrates the findings from the three years of pre-Basslink fluvial geomorphology monitoring. The BBR has identified indicator variables, and draft limits of acceptable change which will be used to identify post-Basslink changes. The outputs of the October 2005 monitoring have been included in the calculation of baseline geomorphology trigger values, but the March 2006 outputs have been excluded.

Details of the monitoring approach, monitoring program and its relationship with the initial Basslink geomorphology investigations are presented in the first pre-Basslink fluvial geomorphology monitoring report (Koehnken and Locher, 2002) and should be consulted for 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, 2005).

4.2 Methodology

Geomorphology monitoring includes the measurement of 200 erosion pins and 25 scour chains located at 48 monitoring sites in the middle Gordon River on a six-monthly basis (October and March), and photo-monitoring of an additional 54 sites on an annual basis in March each year. Site locations and site descriptions are contained in the November 2001–March 2002 field report (Koehnken and Locher, 2002). Figure 4.1 shows the location of the geomorphology monitoring zones in the middle Gordon River.

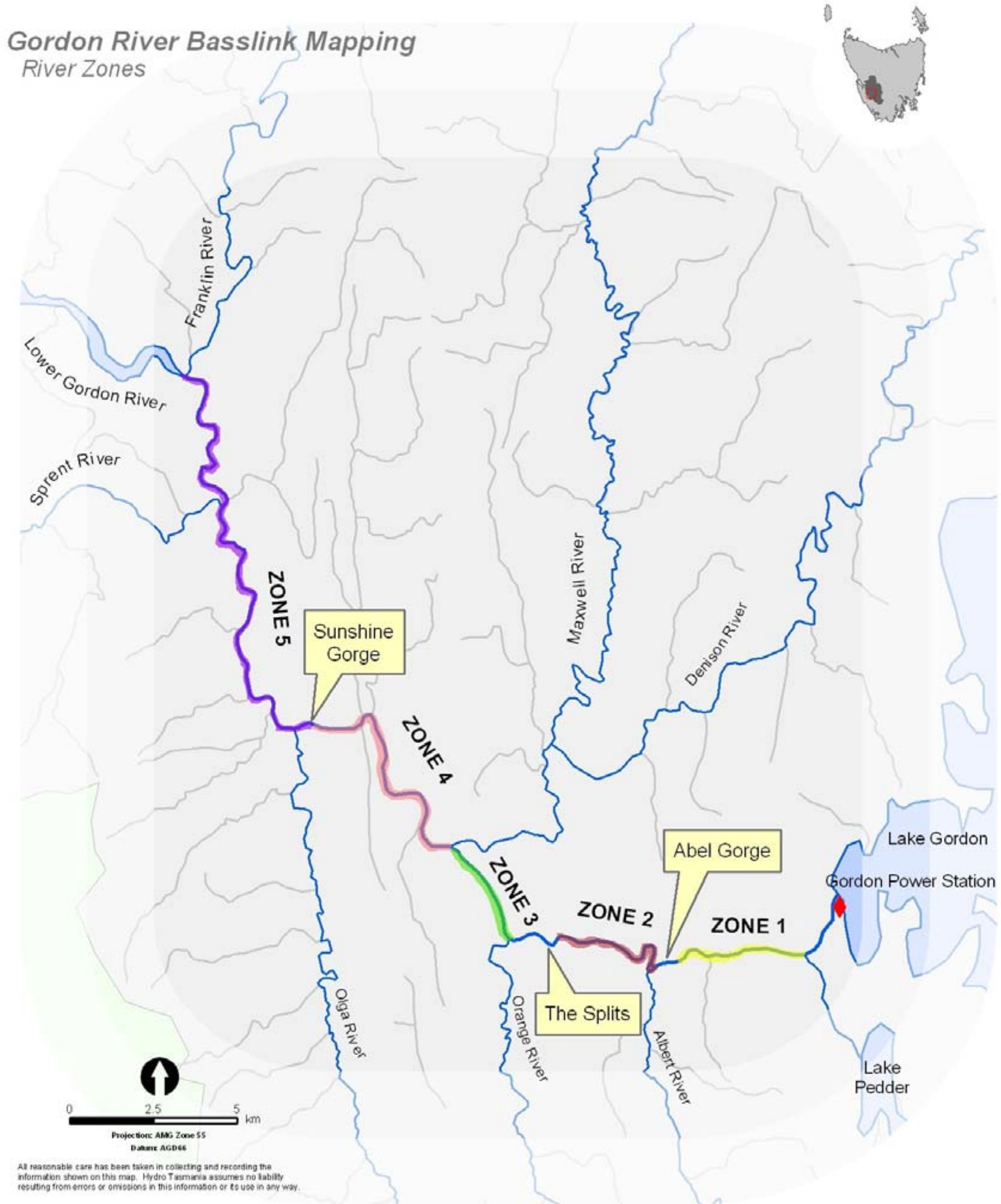


Figure 4.1. Map of middle the Gordon River showing the location of the five geomorphology monitoring zones.

4.3 October 2005 – scheduled Basslink monitoring

Monitoring was completed on 15–16 October 2005 by two boat-based teams. High rainfall preceded the monitoring, and continued through the first day resulting in elevated river levels. These conditions inundated many erosion pins and scour chains located on the toes and lower bank faces, especially downstream of the Denison River. Measurement of inundated pins (when located) was difficult due to the soft nature of the sand at the base of the pin, the depth of the water (up to 1m deep) and cold water temperature. Swimming goggles were used to locate as many pins as possible, and zone 4 was revisited on the Sunday after water levels dropped somewhat, but as shown in Table 4.1, not all pins were located.

Table 4.1. List of erosion pins not located in October 2005.

Pin	Change(s) to site	Reason
2K/1	Not found	probably buried or removed by new tree fall
4B/2	Not found	under water
4F/4	Not found	under water
4Gb/5	Not found	under water
5B/4	Not found	under water
5H/4	Not found	under water

In addition to erosion pin monitoring in October, repeat surveyed cross-sections of the channel were completed in December 2005 for use in both the biological and geomorphology investigations. Deep water depths hindered surveying in zones 4 and 5.

4.4 March 2006 – scheduled Basslink monitoring

Monitoring in March 2006 was completed on 11–12 March by two boat-based teams under conditions of low water and hot sunny days. Two additional cross-sections in zone 5 (11b and 15) were completed in March, as was the photo-monitoring. The very bright sunlight resulted in strong contrasts between sunny and shady areas, and made photo comparison difficult.

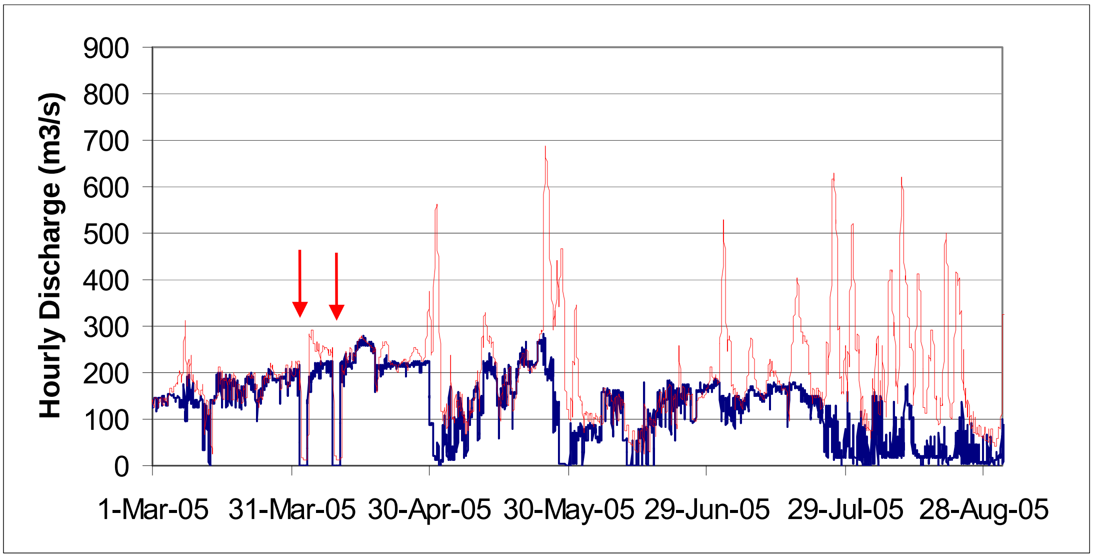
4.5 June 2006 – opportunistic field visit

In addition to the scheduled monitoring, an 'opportunistic' field visit to zones 2 and 3 was completed on 25 June 2006, approximately two months after Basslink operations officially commenced. This visit occurred under high flow conditions, with two turbines operating continuously throughout the day. Field observations from the day are presented in section 4.7.3.

4.6 Overview of hydrology, March 2005–March 2006

Hourly discharge records for the power station and the Gordon above Franklin gauging site are shown in Figure 4.2 for the period 1 March 2005–1 March 2006. Also shown in the figure are arrows indicating the March 2005, October 2005 and March 2006 monitoring trips.

In April 2005, the power station was operated in 'typical' summer mode, with extended 3-turbine power station operation common. May was characterised by continuous power station operation, with discharge increasing through the month prior to a shut-down at the end of the month. Since June, power station operation has been restricted to two turbines due to maintenance being completed on one turbine, and discharge has not exceeded 190 $m^3\ s^{-1}$. This is the longest period during which only two turbines have been in operation since the Basslink monitoring began in late 1999. During June and July, both operational turbines at the power station were in use almost continuously, with shorter duration intermittent operation during August–December. During January and February 2006, extended 2-turbine operation was the norm.



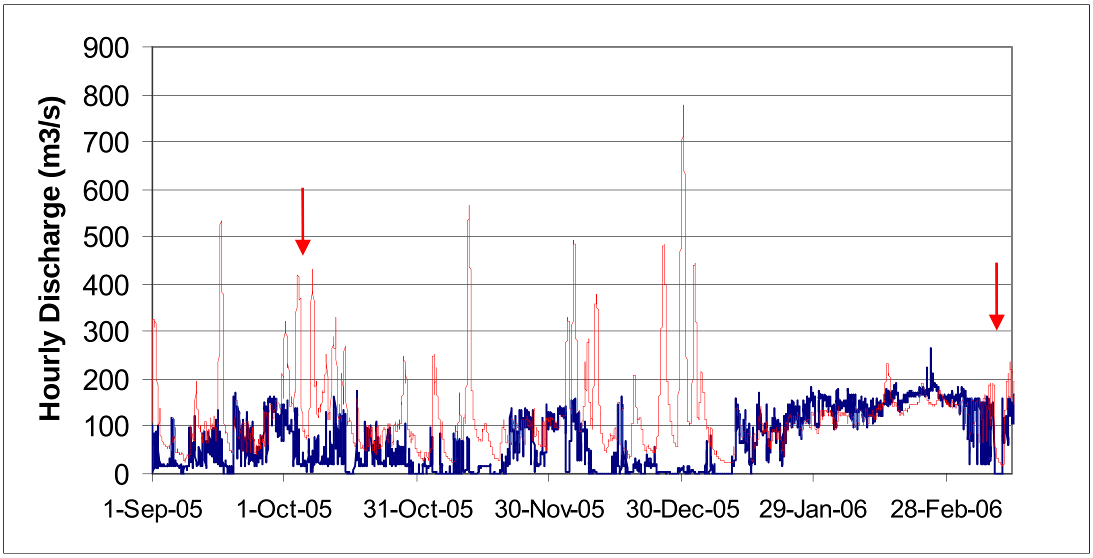


Figure 4.2. Power station discharge, 1 March 2005–15 March 2006. Arrows indicate sampling dates. Blue line shows discharge from the Gordon Power Station, red line shows discharge at the Gordon above Franklin gauging site.

The Gordon above Franklin flow data shows that there were numerous high flow events during the year, although maximum flows at the Gordon above Franklin site remained below 800 $m^3 s^{-1}$. The high flow conditions during the October 2005 monitoring are evident.

4.7 Monitoring results

4.7.1 Field observations – October 2005

Similar to October 2004, the October 2005 monitoring coincided with high inflows resulting in elevated river levels. Flow at the Gordon above Denison compliance site was ~15 $m^3 s^{-1}$and inflows from the Denison and other tributaries were considerable, with flows of 110–120 $m^3 s^{-1}$at the Gordon above Franklin site on Saturday 15 October, and 75–85 $m^3 s^{-1}$on Sunday 16 October.

The high inflows resulted in the widespread deposition of mud and sand on bank toes and faces. In zone 2, the deposition was limited to bank toes and lower banks, and increased in height with distance downstream. Upstream of the Denison, there was no evidence of recent sediment flows or bank saturation in the 2–3 turbine bank zone, consistent with power station discharge being limited to two turbines. Grasses and algae were also widespread upstream of the Denison, again consistent with intermittent, 2–turbine power station usage.

An inspection of the mouth of the Albert River was completed during October 2005, and the spur which separates the Albert and from the Gordon has experienced a substantial rupture, with material falling towards the Albert River (Photo 4.1). The bank had been undercut on the Albert River side, and is currently being held together by roots. Also in the Albert, the tall left bank upstream of the mouth is continuing to erode and overhanging vegetation continues to collapse (Photo 4.2). These changes are consistent with the long–term trend of channel widening in the lower reaches of the Albert River.

In zone 2, additional vegetation has fallen from an overhang on an existing landslip in the long cobble reach where site 2F is located (Photo 4.3). Also in zone 2, a new tree fall resulted in the collapse of a cavity at site 2K. The impact of this collapse on erosion pin results from the site is discussed in section 4.9.

In zone 4, a large Huon pine tree has fallen off a steep bank into the river approximately 1 km upstream of the confluence of Smith and Harrison Creeks, creating a large scarp on the left bank (Photo 4.4 and Photo 4.5).

Photo 4.1. (left) View of slip in spur separating Albert River and Gordon. Photo is taken along crest of bar separating Albert from Gordon, facing towards the mouth of the Albert R. Right in photo is towards Albert River, left is towards Gordon. Field notebook for scale.

Photo 4.2. (right) View upstream Albert River from bank near mouth of river showing continued erosion.

Photo 4.3. Recent collapse of vegetation over existing landslip in zone 2.

Photo 4.4. (left) Huon pine tree fall in zone 4.

Photo 4.5. (right) Scarp created by Huon pine tree fall in zone 4.

4.7.2 Field observations – March 2006

In March 2006, river flow was low and fell throughout the weekend. At the Gordon above Franklin gauging site flow was ~50 $m^3 s^{-1}$ on Saturday morning, and fell to ~23 $m^3 s^{-1}$ by Sunday afternoon.

Upstream of the Denison River, below the 2-turbine water level, the banks showed almost no evidence of recent deposition of mud, sand or organic matter. Above the 2-turbine level, there was deposition of organic matter (predominantly leaves) with grasses and other seedlings present. At site 2A, which consists of erosion pins in a profile over the bank and into a backwater, abundant macrophytes were present in the backwater (Photo 4.6).

Photo 4.6. Backwater at erosion pin site 2A showing presence of macrophytes.

Downstream of the Denison there was a slight increase in the abundance of recently deposited muds and sands compared to the river upstream of the Denison confluence. Deposition was most common above the 2-turbine water level.

Both upstream and downstream of the Denison, the lower banks were wet and, in zone 2, saturated. There was no evidence of recent sediment flows in the 2–3 turbine level, or on the lower banks.

As discussed more fully under chapter 10 (pre-Basslink aerial photo analysis) there were few noticeable changes in landslips. One exception was in zone 2, downstream of the cobble bar where erosion pin 2A is located, where vegetation on a pre-existing slip moved downslope, resulting in the exposure of the underlying sandy substrate (Photo 4.7).

Photo 4.7. Landslip in zone 2, left bank downstream of cobble bar where site 2A is located.

In contrast to the Gordon, there was extensive mud deposition in the lower Albert River, where there was a distinct mud-line. (Photo 4.8, Photo 4.9). This deposition presumably occurred when sediment transported by the Albert River was retained in the river due to high water levels in the Gordon, effectively damming the Albert River flow. Banks were generally wet/saturated below the mud-line, and much drier above.

In the Albert River, there was evidence of continued bank erosion with new tree falls noted along the high vertical bank on the left bank of the river near the mouth (Photo 4.10, Photo 4.11).

Photo 4.8. View of Albert River looking upstream from mouth. Distinct black line is due to mud deposition.

Photo 4.9. Mud deposition near mouth of Albert River.

Photo 4.10. Photo mosaic of left bank, lower Albert River showing boulder sized sediment blocks at base of bank.

Photo 4.11. Three photos of the left bank, lower Albert River downstream of bank in previous photo. Photos show recent tree falls alongbank which separates the Albert River from the Gordon River.

4.7.3 Field observations – June 2006

On 25 June 2006, teams were working in zones 2 and 3 upgrading the piezometer array and completing a flow gauging at the compliance site. Because a helicopter was required for this work, there was an opportunity to access the river, and observe these zones under 2-turbine power station operating conditions. Field access was constrained by the short daylight hours, and widespread morning fog. Time allowed a reconnaissance of zone 2 between the mouth of the Albert River and the piezometer site, the lower Albert River, and zone 3 between erosion pin sites A and E.

Due to safety concerns, this was the first opportunity in the history of the Gordon Basslink monioring that access to the river was gained under 2-turbine power station operating conditions, and allowed confirmation that the prominent Plimsoll line in the river corresponds to 2-turbine power station operation. It also allowed confirmation of erosion pin placement with respect to turbine operating levels at a number of erosion pin and vegetation monitoring sites. This is important as some of the statistical analyses completed using the erosion pin results divide the pins into turbine levels (see BBR for more information).

4.7.3.1 Albert River

Water level under 2-turbine power station operation in the Albert River is shown in Photo 4.12, which can be compared with the right side of Photo 4.10 (Albert under power station off conditions). The 2-turbine flow level is consistent with the lower white foam line present in Photo 4.8. The landslip on the spur dividing the Albert and Gordon Rivers observed in March 2006 was revisited, and found to have widened ~300 mm due to the breaking of roots within the root mat (Photo 4.12).

Photo 4.12. (left) 2– turbine water level in the Albert River, and (right) landslip in spur dividing Albert and Gordon Rivers in June 2006.

4.7.3.2 Zone 2

Within zone 2, photos were taken under the prevailing flow conditions of some photo-monitoring sites and other cobble banks. These are shown in Photo 4.13 through Photo 4.18 and demonstrate that the 2-turbine flow level generally inundates the woody debris at the base of the landslip. One new landslip was observed in the zone, which is shown in Photo 4.19.

Photo 4.13. Comparison of cobble banks on left bank upstream of piezomoeter site under 2–turbine flow in June 2006 (left) and power station off in March 2006 (right) conditions. Not a normal photo–monitoring site. Small woody debris inundated by 2–turbine operation.

Photo 4.14. Comparison of cobble banks on left bank upstream of piezomoeter site under 2–turbine flow in June 2006 (left) and power station off in March 2006 (right) conditions. Note new vegetation on banks above 2–turbine water level. Photo–monitorining site P2–4.

Photo 4.15. Comparison of cobble banks on left bank upstream of piezomoeter site under 2–turbine flow in June 2006 (left) and power station off in March 2006 (right) conditions. Note vegetation above 2–turbine water level. Photo–monitoring site P2–2b.

Photo 4.16. Comparison of cobble banks on left bank upstream of piezomoeter site under 2–turbine flow in June 2006 (left) and power station off in March 2006 (right) conditions. Vegetation slowly being lost from overhang. Photo–monitoring site P2–3.

Photo 4.17. Comparison of cobble banks on left bank upstream of piezomoeter site under 2–turbine flow in June 2006 (left) and power station off in March 2006 (right) conditions. Not a normal photo–monitoring site.

Photo 4.18. Comparison of cobble banks on left bank downstream of erosion pin site 2A under 2–turbine flow in June 2006 (left) and power station off in March 2006 (right) conditions. Not a normal photo–monitoring site.

Photo 4.19. New landslip observed in June 2006. Cobble bank is on the left bank of zone 2, upstream of the piezometer site.

4.7.3.3 Zone 3

Under 2-turbine discharge conditions, the banks in zone 3 are difficult to access due to the presence of overhanging vegetation. Observing the erosion pin sites confirmed that water level changes associated with 3-turbine power station operation are far lower in zone 3 as compared with zone 2. At site 3C, it was estimated that the difference in water level between 2- and 3-turbine power station operation is of the order of 0.3-0.5m. Photo 4.20 shows river conditions in zone 3 under the prevailing flow conditions.

Photo 4.20. View of upper zone 3 under 2–turbine power staiton operating conditions, showing Plimsoll line is equivalent to 2–turbine operating level. Photo looking upstream from near site 2A and B.

4.8 Zone 2 piezometer results

The conditions which promote seepage erosion were investigated during the IIAS (Koehnken *et al.* 2001) and are associated with periods when in-bank water levels in zone 2 exceed 2.75m, and the in-bank water surface slope exceeds 0.1 as determined by water differences at piezometers 1 and 3. These conditions generally follow periods of extended 3-turbine power station usage followed by a rapid shut-down of the power station.

Piezometer results for the period 1 March 2005–12 March 2006 are presented in Figure 4.3. Data are missing between 6–9 April 2005 due to battery failure which occurred when poor weather conditions prevented access. Only results from probes 1, 3 and 5 are displayed in Figure 4.3 for clarity. The in-bank water surface slopes as determined by the difference in water level height between probe 1 and probe 3 (13.3m inland) are shown in Figure 4.4, along with discharge from the power station. The black lines in the graph show periods when there was a high risk of seepage erosion due to high in-bank water surface slopes (>0.1), and elevated water levels in the bank at probe 3 (>2.75m). Four periods of risk are indicated on the graph, associated with 3-turbine to off power station operation on 12 March 2005, 1 April 2005, 1 May 2005 and 28 May 2005. It is possible that an additional period occurred between 6–7 April, but the lack of power at the site prevented recording data associated with the assumed event. In-bank water surface slopes remained high when the power supply was fixed, but the water level at probe 3 was below 2.75m.

No periods of high risk of seepage erosion occurred during the second half of the year, when operation of the Gordon Power Station was limited to two turbines. In-bank water slopes were elevated in March 2006 when the power station was shut-down following extended 2-turbine power station operation. Although in-bank slopes were high, the water level in the bank was below the height which initiates seepage flows in the 2–3 turbine zone. The shut-down creating these conditions was associated with the March Basslink monitoring, and the saturated banks below the 2-turbine operating level observed during monitoring are consistent with the piezometer findings. The lack of seepage erosion features is also consistent with piezometer findings.

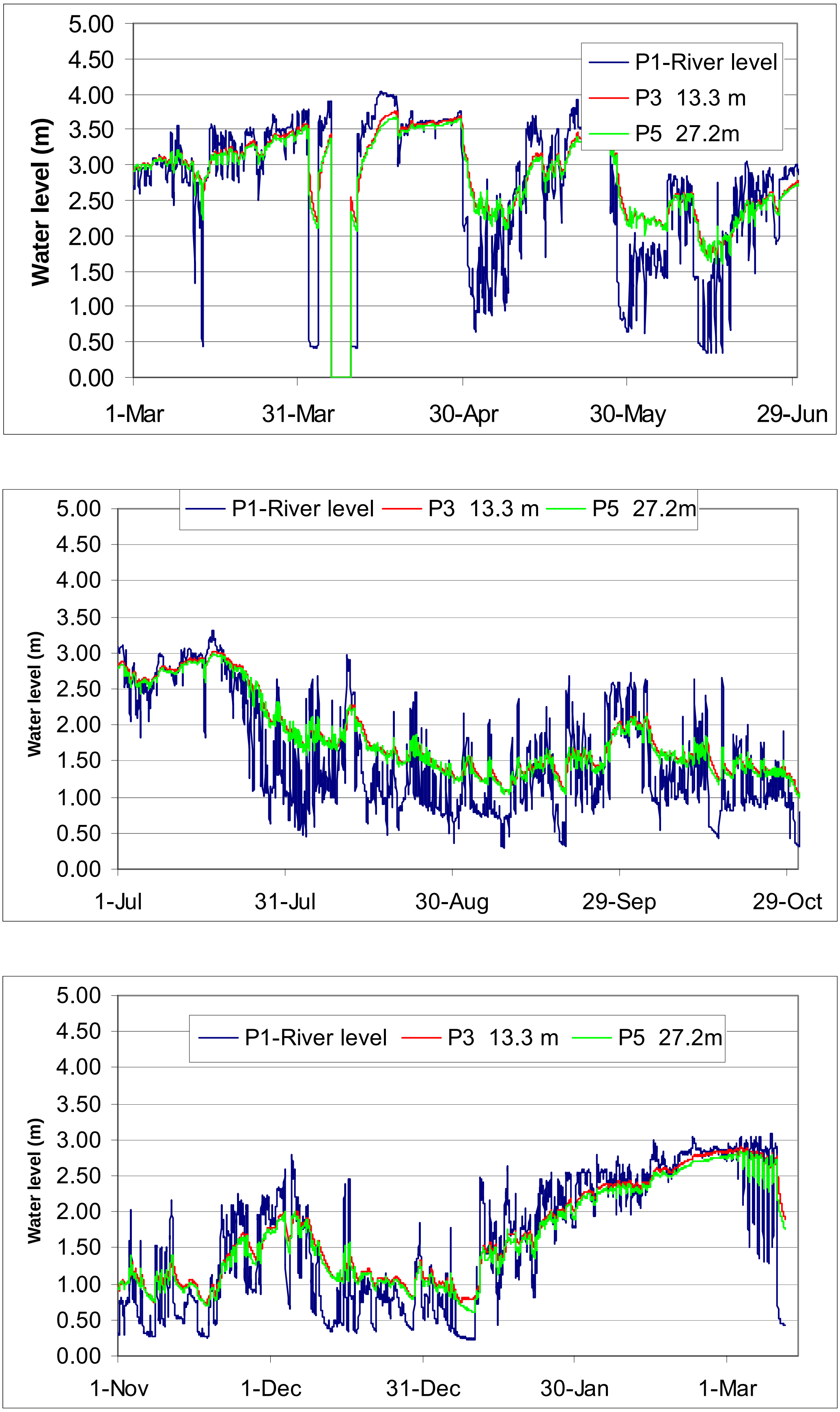


Figure 4.3. Piezometer data for probe 1 (river level) probe 3 (13.3m from bank) and probe 5 (27.2m from bank) between 1 March 2005 and 20 October 2005. Data interval is 15 min. Data missing between 6 and 9 April 2005.

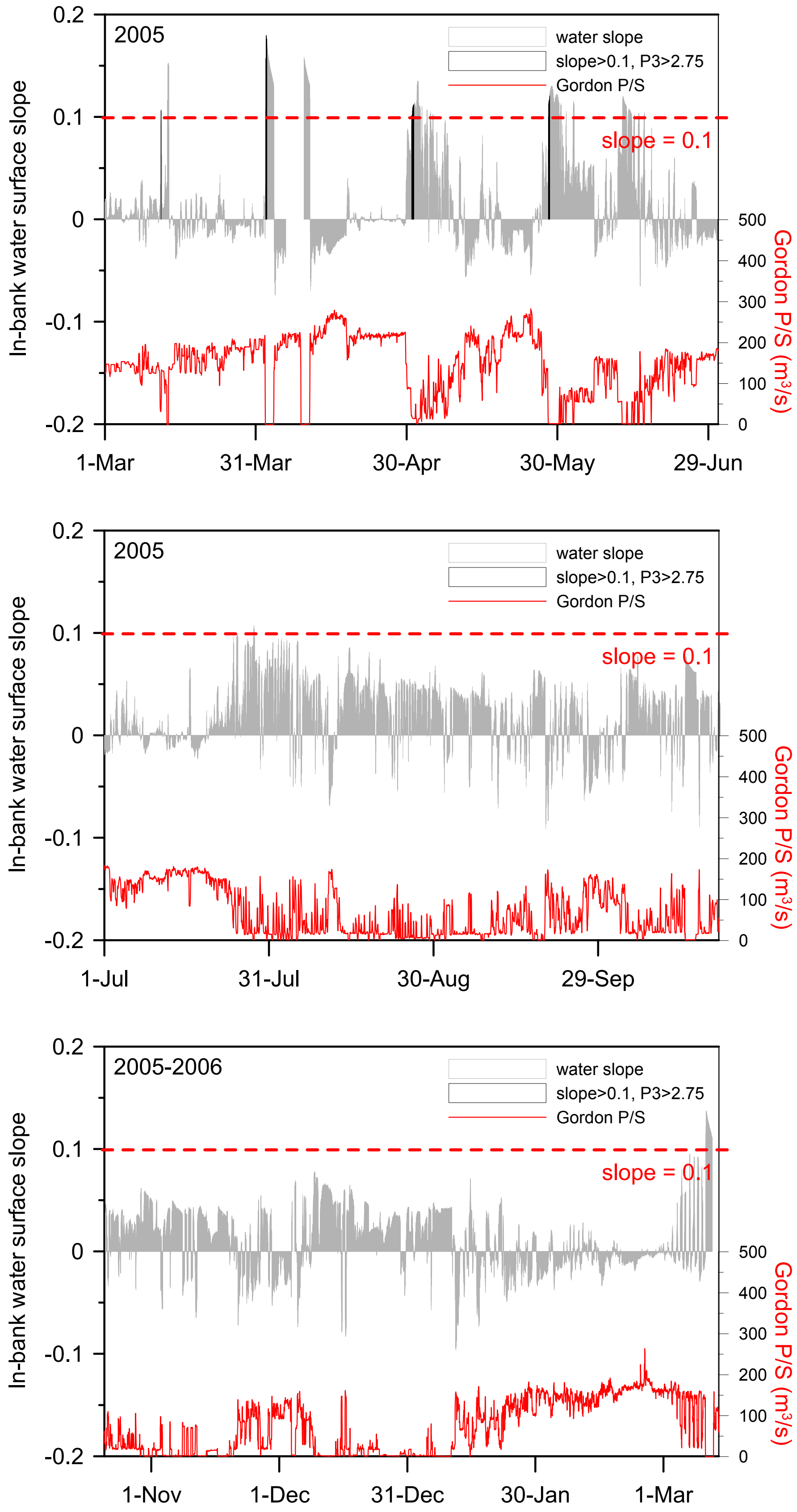


Figure 4.4. In–bank water surface slopes (upper) and discharge from Gordon Power Station (lower). Periods when water slopes exceed 0.1 and water level at probe 3 exceeds 2.75m are highlighted in black.

4.9 Erosion pins

4.9.1 Results grouped by zones and turbine levels

Erosion pins and scour chain results from October 2005 are contained in appendix 1 (Erosion pin graphs) and appendix 2 (Annotated aerial photography maps).

Erosion pin results are plotted in Figure 4.5 through Figure 4.8 based on different groupings of the results. In Figure 4.5, results are grouped by zones (zones 1–5), in Figure 4.6 results are grouped by turbine level (<1–turbine, 1–2 turbine, 2–3 turbine), and in Figure 4.7 and Figure 4.8 results are grouped by turbine levels for zones 2 and 3, and zones 4 and 5, respectively. These groupings are the same as those presented and discussed in the BBR. For each grouping, three graphs are presented. The large first graph ('A') depicts average erosion pin results for pins showing erosion, and pins showing deposition over the monitoring period, with the results plotted separately. The second graph ('B') shows the average results for all erosion pins in the grouping, and the third ('C') shows the ratio of the number of pins in each grouping which recorded erosion to the number of pins which recorded deposition.

In the results grouped by zone (Figure 4.5), all zones except zone 4 show erosion rates for the past year similar to the previous trends (graph 'A'). Erosion in zone 4 shows a marked decrease in the autumn 2006 period. Zones 2, 3 and 5 recorded increased deposition in the spring 2005 monitoring, with deposition decreasing in autumn 2006.

In graph B of Figure 4.5, which shows net erosion, the results from zone 2 show a substantial increase in spring 2005, zone 4 has recorded a decrease in net erosion over autumn 2006, and zone 5 shows a decrease in deposition.

The ratio of pins showing erosion to those showing deposition (graph 'C') increased in zones 1, 2 and 4 in spring 2005, and continued to increase in zone 4 in autumn 2006, whilst the other zones showed a decrease.

The data results grouped by turbine levels provide some insight into the processes operating within the river. The 1–2 and 2–3 turbine levels show similar erosion rates (Figure 4.6, graph 'A') over the past year as during the pre–Basslink monitoring period, with the largest change an increase in deposition in the <1–turbine level. The continued erosion of the 2–3 turbine bank level is somewhat surprising, as only two turbines have been operating for the most of the spring 2005 monitoring period and all of the autumn 2006 monitoring period. These results may suggest that erosion in the 2–3 turbine zone is the result of unregulated inflows downstream of the Denison River, and raindrop impact upstream of the Denison River. These results also suggest that the seepage erosion which is prevalent during summer periods may not be the only important erosion process operating at the 2–3 turbine level.

The average of all pin results, graph 'B' (Figure 4.6), shows similar rates of net erosion for the 1–2 and 2–3 turbine level, with a flattening and reduction in the <1 turbine level over the past 12 months. Comparing these results with graph 'A' suggests that the reduction in net erosion in the <1 turbine level is due to both a reduction in erosion and increase in deposition in autumn 2006. Again, it is noteworthy that erosion rates in the 2–3 turbine level have remained constant in the absence of power station operation.

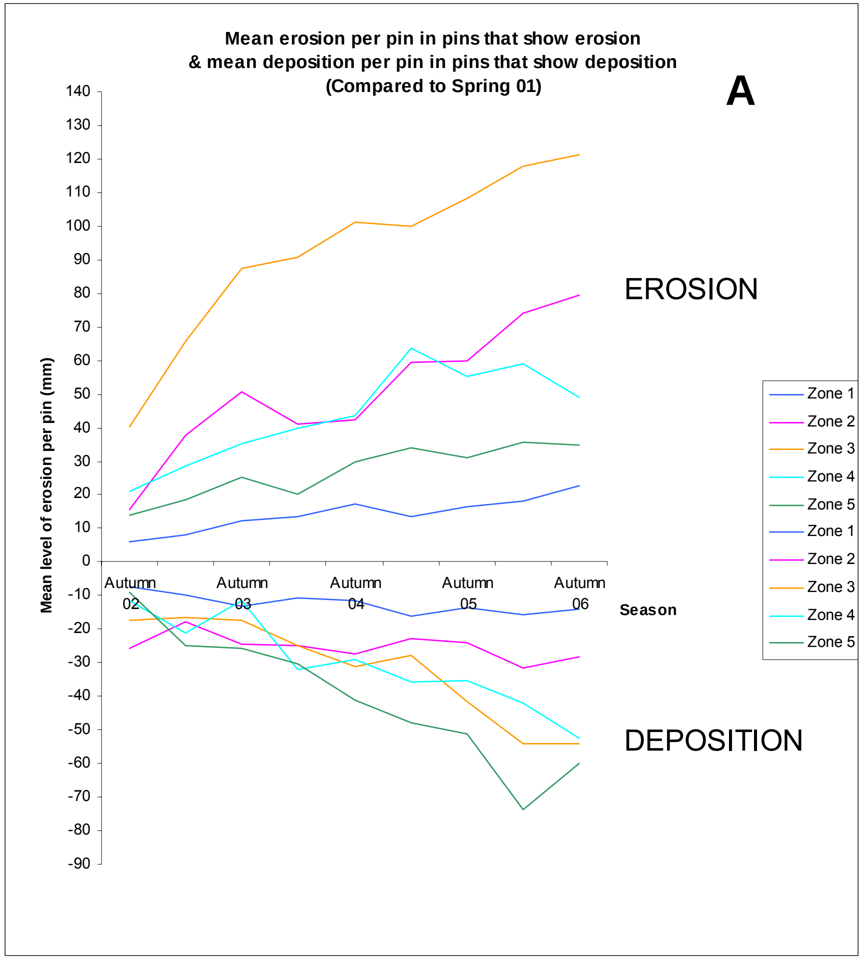
The ratio of pins showing erosion to deposition (graph 'C') shows large changes over the past year, with an increase in the 1–2 and 2–3 turbine levels, and a decrease in the <1 turbine level. Although the ratio of pins showing erosion has increased, the previous graphs (Figure 4.6, graph 'A' and 'B') show there has not been an increase in erosion rates.

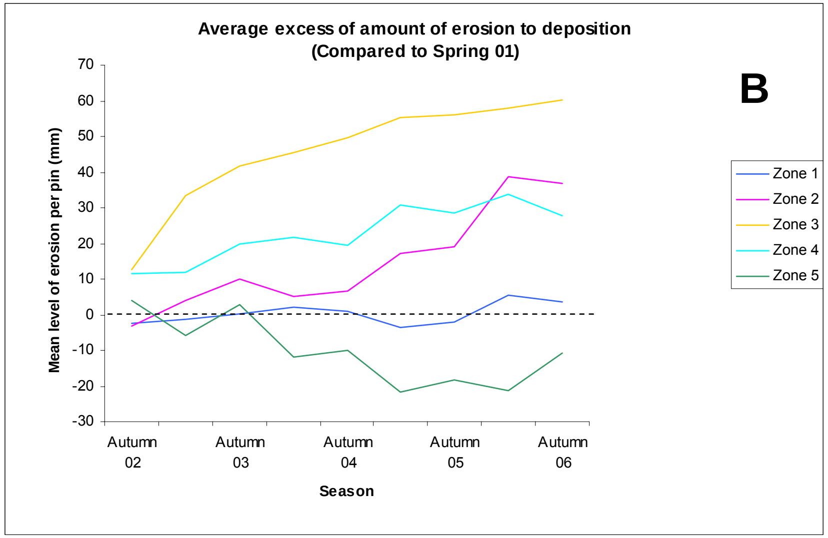
In Figure 4.7 the results are grouped by turbine level for zones 2 and 3 only. Graph 'A' shows that spring 2005 is the first spring monitoring period when there has not been an increase in erosion relative to the previous monitoring period. This may be related to the reduced 3–turbine power station operation in the second half of the year resulting in reduced scour and seepage erosion. The 1–2 turbine zone shows similar trends to previous results, but the <1 turbine level indicates a marked increase in average erosion in pins showing erosion for the spring period, followed by a decrease in autumn 2006. This large increase is the result of a very large change at site 2K, where the <1 turbine pin indicated 190 mm of erosion over the monitoring period. This site is characterised by seepage erosion, with a large sediment flow in the 2–3 turbine zone depositing sediment on the lower bank, including in the <1–turbine zone. Between March 2005 and October 2005, a tree fall at the site collapsed the cavity, obscuring pin #1 (2–3 turbine zone), and altering the delivery of sediment from the cavity to the lower bank. It is hypothesised that the high net erosion rate is the result of a decrease in sediment delivery to the bank combined with toe scour.

Net erosion rates in the 1–2 and 2–3 turbine levels in zones 2 and 3 (Figure 4.6, 'B') are consistent with previous results for turbine levels 1–2 and 2–3, with the <1 turbine level showing a flattening and decrease in net erosion over the past year. Both the 1–2 and 2–3 turbine levels show an increase in the ratio of erosion pins recording erosion in the spring 2005 monitoring results, with the increase in the 1–2 turbine level substantial. It is interesting that during this period, although there was an increase in the relative number of pins recording erosion, there was not a large increase in erosion rates in either graph 'A' or graph 'B'. The past six months have recorded a decrease in the ratio of pins recording erosion in the 1–2 turbine level, but no change in the 2–3 turbine level.

Figure 4.8 groups the erosion pin results by turbine level for zones 4 and 5. These zones are located downstream of the Denison River and receive a high proportion of unregulated flow over the winter months. The graph plotting erosion and deposition separately ('A') shows little change over the past two monitoring periods for the 2–3 and 2–3 turbine level, with the <1–turbine level indicating a large increase in deposition during spring 2005. Net erosion ('B') continues to be greatest in the <1–turbine level, although autumn 2006 is the first autumn sampling where rates have not increased relative to the previous monitoring period. The 1–2 and 2–3 turbine levels continue to record near neutral net changes, although the 1–2 results show two successive periods of increase.

The ratio of pins showing erosion to deposition indicates has also increased in the 1–2 and 2–3 turbine levels for zones 4 and 5 (Figure 4.8) over the past two monitoring periods, while the <1–turbine ratio increased in spring 2005, but remained constant in autumn 2006.





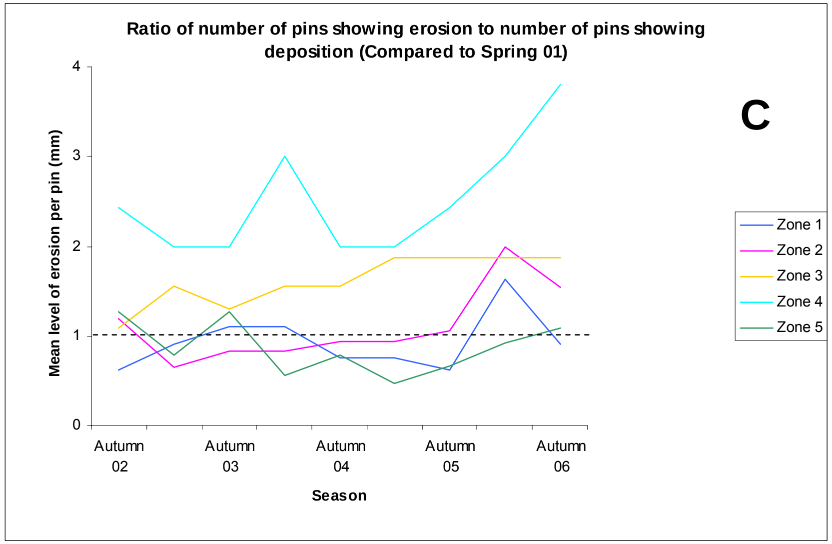


Figure 4.5. Erosion pin results grouped by zones. Monitoring occurs in autumn and spring of each year.

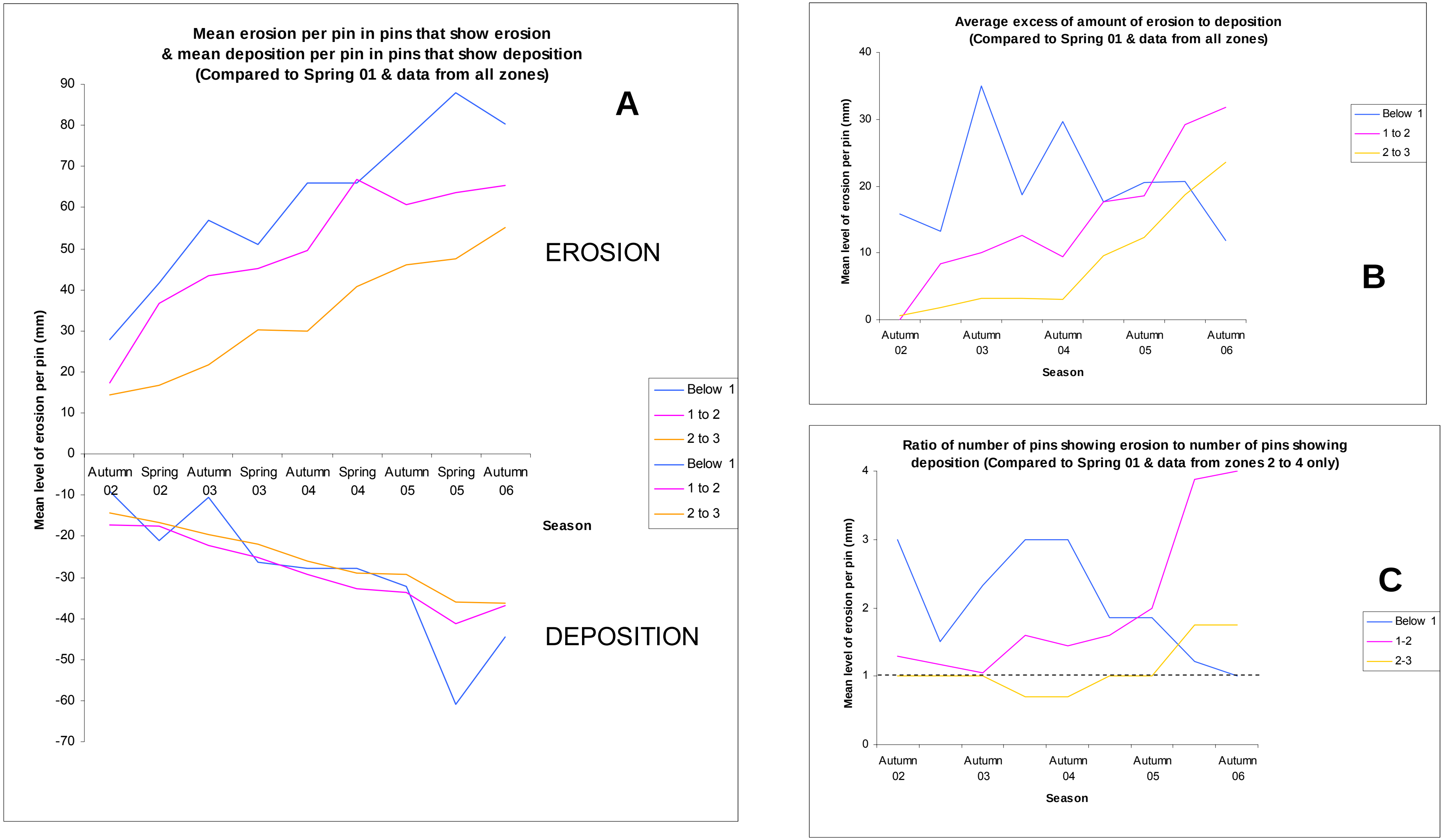


Figure 4.6. Erosion pin results grouped by turbine level.

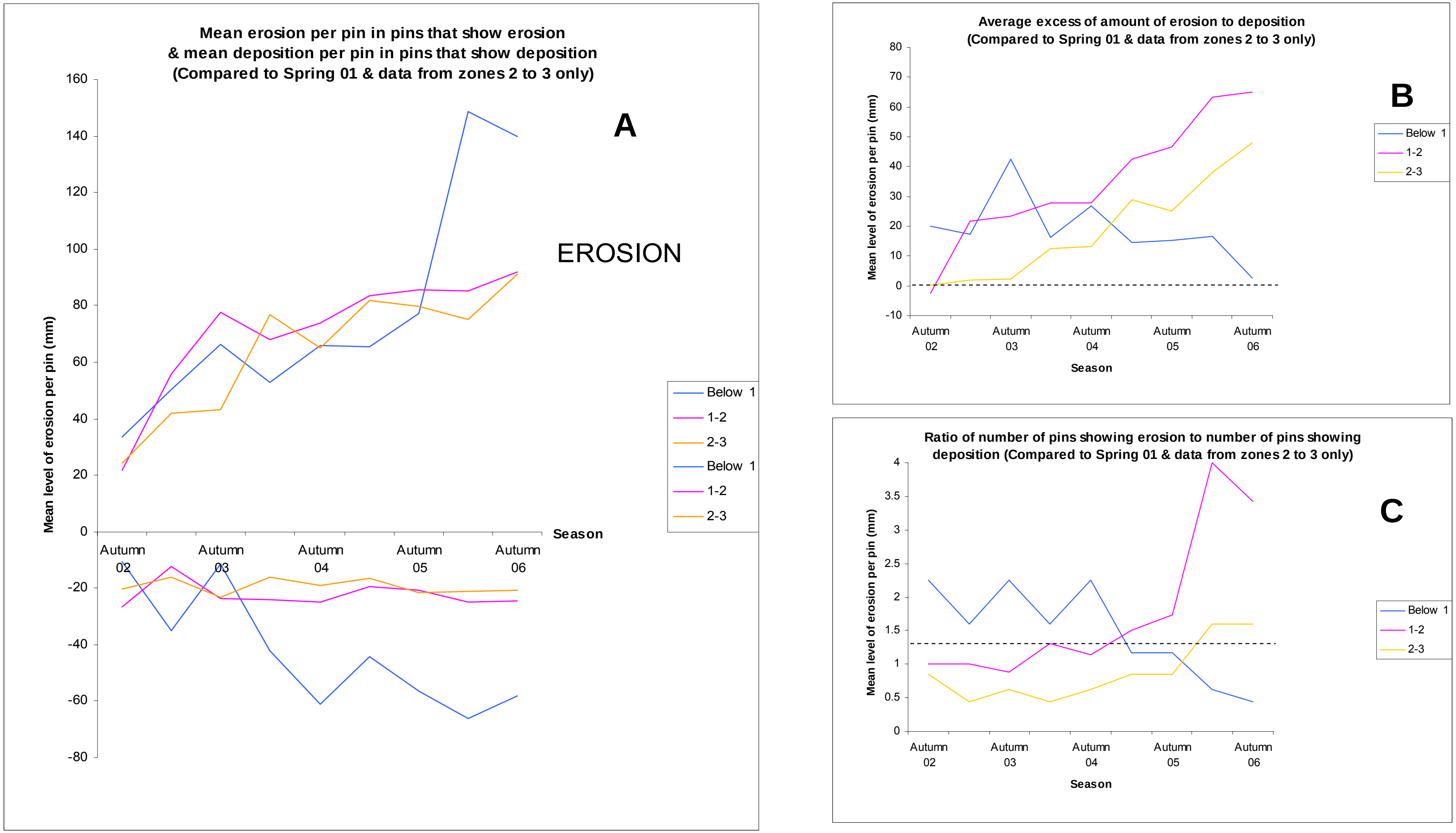
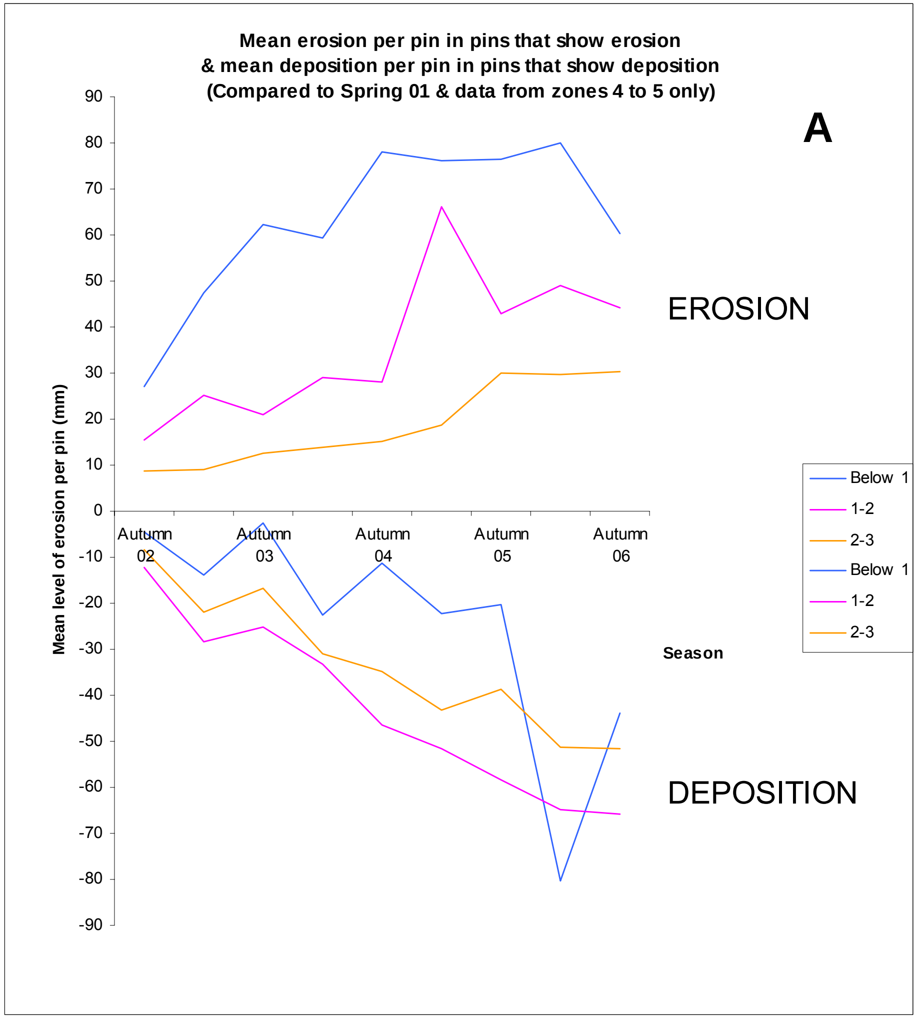
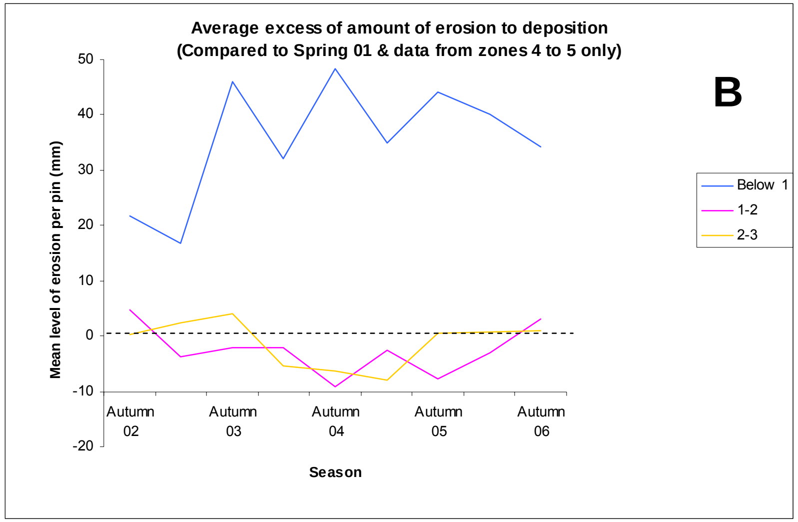


Figure 4.7. Erosion pin results grouped by turbine level for zones 2 and 3 only.





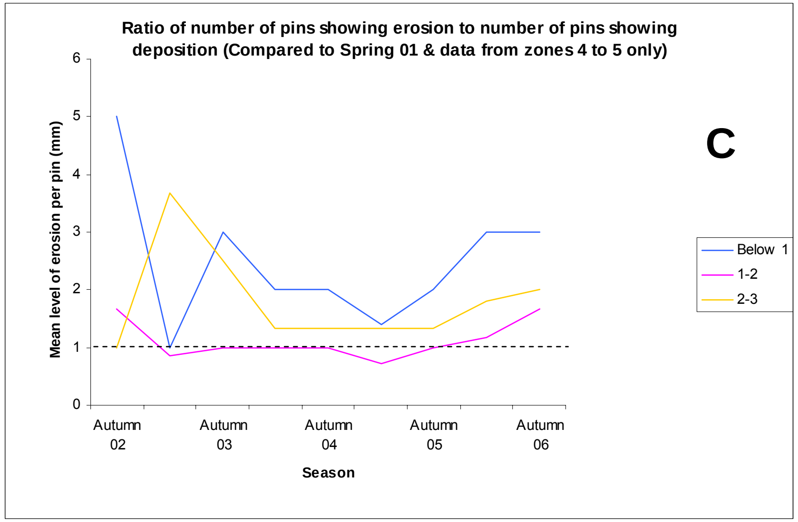


Figure 4.8. Erosion pin results grouped by turbine level for zones 4 and 5.

4.10 Scour in zone 2

Although seepage erosion has been a major focus of the Basslink investigations in zone 2, erosion pin analysis from site 2L combined with field observations show that scour is also occurring in lower zone 2. Site 2L is located on the right bank of the river, immediately upstream of the Splits. The site is located at the downstream end of a cobble bar, and is characterised by cobbles overlain by sands and a muddy root-mat layer (Photo 4.21, Figure 4.9). Pin 2L/2 is presently in the muddy layer, with pins 2L/4 and 2L/3 presently located in sand in front of the muddy layer.

Erosion pin results for the site since December 1999 are presented in Figure 4.10, and show that when the site was installed, erosion was active at pin 2L/4, at the toe of the bank. At this time, the muddy layer extended to the bank toe (see BBR appendix 2 for photos). Erosion at the toe ceased within ~one year, and since that time the toe has been relatively stable, being periodically affected by sand deposition.

In October 2002, erosion began to be recorded at pin 2L/3, and in October 2004, at pin 2L/2. The pin results and field observations show that erosion is associated with the loss of the muddy layer, with erosion ceasing once the muddy root mat has been removed. Based on the horizontal distance between pins 2L/4, 2L/3 and 2L/2, the muddy layer is receding at a horizontal rate of ~0.7 m/year (0.72 m/yr between pins 2L/4 to 2L/3, and 0.74 m/yr between 2L/3 and 2L/2).

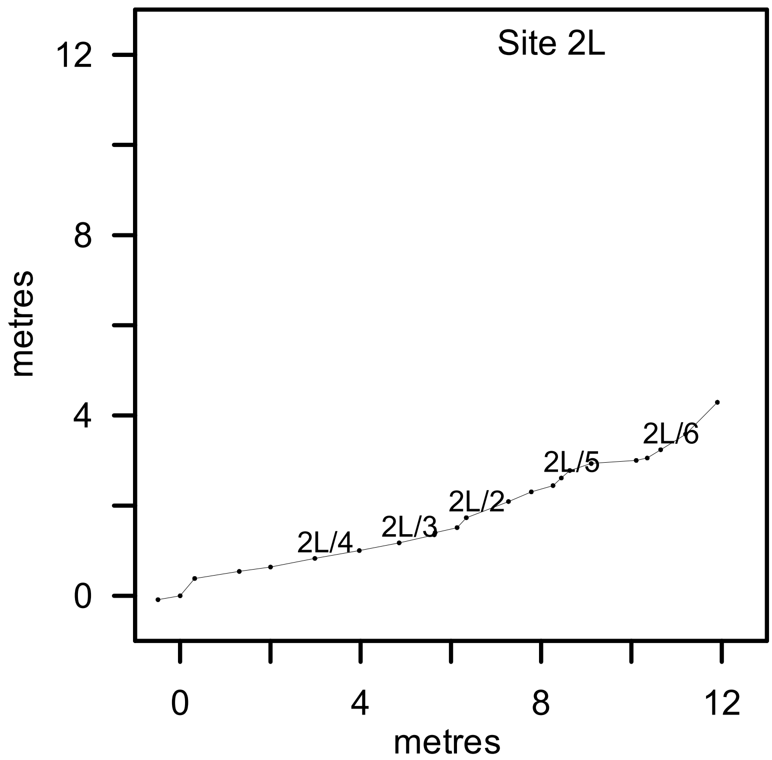


Figure 4.9. Profile of erosion pin site 2L, located on the right bank of the Gordon immediately upstream of the Splits (local datum).

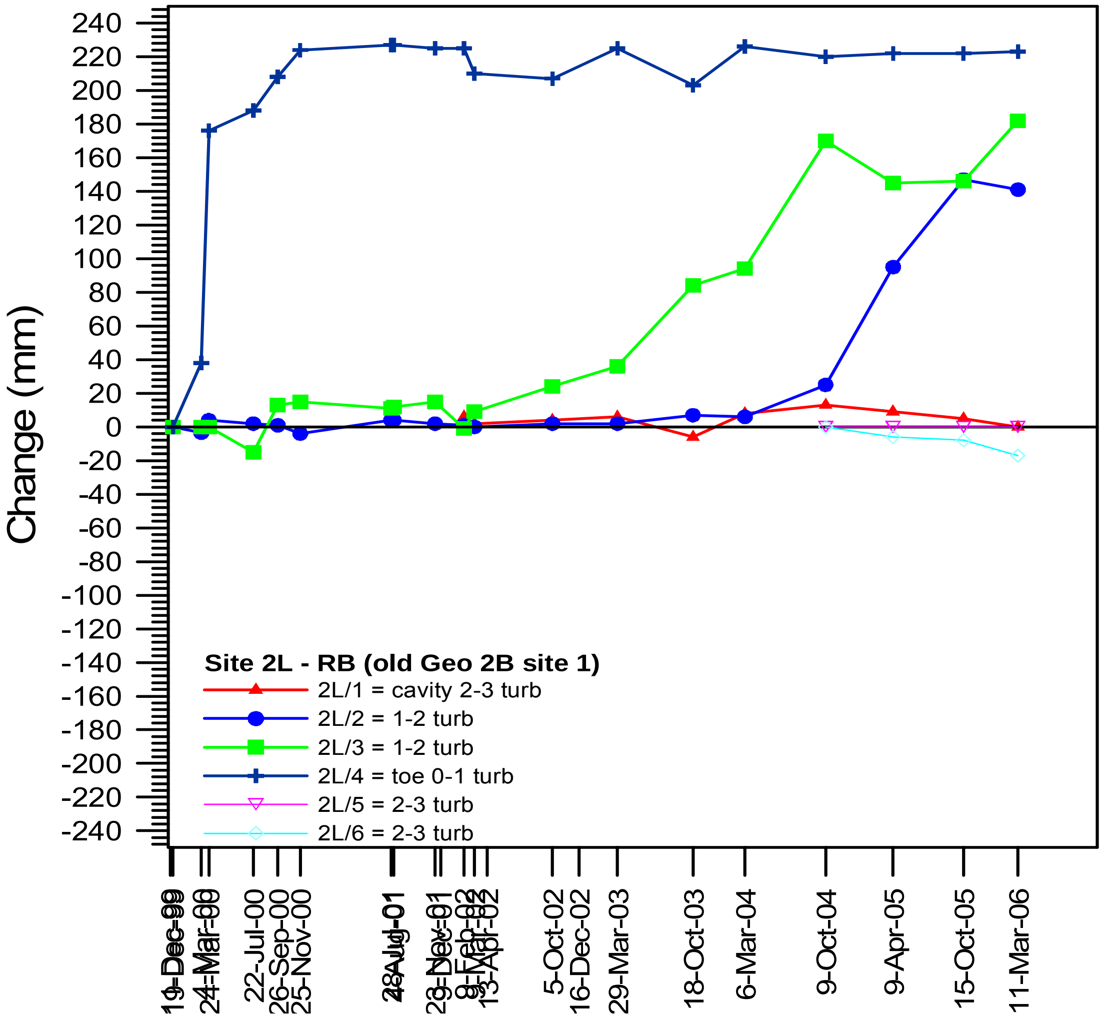


Figure 4.10. Erosion pin results from site 2K. Monitoring dates shown on x–axis.

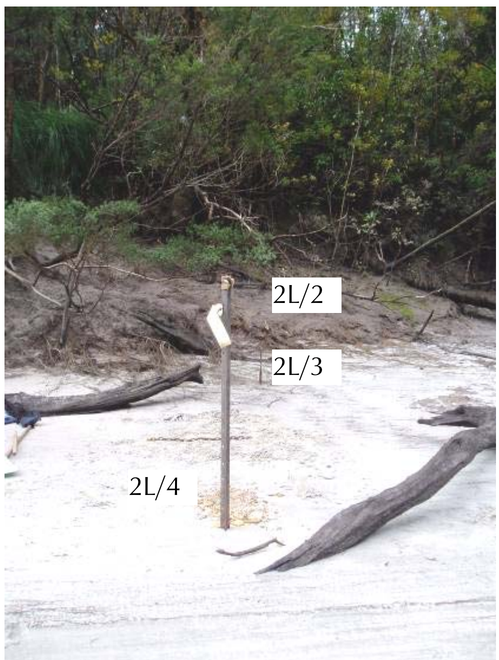


Photo 4.21. Erosion pin site 2L. Photo taken from water's edge.

The morphology of the bank at site 2L is characteristic of banks projected to have low rates of erosion during the initial IIAS assessment (Koehnken *et al.* 2001), with scour the dominant process. This was based on the presence of tea tree with a cohesive root mat, generally low slope, and no signs of seepage processes. These long-term erosion pin results provide a first estimate of scour rates, although obviously these results are limited to site 2L only. Additional erosion pins (2L/5, 2L/6) were installed higher in the bank profile in December 2004 (Figure 4.9) which will allow future monitoring of the erosion to continue.

An erosion pin site with similar characteristics is site 2I (Photo 4.22), where little change to the pins has occurred over the pre-Basslink monitoring period. As shown in the photo, the pins are located within the muddy root mat, which is being scoured at the toe.

Photo 4.22. Site 2I, located on the right bank upstream of 'Bathtub Creek.'

4.11 Photo-monitoring

Photo-monitoring was completed on 11-12 March 2006, but was difficult due to bright sunlight producing shadows and strong contrasts on the banks. At some sites, photos had to be taken closer than desirable, or at different angles compared to historic photos to try and avoid glare from the sun. A confounding problem is that vegetation has increased at many of the sites and partially or totally obscures the initial feature (usually a landslip) chosen for inclusion in the monitoring. The results from the photo-monitoring are summarized in Table 4.2, along with previous results.

Of the 59 monitoring sites, one photo was not obtained, and one may not be of the correct site. Half of the sites (29) showed no change based on comparison with the March 2005 photos. Of the photos depicting change, six showed a loss of vegetation below the power station-controlled water level, and an equal number showed an increase in vegetation upslope of the power station-controlled high-water level. An unusual observation in March 2006 was that ~eight sites showed increased vegetation cover in the 2-3 turbine operating level. This is undoubtedly related to the lack of 3-turbine usage throughout the monitoring period, and demonstrates how quickly the vegetation can re-establish in the absence of inundation. Also of note was that in zone 5, there were several sites which showed increased flood debris deposited on or near the toe of the bank. The debris generally consisted of small woody debris, and was not obviously derived from the adjacent bank. It may be that the lack of 3-turbine power station operation, combined with the lack of very high flow events over the winter, has lead to an increase in the deposition of small woody debris.

Table 4.2. Summary of photo–monitoring results from 2006 along with results from previous years.

Site	Change/Comment
P1–4a	Removal of vegetation at base of slip
P1–4b	Removal of vegetation at base of slip
P2–1a	Increase in vegetation below high–water level
P2–1b	Increase in vegetation below high–water level
P2–2b	Increase in vegetation below high–water level
P2–4	Increased vegetation on slip upslope of high–water level
P2–5	Removal of vegetation at base of slip
P2–6	Loss of cobbles
P2–9	Increased vegetation on slip upslope of high–water level
P3–3	Flood debris
P4–2	Increased vegetation at 2–3 turbine level
P4–4a	Removal of vegetation at base of slip
P4–4b	Removal of vegetation at base of slip
P4–4c	Loss of flood debris
P5–5	Movement of vegetation downslope
P5–6	Increased vegetation on slip upslope of high–water level
P5–7	Increased vegetation on slip upslope of high–water level
P5–10	Increased small woody debris at base
P5–11	Removal of vegetation at base of slip
P5–12	Increased small woody debris at base
P5–14	Increased vegetation on slip upslope of high–water level
P5–17	Increased vegetation at 2–3 turbine level
P5–21	Increased vegetation at 2–3 turbine level

4.12 Channel cross-sections

As part of the Basslink Baseline investigations, nine channel cross-sections initially surveyed in 2000, with some additional work completed in 2002, were re-surveyed. In December 2005, the sites upstream of the Denison River were re-surveyed, but those downstream of the Denison were unable to be completed due to high inflows. Sites G11b and G15 were completed in March 2006. Site G9 was unable to be completed in March due to time constraints. The cross-section locations are shown in Figure 4.11, with the cross-sections presented in Figure 4.12.

In general, the cross-sections show little or no change between 2000 and 2006. The following points summarize the reasons for discrepancies present in some of the plots in Figure 4.12:

- the original (2000) head peg at site G4 was not found in 2002 so a new one was established and used in 2002 and 2005, which resulted in a slight change in the positioning of the section;
- obtaining an accurate depth for the deepest part of the channel at site G6 is difficult due to the depth and velocity of the river, even at low flow;
- the sections at G9 and G11b have varied due to not being able to locate the non-head peg at the cross-section. At both sites, the river is funneling past a cobble bar, with a deep channel occurring next to the bar. Differences in the cross-sections have resulted from slight changes in the actual placement of the cross-section. Discussions with the biologists who monitor these sites indicate that the deep channel at G9 is bedrock controlled and has not changed over the pre-Basslink period. At site 11b, an aerial photo (Photo 4.23) shows the cross-section used by the biologists and surveyed in 2000. The red line of the photo indicates the placement of the cross-section in 2006, accounting for the differences in the surveyed cross-sections; and
- at sites G9 and G10, flow was too high in 2005 to complete the survey, and there was insufficient field time to attempt to re-survey the site during the autumn 2006 field trips.

Apart from these changes, the repeat cross-sections show very little change over the past five years, with variations within the limits of the surveying.

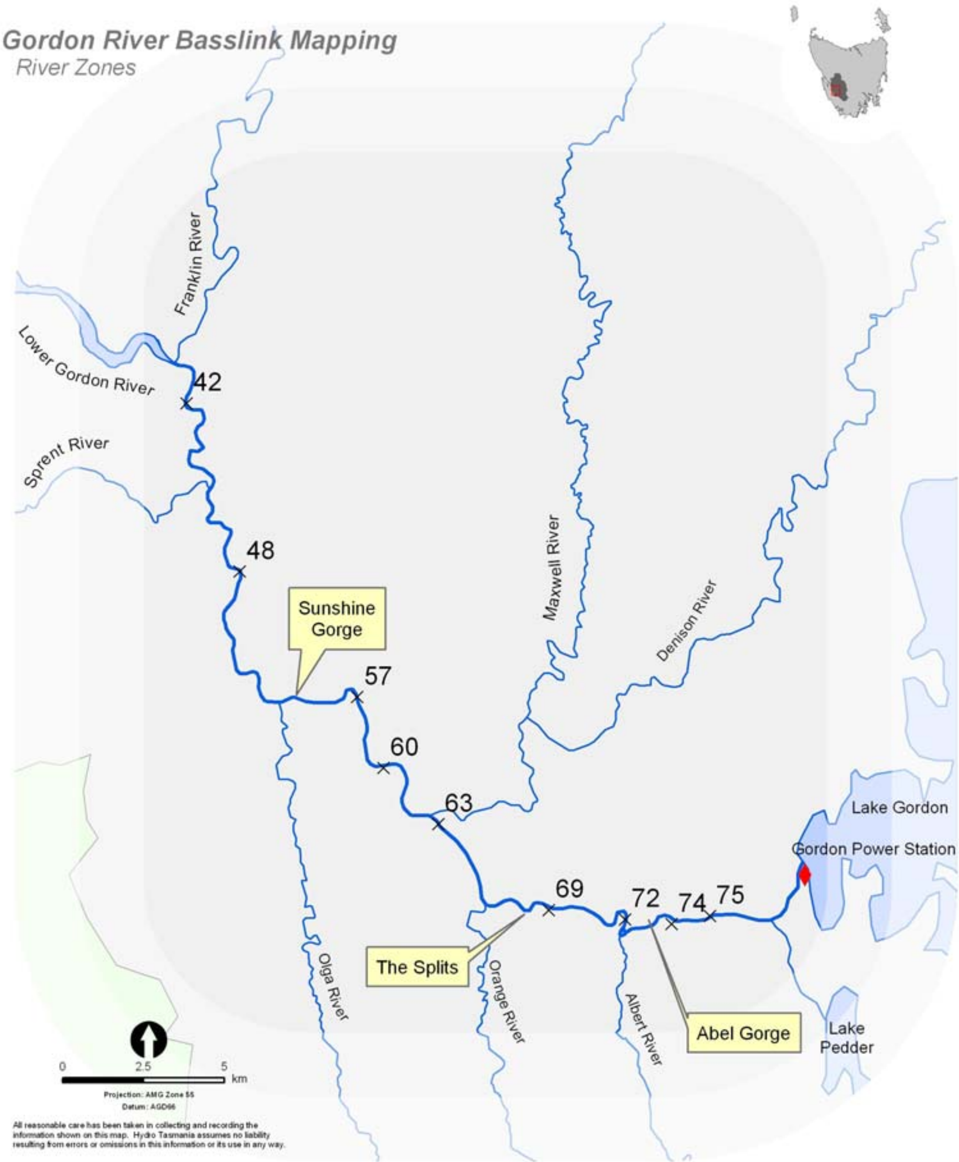


Figure 4.11. Map of middle Gordon River showing location of cross–sections.

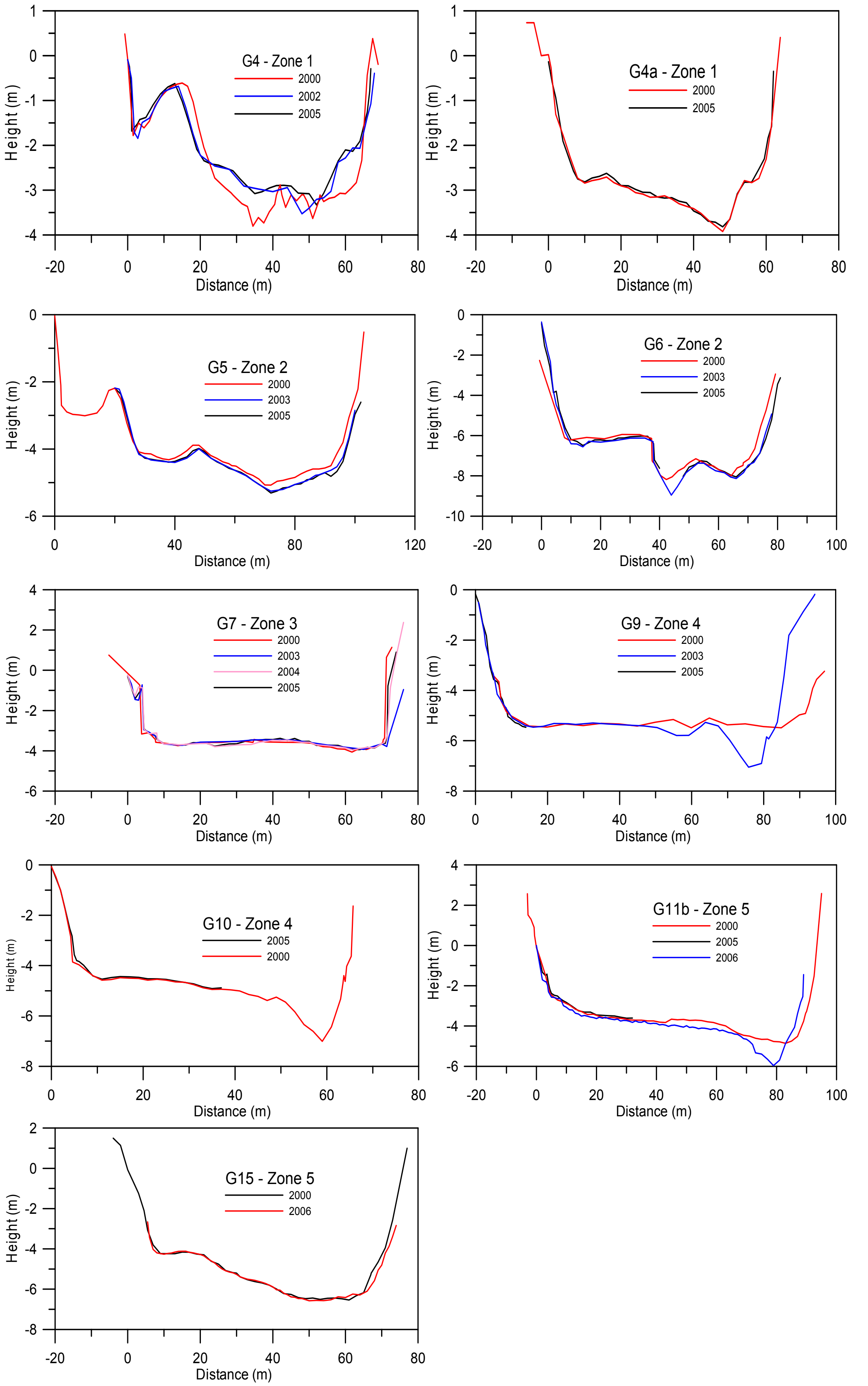


Figure 4.12. Cross–sections of middle Gordon River.

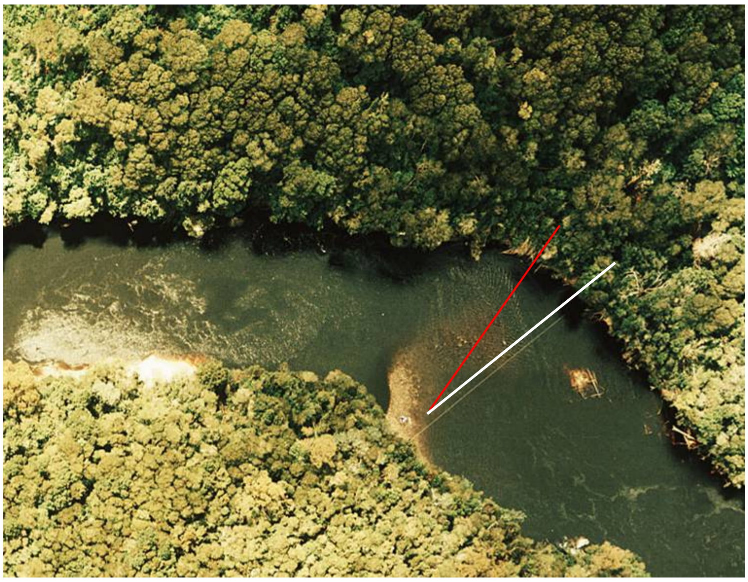


Photo 4.23. Aerial photo of site 11b showing difference in survey line in 2000 (white line) and in 2006 (red line) accounting for differences in channel profile.

4.13 Summary

The major findings of the 2005-06 geomorphology monitoring include:

- the 2005-06 monitoring year was characterised by unusual hydrologic conditions due to the refurbishment of one of the turbines at the power station which limited discharges to 2-turbines for most of the year. The hydrology also differed compared to previous monitoring periods due to the trialling of Basslink;
- piezometer results reflected the operating pattern of the power station, with the risk of seepage erosion occurring, limited to early in the monitoring year when 3-turbines were available for hydro generation. High risk periods of seepage were again associated with power station shut-down following extended operations. There were no high risk periods of seepage erosion during the second half of 2005 or beginning of 2006 when the power station discharge was limited to two turbines;
- field observations were consistent with the operation of 2-turbines; there was no evidence of seepage erosion in the 2-3 turbine zone, with vegetation and deposition of organic debris (derived from vegetation on the bank and not fluvial deposition) increasing at this bank level;
- in spite of the limited operation of 3-turbines at the power station, erosion of the 2-3 turbine level did not decrease in zones 2 and 3, indicating other processes, such as the direct impact of rain drops on the denuded banks are important;
- erosion of the < 1-turbine level in zones 4 and 5 decreased during the monitoring period, and is probably attributable to reduced shear stress on bank toes due to reduced

3-turbine operation, and/or deposition from high natural inflows which occurred in November and December 2005;

- long-term erosion pin results at site 2L in zone 2 have provided an estimate of scour rates at this site. A muddy root-mat has been progressively eroded since December 1999 at a horizontal recession rate of ~0.7 m/yr;
- re-surveyed cross-sections of the channel show there has been little or no change in the channel since 2000 when the surveying was first completed; and
- photo-monitoring revealed few changes at the photo-monitoring sites, with increased vegetation above the 2-turbine operating level a common observation.

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5 Karst geomorphology

5.1 Karst areas

Key karst features are monitored in both the Gordon–Albert and Nicholls Range karst areas twice per year. During 2005–06, monitoring trips were undertaken on 15 October 2005 and 11 March 2006. Figure 5.1 shows the location of the two karst areas investigated by the monitoring program.

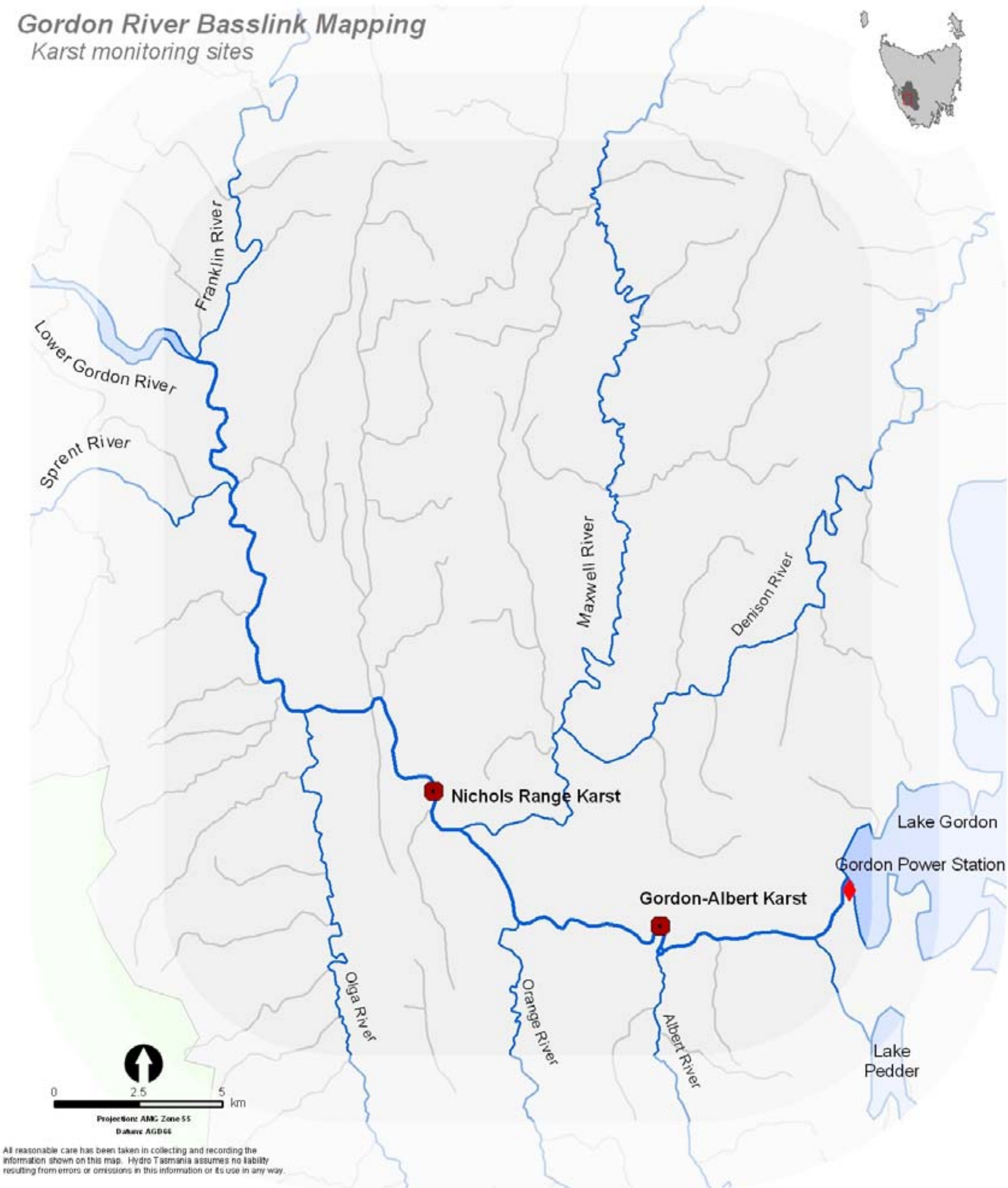

Figure 5.1. Map of the karst monitoring sites in the Gordon River.

5.1.1 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 the GA–X1 cave with a doline at the 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.

The GA–X1 cave is 28m long (including the large entrance area), 10m deep and is located approximately 10–20m from the Gordon River. There are two entrances to the cave: the smaller entrance lies on the western (river) end of the feature and 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 level as the Gordon River.

5.1.2 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. Bill Neilson Cave contains a cave stream. Both sites are accessed by boat. Kayak Kavern has five erosion pins installed and a photo-monitoring site. Bill Neilson Cave site has 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 which are occasionally moved around for comparison purposes. Water levels are recorded every 10 minutes over a range between 1.0–2m.

5.2 Methods and results

5.2.1 Erosion pin data

All erosion pins were measured to the nearest mm using a steel 300 mm ruler placed to the right side of the pin, on the contour level. Data for all sites are summarised in Table 5.1. Distances between the tops of the doline pins at sites 3 and 4 were also measured to assess whether any major structural change had occurred. The measurements are summarised in Table 5.2.

Table 5.1. Erosion pin data for karst sites from 2001–06. Postitive change values indicate deposition, negative values indicate erosion.

Site description and site no.	Pin no.	Length previous trips (mm)									Length this trip (mm)	Change in sed this summer	Change in sed 12 months	Comments and interpretation
		S01	A02	S02	A03	S03	A04	S04	A05	S05				
Channel Cam (S1)	1	322	318	318	316	318	322	314	323	320	322	–2	+1	Erosion at both pins this period despite not being inundated, but net gain over 12 months.
	28	n/a	n/a	245	245	248	248	243	256	245	248	–3	+8	
GA–X1 cave (S2)	2	250	239	238	244	242	245	248	251	250	251	–1	0	Erosion at pin 4 at the lower levels in the cave this period and over 12 months. Little change at mid levels and slight gain at pin 3 above the inundation zone.
	3	190	189	193	195	196	194	194	194	195	193	+2	+1	
	4	154	161	160	163	159	165	168	168	176	178	–2	–10	
Doline at cave entrance	9	214	213	220	217	219	224	201	215	213	215	–2	0	Minor losses in debris over winter and over 12 months.
	10	278	278	293	290	291	290	283	286	286	288	–2	–2	
Doline adjacent to GA–X1 (S3)	5	259	287	294	297	284	283	291	290	292	290	+2	0	Net debris gain at most pins this period. Minor losses at the mid–lower level over 12 months. 12 mm of debris loss at the mid upper level and 5 mm of debris gain towards the rim over 12 months.
	6	300	300	294	306	297	290	296	296	295	297	–2	–1	
	7	254	252	258	261	257	252	250	248	261	260	+1	–12	
	8	195	196	192	200	194	192	195	194	192	189	+3	+5	
Small doline (S4)	12	192	171	170	172	152	155	156	145	151	150	+1	–5	General increase in debris at lower levels this period with relatively large loss towards the rim. Opposite change over 12 months with general debris loss at lower levels.
	13	234	238	231	231	245	241	240	225	236	232	+4	–7	
	14	253	256	244	262	257	257	250	257	249	255	–6	+2	
	31	n/a	n/a	n/a	n/a	n/a	n/a	570	564	568	568	0	–4	
	32	n/a	n/a	n/a	n/a	n/a	n/a	776	770	750	768	–18	+2	
Kayak Kavern (S5)	16	309	308	319	359	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Relatively large increases in sediment were observed at pins 17 and 19 on the slope of the sediment bank. By contrast however, 17 mm of sediment loss was recorded at pin 33 which is adjacent to pin 17. Large net increases at pins 17, 19 and 29 over 12 months with minor losses at pins 18, 30 and 33.
	17	293	291	284	288	339	384	349	320	366	302	+64	+18	
	18	267	266	255	263	258	252	256	271	269	272	–3	–1	
	19	249	245	271	267	225	220	222	232	215	115	+100	+117	
	29	n/a	n/a	n/a	n/a	n/a	273	?	272	?	233	n/a	+39	
	30	n/a	n/a	n/a	n/a	n/a	259	?	241	243	245	–2	–4	
	33	n/a	n/a	n/a	n/a	n/a	n/a	n/a	275	266	283	–17	–8	
Bill Neilson (S6): 6A at entrance	20	483	480	499	495	501	493	502	497	497	495	+2	+2	Deposition occurred at the lower level this summer and over 12 months, in contrast to erosion at mid levels over the same periods. Slight deposition at higher levels.
	21	300	299	302	301	304	305	301	300	304	306	–2	–6	
	22	272	272	269	272	271	271	270	271	270	270	0	+1	
Bill Neilson: 6B Sed bank II	25	194	195	195	195	198	198	205	203	204	204	0	–1	Minor losses at higher pins over 12 months. Minor losses at lower pins over 12 months.
	26	203	203	202	202	202	204	206	204	204	205	–1	–1	
	27	215	216	214	213	212	208	210	210	209	210	–1	0	
Bill Neilson: 6C Dry sed bank	23	297	297	295	298	298	297	297	297	296	297	–1	0	No significant change. Consistent trends.
	24	227	226	202	203	203	203	203	203	203	203	0	0	

5.2.2 Water level recorders

The hydrographs from the three water level recorders in Bill Neilson Cave for this period are shown in Figure 5.3. The water level data for GA-X1 for the same period is shown in Figure 5.5, together with the corresponding water levels at site 72 (G5) for comparison. Figure 5.2 also shows the water level data at the Gordon below Denison site with the power station flows.

Hydrographs from the three water level recorders in Bill Neilson Cave, between 15 October 2005 and 11 March 2006, are shown in Figure 5.4. The water level data for GA-X1 for the same period is shown in Figure 5.6, together with the corresponding water levels at site 72 (G5) for comparison.

5.2.3 Photo-monitoring

Photographs were taken at all photo-monitoring sites as planned. Due to unavoidable circumstances, the photos for the March 2006 monitoring were not available during the writing of this report and so assessments are not included. The photos will be reviewed in the 2006-07 report.

Table 5.2. Erosion pin survey data, doline sites 3 and 4.

Site No.	Pins measured	Distance between pins (m)							
		S02 06/10/02	A03 30/03/03	S03 15/10/03	A04 06/03/04	S04 09/10/04	A05 02/04/05	S05 15/10/05	A06 11/03/06
3	Photo–monitoring peg to pin 5	3.280	3.295	3.295	3.295	3.298	3.300	3.290	3.290
	Pin 5 to Pin 6	1.055	1.055	1.050	1.055	1.050	1.050	1.049	1.053
	Pin 6 to Pin 7	1.350	1.345	1.345	1.355	1.359	1.356	1.359	1.355
	Pin 7 to Pin 8	1.850	1.850	1.850	1.845	1.852	1.850	1.854	1.851
	Sum Pins 5 to 8	*4.255*	*4.250*	*4.245*	*4.255*	*4.261*	*4.256*	*4.262*	*4.259*
4	Photo–monitoring peg to pin 12	2.620	2.620	2.630	2.625	2.628	2.630	2.626	2.630
	Pin 12 to Pin 13	1.515	1.515	1.515	1.515	1.522	1.517	1.517	1.520
	Pin 13 to Pin 14	1.435	1.435	1.435	1.435	1.440	1.435	1.438	1.435
	Pin 12 to Pin 31 (stick)	n/a	n/a	n/a	n/a	0.530	0.530	0.524	0.525
	Pin 12 to Pin 32	n/a	n/a	n/a	n/a	0.722	0.720	0.720	0.720
	Sum Pins 12 to 14	*2.950*	*2.950*	*2.950*	*2.950*	*2.962*	*2.952*	*2.955*	*2.955*

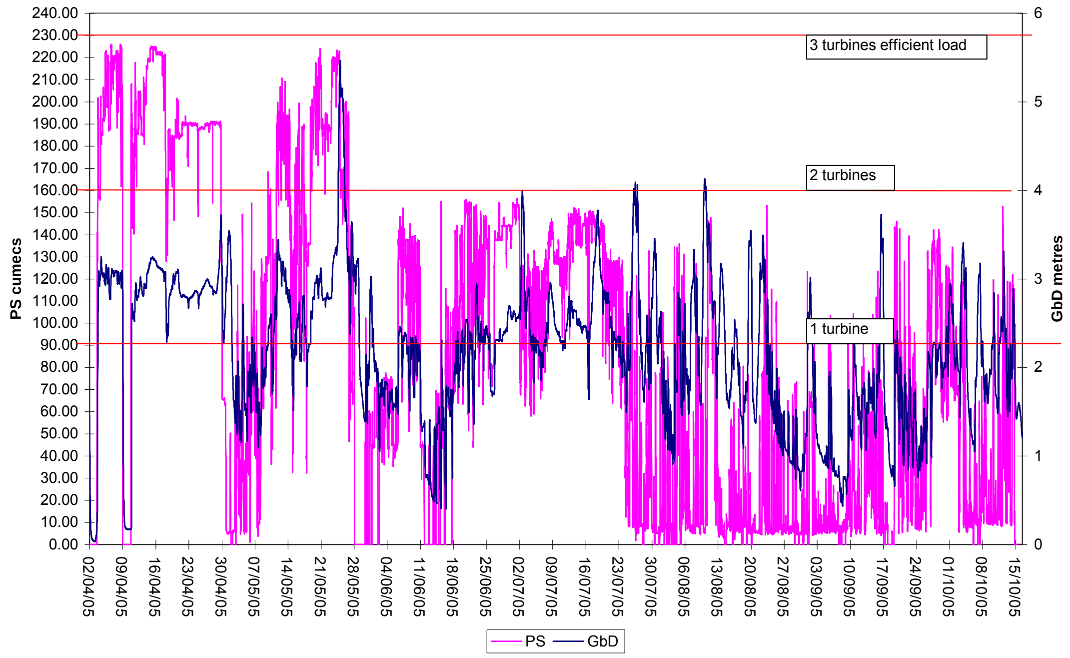

Figure 5.2. Power station output in cumecs together with the flow level data from the Gordon below Denison (site 62) gauging station for the period 2 April–15 October 2005.

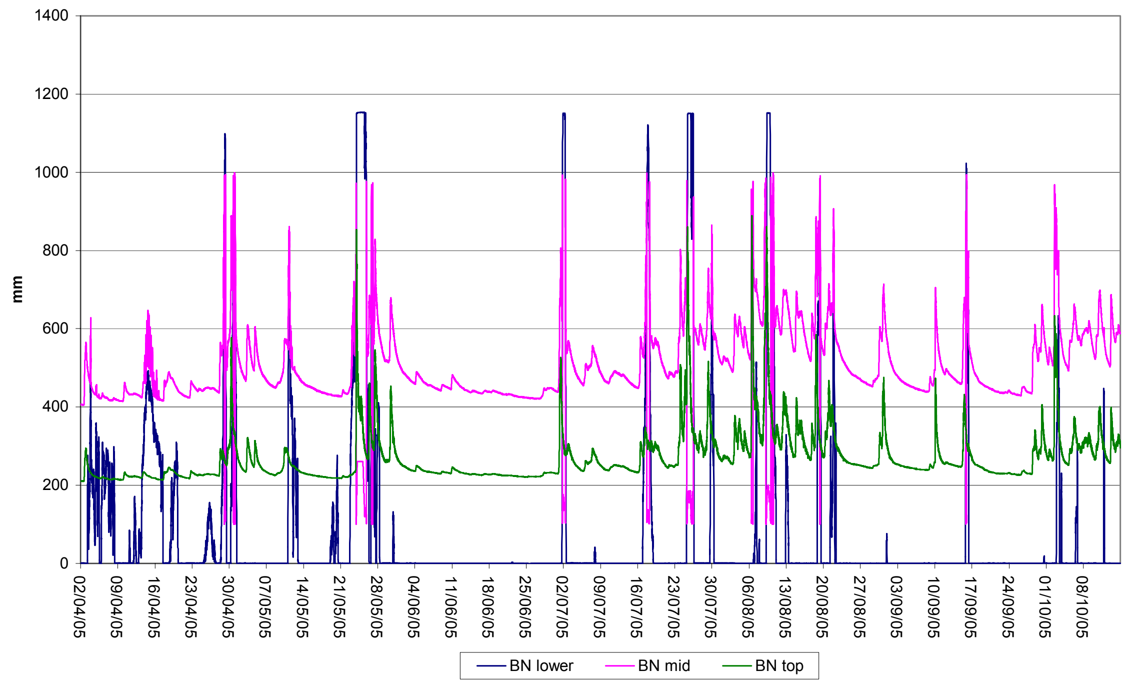

Figure 5.3. Bill Neilson Cave water level recorder data (cave stream only: BN cave top; cave stream and Gordon river water backflooding: BN cave mid; Gordon River backflooding only: BN cave lower) for the period of 2 April–15 October 2005.

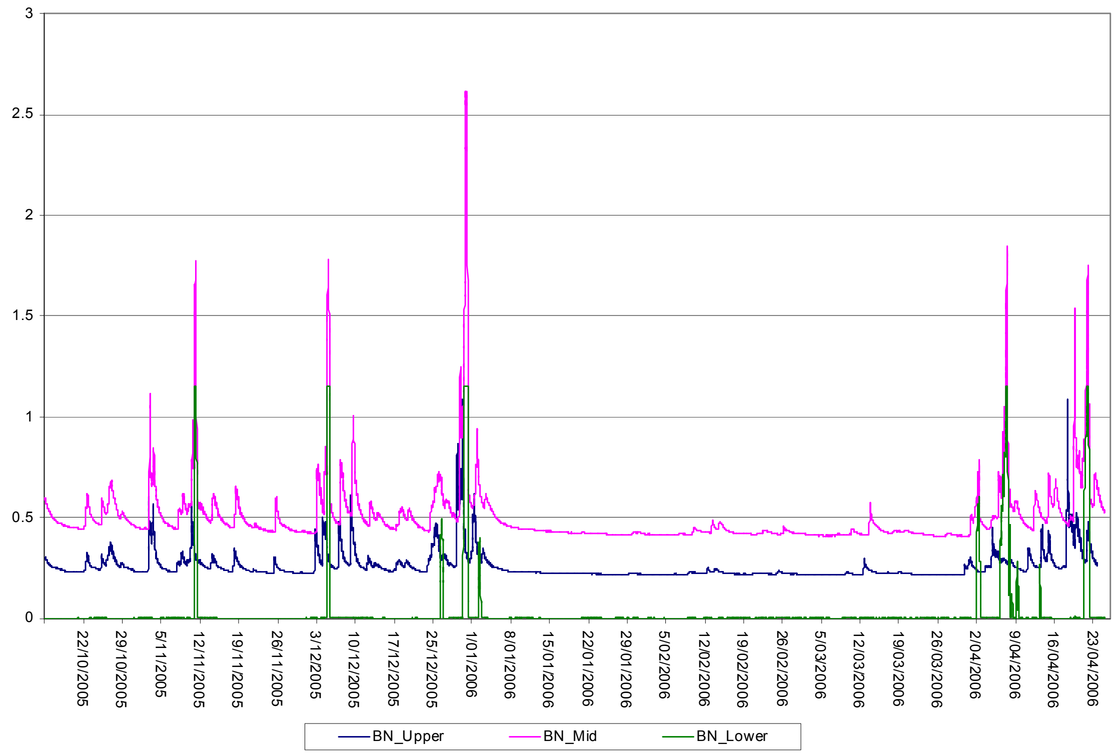

Figure 5.4. Bill Neilson Cave water level recorder data (BN_Upper: cave stream only; BN_Mid: cave stream and Gordon river water backflooding; BN_Lower: Gordon River backflooding only) for the period 16 October 2005 to 11 March 2006.

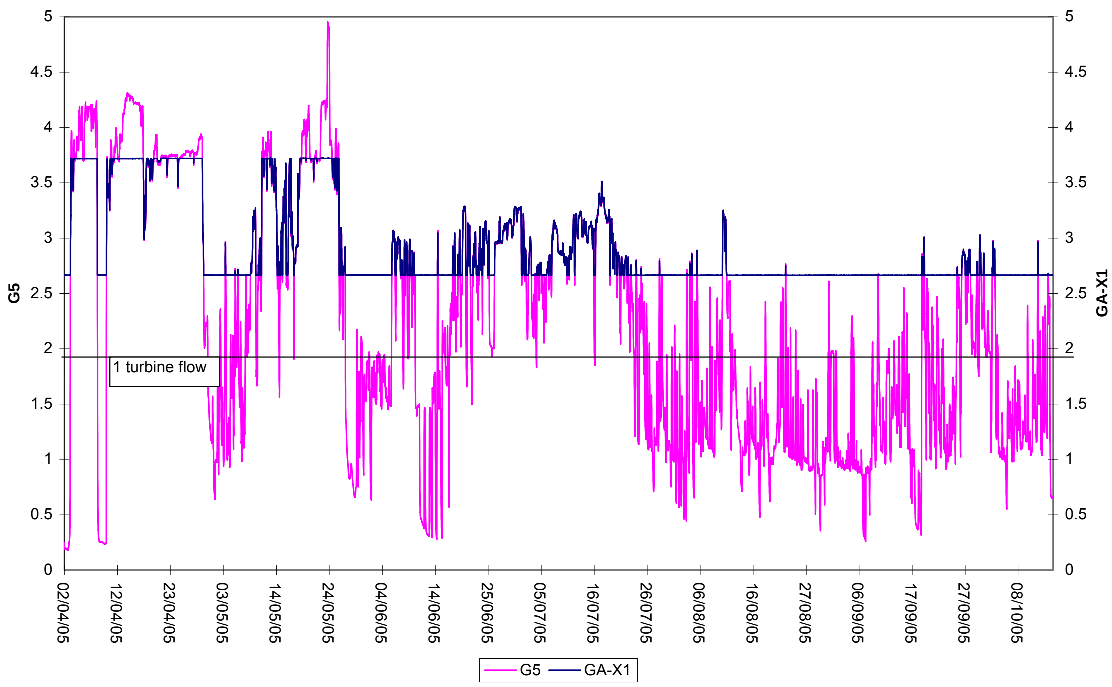

Figure 5.5. GA–X1 water level recorder with water levels from site 72 (G5) for comparison for the period of 2 April–15 October 2005. Data in metres above arbitrary zero datum.

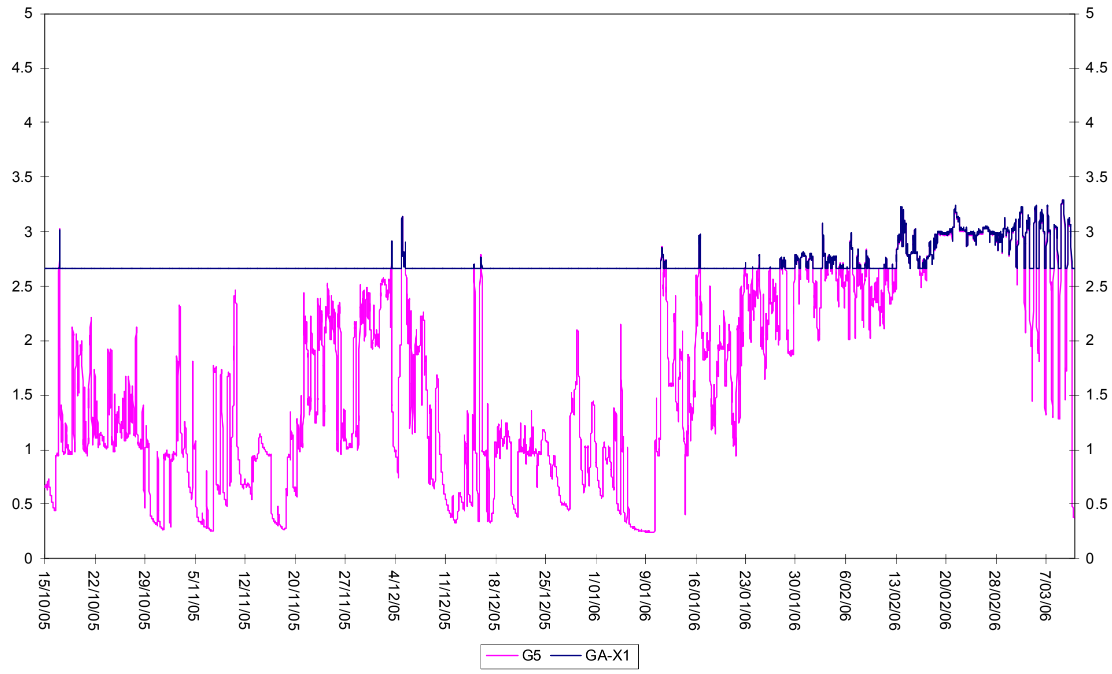

Figure 5.6. GA–X1 water level recorder with water levels from site 72 (G5) for comparison for the period 16 October 2005–11 March 2006. Data in metres above arbitrary local zero datum.

5.3 Discussion

5.3.1 Bill Neilson Cave

During the October 2005 monitoring no obvious changes were observed in the condition of the Bill Neilson Cave. Fresh platypus scats indicated their continued presence in the cave. Recent plant fragments were noted at the entrance to a platypus burrow in a sediment bank near the upstream stage monitoring site. The following species were represented in a sample of the plant fragments that was collected for identification:

- *Acacia melanoxylon* (blackwood);
- *Eucalyptus nitida* (western peppermint);
- *Dicksonia antarctica* (treefern);
- *Selaginella uliginosa* (fern allie); and
- *Libbertia pulchella* (iris) or *Hierochloe fraseri* (grass) (J. Balmer, pers. comm.).

These were presumably carried into the cave by platypuses for use in nesting.

During the March 2006 monitoring, again no significant changes were noted in Bill Neilson Cave, which probably reflects the unusually low power station flow in comparison to previous summers and the consequent general lack of inundation in the cave.

5.3.1.1 Sediment transfer

There are three sets of erosion pin data collected in Bill Neilson Cave:

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

The lowest erosion pin (pin 20) at the first wet sediment bank showed no change in the depth of the sediment over winter (measured October 2005). Over summer (measured March 2006), just 2 mm of sediment was deposited at this pin which is less than has occurred in previous summers during the monitoring program [range 2–8 mm]. The net change at this pin over 12 months is +2 mm. This year's results are slightly different to previous years which have shown much stronger seasonal patterns of deposition of sediment in summer and erosion in winter. Changes can be attributed to altered power station operations, i.e an increase in 2-turbine flows during the winter period, coupled with relatively low cave stream flows, would have created more ponding in the cave entrance. In addition, low power station flows over summer caused a general lack of inundation. Nonetheless, the data imply that there has been little net loss or gain of sediment at pin 20 over the last three years, although the surface is 12 mm lower than when monitoring commenced in December 2001.

At the mid-level on the same sediment bank, pin 21 recorded 4 mm of erosion over winter and a 2 mm loss of sediment over the summer with a net loss of 6 mm over 12 months. At the higher level (pin 22), there was negligible change over either period. The pattern of change at these higher levels (pins 21 and 22) is similar to that which occurred during the 2003–04 sampling period.

The second wet sediment bank showed little change in sediment this year. There was just 1 mm of erosion at the lowest level (pin 25) over winter and zero change over summer. At the middle level (pin 26) there was zero change over winter and just 1 mm of erosion over summer , while at the highest level (pin 27) there was 1 mm of deposition over winter and 1 mm of erosion over summer (zero change over 12 months). These changes are relatively small in comparison to other years and are again likely to result from the reduction in inundation.

Erosion pins at the dry sediment bank higher in the cave showed little change all year. There was no change at the higher of the two pins (pin 24) over the 12 months. The lower pin (pin 23) showed 1 mm of erosion over the summer which counter-balanced the 1 mm of winter deposition to give zero net change. The measured change in sediment at this site has been very small over the last three years, varying across ranges of only 3 mm (pin 23) and 1 mm (pin 24).

5.3.1.2 Photo-monitoring

Photo-monitoring sites have been established in the cave to support the erosion pin data in determining sediment transfer in the cave. There was no evidence of any major sediment shift at any of the monitoring sites within the cave from the photos taken during the October 2005 monitoring.

5.3.1.3 Water level monitoring

The largest flood over winter took place on 25 May as a result of high flows in the Denison River in combination with high power station flow. The resulting flow was the only one in this reporting period large enough to reach the pins in the dry sediment bank and it is therefore likely to have been responsible for the very limited sediment deposition (1 mm) recorded at the lower of the pins (pin 23). Generally low flow over winter was likely to have created more ponding in the entrance chamber to the cave and consequently less erosion at the lower levels of the banks (pins 20 and 25).

5.3.1.4 Bill Neilson Cave summary

The October 2005 field trip indicated that slight deposition occurred at the higher levels and slight erosion at the lower levels of the wet sediment banks. The lowest pin (pin 20) in the first wet sediment bank was an exception – it recorded zero change compared to the winter erosion that more typically occurs. This is likely to have been a consequence of the greater proportion of 2-turbine power station activity over winter and the lower cave stream flow which would have created more ponding in the entrance chamber to the cave and consequently less erosion at the lower levels of the banks. There was little change at the dry sediment bank, although one flood event in May was high enough to reach the bank and it is likely that this was responsible for the 1 mm of sediment deposition that was recorded.

A series of uncharacteristically low discharges from the power station over the summer period resulted in less sediment change during the March 2006 monitoring than in previous years due to the general lack of inundation in the cave. The pattern of change at the wet sediment banks over the 12-month period was similar to that which has occurred in other years, i.e winter erosion and summer deposition at the lower levels in the cave due to the action of the cave stream; minor net erosion at mid levels; and minor net deposition at higher levels due to the backflooding by the Gordon River. Consistent with other years, there was zero net change at the dry sediment bank over the 2005-06 monitoring season.

5.3.2 Kayak Kavern

During the October 2005 monitoring trip, water levels were higher than usual, causing pin 28 to be partially submerged. Pin 17 had become tilted at an angle of about 10 degrees in the downslope direction and was considered likely to fall out. An area of minor slumping was noted in the vicinity of pin 19, starting about 400 mm directly upslope of the pin and affecting an area of a few square metres. Evidence of possible rotational slumping was also observed in the vicinity of pin 17, comprising a poorly defined breakway scarp about 1500 mm wide and 300 mm upslope of the pin.

During the March 2006 monitoring trip, it was observed that pin 19 on the eddy slope is no longer vertical and appears to have been knocked to one side, potentially by floating debris. Minor slumping in the vicinity of the pin is also evident. The results for this pin this period therefore need to be treated with caution. No other significant changes were noted.

5.3.2.1 Sediment transfer

Pin 18, which is located on the mostly flat upper surface of the sediment pile, showed a very modest increase in the depth of sediment over winter (+2 mm) and a similar decrease in sediment over summer (–3 mm). The depth of sediment at this location has varied across a range of 17 mm since the program commenced in December 2001. This pin is probably most representative of general sediment conditions as it is not affected by the processes on the slope of the mound.

Pin 17, on the slope, experienced a reduction of 46 mm in the depth of the sediment over winter and a large increase in sediment of 64 mm over summer. To a large extent these changes are likely to reflect mass movements on this side of the sediment pile, which is prone to slumping.

The depth of sediment at pin 19 on the slope in the eddy increased by 17 mm over the winter period, with a further 100 mm increase over the summer period. As at pin 17, this site is affected by slumping, with evidence of recent movement in the vicinity of the pin.

In summary, over the 12-month period, there has been very minor net erosion on top of the sediment mound (pin 18: –1 mm), minor net erosion on parts of the active slope (pin 30: –4 mm and pin 33: –8 mm), and relatively large net deposition on other parts of the active slope and in the eddy (pin 17: +18 mm; pin 29: +39 mm and pin 19: +117 mm). There are no consistent seasonal trends in sediment change evident in Kayak Kavern.

5.3.2.2 Photo-monitoring

The photos from the photo-monitoring during the October 2005 monitoring show that no significant changes have occurred in Kayak Kavern over the winter period.

5.3.2.3 Kayak Kavern summary

The October 2005 results indicated that the typical trend of winter deposition had continued at pin 18 on the top of the sediment mound, albeit very limited. Pins 17 and 19 were both affected by slumping over the winter period which was associated with relatively large losses of sediment at pin 17 on the active slope and increases at pin 19 in the eddy. Pin 17 had been tilted in the downslope direction and appeared likely to be displaced.

Sediment change in Kayak Kavern during the March 2006 monitoring period was primarily minor, from the upper surface of the sediment mound and on the middle parts of the active slope. The pins on the extremities of the slope recorded relatively large deposition but there is some evidence of disturbance of the pins and the data must be treated with caution. Over the 12-month period, there has been very minor net erosion on top of the sediment mound, and both minor net erosion and relatively large net deposition on various parts of the active slope. There are no consistent seasonal trends in sediment change evident in Kayak Kavern.

5.3.3 GA-X1

No significant changes were observed in GA-X1 for the period 2 April–15 October 2005. During the March 2006 monitoring trip, it was observed that there was significant sediment build up occurring up-gradient of pin 2 due to the presence of a stick lodged against the pin. Small eddies around the pin when the water in the cave rises and falls appear to be influencing sediment changes. An additional pin will be installed on the next trip adjacent to pin 2 to corroborate the results. No other significant changes were observed at GA-X1 this period.

5.3.3.1 Sediment transfer

The two pins in the entrance doline (pins 9 and 10) showed minor changes in the depth of leaf litter and debris over winter and summer which are independent of the power station. Pins 2 and 3, in the middle and upper sites inside the cave, remained essentially stable over winter and summer, with only minor changes recorded (-1 mm at pin 3 at the higher level and +1 mm at pin 2 at the mid level). However, 8 mm of sediment was eroded at the lower level at pin 4 during winter and a further 2 mm was eroded over summer. Over the 12-month period, there has been net loss of 10 mm of sediment at the lower level in the cave, but negligible change at the mid and higher levels. These results continue the trend since the program began of continued erosion at the lower level and slight net erosion at the mid and upper levels.

5.3.3.2 Water level monitoring

The water level data from GA-X1 for the periods between sampling trips, together with the corresponding data from G5, are shown in Figure 5.5 and Figure 5.6. Water levels in the cave correlated well with the G5 water levels for both winter and summer periods.

The data show that the water level fluctuations within the cave during the latter part of the winter period were predominantly at relatively low levels within the cave, reflecting the high proportion of time the station was operating at just one turbine. At these levels of operation, only the lowest pin was subjected to the fluctuations in the river. These fluctuations are likely to have been responsible for the slight erosion which occurred over winter at the lower pin. The very small sediment changes at the upper two pins can be related to the lack of inundation this period.

Over summer, the cave was relatively dry as would be expected from the low flows in the river and the low power station output. Peak flows were not high enough to reach the top of the recorder as they have done in previous years.

In summary, the majority of water level fluctuation activity was at the lower levels in the cave over the 12-month period which supports the net erosion at pin 4. Pin 3 was, for the most part, outside the inundation zone and is accumulating sediment, most likely from the influx of material with rainfall through the second cave entrance located above the pin.

5.3.3.3 Photo-monitoring

The photo-monitoring for October 2005 suggests that there may have been more widespread deposition at the lower levels in the cave, contrary to the erosion pin data (pin 4). This apparent contradiction in data will be further investigated in future trips.

5.3.3.4 GA-X1 summary

The October 2005 results showed that there has been relatively little inundation in GA-X1 over winter reflecting the dominance of 1-turbine operations at the power station. Little sediment change has consequently been recorded at the two upper level pins. Eight millimeters of sediment was eroded from the pin at the lower level in the cave which is likely to be related to the extent of fluctuations during the single turbine operations. The photo-monitoring suggested, however, that there may have been more widespread deposition at this level over winter. The overall trend of the erosion pin data at the GA-X1 cave site suggests that a progressive depletion of sediment may be occurring.

The March 2006 results indicated there was little sediment change in GA-X1 over summer due mainly to the relatively low Gordon River levels and the lack of inundation in the cave. The majority of water level fluctuation activity was at the lower levels in the cave over the 12-month period, and provides evidence for the causal mechanism of erosion. The highest pin was, for the most part, outside the inundation zone accumulated sediment, most likely from the influx of material with rainfall through the second cave entrance located above the pin.

5.3.4 Dolines

There are two doline sites being monitored in zone 2:

- site 3 adjacent to GA-X1; and
- site 4 adjacent to Channel Cam.

The erosion pins at site 3 are arranged with pin 5 in the base of the depression with a succession of pins arrayed in a line up the side of the feature at 1-2m distance apart up to pin 8. Three of the pins showed small increases of 1-3 mm in debris over summer, while the fourth (pin 6) had a small decrease of 2 mm. Over the 12–month period, the net change was zero at the base of the feature, a decrease in debris at the mid levels and an increase towards the top.

There are now five erosion pins at site 4. Pins 12–14 are positioned in an array up the side of the feature with pins 31 and 32 supporting pin 12 at the base. Two of the pins (pins 12 and 13) showed an increase in debris this summer, while two (pins 14 and 32) indicated a decrease and pin 31 showed no change. Three of the pins (12, 13 and 31) show a slight net decrease over 12 months in comparison to the slight net increase at pins 14 and 32.

As noted in previous reports, the changes in the lengths of the erosion pins are not determined by the inundation regime of the Gordon River and are of less consequence than any changes in the distances between the tops of the pins. Consistent with previous trips, there were no significant changes between the pins within the precision of the measuring method. This suggests that the morphology of the dolines has remained stable since the program commenced.

5.3.5 Channel Cam

The water level at the gauging station at G5 only exceeded 4.1m, which is the level of inundation of the channel, in April and May – the channel remained isolated from the river for the remainder of the year. Rainfall and resulting surface runoff is likely to have contributed to the winter deposition of 3 mm (pin 1) and –11 mm (pin 28). This is supported by the photo–monitoring that shows significant ponding of surface water in the channel despite the lack of inundation. Over summer, 2 and 3 mm of erosion was detected, despite the complete lack of inundation by the Gordon River. The erosion is likely to have occurred with rainfall pooling and draining from the channel.

In summary, the winter deposition and summer erosion trend of the previous monitoring season has been continued this year, although this year the net change is 0–8 mm of deposition, in contrast to the net erosion of 1–8 mm in 2004–05. The net change since the program began is very small at 0 to –3 mm.

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6 Riparian vegetation

6.1 Introduction

The riparian vegetation component of the Basslink Monitoring Program collects data on the cover and abundance of existing vascular riparian species at permanent plots located in the middle Gordon River and in two reference rivers, the Franklin and Denison. Future analysis of these data will provide:

- a greater understanding of the current processes, trends and condition of riparian vegetation within the middle Gordon River;
- datasets to allow quantification of any potential effects of the Basslink project; and
- a scientific basis for adaptive management.

This report provides results of the monitoring events in December 2005 and April 2006. The spring data has been previously analysed and is included in the reports for trigger level development. The autumn period did have some 'Basslink' flow patterns and abnormal flow patterns as a result of the pre-Basslink testing phases and the lack of 3-turbine operation due to maintenance. Therefore the results presented in this report are not formally analysed.

6.2 Methods

The field data collection includes assessment of seedling recruitment and vegetation cover in permanent plots and photo-monitoring on 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 (Koehnken *et al.* 2001) which divided the middle Gordon River into five zones based on the presence of hydraulic controls, such as gorges or the confluence of tributaries. No bank sites were established in zone 1, the zone closest to the power station, as it is dominated by bedrock substrate with little substrate suitable for vegetation.

Site selection within the Denison and Franklin Rivers was largely dictated by logistical constraints; only those sites accessible by helicopter under a range of flow levels (except very high flows) were selected for quadrat sites. This resulted in all bank monitoring sites being adjacent to, or accessible from, cobble bars.

6.2.1 Sampling design

At each site one permanent transect, comprising eight 1-metre square quadrats, was established. Quadrats were offset by 0.5m from the transect line to avoid trampling impacts, and located with reference to the high-water mark as shown in Figure 6.1. At most of the quadrat sites the high-water mark was delineated by a star picket previously installed during 3-turbine operation. At sites where there was no delineation of high-water mark, this was estimated by changes in litter cover and ground disturbance. Sites were permanently marked.

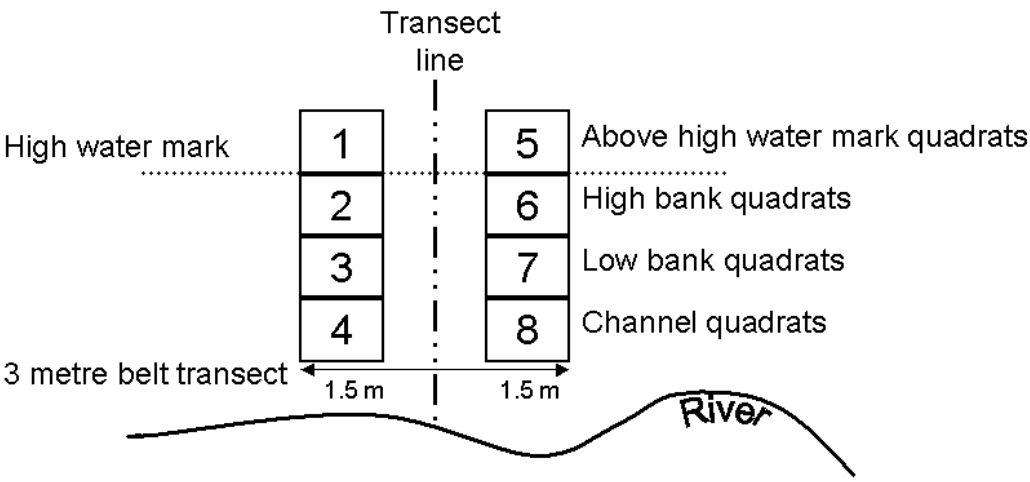


Figure 6.1. Diagrammatic representation (plan view) of quadrat positions along transects in Gordon, Franklin and Denison Rivers.

Monitoring within these sites included assessment of ground species cover, seedling numbers, density of trees and shrubs, health of vegetation and habitat variables including substrate and aspect.

Table 6.1. Riparian vegetation monitoring program schedule.

Sites	Season		Monitored variable/method of assessment		
	Autumn	Summer	Quadrat studies	Seedling recruitment	Photo-monitoring
Gordon zones 2–5		*		✓	✓
Gordon zones 2–5	*		✓	✓	
Tributary sites	*		✓	✓	✓

Note: Quadrat studies include species cover, root exposure and tree and shrub stem counts.

6.3 Results

6.3.1 Vegetation cover and bare ground

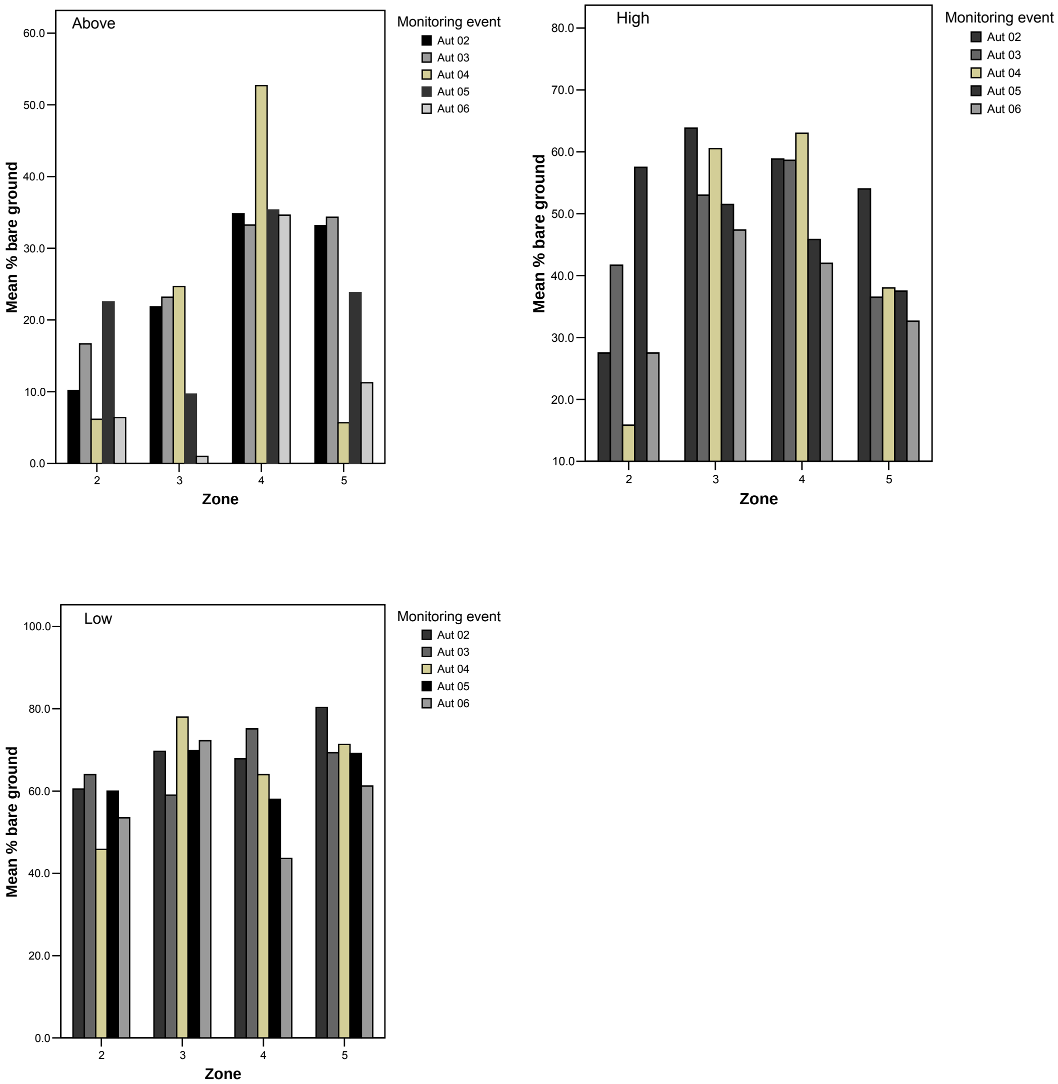


Figure 6.2. Mean % bare ground cover by quadrat type for all zones over the pre–Basslink monitoring events.

Patterns of abundance in % cover of bare ground continued to be dominated by relative position on the bank and hence the relative amount of disturbance (Figure 6.2).

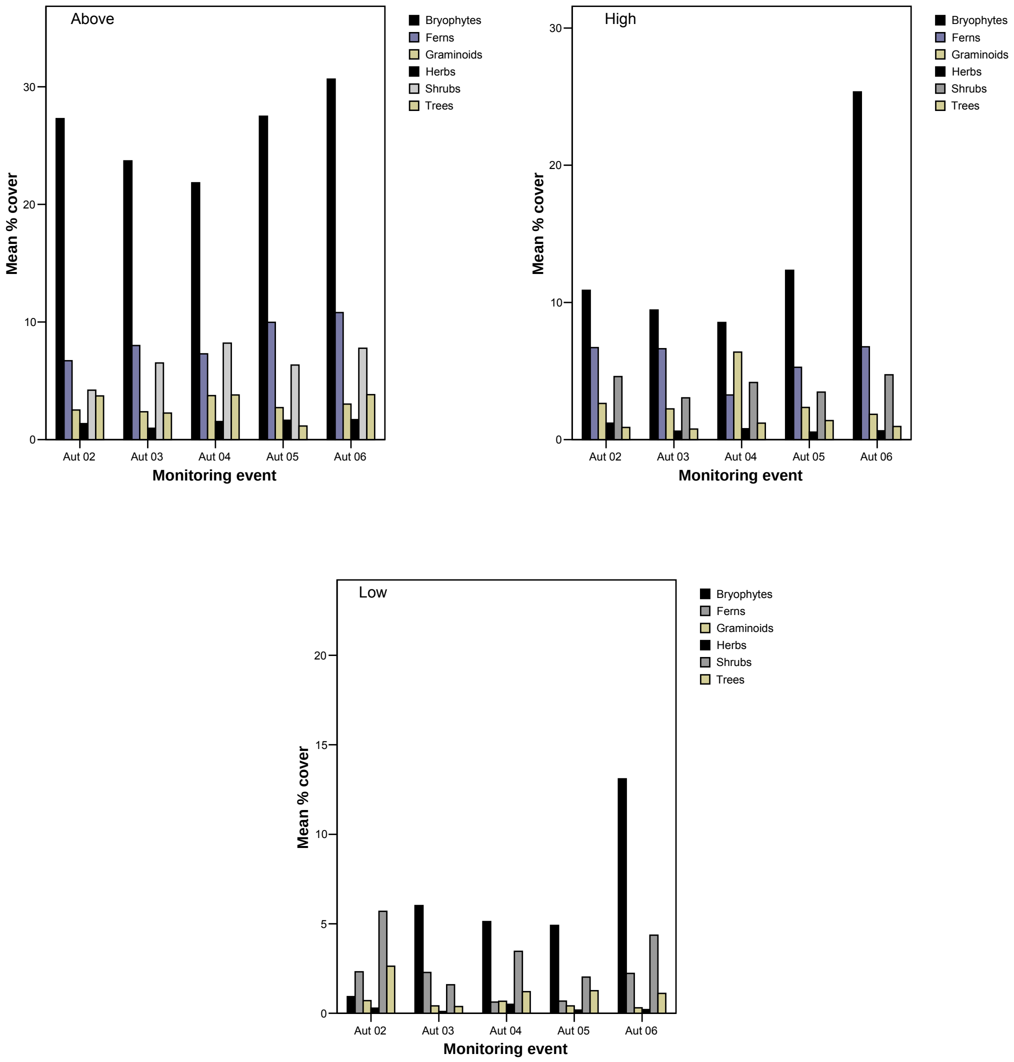


Figure 6.3. Mean % ground cover for major life form groups by quadrat type for grouped data (all zones) over the pre–Basslink monitoring events.

Patterns of abundance of vegetation life forms were generally stable for all life forms over the monitoring events with the exception of bryophytes (Figure 6.3). Bryophyte cover appeared to increase in the low and high quadrats in autumn 2006. Whilst it is probable this increase in cover is a significant change, these data were not formally analysed due to the intermediate nature of the monitoring period as discussed in the introduction. If this trend continues in the post–Basslink data, this may trigger further analysis and explanation.

6.3.2 Species richness

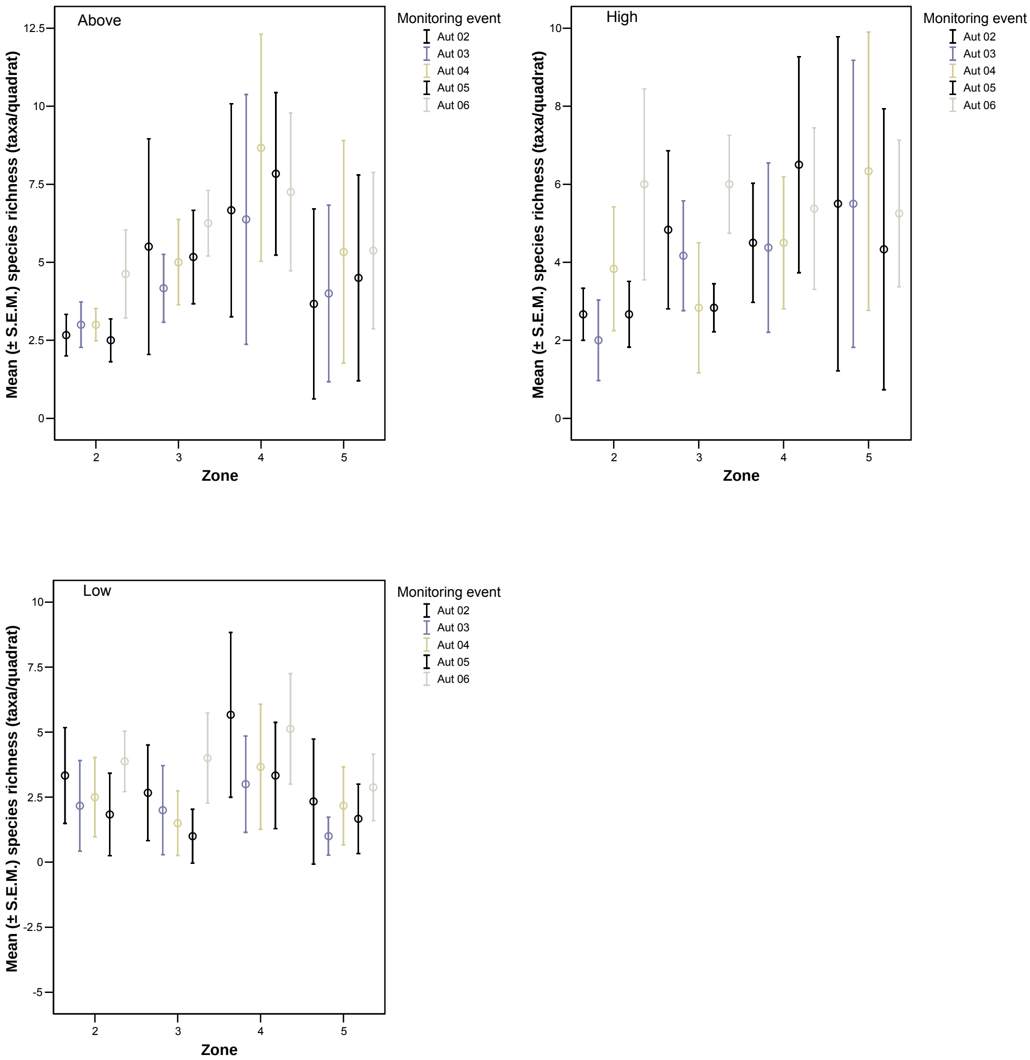


Figure 6.4. Mean (± S.E.M.) species richness for all quadrat types for all pre–Basslink monitoring events.

Species richness in autumn 2006 continued to be most strongly influenced by the quadrat location in zones 2 and 3 (Figure 6.4). This pattern was not as apparent in zones 4 and 5. This pattern is consistent with that reported in the Basslink Baseline Report (BBR).

6.3.3 Seedling recruitment

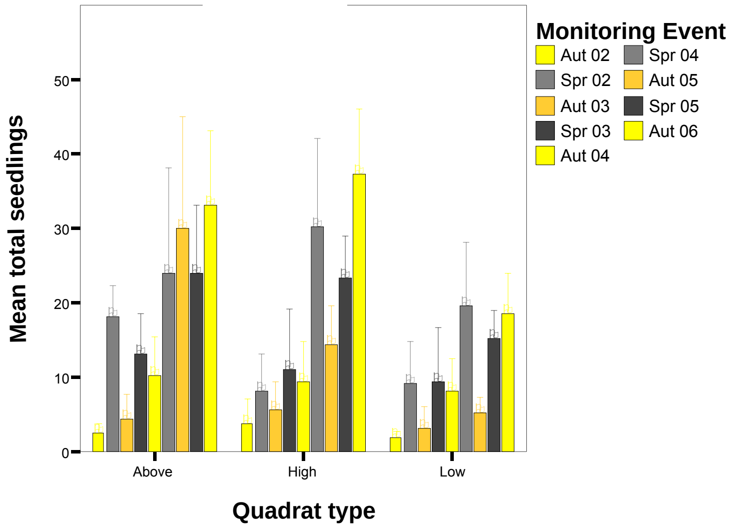


Figure 6.5. Mean number of seedlings (± standard error of the mean) per quadrat by quadrat type for zone 2 for all pre–Basslink monitoring events.

Seedling numbers in zone 2 fluctuated over the monitoring events in all quadrats; however no significant patterns were detected. The distinguishing patterns were again between the quadrat locations with higher seedling numbers in the above and high quadrats (Figure 6.5). The most abundant seedlings in zone 2 over all pre–Basslink monitoring events were the tree *Nothofagus cunninghamii* (myrtle) (<5cm), the small herb *Drymophila cyanocarpa* (Native Solomon's Seal) (<5cm), and unknown dicotyledon and monocotyledon seedlings (<5cm). These taxa all had a mean occurrence greater than 1 (seedlings/quadrat) for all quadrats. Other species were more abundant only in one or two types of quadrats. The above and high quadrats had a high abundance of *Anopterus glandulosus*, *Coprosma quadrifida* and *Leptospermum riparium*, all of which were in the <5cm size class. Species with a mean abundance >1 in low quadrats included *Nothofagus cunninghamii* and *Leptospermum riparium*.

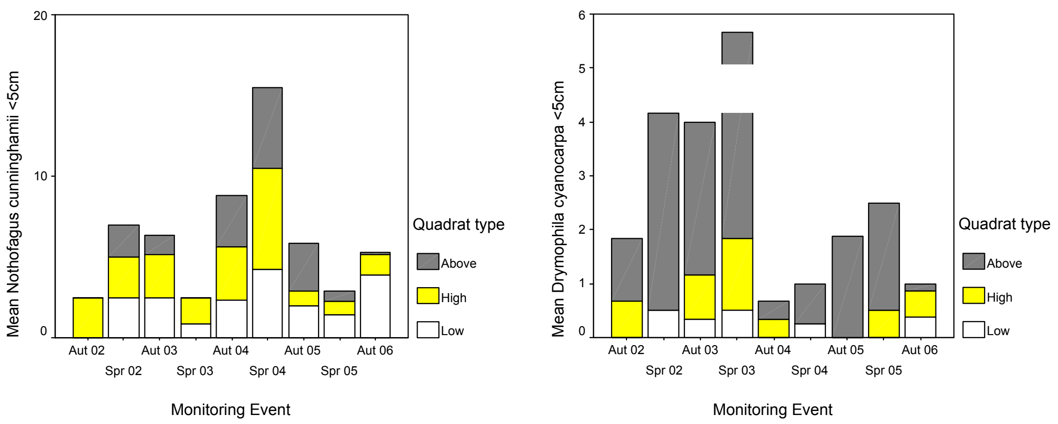


Figure 6.6. Mean seedling numbers by quadrat type for most abundant species over all monitoring periods in zone 2.

Nothofagus seedlings were most abundant seedlings in all quadrats. Seedling numbers have fluctuated over the baseline monitoring period in all quadrat types. *Drymophila cyanocarpa* was more abundant in the less disturbed 'above' quadrats that are above the high-water mark for 3-turbine operation than all other quadrats (K-W test p<0.05). This is likely to indicate that this species is less tolerant of high disturbance for germination or persistence than species such as Nothofagus.

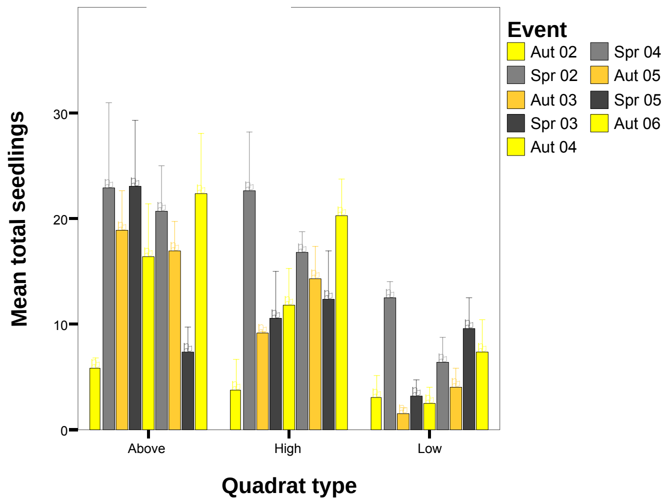


Figure 6.7. Mean number of seedlings per quadrat by quadrat type for zone 3 over all monitoring events.

Zone 3 also showed a lack of significant seasonal patterns (repeated measures ANOVA; p< 0.05). Again, the stratification between the higher quadrats and the lower quadrats was pronounced. Seedling numbers in the above high-water quadrats were higher indicating a more favourable environment for establishment.

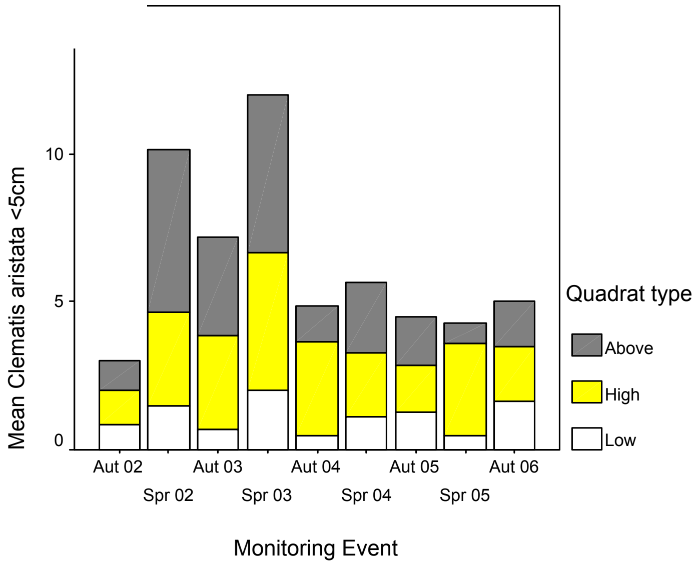


Figure 6.8. Mean number of seedlings for major species in zone 3 showing abundance in each quadrat type for all pre–Basslink monitoring events.

The most abundant seedlings in zone 3 over the all pre–Basslink monitoring events in were the trailing herb *Clematis aristata* (Clematis) < 5cm, *Nothofagus cunninghamii* (myrtle) (<5cm), unknown dicotyledons and monocotyledons <5cm and the shrub *Anopterus glandulosus* (native laurel) <5cm.

Clematis is a trailing herb that often has high numbers of seedlings present and few adult plants. Seedlings were most abundant in the upper, less disturbed quadrats including the above and high quadrats. However, the species was also present in the low quadrats, particularly on vertical alluvial faces, sometimes after continued periods of high duration of power station operation, indicating a high tolerance by seedlings to inundation and mechanical stress. Nothofagus seedlings followed the quadrat stratification pattern displayed in zone 2. Anopterus is a small to medium sized shrub that is commonly found on the banks in the middle Gordon River in all life stages. The 'seedlings' counted in these studies may actually represent small vegetative reproductive suckers off adult plant roots, explaining the often dense clusters found in quadrats. These clusters were also subject to the distinct zonation characteristic of the banks in the middle Gordon River.

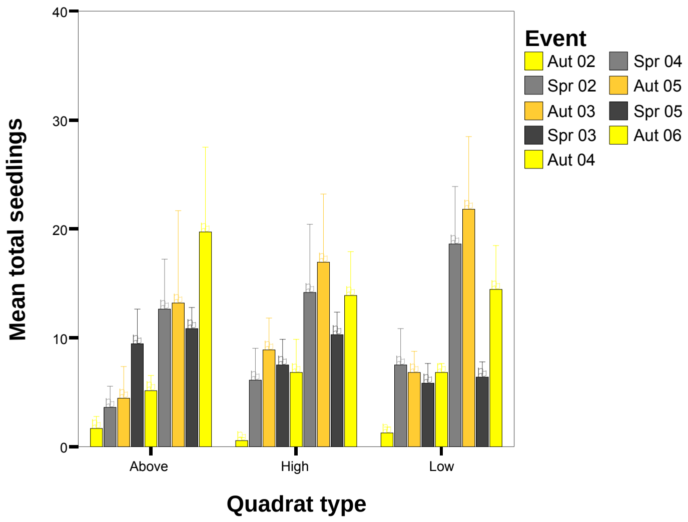


Figure 6.9. Mean number of seedlings per quadrat by quadrat type for zone 4 over all monitoring events.

Seedling abundance in zone 4 displayed almost every possible permutation of patterns between the all pre-Basslink monitoring events. Clearly this zone is more highly variable and the patterns between the quadrat locations not as distinct. This is supported in all data collected from this zone, including the cover data for all species (see discussion below). This is likely to reflect the more natural flows in this zone. This zone receives inflows from the Denison River and significant winter flows.

The most abundant seedlings in zone 4 over the all pre-Basslink monitoring events in descending order of total abundance were *Nothofagus cunninghamii* (<5cm), unknown dicotyledon and monocotyledon seedlings (<5cm), *Clematis aristata* (<5cm) and the shrub *Coprosma quadrifida* (native currant) (<5cm).

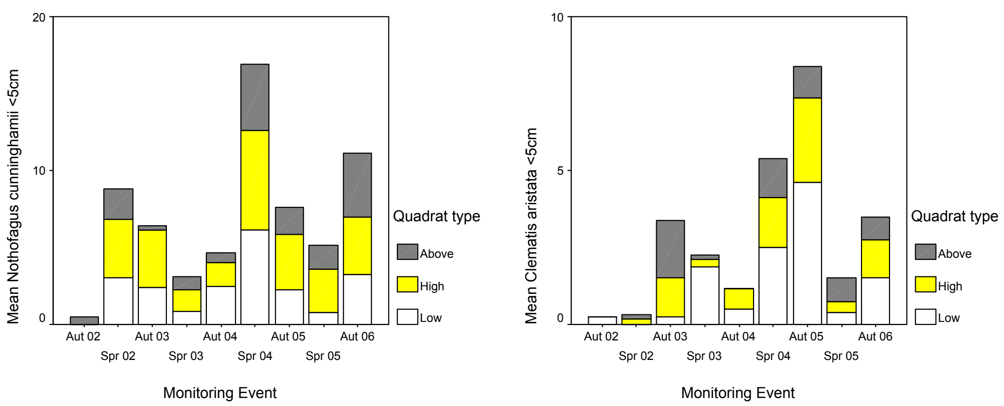


Figure 6.10. Mean number of seedlings for major species in zone 4 showing abundance in each quadrat type for the pre–Basslink monitoring events.

All the major seedling species in zone 4 showed less stratification by quadrat types with higher numbers of all species being present in the low quadrats. Again, Nothofagus seedlings were well represented in most monitoring events. Clematis seedlings were recorded in most quadrat types in the later monitoring events.

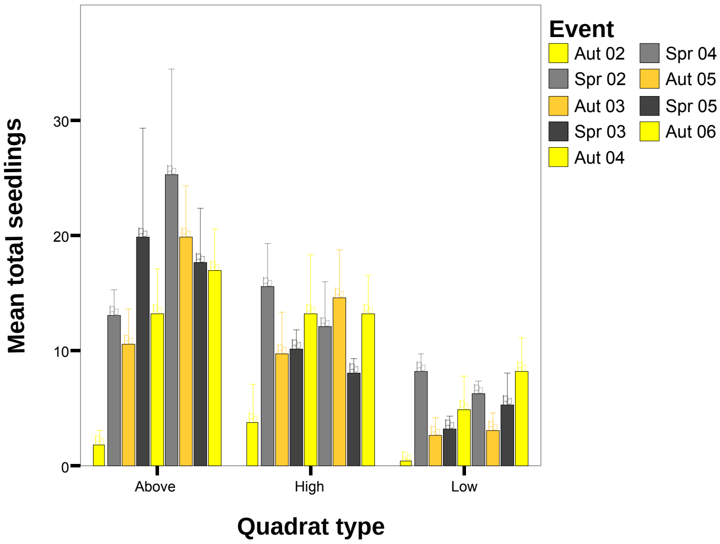


Figure 6.11. Mean number of seedlings per quadrat by quadrat type for zone 5 over all monitoring events

Seedling abundance in zone 5 showed similar fluctuations to those of zone 4 and no significant patterns over time. The most abundant seedlings in zone 5 over the all pre-Basslink monitoring events were unknown dicotyledon and monocotyledon seedlings (<5cm), Nothofagus <5cm, *Leptospermum riparium* (<5cm) *Clematis aristata* (<5cm), *Coprosma quadrifida* (<5cm). As in zones 2 and 4, Nothofagus seedlings were present in all quadrat types for most monitoring events as was Coprosma. The significant bank stabilising species *Leptospermum riparium* (tea tree) was more abundant in zone 5 compared with other zones for all monitoring periods except December 2004 when it was not recorded. The substantial numbers of unknown seedlings present may reflect an increasing diversity of seeds reaching the banks compared with the upper zones. This zone receives natural inflows from the Denison and Olga Rivers, with power station inflows only having moderate influence on total flow, sediment and propagule inputs.

6.3.4 Population structure and seedling persistence

Seedlings in all zones continue to be dominated by smaller size classes, while larger seedlings are far less prevalent (Figure 6.12). This pattern is a similar, although more extreme, example of the reverse 'j-curve' that generally characterises population structure in most plant communities (see Kirkpatrick *et al.* 2002 for description of methods).

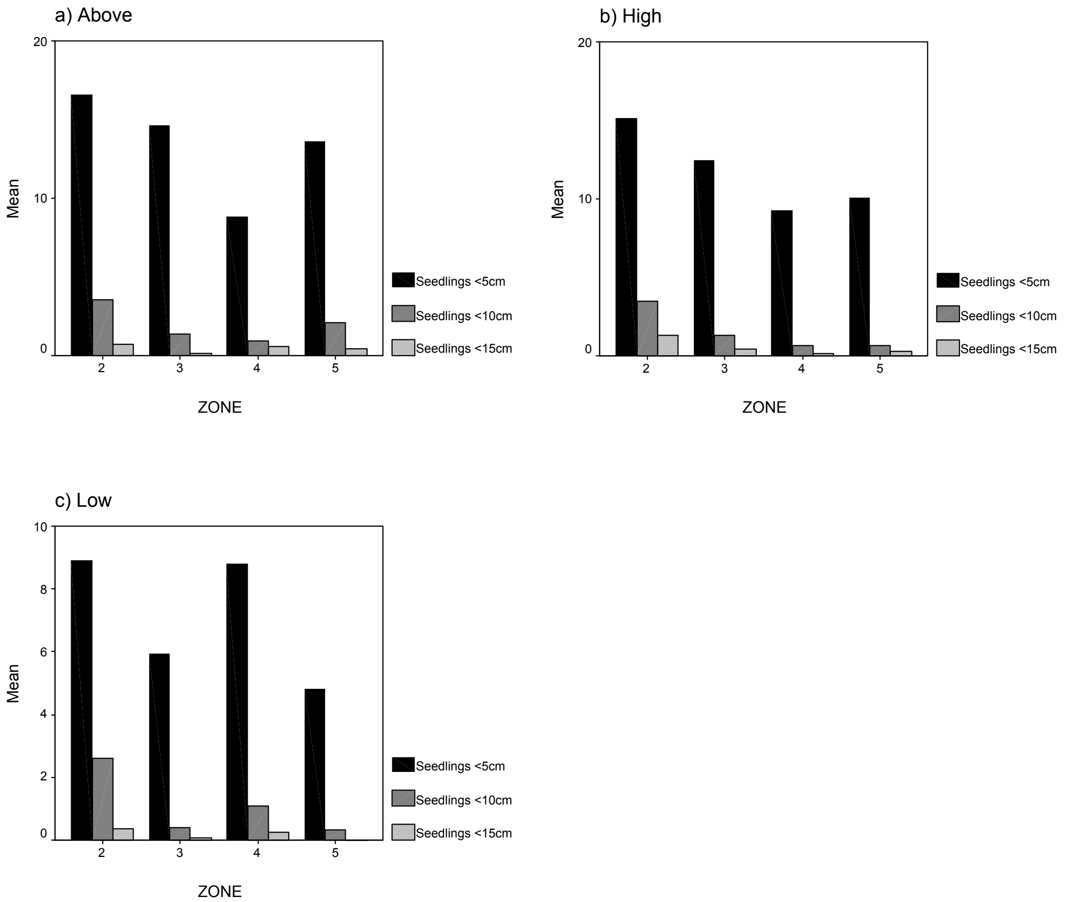


Figure 6.12. Mean number of seedlings in three size classes by quadrat type for all monitoring events in all zones of the Gordon River.

The lack of older size classes (and therefore older individuals) shows that while conditions are amenable to germination of many species in the higher quadrats, conditions are not suitable for persistence of these seedlings. The factors most likely responsible are the frequent disturbance of substrate and the total inundation of leaf and stem material precluding, or severely inhibiting, photosynthesis.

Few species have seedlings recorded in the 5–10 cm or 10–15 cm size classes. The most abundant species in the larger size classes include *Acacia* spp. (5–10cm), Clematis (5–10cm), *Acacia* spp. (>10cm), *Leptospermum riparium* (5–10cm), *Leptospermum riparium* (>10cm), Coprosma (5–10cm) and the snow berry *Gaultheria hispida* (5–10cm). These species still have the classic j-curve pattern, although the *Acacia* spp. seedlings have greater survival than most other species (Figure 6.13).

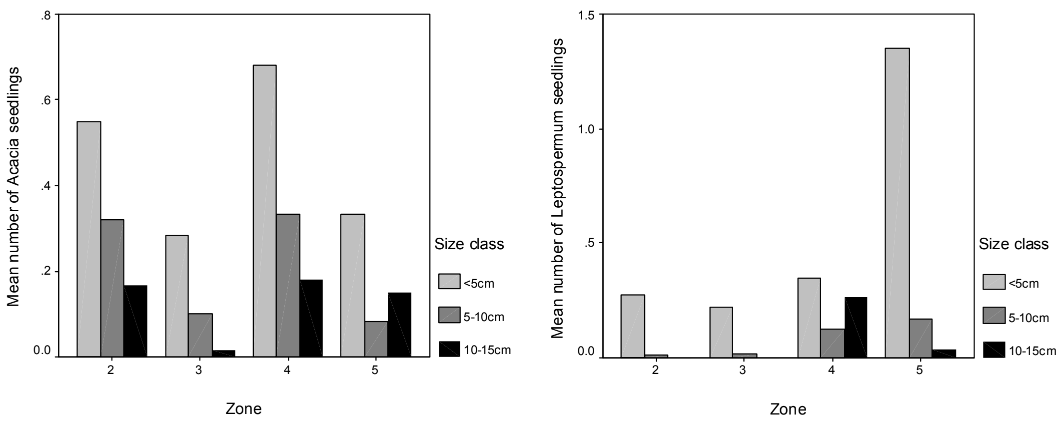


Figure 6.13. Mean number of *Acacia* spp. and *Leptospermum riparium* seedlings for three size classes by zone in the Gordon River – grouped data for all pre–Basslink monitoring events.

6.4 Discussion

Patterns of vegetation cover, species richness and seedling recruitment recorded in the spring 2005 and autumn 2006 monitoring events generally continued to follow the established patterns reported in the Basslink Baseline Report (BBR). These results were not formally analysed due to the intermediate nature of the autumn monitoring period. The spring data has been previously analysed and presented in the reports for trigger level development. The autumn period did have some 'Basslink' flow patterns and abnormal flow patterns as a result of the pre-Basslink testing phases and the lack of 3-turbine operation due to maintenance. Therefore this period has not been included in the development of trigger values.

7 Macroinvertebrates

7.1 Introduction

Macroinvertebrate monitoring was conducted in spring (October–November) 2005 and autumn (March) 2006. Both quantitative (surber) and rapid bioassessment (RBA) sampling was conducted at nine sites in the Gordon River between the power station and the Franklin confluence. Sampling was also conducted at six reference sites in rivers within the Gordon catchment.

The locations of the monitoring and reference sites are shown in Figure 7.1.

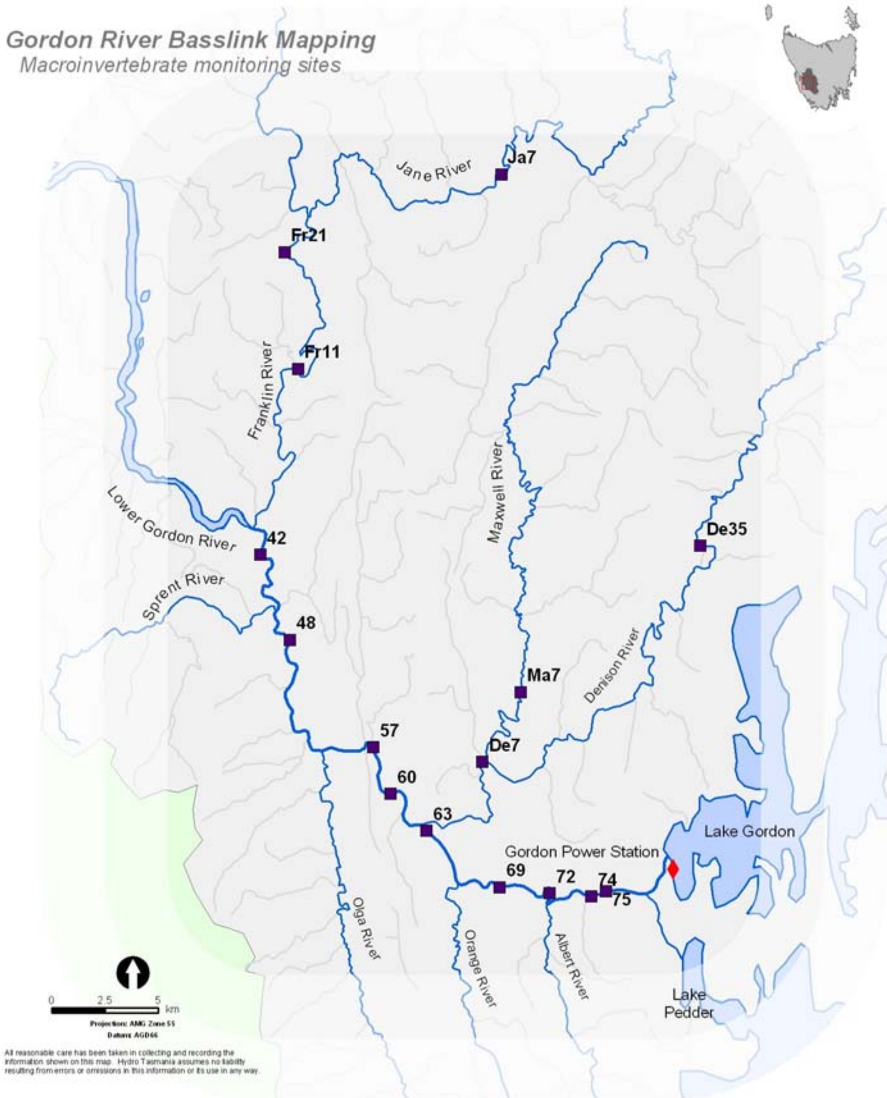


Figure 7.1. Map of the locations of macroinvertebrate monitoring sites in the Gordon, Denison and Franklin Rivers.

7.2 Methods

7.2.1 Sample sites and timing

All 15 sites were sampled in October–November (spring) 2005 and March (autumn) 2006. In October–November 2005, sites were sampled over a period of several weeks due to high river flows. Sampling was conducted on 15 October (sites 75, 74, 72 and 69), 17–18 November (sites 63, 60, 57, 48 and 42) and 24 November 2005 (reference sites). This does not have major implications for data compatibility. In March, all sampling was undertaken on 11–12 March. Table 7.1 gives the locations of the sampling sites.

Table 7.1. Macroinvertebrate monitoring sites sampled in October–November (spring) 2005 and March (autumn) 2006.

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 monitoring

The same sampling method was utilised at all sites. At each site at low flows, riffle habitat was selected and sampled by:

- Quantitative analysis: collecting 10 surber samples (30 x 30 cm area, 500 micron mesh) by hand disturbance of substrate to a depth of 10 cm and washing into the net; and
- Rapid biological assessment (RBA): disturbing the substrate by foot and hand immediately upstream of a standard 250 micron kick net over a distance of 10m.

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 ephemeroptera, plecoptera, trichoptera and coleoptera (EPTC fauna).

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 same taxonomic levels as described above.

7.2.3 Habitat variables

A set of standard physical habitat variables were recorded at each site and a number of variables were recorded from maps.

7.2.4 Analysis

O/E scores and summary trends were derived from the RBA data using the spring and autumn Hydro Tasmania RIVPACS models developed by Davies *et al.* 1999.

O/Epa and O/Erk values were 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.

Combined season values were not derived, as in previous years, because these are no longer being used as a trigger value and as a level of acceptable change (LOAC) measure. In addition, spring sampling occurred prior to the commissioning of Basslink, while autumn data occurred in the transitional phase following testing of the Basslink cable, in which some alteration in power station operation had occurred. As a result, autumn data are treated separately in this report.

7.3 Results

7.3.1 Quantitative (surber) sampling

Macroinvertebrate abundance data identified to the family level for spring (October–November 2005) are shown in Table 7.2 and results were comparable with previous years. Spring sampling results showed that diversity and abundance were generally higher downstream of the Denison confluence. Autumn sampling indicated similar trends and, in addition, had high diversity in the vicinity of the Denison confluence (sites 63, 60 and 57) due to elevated abundances of hydropsychids, simuliids and oligochaetes (Table 7.3, Figure 7.2).

The abundance, diversity and composition of the EPTC taxa strongly discriminated Gordon River sites from reference sites (Table 7.4, Table 7.5). Gordon River EPTC taxa in both seasons were dominated by *Nousia* spp. AV5/6, *Asmicridea* spp. AV1 and to a lesser extent by *Trinotoperla zwicki* larvae. Gordon River abundance and diversity was significantly higher in spring, in which a number of other species were sub-dominant, including *Moruya opora* and *Cardioperla media/lobata*. Reference sites had the same dominant taxa, as well as *Baetid* Genus 2 MV sp. 3 and *Tillyardophlebia* sp. AV2.

Table 7.2. Macroinvertebrate abundance data (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in spring (October–November) 2005.

Class	Order	Family	Gordon									Franklin		Denison		Maxwell	Jane
			75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Platyhelminthes	**Turbellaria**		**3**	**4**		**1**	**2**	**7**	**3**	**6**	**2**	**11**	**6**	**2**		**15**	**3**
Nematoda				**12**			**2**	**2**		**13**	**3**	**28**					**2**
Mollusca	**Bivalvia**	**Sphaeriidae**					**1**	**1**				**2**	**1**			**3**	**5**
	Gastropoda	**Hydobiidae**		**1**		**8**		**2**	**7**	**3**	**8**	**3**	**1**	**4**	**1**	**198**	**19**
		Ancylidae										**1**	**5**				
		Glacidorbidae		**1**		**1**		**1**									
Annelida	**Oligochaeta**			**115**	**161**	**75**	**63**	**159**	**124**	**466**	**340**	**314**	**11**	**53**	**96**	**337**	**107**
Arachnida	**Acarina**			**1**						**1**		**3**	**2**	**2**		**8**	**1**
Crustacea	**Amphipoda**	**Paramalitidae**						**1**	**9**	**18**	**2**	**1**				**12**	
		Neoniphargidae	**22**	**6**	**1**	**5**		**3**		**1**	**2**					**2**	
	Isopoda	**Phreatoicidea**				**6**										**1**	**1**
		Janiridae	**97**	**59**	**9**	**11**	**9**	**3**	**5**	**9**	**5**	**97**	**20**	**3**		**3**	
Insecta	**Plecoptera**	**Eustheniidae**	**2**	**3**	**1**		**1**	**6**	**4**	**11**	**4**		**7**	**3**	**25**	**1**	
		Austroperlidae			**1**		**1**			**1**					**1**		
		Gripopterygidae	**3**	**16**	**61**	**13**	**97**	**48**	**43**	**29**	**33**	**8**	**26**	**12**	**36**	**104**	**23**
		Notonemouridae				**2**	**2**				**1**						
	Ephemeroptera	**Leptophlebiidae**	**5**	**2**	**27**	**4**	**16**	**135**	**77**	**85**	**101**	**313**	**198**	**245**	**233**	**305**	**134**
		Baetidae					**1**	**14**	**2**	**3**	**4**	**12**	**12**	**11**	**78**	**123**	**47**
	Odonata	**Telephlebiidae**												**1**			**1**
	Diptera	**Chironomidae: Chironominae**		**2**	**4**	**3**	**9**	**7**	**4**	**6**	**21**	**3**	**5**	**21**	**10**	**5**	**13**
		Chironomidae: Orthocladiinae	**10**	**10**	**27**	**2**	**9**	**11**	**7**	**16**	**10**	**1**	**27**	**1**	**6**	**18**	**12**
		Chironomidae: Podonominae		**1**	**3**		**8**	**16**	**19**	**22**	**9**	**7**	**7**	**12**	**19**	**8**	**7**
		Chironomidae: Tanypodinae										**1**					
		Chironomidae: Diamesinae	**10**	**11**	**4**								**2**			**1**	
		Chironomidae: Aphroteniinae								**1**		**4**	**1**			**2**	**2**
		Simuliidae	**1**	**82**	**58**	**17**	**15**	**268**	**281**	**349**	**87**	**526**	**1000**	**91**	**515**	**100**	**120**
		Tipulidae			**9**			**6**	**3**	**5**	**2**	**4**		**3**	**1**	**2**	**1**
		Athericidae											**1**				
		Blephariceridae		**1**	**3**			**3**	**2**	**11**	**3**	**53**	**169**	**2**	**17**		**1**
		Ceratopogonidae										**9**	**4**		**1**	**1**	**1**
		Chaoboridae	**2**														
		Empididae		**1**	**1**	**1**	**1**			**1**	**2**	**1**		**1**	**1**	**4**	**3**
		Tanyderidae															**1**
		Dip. Unid. Pup.	**2**	**2**	**3**	**2**	**2**	**3**	**12**	**13**	**35**	**5**	**9**	**8**	**28**	**2**	**3**
	Trichoptera	**Calocidae**		**4**						**1**		**1**		**1**	**2**	**26**	**53**
		Conoesucidae		**1**	**19**		**10**	**6**	**1**	**1**	**4**		**7**			**50**	**20**
		Glossosomatidae					**1**	**1**						**1**		**6**	**29**
		Helicophidae									**1**						**1**
		Helicopsychidae														**2**	
		Hydrobiosidae	**1**	**6**	**4**	**4**	**11**	**31**	**19**	**31**	**14**	**24**	**27**	**14**	**17**	**23**	**14**
		Hydropsychidae				**1**	**78**	**313**	**67**	**29**	**9**	**1**	**3**	**5**	**4**	**18**	**5**
		Hydroptilidae			**1**		**2**	**2**									
		Leptoceridae	**1**	**2**		**3**		**10**	**8**	**10**	**5**	**17**	**36**	**7**	**32**	**2**	**29**
		Philopotamidae						**6**					**1**			**4**	
		Philorheithridae						**2**	**1**		**2**	**4**	**4**		**9**	**22**	**26**
		Polycentropodidae													**1**		
		Trich. Unid. Pup.					**1**	**5**	**2**	**9**	**1**	**2**			**1**		**8**
	Coleoptera	**ElmidaeA**			**1**		**5**	**10**	**16**	**2**	**3**	**69**	**67**	**99**	**70**	**456**	**144**
		ElmidaeL	**1**	**3**	**27**		**12**	**37**	**14**	**13**	**1**	**147**	**92**	**143**	**118**	**178**	**298**
		ScirtidaeL			**2**	**1**	**2**	**5**		**4**		**69**		**9**	**30**	**2**	**13**
		PsephenidaeL			**4**						**1**	**3**	**4**	**9**		**23**	**8**
Nematomorpha		**Gordiidae**											**1**			**1**	
Total Abundance			160	346	431	160	361	1124	730	1170	720	1744	1756	763	1352	2068	1155
N Taxa			14	24	23	19	26	32	24	31	30	33	31	27	26	37	35

Table 7.3. Macroinvertebrate abundance data at the family level (abundances as n per 0.18 m^2) for Gordon River and reference sites sampled in autumn (March) 2006.

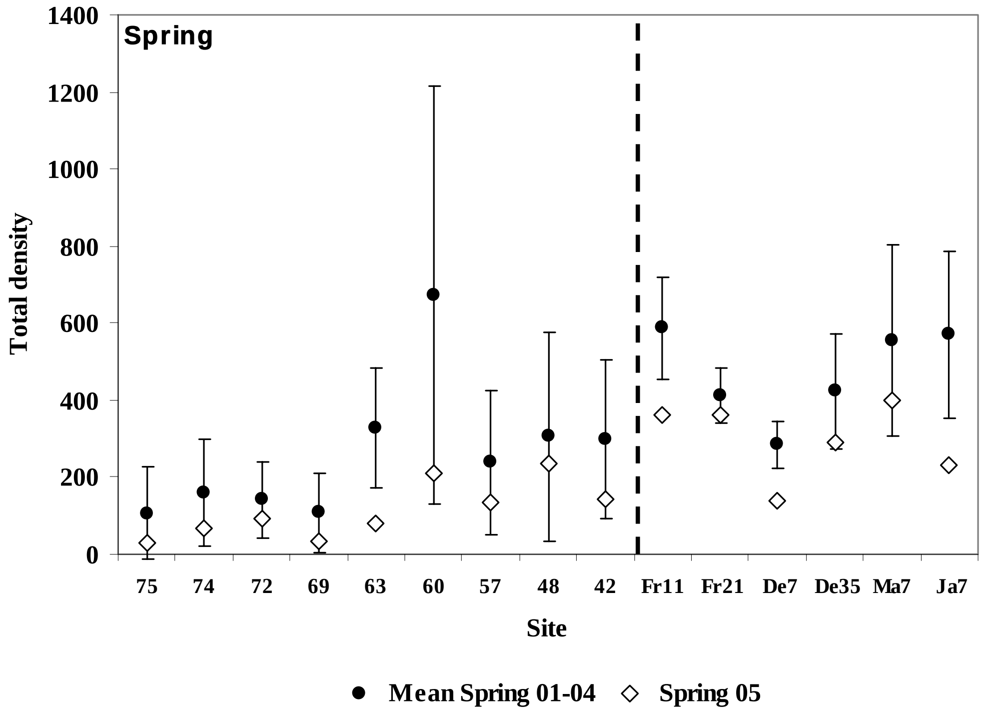
Class	Order	Family	Gordon									Franklin		Denison		Maxwell	Jane
			75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Platyhelminthes	**Turbellaria**					**1**	**1**		**3**			**2**	**16**			**8**	**1**
Nematoda							**2**		**1**	**1**			**9**	**5**		**4**	
Mollusca	**Bivalvia**	**Sphaeriidae**				**3**											
	Gastropoda	**Hydobiidae**			**1**	**2**	**3**	**1**	**13**	**1**		**11**	**3**	**3**	**1**	**22**	**2**
		Ancylidae											**2**				**1**
		Glacidorbidae			**1**												
Annelida	**Oligochaeta**			**2**	**36**	**20**	**76**	**31**	**74**	**38**	**12**	**6**	**73**	**27**	**35**	**147**	**165**
Arachnida	**Acarina**												**1**			**2**	
Crustacea	**Amphipoda**	**Paramalitidae**						**1**		**2**			**1**		**1**	**2**	
		Neoniphargidae	**2**	**1**							**2**						
	Isopoda	**Phreatoicidea**			**2**	**1**		**3**									
		Janiridae	**2**	**1**		**2**	**1**		**2**			**7**	**51**			**3**	**2**
Insecta	**Plecoptera**	**Eustheniidae**	**1**			**2**		**1**	**1**	**1**					**2**	**2**	
		Gripopterygidae	**5**	**10**	**7**	**5**	**10**	**6**	**1**	**3**	**8**	**5**	**10**			**2**	**8**
	Ephemeroptera	**Leptophlebiidae**	**3**	**1**	**14**	**8**	**16**	**6**	**11**	**17**	**9**	**53**	**168**	**71**	**97**	**102**	**116**
		Baetidae							**2**	**1**	**2**	**2**	**26**	**5**	**13**	**26**	**40**
	Odonata	**Telephlebiidae**					**1**										
	Hemiptera	**Corixidae**														**1**	
	Diptera	**Chironomidae: Chironominae**			**12**	**23**	**1**		**2**	**1**	**15**		**1**		**5**	**4**	**2**
		Chironomidae: Orthocladiinae		**2**	**22**	**9**	**5**	**5**	**5**	**3**	**2**	**8**	**7**	**3**	**14**	**18**	**7**
		Chironomidae: Podonominae					**1**	**1**			**2**	**2**	**2**				**1**
		Chironomidae: Tanypodinae				**1**											
		Chironomidae: Diamesinae	**1**				**1**										
		Simuliidae	**1**	**28**	**18**	**25**	**80**	**74**	**103**	**236**	**145**	**31**	**162**	**16**	**5**	**17**	**145**
		Tipulidae				**2**	**1**			**1**		**2**	**2**	**3**	**3**	**1**	**3**
		Blephariceridae		**1**	**2**			**1**	**1**	**3**	**3**	**1**	**3**				
		Ceratopogonidae											**2**			**2**	
		Dolichopdidae						**1**					**1**				
		Empididae				**4**	**4**		**2**				**2**				
		Dip. Unid. Pup.		**1**	**2**		**2**	**1**	**1**	**1**			**1**		**2**	**1**	
	Trichoptera	**Calocidae**												**2**	**1**	**5**	**3**
		Conoesucidae			**4**		**2**	**10**	**3**		**2**	**5**	**4**	**1**	**1**	**7**	**5**
		Glossosomatidae			**3**		**4**	**1**				**8**	**7**				**34**
		Helicophidae															**1**
		Hydrobiosidae	**2**	**3**	**6**	**2**	**7**	**1**	**6**	**5**	**1**	**4**	**10**	**1**	**6**	**6**	**7**
		Hydropsychidae			**6**	**10**	**270**	**294**	**172**	**5**	**6**	**16**	**10**		**2**	**18**	**57**
		Hydroptilidae													**2**		
		Leptoceridae				**2**		**5**				**7**	**8**	**2**	**45**	**11**	**1**
		Philorheithridae			**1**			**1**				**6**	**7**	**4**	**12**	**3**	**1**
		Trich. Unid. Pup.			**1**		**2**		**3**				**2**		**2**		
	Coleoptera	**ElmidaeA**					**4**	**5**	**12**	**2**	**1**	**6**	**13**	**4**	**5**	**58**	**132**
		ElmidaeL		**1**	**2**		**7**	**16**	**8**	**3**		**77**	**197**	**95**	**140**	**173**	**184**
		ScirtidaeL			**5**	**3**		**2**	**4**	**1**		**36**	**101**	**33**	**36**	**40**	**41**
		PsephenidaeL					**1**	**1**				**1**	**4**		**8**	**3**	**5**
		DytiscidaeL													**1**		
		Total Abundance	17	51	145	125	502	468	430	325	210	296	906	275	439	688	964
		N Taxa	8	11	19	19	24	23	22	19	14	22	32	16	24	28	25

Table 7.4. Quantitative macroinvertebrate data for EPTC taxa – Ephemeroptera, Plecoptera, Trichoptera and Coleoptera – (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in spring (October–November) 2006.

Order	Family	Genus/Species	Gordon									Franklin		Denison		Maxwell	Jane
			75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Ephemeroptera	Baetidae	Baetid Genus 2 MV sp.3					1	14	2	3	4	12	12	11	78	123	47
	Leptophlebiidae	Austrophlebioides sp. AV7										1			1		
		Nousia sp. AV5/6	1	1	21	2	4	124	68	78	87	303	189	223	188	267	94
		Nousia sp. AV7	4	1	6	2	11	7	1	6	13			2	3		9
		Nousia sp. AV8					1						1			37	
		Nousia sp. AV9						1									
		Tilyardophlebia sp. AV2						3	8	1	1	9	8	20	41	1	31
	Eustheniidae	Eusthenia costalis			1				1	2	2			3	1		
		Eusthenia spectabilis	2	3			1	6	3	9	2		7		24	1	
Plecoptera	Austroperlidae	Cryptoperla paradoxa					1										
		Tasmanoperla thalia			1					1					1		
	Gripopterygidae	Cardioperla incerta		1	16	2		4	6	4	15	2					1
		Cardioperla media/lobata			27	4	14	5	6	5	6	2		7		43	4
		Cardioperla spinosa					11									37	
		Dinotoperla marmorata							1								
		Dinotoperla serricauda											2	1			
		Leptoperla varia	2		9	3	9			2	3			1			1
		Trinotoperla inopinata				1											
		Trinotoperla tasmanica				1	6	3	3		1					15	2
		Trinotoperla zwicki	1	15	9	2	57		27	18		4	24	3	32	9	14
	Notonemouridae	Austrocercoides sp.				2											
		Kimminsoperla albomacula					2										
	Calocidae	Caenota plicata								1							
Trichoptera		Tamasia variegata		4								1		1	2	26	53
	Conoesucidae	Conoesucus brontensis					2									8	
		Conoesucus fromus			10											5	
		Conoesucus nepotulus			2		8						3			9	
		Conoesucus norelus						5		1	4		4				4
		Conoesucus sp. AV6		1				1									
		Costora delora														11	
		Costora luxata														4	
		Costora ramosa/krene			7												
		Hampa patona							1								15
		Lingora aurata														8	1
		Matasia satana														5	
	Glossosomatidae	Agapetus sp. AV1					1	1						1		6	29
	Helicophidae	Allocoella grisea									1						
		Allocoella longispina															1
	Helicopsychide	Helicopsyche murrumba														2	
	Hydrobiosidae	Apsilochorema obliquum										2			2		2
		Apsilochorema gisbum	1														
		* Ethochorema nesydrion															1
		Genus Hydb A		1													
		Moruya opora			3		5	17	10	21	12	6	9			2	1
		Moruya sp. AV1															1
		Mruya sp. AV2		2													
		Tanjilana akroreia													1		
	Includes all *	Taschorema complex					3					2		5		8	
		#* Taschorema apobamum						6	3	5	1	3	3	1	4		3
		#* Taschorema asmanum		2		3		4	4	2	1	5		2	7	4	5
	Includes all#	* Taschorema ferulum grp		1	1	1	3	3	1	3		6	12	6	2	6	1
		* Taschorema sp. AV1														1	
		Ulmerochorema rubiconum						1	2				3		1	2	
	Hydropsychidae	Asmicridea sp. AV1				1	77	313	67	29	9	1	3	5	4	11	5
		Smicrophylax sp. AV3					1									7	
	Hydroptilidae	Maydenoptila cuneola			1		2	2									
	Leptoceridae	Notalina sp. AV1	1	2		2				10	5	3	36	7	1	2	1
		Notalina sp.						10	7			13			31		28
		Triplectides proximus				1						1					
		Triplectides similis							1								
	Philopotamidae	Hydrobiosella waddama						6								5	
		Hydrobiosella sp. AV10											1				
	Philorheithridae	Kosrheithrus remulus														2	
		Tasmanthrus angustipennis															2
		Tasmanthrus galbinomaculatus										4	4			20	2
		Tasmanthrus sp.						2	1		2				9		22
		Total Abundance	12	34	114	27	220	538	223	201	169	380	321	299	433	687	381
		N Taxa	7	12	14	14	21	22	21	19	18	19	17	17	20	31	28

Table 7.5. Quantitative macroinvertebrate data for EPTC taxa – Ephemeroptera, Plecoptera, Trichoptera and Coleoptera (abundances as n per 0.18 m^2) for Gordon and reference sites sampled in autumn (March 2006).

Order	Family	Genus/Species	Gordon									Franklin		Denison		Maxwell	Jane
			75	74	72	69	63	60	57	48	42	Fr11	Fr21	De7	De35	Ma7	Ja7
Ephemeroptera	Baetidae	Baetid Genus 2 MV sp.3							2	1	2	2	26	5	13	26	40
	Leptophlebiidae	Austrophlebioides sp. AV7											1				1
		Austrophlebioides sp. AV5										1					
		Nousia sp. AV5/6	1		15	3	12	1	8	16	8	50	151	69	66	90	110
		Nousia sp. AV7				2	2	5	3	1	1				3	4	3
		Nousia sp. AV8										1					2
		Nousia sp. AV9														5	
		Tilyardophlebia sp. AV2				2	2					1	15	2	28	3	
Plecoptera	Eustheniidae	Eusthenia spectabilis		1					1	1					2	2	
		Eusthenia costalis	1					1									
	Austroperlidae	Tasmanoperla thalia				1											
	Gripopterygidae	Cardioperla media/lobata			1	1						1				1	2
		Cardioperla spinosa					1										
		Dinotoperla serricauda										1	1			1	
		Trinotoperla tasmanica					1				1	1	1				1
		Trinotoperla zwicki	4	6	6	3	8	6	1	3	7	2	8				5
		Trinotoperla inopinata		1													
		Leptoperla varia				1											
Trichoptera	Calocidae	Tamasia variegata												2	1	5	3
	Conoesucidae	Conoesucus brontensis			4		1									4	
		Conoesucus nepotulus	1	2				5			2	5	3			1	4
		Conoesucus sp. AV7					1										
		Conoesucus fromus			1									1			
		Conoesucus sp.							3								
		Costora delora															1
		Costora luxata											1				
		Costora rotosca						1								1	
		Hampa patona													1	1	
	Glossosomatidae	Agapetus sp. AV1			3		4					8	7				34
	Helicophidae	Allocoella grisea															1
	Hydrobiosidae Includes all#	Apsilochorema obliquum				1									1		
		Apsilochorema gisbum											1				
		* Ethochorema nesydrion											2		1		
		Ethochorema hesperium													1		
		Moruya opora	1	1			3		2		1						
		#* Taschorema apobamum		1	2		4	1	2	1		1	1			2	4
		#* Taschorema asmanum			3				1			2	1		2	3	
		#* Taschorema ferulum	1	2						1			3	1			
		* Taschorema ferulum grp.		1	1	1			1				3		1		1
		Tanjilana akoreia														1	
		Ulmerochorema rubiconum															2
		Ulmerochorema rubiconum grp.								3		1					
	Hydropsychidae	Asmicridea sp. AV1		1	5	10	270	294	172	5	6	16	10			18	52
		Diplectrona AV6													2		
		Smicrophylax sp. AV3			2												5
	Hydroptilidae	Oxyethira mienica													1		
		Hellyethira basilobata													1		
	Leptoceridae	Notalina sp. AV1			1	2		5				7	8	2	45	7	1
		Notalina bifaria.														4	
	Philorheithridae	Tasmanthrus angustipennis										1		1			
		Tasmanthrus galbinomaculatus											3				1
		Tasmanthrus sp.						1				5	4	3	12	2	
		Kosrheithrus remulus														1	
		Total Abundance	9	16	44	27	309	324	196	32	28	106	250	86	181	182	273
		N Taxa	6	9	12	11	12	10	11	9	8	18	20	9	17	21	20



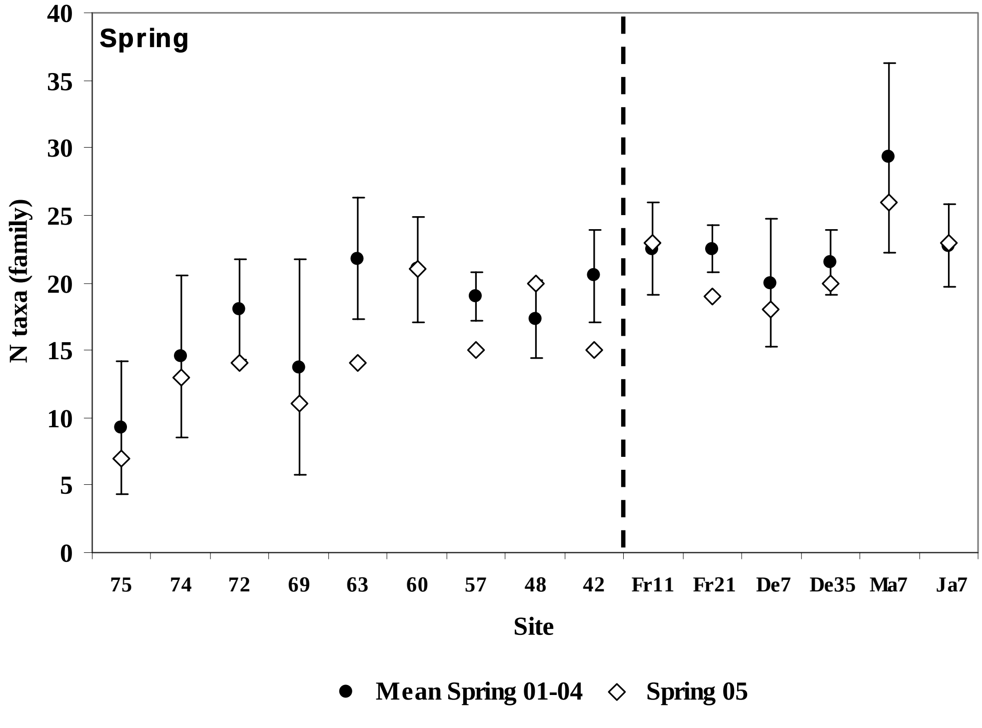
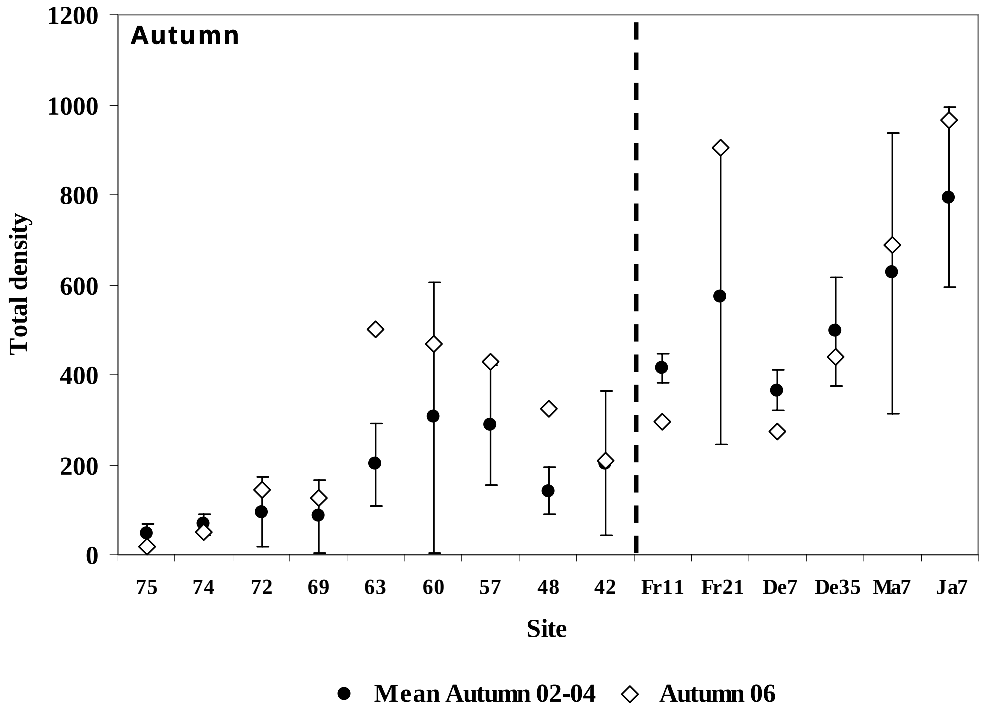


Figure 7.2. Comparison on total abundance and diversity (number of taxa at family level) for spring 2005 with spring values from previous years. Error bars indicate standard deviations around the 2001–04 mean.



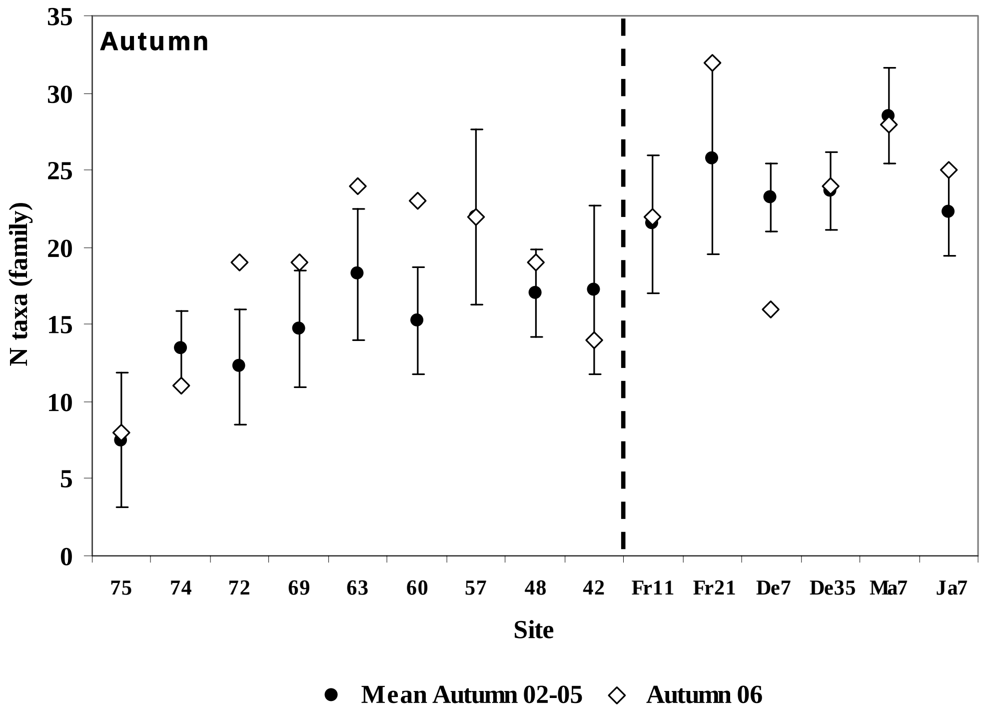


Figure 7.3. Comparison on total abundance and diversity (number of taxa at family level) for autumn 2006 with values from previous years. Error bars indicate standard deviations around the 2002–05 mean.

7.3.2 RBA (kick) sampling

7.3.2.1 Single season O/E values

All RBA samples from years one to five (2001–02 to 2005–06) of pre–Basslink monitoring were analysed using the relevant autumn or spring models, and O/Epa and O/Erk values were generated for each sampling occasion. Results for 2001–02, 2002–03, 2003–04, 2004–05 and 2005–06 were generated for each duplicate sample and the mean O/E values are reported in Table 7.8, and the most recent spring and autumn O/E values compared to the mean of previous samplings (Figure 7.4).

For spring 2005, overall values of O/Epa and O/Erk (Table 7.5) are comparable with previous years. These results do not indicate any substantial change from conditions in previous years.

For autumn 2006, O/Erk values fell within the ranges observed previously in 2001–02 to 2004–05, with values above Denison being lower (0.53–0.8) than below (0.74–0.94). O/Epa values, however, were consistently higher than observed in previous years at all sites upstream of the Denison, with downstream values falling at the upper end of the established range (Figure 7.4, Table 7.6). O/Epa values for reference sites fell within established ranges, except for site Fr21. O/Erk values for reference sites were generally lower than previously observed.

Table 7.6. RBA macroinvertebrate data (abundance per live–picked sample) for Gordon River and reference sites sampled in spring (October–November) 2005. (1) and (2) denote replicate samples taken at each site.

			River	Gordon																		Franklin				Denison				Maxwell		Jane	
			Site	**75**		**74**		**72**		**69**		**63**		**60**		**57**		**42**		**48**		**Fr11**		**Fr21**		**De7**		**De35**		**Ma7**		**Ja7**	
Class	**Order**	**Family**	**Sub–Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Platyhelminthes	Turbellaria				6	1	3					1	2	1										1	2								
Nematoda																										1							
Mollusca	Bivalvia	Sphaeriidae															1																
	Gastropoda	Hydrobiidae															1					2											
Annelida	Oligochaeta				13	28	17	12	11	7	18	12	13	10	7	5	12	13	16	27	27	2	6	25	11	8	8	6		2	6	2	26
Arachnida	Acarina																					1			3	2	1		1	2	1		
Crustacea	Amphipoda	Paramelitidae						2				1				7	12	8	1	2		2	1	1						1			
		Neoniphargidae		2	2	1	4		1	7	7	2	1			1																	
	Isopoda	Phreatoicidea								1							1																
		Janiridae		7	24	2					1					1																	
Insecta	Plecoptera	Eustheniidae		6	1	1				3	7	2	1	2	1		2	5	4	3	3	4		5	8	6	2	4	19	1	2	2	
		Austroperlidae							1	1	1							1															
		Gripopterygidae		1	2	4	5	19	50	4	24	23	31	23	13	15	6	13	7	12	6	5	2	7	4	8	7	5	21	32	37	9	21
		Notonemouridae		1						1	3		1					1		1													
	Ephemeroptera	Leptophlebiidae		1	1	2	1	20	34	2	13	20	17	45	40	48	53	45	36	45	23	28	101	73	72	68	96	66	50	71	63	63	67
		Baetidae												1	2	2	3		4		2	25	16	18	2	14	6	20	16	13	11	14	34
	Odonata	Telephlebiidae								1																							1
	Diptera	Chironomidae:	Chironominae				1	1		1	12	2	2							4		1				2	2	2	1				2
		Chironomidae:	Orthocladiinae	10	12	4	2	4	9	1	6	1	6	1	2			2	3	7				2	2	1			3	5			1
		Chironomidae:	Podonominae	4	7			3	8	1		15	16	35	18	10	12	7	11	31	15	15	8	27	4	13	44	17	6	3	7	18	13
		Chironomidae:	Tanypodinae																				2				1						
		Chironomidae:	Diamesinae	4	10	3	5																	1									
		Simuliidae				4		4	15	2	2	1	2	28	22	18	20	32	23	12	11	33	31	67	34	6	10	22	32	9	24	14	15
		Tipulidae			1			1	2	4	3	1	1			1						1		2		2	3	1	2		2	1	5
		Blephariceridae				1													1			8	2	13	4			2	2		1		1
		Ceratopogonidae																						8	1								
		Chaoboridae		2																													
		Empididae					1		1				1									1				1	1						
		Dip. Unid. Pup.																	1	1	3				1								
	Trichoptera	Calocidae																											2			1	2
		Conoesucidae						2	4			5	4			1	1	1		2		4		5					6	8	6	1	5
		Glossosomatidae																				1					1			1			5
		Helicophidae										1																					
		Hydrobiosidae		7	8	7	9	3	10	9	24	34	29	16	32	23	13	24	21	23	9	35	30	34	24	14	20	38	21	11	26	27	24
		Hydropsychidae									4	64	23	6	34	16	17	2	1	1				1		1	1		2	4	10	1	
		Leptoceridae		1						2	3		1		1	3	3		2	2	1	4	4	3	6	5	2	4		3	1		
		Philopotamidae													1	1	1	2				1		1		1	1			1	1	1	
		Philorheithridae								1		1		1		4	1	1			1	6	3		2		6	5	2	1		4	1
		Trich. Unid. Pup.										1			3		1	3		1					3	2						2	
	Coleoptera	ElmidaeA										1	1	14	9	13	12	2	3	1	1	13	15	22	9	13	14	21	25	23	34	7	35
		ElmidaeL													1				1			4	1	3			3	5		1	6		1
		ScirtidaeL								1				1	5							2	3	2	9	10	2		2		1		
	Coleoptera	PsephenidaeL										1	1											2	2	1	4		1		2	2	2
Nematomorpha		Gordiidae																	1											1	1		
N Taxa				**12**	**12**	**12**	**10**	**11**	**12**	**18**	**15**	**20**	**19**	**14**	**16**	**17**	**19**	**17**	**17**	**17**	**12**	**23**	**15**	**23**	**20**	**21**	**22**	**15**	**19**	**20**	**20**	**17**	**19**

Table 7.7. RBA macroinvertebrate data (abundances per live–picked sample) for Gordon River and reference sites sampled in autumn (March) 2006. (1) and (2) denote replicate samples taken at each site.

			River :	Gordon																		Franklin				Denison				Maxwell		Jane	
			Site :	75		74		72		69		63		60		57		42		48		Fr11		Fr21		De7		De35		Ma7		Ja7	
Class	**Order**	**Family**	**Sub–Family**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Platyhelminthes	Turbellaria											1			2																		
Nematoda																				1													
Mollusca	Bivalvia	Sphaeriidae																															1
	Gastropoda	Hydrobiidae			1																		3							1	3		
Annelida	Oligochaeta			6	1	6	2	2	5	8	2	9	10	9	8	7	9	28	9	35	26	21	16	27	5	14	11	13	13	6	10	13	17
Arachnida	Acarina																							1			1	1		3		1	
Crustacea	Amphipoda	Paramelitidae													10	11	7										2	2			1		
		Ceinidae														1																	
		Neoniphargidae		2	15	5		4	5	4		2			1						2		1										
	Isopoda	Phreatoicidea					1		1		1					2																	
		Janiridae		10	3				1													1											1
Insecta	Plecoptera	Eustheniidae		1	5	12	3	1		1				3	2	1	3	1	6	12	6	1	6			3	8	9	3				2
		Austroperlidae				1					2																						
		Gripopterygidae		29	29	49	74	31	13	3	7	32	12	12	19	10	22	4	1	39	3	2			1	5			2	2	1	19	12
		Notonemouridae		7	6				1		1							1										4	3				
		Leptophlebiidae		9	16	8	4	44	57	26	13	30	28	3	21	15	19	23	46	51	41	115	38	72	70	54	35	35	61	74	70	61	58
	Ephemeroptera	Baetidae												1	5			1	3	26	11	10	9	11	5	10	10	1	2	30	19	21	10
	Odonata	Telephlebiidae																															1
	Mecoptera	Nannochoristidae									1																						
	Diptera	Chironomidae :	Chironominae					3	15	2	1							4		3	6					1	3		3				
		Chironomidae :	Orthocladiinae	9	15	6	9		3		2	3		1	3	2	6		2		3	1				1				2		2	1
		Chironomidae :	Podonominae	9	3		1			1		1			3		1	5	4	4	13		3	4		2	1	1		1		3	2
		Chironomidae :	Tanypodinae		1																							1					
		Chironomidae :	Diamesinae	2	2		1		1																								
		Simuliidae		14	4	20	23	20	16	27	19	18	7	38	20	18	35	50	106	72	29	15	16	161	27	12	11			9	1	19	16
		Tipulidae							2	1					2		1	1	10		3	4	1			5	5	10	25		4		3
		Athericidae																								1	1	5	3				
		Blephariceridae						1										9	6	6	6											2	
		Ceratopogonidae																				1											1
		Empididae										1															1						
		Dip. Unid. Pup.		1			1			1																							
	Trichoptera	Calocidae															1					1					1		1		1		1
		Conoesucidae				5	1		2				1			1			1		1	1	4			2				10	7		3
		Ecnomidae																										1	1				
		Glossosomatidae				1									1							2	4									26	9
		Helicopsychidae																								1	1				1		
		Hydrobiosidae		182	46	47	73	74	71	18	11	52	43		19	26	35	12	11	25	8	35	36	12	12	10	12	14	6	14	17	27	46
		Hydropsychidae				2			1		4	31	20	37	29	17	26	6	6	6	3	1	3							13		1	
		Hydroptilidae																										1					
		Leptoceridae		3				1	1	1	2	1		3	8	2	5		4	1		2	17			5	18	31	41	2	21		8
		Philopotamidae						1											1	2													
		Philorheithridae			1				1		1				2			1	1	2	1	1	10			6	8	8	8	6	21		8
		Trich. Unid. Pup.				2			1			3	3		2			5	5	3													
	Coleoptera	ElmidaeA			2	3	3	2	1	1		4	2	6	9	18	17	1	3	2	2	18	15	3	3	8	9	3	2	32	20	28	31
		DytiscidaeA									1																1	2	2				
		ElmidaeL				1						1		1			1					2	2	5	3	3	13	10	8	6	21	7	11
		ScirtidaeL						5	3	1	1	2		1	2		1	2	1			24	11	6	3	1	3	14	4	1	12	7	11
		PsephenidaeL				1		1	1								2					1	4			10	1	4		8	15	1	7
		DytiscidaeL																											1				
			N Taxa	**14**	**16**	**16**	**13**	**14**	**21**	**14**	**16**	**16**	**9**	**12**	**20**	**14**	**17**	**17**	**19**	**17**	**17**	**21**	**19**	**10**	**9**	**20**	**22**	**21**	**19**	**18**	**18**	**16**	**23**

Table 7.8. O/Epa and O/Erk values for all sites sampled in spring 2005, for individual replicate samples, and averages. Impairment bands also indicated. O/EPa, O/Erk = derived using presence/absence and rank abundance data, respectively. Results shown for two replicate samples per site and their mean.

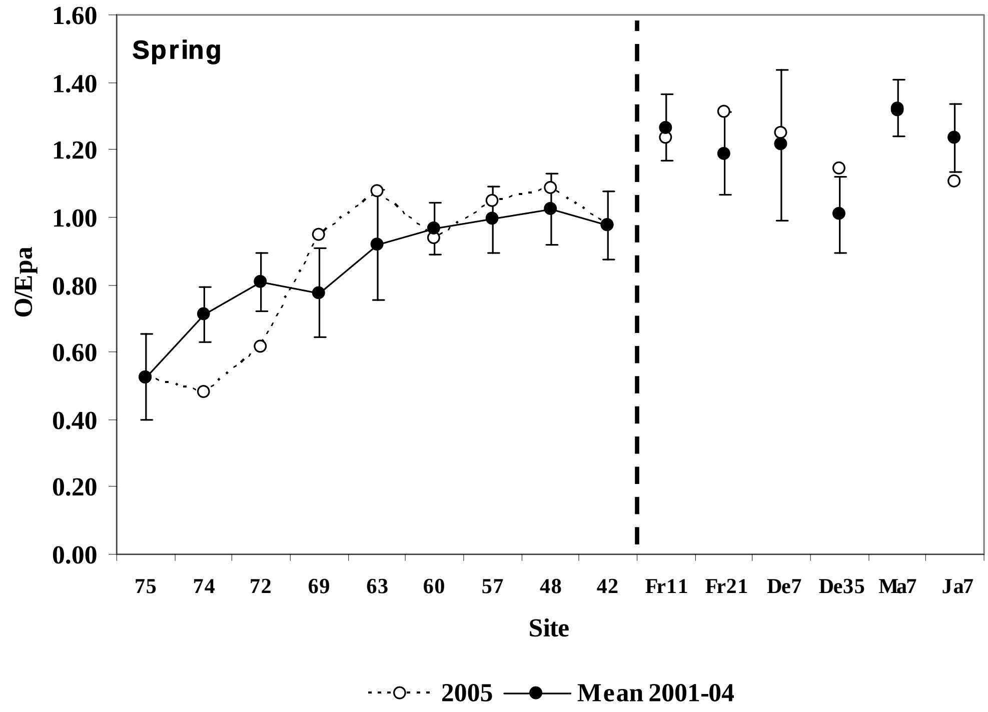
River	Site	Replicate	O/Epa	Band	O/Erk	Band
Gordon	**75**	1	0.53	B	0.50	B
		2	0.53	B	0.59	B
		Mean	**0.53**	**B**	**0.55**	**B**
	74	1	0.59	B	0.65	B
		2	0.37	B	0.46	B
		Mean	0.48	B	0.56	B
	72	1	0.58	B	0.69	B
		2	0.65	B	0.74	B
		Mean	0.62	B	0.72	B
	69	1	0.98	A	0.91	A
		2	0.91	A	1.07	A
		Mean	0.95	A	0.99	A
	63	1	1.11	A	1.18	A
		2	1.04	A	1.16	A
		Mean	1.08	A	1.17	A
	60	1	0.90	A	1.10	A
		2	0.97	A	1.18	A
		Mean	**0.94**	**A**	**1.14**	**A**
	57	1	1.05	A	1.18	A
		2	1.05	A	1.00	A
		Mean	**1.05**	**A**	**1.09**	**A**
	42	1	1.12	A	1.17	A
		2	1.04	A	1.04	A
		Mean	**1.08**	**1**	**1.11**	**A**
	48	1	1.05	A	1.10	A
		2	0.90	A	1.06	A
		Mean	**0.97**	**A**	**1.08**	**A**
Franklin	**Fr11**	1	1.42	X	1.53	X
		2	1.05	A	1.05	A
		Mean	**1.24**	**X**	**1.29**	**X**
	Fr21	1	1.35	X	1.58	X
		2	1.27	X	1.23	X
		Mean	**1.31**	**X**	**1.41**	**X**
Denison	**De7**	1	1.14	A	1.00	A
		2	1.37	X	1.23	X
		Mean	1.25	X	1.11	A
	De35	1	1.03	A	1.11	A
		2	1.26	X	1.21	X
		Mean	**1.15**	**A**	**1.16**	**A**
Maxwell	**Ma7**	1	1.28	X	1.15	A
		2	1.35	X	1.41	X
		Mean	**1.31**	**X**	**1.28**	**X**
Jane	**Ja7**	1	1.11	A	1.11	A
		2	1.11	A	1.09	A
		Mean	**1.11**	**A**	**1.10**	**A**

Table 7.9. O/Epa and O/Erk values for all sites sampled in autumn 2006, for individual replicate samples, and averages. Impairment bands also indicated. O/EPa, O/Erk = derived using presence/absence and rank abundance data, respectively. Results shown for two replicate samples per site and their mean.

River	Site	Replicate	O/Epa	Band	O/Erk	Band
Gordon	75	1	0.78	B	0.45	B
		2	0.88	A	0.62	B
		Mean	0.83	B	0.53	B
	74	1	1.27	X	0.80	B
		2	0.88	A	0.58	B
		Mean	1.08	A	0.69	B
	72	1	1.17	A	0.71	B
		2	1.37	X	0.85	A
		Mean	1.27	X	0.78	B
	69	1	1.08	A	0.71	B
		2	0.98	A	0.67	B
		Mean	1.03	A	0.69	B
	63	1	1.08	A	0.85	A
		2	0.78	B	0.58	B
		Mean	0.93	B	0.71	B
	60	1	1.17	A	0.71	B
		2	1.56	X	1.16	A
		Mean	1.37	X	0.94	A
	57	1	1.17	A	0.89	A
		2	1.47	X	1.07	A
		Mean	1.32	X	0.98	A
	42	1	1.37	X	0.71	B
		2	1.56	X	0.76	B
		Mean	1.47	X	0.74	B
	48	1	1.27	X	0.80	B
		2	1.37	X	0.85	A
		Mean	1.32	X	0.82	B
Franklin	Fr11	1	1.76	X	0.98	A
		2	1.66	X	1.16	A
		Mean	1.71	X	1.07	A
	Fr21	1	0.88	A	0.53	B
		2	0.88	A	0.53	B
		Mean	0.88	A	0.53	B
Denison	De7	1	1.56	X	0.94	A
		2	1.47	X	1.25	X
		Mean	1.52	X	1.09	A
	De35	1	1.37	X	1.07	A
		2	1.27	X	0.85	A
		Mean	1.32	X	0.96	A
Maxwell	Ma7	1	1.47	X	0.89	A
		2	1.47	X	0.98	A
		Mean	1.47	X	0.94	A
Jane	Ja7	1	1.37	X	0.98	A
		2	1.66	X	1.16	A
		Mean	1.52	X	1.07	A

Table 7.10. Single season O/E values for all sites monitored in the Gordon River and reference rivers from spring 2001 to autumn (March) 2006.

	Year	2001		2002		2002		2003		2003		2004		2004		2005		2005		2006	
	Season	Spring		Autumn		Spring		Autumn		Spring		Autumn		Spring		Autumn		Spring		Autumn	
	OE output	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk	OEpa	OErk
River	Site																				
Gordon	75	0.68	0.71	0.59	0.61	0.38	0.60	0.49	0.43	0.49	0.58	0.68	0.56	0.56	0.58	0.49	0.56	0.53	0.55	0.83	0.54
	74	0.66	0.64	0.88	0.66	0.81	0.61	1.03	0.83	0.63	0.73	0.88	0.73	0.74	0.88	0.78	0.50	0.48	0.56	1.08	0.68
	72	0.87	0.97	0.88	0.71	0.69	0.77	0.88	0.73	0.80	0.92	1.03	0.73	0.87	0.83	1.08	0.86	0.62	0.72	1.27	0.76
	69	0.91	1.12	0.98	0.73	0.68	0.61	0.78	0.74	0.87	0.81	0.83	0.68	0.64	0.76	0.64	0.47	0.95	0.99	1.03	0.65
	63	1.04	1.16	1.27	1.11	1.08	1.06	1.17	0.95	0.82	0.94	1.17	1.03	0.74	0.68	0.98	0.81	1.08	1.17	0.93	0.97
	60	0.90	1.12	1.37	1.11	0.90	1.14	1.17	0.83	1.05	1.02	1.27	0.91	1.01	0.96	0.88	0.58	0.94	1.14	1.37	0.86
	57	0.97	1.06	1.08	0.86	1.05	1.12	1.7	1.08	0.86	0.85	1.42	1.03	1.09	1.06	1.37	0.96	1.05	1.09	1.32	0.98
	48	0.96	0.98	1.27	0.95	0.92	1.17	1.08	0.93	1.04	0.98	1.17	0.93	1.16	1.23	1.27	0.85	1.08	1.11	1.47	0.91
	42	1.12	1.17	1.37	1.01	0.90	1.13	1.03	0.85	0.94	0.96	1.17	0.86	0.94	0.90	1.27	0.88	0.97	1.08	1.32	0.90
Reference	**Site**																				
Franklin	**Fr11**	1.35	1.40	1.57	1.01	1.31	1.17	1.52	1.16	1.12	1.20	1.27	0.93	1.27	1.20	1.47	1.16	1.24	1.29	1.71	1.06
	Fr21	1.20	1.18	1.66	1.21	1.35	1.17	1.47	1.18	1.05	1.03	1.32	1.13	1.16	1.23	1.37	1.11	1.31	1.41	0.88	1.16
Denison	**De7**	0.91	1.00	1.66	1.36	1.18	1.14	1.42	1.13	1.37	1.23	1.52	1.19	1.40	1.29	1.32	1.16	1.25	1.11	1.52	1.21
	De35	1.11	1.03	1.66	1.21	1.11	1.01	1.32	1.14	0.91	1.04	–	–	0.91	0.83	1.56	1.19	1.15	1.16	1.32	1.18
Maxwell	**Ma7**	1.35	1.41	1.66	1.21	1.43	1.04	1.66	1.14	1.24	1.22	1.56	1.13	1.28	1.22	1.56	1.13	1.31	1.28	1.47	1.15
Jane	**Ja7**	1.34	1.15	1.47	1.06	1.26	1.07	1.47	1.19	1.11	1.16	1.52	1.24	1.22	1.16	1.42	0.96	1.11	1.10	1.52	1.11



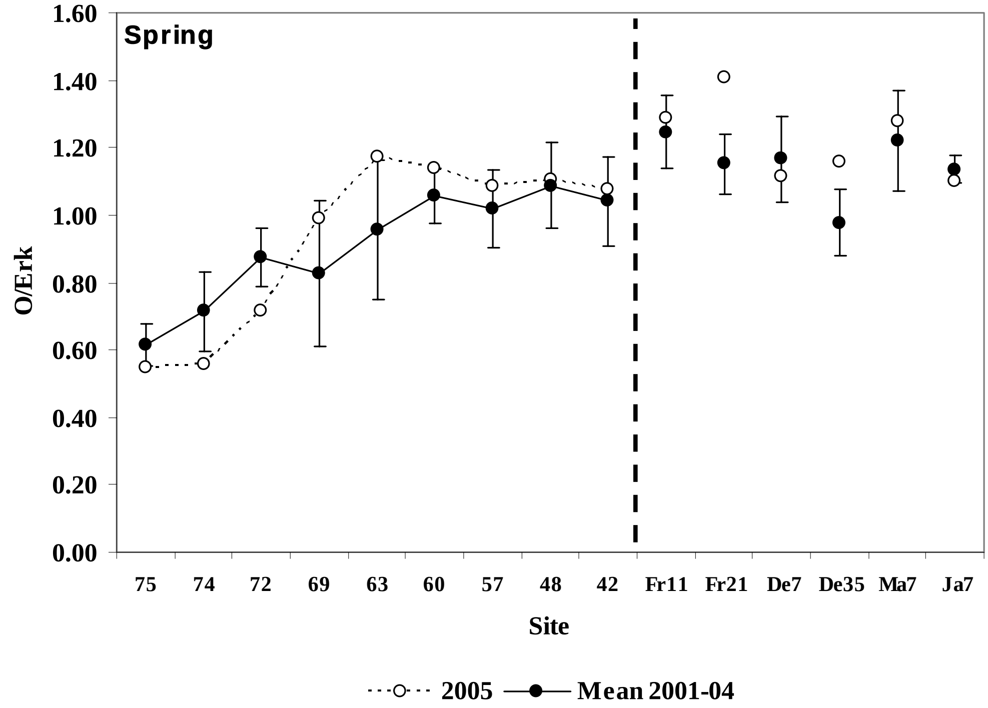


Figure 7.4. Comparison on O/Epa and O/Erk values for spring 2005 with values from previous years. Note consistently high O/Epa values at sites 69–75 upstream of Denison. Error bars indicate standard deviations around the 2001–04 mean.

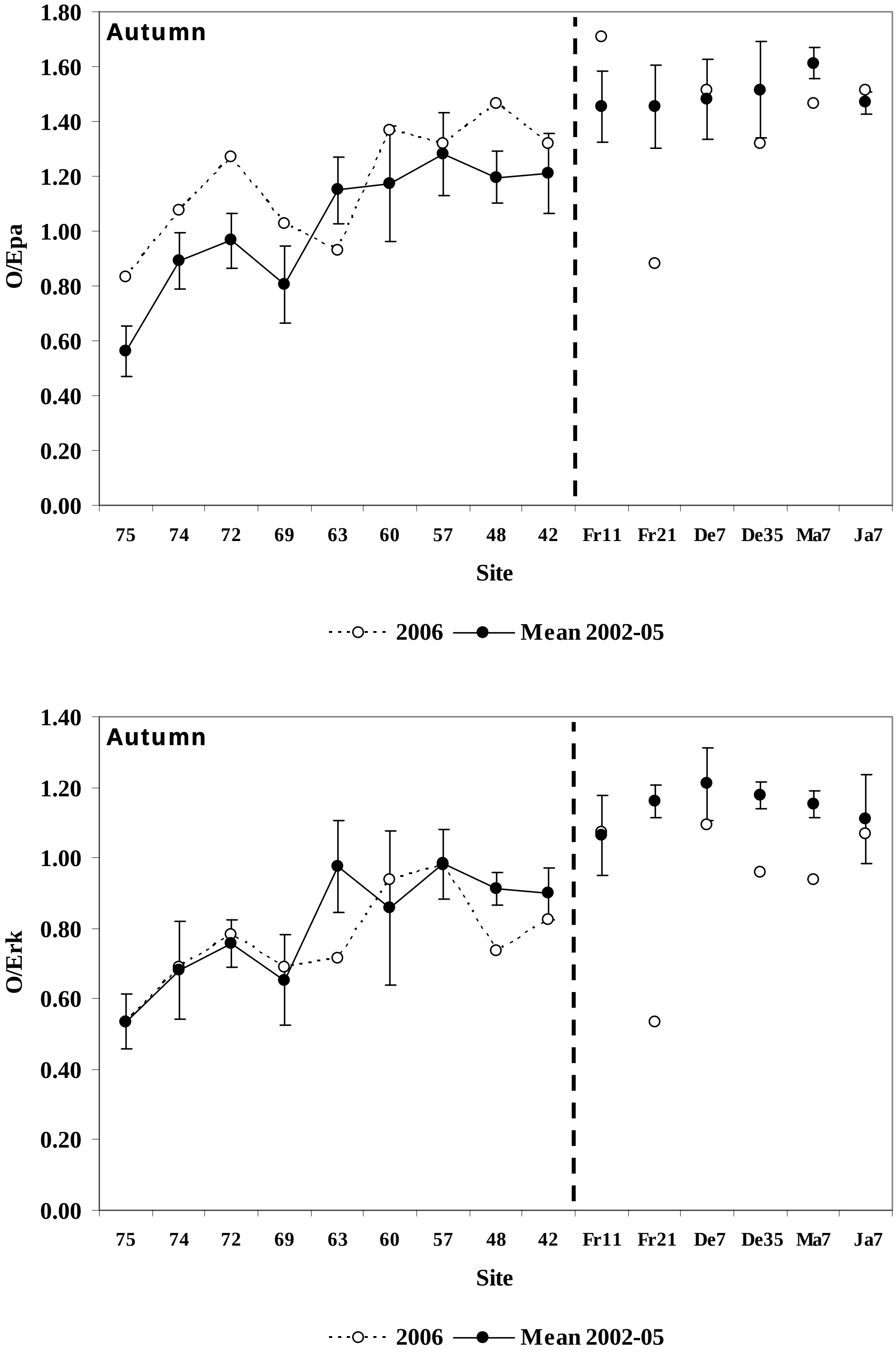


Figure 7.5. Comparison on O/Epa and O/Erk values for autumn 2006 with values from previous years. Note consistently high O/Epa values at sites 69–75 upstream of Denison. Error bars indicate standard deviations around the 2002–05 mean.

7.4 Conclusion

Monitoring was conducted successfully to meet the requirements of the Gordon River Basslink monitoring program. For spring 2005, the overall patterns in community composition, abundance and diversity are similar to previous sampling events.

Autumn 2006 sampling could nominally be described as the first 'post-Basslink' sampling event. However, the flow regime prior to sampling was dictated by early Basslink power station trials, and did not fully represent projected post-Basslink conditions. The macroinvertebrate data can therefore be considered as 'transitional' in nature, and not fully representative of post-Basslink condition. It is still of interest, however, to identify whether there were any significant differences between the autumn 2006 data and data from preceding, 'pre-Basslink' autumn sampling rounds.

Overall patterns of diversity, community composition and abundance derived from quantitative data in autumn are similar to those observed previously, and there is no evidence of any substantial change.

Autumn O/Erk values followed the same trends as observed by Davies and Cook. 2001 in 2001-02, 2002-03, 2003-04 and 2004-05. However, O/Epa values were significantly higher at sites upstream of the Denison in the Gordon. This suggests that the more constrained flow conditions occurring during the pre-Basslink trial allowed an increase in overall diversity of common (expected) families, but did not change the relative abundance of the dominant families.

8 Instream algae and moss

8.1 Introduction

Benthic algae were surveyed in spring (October–November) 2005 and autumn (March) 2006 to meet the requirements of the Basslink Monitoring Program for the Gordon River. Quantitative (quadrat-based) assessment of algal 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 for the first time.

8.2 Methods

8.2.1 Monitoring sites

Survey sites were the same as for the benthic macroinvertebrate sampling sites, as shown in Table 8.1 and Figure 8.1. Some delays were experienced in sampling due to high flows, with the result that several sites were sampled on occasions several weeks apart. For the spring sampling program, sampling was conducted on 15 October (sites 75–69), 17–18 November (sites 63–47) and 24 November 2005 (reference sites). While this caused delays in scheduling, it does not have major implications for data compatibility. For the autumn sampling program, sampling was conducted on 10–12 March 2006.

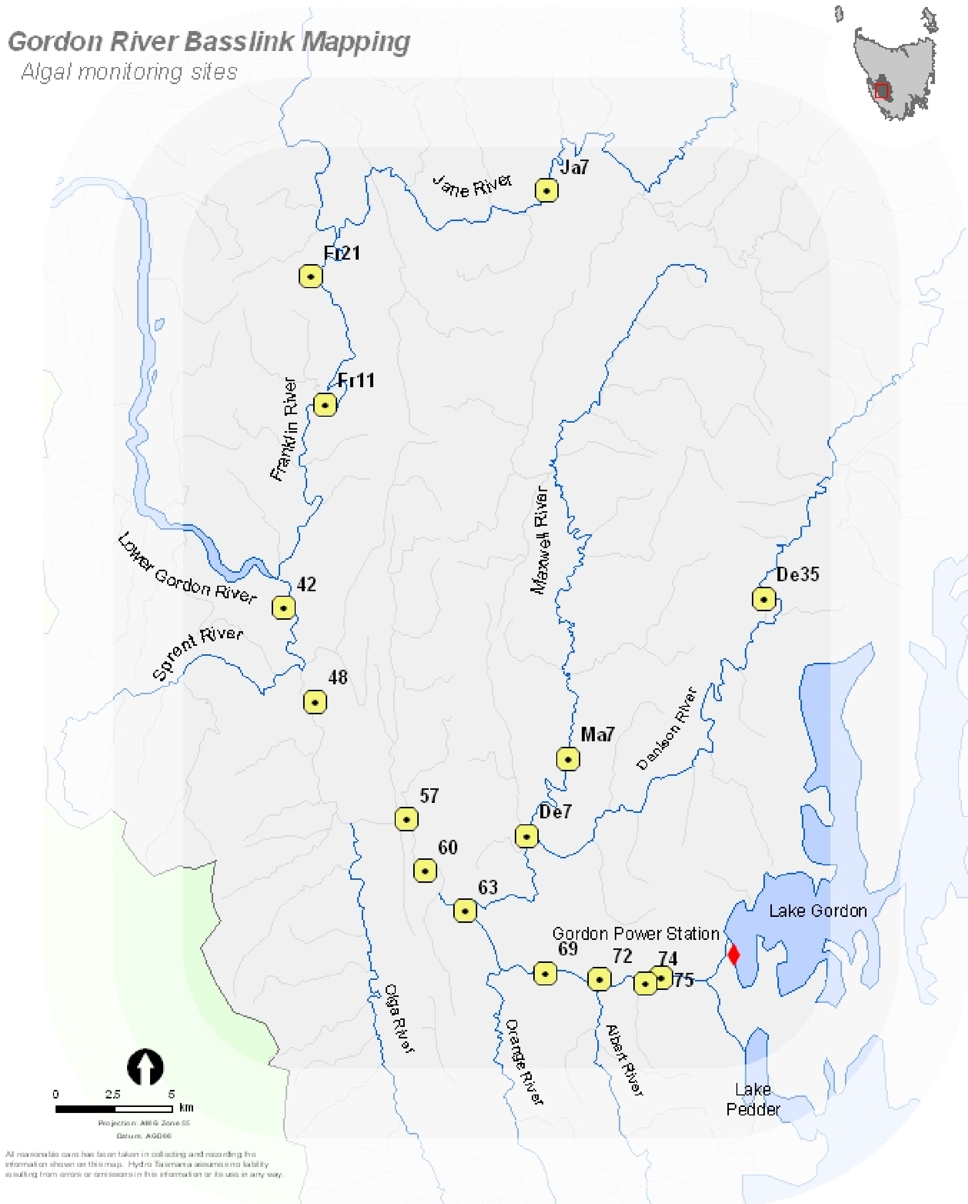


Figure 8.1. Map of the algal monitoring sites in the Gordon River and reference sites.

Table 8.1. Sites samples in (Oct–Nov) 2005 and March 2006 for 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

8.2.2 Benthic algal survey

All algal assessment at Gordon River sites was conducted by measuring % 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, 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 density, as % cover, was recorded using a 30 cm x 30 cm quadrat at 2.5m intervals in three locations – 1m upstream of the transect line, on the transect line, and 1m 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.

Five scrapes of filamentous algae and moss were taken from the upper surface of boulders or cobbles in the centre of each zone at each site on all sampling occasions. All scrapes were pooled, resulting in a single, composite and representative sample of the dominant benthic species present within each zone. These samples were preserved in 10 % formalin for later identification.

8.2.3 Reference 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. Data comparability between these sample sets and those for the Gordon River is therefore restricted to filamentous algae only.

8.2.4 Analysis

No detailed analysis has been conducted for this report, other than to summarise plant cover scores. Following completion of this monitoring program, all post-Basslink cover data will be compared with pre-Basslink data by conducting paired t-tests (paired by transect) of overall mean algal cover, in order to assess the significance of any changes. The locations of peak algal abundance and of upper and lower margins will also be compared between years to assess shifts in algal distribution within the channel.

8.3 Results

8.3.1 2005-06

Surveys were successfully completed across the entire river channel for sites 75, 74, 72, 69 and 63. The presence of deep, fast flowing water in both October-November 2005 and March 2006 prevented a survey across the entire channel for sites 57, 48 and 42. In October-November, an average of 63m of river bed was surveyed across all sites, ranging from 37.5 to 87.5m, while in March an average of 68m was surveyed ranging from 42.5 to 82.5m.

Data from surveys are summarised in Table 8.3. Both monitoring trips revealed that aquatic flora had a consistently low to moderate cover across all sites. Moss and filamentous algae were the dominant forms with low to moderate overall mean % cover across all sites (0-18 % of benthic area combined) for October-November 2005 and (0-19 % of benthic area combined) for March 2006. Macrophytes for both monitoring trips only occurred at site 72 in any abundance, with both *Callitriche* sp. (starworts) and *Isolepis fluitans* observed at low density.

In October-November 2005, filamentous algal cover in the reference river samples was very low. Gordon sites upstream of site 69 have substantially higher filamentous algal cover than reference sites, consistent with current conceptual understanding. In March 2006, filamentous algal cover in the reference river samples was low with the exception of site Fr11, which showed a minor autumn peak in algal cover.

Table 8.2. Summary cover data for algae, moss and macrophytes surveyed in the Gordon River during spring (Oct–Nov) 2005. * indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated.

Site	Mean cover (%)				Width surveyed (m)
	Moss	Filamentous algae	Nitella/Chara	Macrophytes	
Gordon					
75	2.86	14.95	0	0	68
74	3.27	11.22	0.65	0	65
72	0.11	6.99	0.04	0.20	80
69	0.21	0.23	0	0.03	37.5
63	0.63	2.55	0	0	72.5
60*	3.20	0	0	0	87.5
57*	1.15	0	0	0	47.5
48*	0.24	2.13	0	0	65
42*	4.17	1.75	0	0	37.5
Reference					
Fr11	0	0.10	0	0	
JA7	0.03	0.13	0	0	
De35	0	0	0	0	

Table 8.3. Summary cover data for algae, moss and macrophytes surveyed in the Gordon River during autumn (March) 2006. * indicates transects for which only part of the channel could be surveyed. Total distances surveyed from the transect head pegs are indicated.

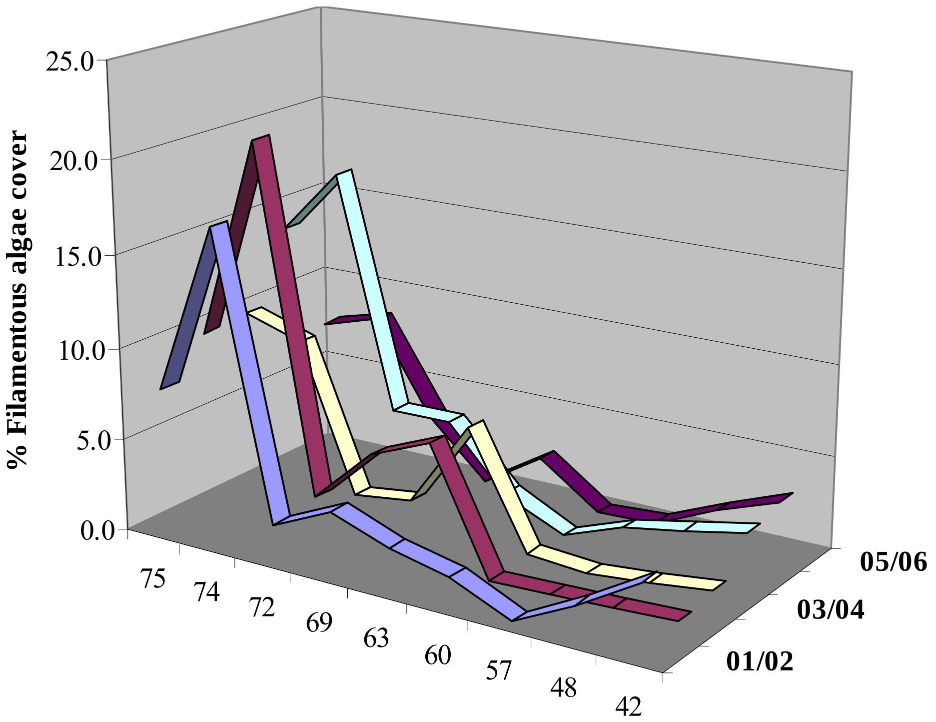
Site	Mean cover (%)				Width surveyed (m)
	Moss	Filamentous algae	Nitella/Chara	Macrophytes	
Gordon					
75	1.02	0.28	0.18	0	68
74	13.98	5.76	6.65	0	65
72	0	0.05	0.66	1.14	80
69	2.88	0.43	0	0.01	37.5
63	0.37	2.42	0	0	72.5
60*	0.07	0.19	0	0	87.5
57*	0.13	0.53	0	0	47.5
48*	0.25	1.39	0	0.44	65
42*	0	4.18	0	0	37.5
Reference					
Fr11	0	5.07	0	0	
JA7	0.03	0.01	0	0	
De35	0	0	0	0	

8.4 Comparison with previous years

Overall mean % cover for moss and filamentous algae are shown for all sites for each year (as means across each transect over the two sampling occasions), in Table 8.4. There was no significant difference in % cover of either moss or filamentous algae between 2005–06 and previous years. Plots of the downstream trends in annual mean of moss and filamentous algae for all five years (2001–02 to 2005–06) are shown in Figure 8.2.

Table 8.4. Annual mean % cover for moss and filamentous algae at all transects in 2001–02 to 2005–06 in the lower Gordon River.

Site	01–02 mean		02–03 mean		03–04 mean		04–05 mean		05–06 mean	
	Moss	Filamentous	Moss	Filamentous	Moss	Filamentous	Moss	Filamentous	Moss	Filamentous
75	6.09	7.79	2.07	9.88	2.09	10.10	4.91	13.99	1.94	7.61
74	10.63	17.00	8.16	20.73	6.18	9l.08	12.62	17.43	8.63	8.49
72	0.14	1.86	1.06	2.18	0.07	1.18	0.54	4.87	0.06	3.52
69	8.50	3.35	3.42	5.28	1.64	1.56	0.76	4.95	1.54	0.33
63	1.05	2.19	2.46	6.59	2.15	6.31	2.14	1.55	0.50	2.48
60	0.33	1.51	0.13	0.03	0.98	0.18	1.98	0.00	1.63	0.09
57	0.80	0.01	0.25	0.09	0.75	0.00	0.25	1.20	0.64	0.26
48	2.84	1.72	0.54	0.26	0.87	0.32	1.59	1.84	0.25	1.76
42	3.10	3.72	0.06	0.44	0.62	0.67	0.41	2.50	2.08	2.96
Grand Mean	3.72	4.35	2.01	5.05	1.71	3.27	2.80	5.37	1.92	3.06
Mean u/s Denison	5.28	6.44	3.43	8.93	2.43	5.65	4.19	8.56	2.53	4.49
Mean d/s Denison	1.77	1.74	0.24	0.21	0.81	0.29	1.06	1.38	1.15	1.27



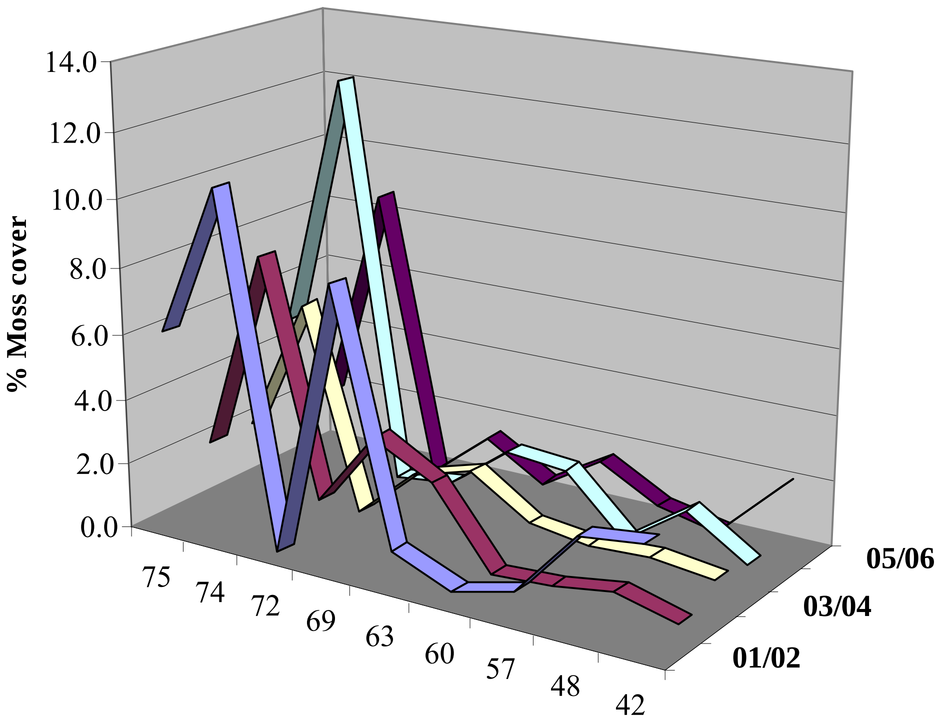


Figure 8.2. Downstream trend in mean % moss cover (below) and mean % filamentous algal cover (above) in the Gordon in 2001–02, 2002–03, 2003–04, 2004–05 and 2005–06.

8.5 Conclusion

Sampling was conducted successfully according to the requirements of the Gordon River Basslink Monitoring Program.

As in spring 2001–04, plant cover was low for spring 2005, and tended to decrease downstream from the Gordon Power Station to the Franklin confluence.

As in autumn 2001–05, plant cover was low for autumn 2006. Moss cover was very low downstream of the Denison confluence. Filamentous algal levels were low, as usual in autumn in the Gordon, with slightly raised levels in the lower sites probably due to the anomalous Basslink trial flows.

There have been no major differences in algal or moss cover in 2005–06 compared to previous years.

9 Fish

9.1 Introduction

The objectives of the Gordon River Fish Monitoring Program are to:

- quantify pre and post-Basslink variability in the relative abundance of fish populations to allow statistical comparison between these times and appropriate reference sites;
- 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;
- detect and assess potential changes in catch per unit effort which may result from Basslink operations;
- determine the incidence of fish stranding both pre- and post-Basslink; and
- determine any changes to the fish populations of affected tributaries, in particular, if recruitment success for juvenile galaxiids is changed once Basslink is operational.

This report summarises the results of the final year of the pre-Basslink fish monitoring surveys. A comprehensive analysis of the pre-Basslink dataset to April 2005 is contained in the Basslink Baseline Report.

The fish monitoring zones are defined a 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 or downstream of the Yolande River

Zone 14 Henty River upstream of the Yolande River

9.2 Methods

The summer 2005 monitoring surveys were conducted between late November 2005 and early January 2006, and the autumn surveys took place in April and early May 2006. The summer surveys could not be completed over the usual consecutive four day trip due to Basslink cable commissioning tests and inclement weather disruptions. Cable commissioning tests required Gordon Power Station availability for frequency control ancillary services support during December and so outages were restricted to durations of one day, as opposed to the usual two consecutive days. The combination of extended periods of inclement weather and Gordon Power Station outage constraints meant that several trips were required to complete the sampling program. Extended periods of high rainfall and flows meant that the autumn trip was postponed to late April/early May.

Eight previous monitoring surveys had been completed prior to the 2005–06 sampling round. These were conducted in December 2001, April 2002, December 2002, March 2003, November 2003, April 2004, December 2004 and April 2005.

Thirty one Gordon catchment test sites were scheduled for sampling on each occasion (Table 9.1) which were located in zones 1 to zone 5. Figure 9.1 shows the location the Gordon catchment monitoring zones. The rationale behind the zone allocations is discussed in Howland *et a.l.* (2001). Seven river and four tributary reference sites were scheduled for sampling in conjunction with the test sites, and these reference sites are listed in Table 9.2.

Table 9.1. Gordon catchment (test) monitoring sites. Alternative site names are shown in parenthesis. *Orange River has replaced the Denison u/s Maxwell site due to ongoing access difficulties at the latter.

Zone	River sites	Tributary sites
1	75 (G4), 74 (G4a), 73 (G3 u/s and d/s)	Serpentine River, 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

Table 9.2. Reference monitoring sites

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

'Optional' sites, listed in Table 9.3, were included in the monitoring regime and consisted of 11 test and three reference sites that were located in both tributaries and rivers. These sites were included to provide additional data for the monitoring program in the event of failure to sample some of the core sites. 'Optional' sites were sampled if time and logistics permitted, however core sites took priority in the sampling regime. The Orange River test site (formerly classified as optional) has been reclassified as essential following ongoing access problems with the Denison u/s Maxwell site.

All of the essential sites and nine optional sites were monitored during summer 2005 sample. During the summer trip it was noted that high flows had reduced the size of the cobble bar at the mouth of Platypus Creek. Unfortunately, this landing site could not be used in autumn due to elevated river levels resulting in the loss of two essential sites. Eight optional sites were fished in autumn.

Table 9.3. Optional sites surveyed during the monitoring program. The Orange River site has been reclassified as essential due to ongoing access difficulties at the Denison u/s Maxwell site. Alternative site names are shown in parenthesis.

Zone	River sites	Tributary sites
1	76 (G2)	Left bank Creek @ site 75
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
8 (Franklin)	Franklin @ Forester Creek, Franklin @ Wattle Camp Creek	none
14 (Henty)	Henty @ West Sister	none

Table 9.4 of this report summarises the sites sampled during each of the 10 fishing surveys carried out between December 2001 and May 2006 inclusive, and lists classification information, zone allocation and sampling priority of each site.

Fish surveys were undertaken by backpack electrofishing, following the methods detailed in Howland *et al.* 2001. Surveys of the Gordon test 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 sample a range of representative habitats at each site. Fish are identified, counted and fork lengths are recorded to the nearest mm. Qualitative assessments of general aquatic habitat descriptors are recorded for each site.

Figure 9.1. Fish monitoring zones in the Gordon River (1–5), Franklin River (7–8), Birches Inlet (9) and Henty River (13–14).

Table 9.4. Sites sampled between December 2001 and April 2006, including site classification information. ! represents essential sites that could not be sampled. Colours represent different sampling events.

Zone	Type	Class	Priority	Site Name	Site No.	Dec 2001	Apr 2002	Dec 2002	Mar 2003	Nov 2003	Apr 2004	Dec 2004	Apr 2005	Dec 2005	Apr 2006
1	River	test	essential	Gordon @ G3 (d/s)	73										
1	River	test	essential	Gordon @ G3 (u/s)	73										
1	River	test	essential	Gordon @ G4	75										
1	River	test	essential	Gordon @ G4a	74										
1	River	test	optional	Gordon @ G2	76										
1	Tributary	test	essential	Indigo Creek											
1	Tributary	test	essential	Piguenit Rivulet											
1	Tributary	test	essential	Serpentine River											
1	Tributary	test	optional	Left bank creek at G4											
2	River	test	essential	Gordon @ G5 (lower)	72										
2	River	test	essential	Gordon @ G5 (upper)	72										
2	River	test	essential	Gordon @ G5a (pipe)	71										
2	River	test	essential	Gordon @ G5a (water)	71										
2	River	test	essential	Gordon @ G6	69		!								
2	River	test	optional	Gordon @ Grotto Creek	64										
2	Tributary	test	essential	Albert River											
2	Tributary	test	essential	Mudback Creek			!								
2	Tributary	test	essential	Splits Creek											
2	Tributary	test	optional	Grotto Creek											
3	River	test	essential	Gordon @ G7	63										
3	River	test	essential	Gordon @ Harrison Creek (G16)	57										
3	River	test	essential	Gordon @ Orange River (G6a)	68										
3	River	test	optional	Gordon @ G9	60										
3	River	test	optional	Gordon @ G8											
3	River	test	optional	Gordon @ Fluffies											
3	Tributary	test	essential	Denison u/s Gorge											
3	Tributary	test	removed	Denison u/s Maxwell		!	!	removed	removed	removed	removed	removed	removed	removed	removed
3	Tributary	test	essential	Denison @ Maxwell River		!									
3	Tributary	test	essential	Harrison Creek											
3	Tributary	test	essential	Smith River											
3	Tributary	test	opt/essent	Orange River		optional	optional	essential	essential	essential	essential	essential	essential	essential	essential
3	Tributary	test	optional	Denison @ Denison Camp											
4	River	test	essential	Gordon @ Howards Creek	54										
4	River	test	essential	Gordon @ Platypus Creek	51										!
4	River	test	essential	Gordon u/s Sprent River	46										
4	Tributary	test	essential	Howards Creek											
4	Tributary	test	essential	Olga @ Gordon											
4	Tributary	test	essential	Platypus Creek											!
4	Tributary	test	essential	Sprent River											
4	Tributary	test	optional	Howards Creek inundation											
4	Tributary	test	optional	Olga @ Riffles											
5	River	test	essential	Gordon @ G14	44										
5	River	test	essential	Gordon @ G15	42										
5	River	test	essential	Gordon d/s Sprent River	45										
5	River	test	optional	Gordon @ Angel Cliffs	45a										
5	River	test	essential	Franklin @ Pyramid Island											
7	River	reference	essential	Franklin d/s Big Fall									!		
8	River	reference	essential	Franklin @ Canoe Bar											
8	River	reference	essential	Franklin u/s Big Fall											
8	River	reference	optional	Franklin @ Forester Creek											
8	River	reference	optional	Franklin @ Wattle Camp Creek											
8	Tributary	reference	essential	Ari Creek											
8	Tributary	reference	essential	Forester Creek											
8	Tributary	reference	essential	Wattle Camp Creek				!							
9	River	reference	essential	Sorell River											
9	Tributary	reference	essential	Pocacker River		!									
13	River	reference	essential	Henty @ Yolande											
13	River	reference	essential	Henty u/s Bottle Creek											
14	River	reference	essential	Henty @ Sisters											
14	River	reference	optional	Henty @ West Sister											

9.3 Results and discussion

Catch summaries and catch per unit effort statistics for each zone are presented in Table 9.5 and Table 9.6 of this report. Summary tables show total species catch and species CPUE (fish per 1200 seconds) for each zone. Catches were low in both summer and autumn, with identical numbers of fish caught in each survey. A total of 342 fish were captured, representing eight species in summer and nine species in autumn.

Salmo trutta was the only exotic species captured in summer, as redfin (*Perca fluviatilis*) were only caught in autumn. *Anguilla australis* was the only eel species captured, and two species of lamprey (*Mordacia mordax* and *Geotria australis*) were collected, which is consistent with previous surveys. *Galaxias brevipinnis*, *G. maculatus*, *G. truttaceus,* were sampled, as were sandys (*Pseudaphritis urvillii)*. Tasmanian mudfish (*Neochana cleaveri*) and Australian grayling (*Prototroctes maraena*) have been caught in very small numbers in past surveys, but were absent from the 2005–06 surveys.

Table 9.5. Numbers of each fish species caught in summer 2005 and autumn 2006, summarised by site type and zone.

December 2005

Zone	Type	Shocker effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. urvillii*	*S. trutta*
1	River (Gord.)	5252	0	0	0	0	0	0	0	**11**
2	River (Gord.)	7756	0	0	0	0	0	0	0	**9**
3	River (Gord.)	6467	**2**	0	0	0	0	0	0	**20**
4	River (Gord.)	3175	**1**	0	0	0	0	0	**1**	**6**
5	River (Gord.)	6580	**1**	0	**11**	**2**	**3**	0	**6**	0
7	River (Frank.)	1192	0	0	**1**	0	**4**	0	**3**	**2**
8	River (Frank.)	4978	**8**	**2**	**1**	0	0	0	**2**	**18**
1	Tributary (Gord.)	3005	0	0	0	0	0	0	0	0
2	Tributary (Gord.)	5245	0	0	0	0	0	0	0	**15**
3	Tributary (Gord.)	6403	**2**	**5**	0	0	0	0	0	**50**
4	Tributary (Gord.)	5434	**2**	0	**1**	0	**21**	0	**4**	**12**
8	Tributary (Frank.)	3659	**1**	0	0	0	**4**	0	0	**7**
9	River (Birches)	2754	0	0	0	**3**	**7**	0	**14**	**1**
13	River (Henty)	3077	**3**	**8**	0	0	**26**	**3**	**15**	**5**
14	River (Henty)	1402	**2**	0	0	0	**1**	0	**1**	**15**

April 2006

Zone	Type	Shocker effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. urvillii*	*S. trutta*	*P.fluviatillis*
1	River (Gord.)	4938	0	0	0	0	0	0	0	**4**	0
2	River (Gord.)	7383	0	0	0	0	0	0	0	**29**	**3**
3	River (Gord.)	6134	**1**	**4**	0	0	0	0	0	**7**	0
4	River (Gord.)	2117	**2**	0	0	**1**	**12**	0	**1**	**1**	0
5	River (Gord.)	6125	**4**	**9**	0	0	**13**	**3**	**7**	**1**	0
7	River (Frank.)	1390	0	**3**	0	**1**	**1**	0	**5**	**1**	0
8	River (Frank.)	4887	**2**	**7**	0	0	0	0	**2**	**11**	0
1	Tributary (Gord.)	3263	0	0	0	0	0	0	0	**3**	0
2	Tributary (Gord.)	4868	0	0	0	0	0	0	0	**7**	0
3	Tributary (Gord.)	6098	0	**2**	0	0	0	0	0	**42**	0
4	Tributary (Gord.)	6392	**2**	**1**	0	0	**5**	0	**2**	**21**	0
8	Tributary (Frank.)	3790	0	0	**2**	0	**13**	0	0	**12**	0
9	River (Birches)	1517	**3**	**2**	0	0	**13**	0	**15**	0	0
13	River (Henty)	2251	0	**2**	0	**3**	**16**	0	**13**	**4**	0
14	River (Henty)	1056	**1**	**2**	0	0	0	0	**2**	**19**	0
											0

Table 9.6. Catch per unit effort for each fish species caught in summer 2005 and autumn 2006, summarised by site type and zone.

December 2005

Zone	Type	Shocker effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. urvillii*	*S. trutta*
1	River (Gord.)	5252	0	0	0	0	0	0	0	**2.51**
2	River (Gord.)	7756	0	0	0	0	0	0	0	**1.39**
3	River (Gord.)	6467	**0.37**	0	0	0	0	0	0	**3.71**
4	River (Gord.)	3175	**0.38**	0	0	0	0	0	**0.38**	**2.27**
5	River (Gord.)	6580	**0.18**	0	**2.01**	**0.36**	**0.55**	0	**1.09**	0
7	River (Frank.)	1192	0	0	**1.01**	0	**4.03**	0	**3.02**	**2.01**
8	River (Frank.)	4978	**1.93**	**0.48**	**0.24**	0	0	0	**0.48**	**4.34**
1	Tributary (Gord.)	3005	0	0	0	0	0	0	0	0
2	Tributary (Gord.)	5245	0	0	0	0	0	0	0	**3.43**
3	Tributary (Gord.)	6403	**0.37**	**0.94**	0	0	0	0	0	**9.37**
4	Tributary (Gord.)	5434	**0.44**	0	**0.22**	0	**4.64**	0	**0.88**	**2.65**
8	Tributary (Frank.)	3659	**0.33**	0	0	0	**1.31**	0	0	**2.30**
9	River (Birches)	2754	0	0	0	**1.31**	**3.05**	0	**6.10**	**0.44**
13	River (Henty)	3077	**1.17**	**3.12**	0	0	**10.14**	**1.17**	**5.85**	**1.95**
14	River (Henty)	1402	**1.71**	0	0	0	**0.86**	0	**0.86**	**12.84**

April 2006

Zone	Type	Shocker effort (s)	*A. australis*	*G. australis*	*G. brevipinnis*	*G. maculatus*	*G. truttaceus*	*M. mordax*	*P. urvillii*	*S. trutta*	*P. fluviatillis*
1	River (Gord.)	4938	0	0	0	0	0	0	0	**0.97**	0
2	River (Gord.)	7383	0	0	0	0	0	0	0	**4.71**	**0.49**
3	River (Gord.)	6134	**0.20**	**0.78**	0	0	0	0	0	**1.37**	0
4	River (Gord.)	2117	**1.13**	0	0	**0.57**	**6.80**	0	**0.57**	**0.57**	0
5	River (Gord.)	6125	**0.78**	**1.76**	0	0	**2.55**	**0.59**	**1.37**	**0.20**	0
7	River (Frank.)	1390	0	**2.59**	0	**0.86**	**0.86**	0	**4.32**	**0.86**	0
8	River (Frank.)	4887	**0.49**	**1.72**	0	0	0	0	**0.49**	**2.70**	0
1	Tributary (Gord.)	3263	0	0	0	0	0	0	0	**1.10**	0
2	Tributary (Gord.)	4868	0	0	0	0	0	0	0	**1.73**	0
3	Tributary (Gord.)	6098	0	**0.39**	0	0	0	0	0	**8.27**	0
4	Tributary (Gord.)	6392	**0.38**	**0.19**	0	0	**0.94**	0	**0.38**	**3.94**	0
8	Tributary (Frank.)	3790	0	0	**0.63**	0	**4.12**	0	0	**3.80**	0
9	River (Birches)	1517	**2.37**	**1.58**	0	0	**10.28**	0	**11.87**	0	0
13	River (Henty)	2251	0	**1.07**	0	**1.60**	**8.53**	0	**6.93**	**2.13**	0
14	River (Henty)	1056	**1.14**	**2.27**	0	0	0	0	**2.27**	**21.59**	0

9.3.1 Exotic species

9.3.1.1 Brown trout (Salmo trutta)

Brown trout are widely distributed in the test and reference rivers. The results from this survey are generally consistent with previous results in terms of distribution and representation in catches. Table 9.7 and Table 9.8 show that trout recorded the highest CPUE in the majority of the test and reference zones, which is consistent with past results, with highest catches from the zone 3 tributaries and upper Henty zone. December 2005 catch rates were generally similar to mean catches recorded from previous surveys, while April 2006 mean catches were lower.

Summer catches from the zone 1 river sites (Abel Gorge) were significantly above average due to the unusual occurrence of fry (<35mm) in the shallow margins of site G3 indicating that trout had spawned successfully in the vicinity of this site.

Brown trout catch rates at the reference sites were at or above average for the monitoring program, with another isolated occurrence of a single trout from Sorell River in December 2005. This supports previous observations that trout are not well established in the downstream reaches of this river, however the factors limiting their distribution in Sorell River are not known.

Table 9.7. *S. trutta* catch per unit effort (standardised to fish per 1200 seconds) for all river zones between December 2001 and April 2006.

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
1	0.74	0.2	0.25	0.2	0.56	0.24	0.19	0.24	2.51	0.97
2	5.34	2.11	2.58	3.48	1.7	2.17	2.06	1.34	1.39	4.71
3	7.5	1.62	1.59	3.47	13.45	2.3	3.67	2.1	3.71	1.37
4	3.24	2.26	0.77	2.62	3.12	2.18	4.3	0	2.27	0.57
5	2.08	0.94	1.81	0.95	1.48	0.9	1.67	0.39	0	0.2
7	1.91	2.51	0	0	4.96	0	0	na	2.01	0.86
8	6.12	8.05	3.73	5.46	6.43	3.6	1.16	1.39	4.34	2.7
9	0	0	0	0.45	0	0.45	0	0	0.44	0
13-14	11.26	4.36	1.99	5.67	1.67	4.71	2.23	5.04	5.36	8.35

Table 9.8. *S. trutta* catch per unit effort (standardised to fish per 1200 seconds) for all tributary zones between December 2001 and April 2006.

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
1	1.29	3.15	1.3	0.97	0.94	1.05	0.33	0	0	1.1
2	3.77	2.15	3.87	3.17	4.85	2.34	3.76	5.7	3.43	1.73
3	8.98	10.58	5.22	14.44	13.82	8.21	6.5	15.59	9.37	8.27
4	7.93	5.3	3.2	8.47	1.74	8.02	6.01	5.68	2.65	3.94
5	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-
8	5.62	5.43	2.38	2.42	2.89	5.35	3.49	2.27	2.3	3.8
9	-	-	-	-	-	-	-	-	-	-
13-14	-	-	-	-	-	-	-	-	-	-

9.3.1.2 Redfin perch (Perca fluviatilis)

Table 9.9 shows the location and number of redfin perch captured in the Gordon River between December 2001 and April 2006, and Table 9.10 lists the catch rates in zones 1 and zone 2. It is noteworthy that redfin perch were not observed or captured during the December 2005 survey, and there appears to have been a general decline in redfin numbers since March 2003.

Table 9.9. Redfin (*Perca fluviatilis*) capture locations and numbers caught between December 2001 and Aprl 2006. (*stranded on river bank, N/S represents site not sampled).

Site	Dec 01	Apr 02	Dec 02	Mar 03	Nov 03	Apr 04	Dec 04	Apr 05	Dec 05	Apr 06
Zone 1										
Gordon @ Serpentine	*2	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S	N/S
site 76 (Gordon @ G2)	N/S	0	N/S	0	0	N/S	0	N/S	N/S	N/S
site 75 (Gordon @ G4)	0	0	3	0	11	0	0	0	0	0
site 74 (Gordon @ G4a)	0	0	2	0	1	0	0	0	0	0
site 73 (Gordon @ G3, d/s)	0	2	0	3	1	1	0	0	0	0
site 73 Gordon @ G3, u/s)	0	0	0	0	0	0	0	3	0	0
Zone 2										
site 72 (Gordon @ G5, lower)	0	2	0	3	0	5	2	1	0	0
site 72 (Gordon @ G5, upper)	0	7	2	13	0	1	3	0	0	0
site 71 (Gordon @ G5a, pipe)	0	0	0	0	0	1	0	0	0	3
site 71(Gordon @ G5a, water)	0	2	0	2	0	1	3	2	0	0
site 69 (Gordon @ G6)	1	N/S	0	0	0	0	0	0	0	0
site 64 (Gordon @ Grotto Ck)	N/S	0	N/S	0	0	N/S	0	0	0	0
TOTALS	**3**	**13**	**7**	**21**	**13**	**9**	**8**	**6**	**0**	**3**

Table 9.10. Redfin catch per unit effort in the Gordon River zones between December 2001 and April 2006. CPUE statistics were calculated on fish captured by electrofishing, and *excludes stranded or hand collected fish.

Zone	Dec 01	Apr 02	Dec 02	Mar 03	Nov 03	Apr 04	Dec 04	Apr 05	Dec 05	Apr 06
1	0*	0.40	1.23	0.61	2.42	0.24	0	0.72	0	0
2	0.25	2.11	0.32	1.55*	0.00	1.58	1.27	0.50	0	0.49
1 & 2 pooled	0.11	1.27	0.68	1.18	1.22	0.98	0.70	0.59	0	0.29

Previous annual reports have discussed that the factors controlling redfin introduction and distribution in the middle Gordon River are not well understood, but it is likely that their introduction below the middle river below the power station is linked to low lake levels increasing accessibility to the power station intake.

Figure 9.2 shows water levels in Lake Gordon between October 1995 and May 2006. The effects of a wet 2005–06 summer and autumn are evident on the lake level plot, with lake levels continuing to rise until mid January, falling during February and March, and rising again throughout April and May 2006. In previous years levels have generally peaked around December before falling throughout late summer and autumn.

While there has only been a change of several metres in seasonal minimum or maximum levels between 2002 and 2005, levels between 2001 and 2006 are significantly lower and more variable than the preceding period, and coincide with the discovery of redfin perch in zones 1 and 2.

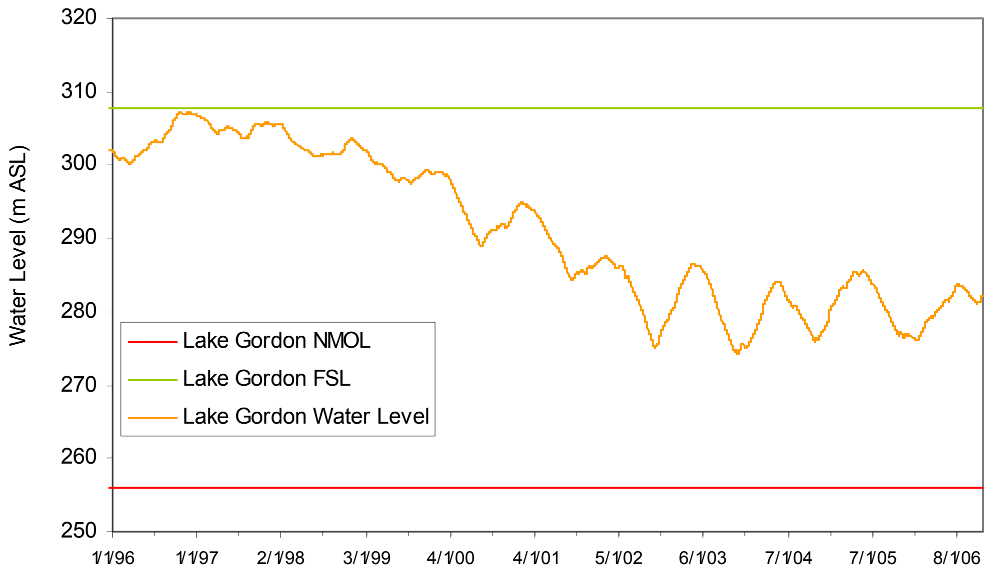


Figure 9.2. Water levels in Lake Gordon between January 1996 and May 2006.

9.3.2 Eels and lampreys

9.3.2.1 Short headed lamprey (Mordacia mordax)

Mordacia mordax were absent from most sites during the 2005–06 surveys, with only three fish collected from the Henty River in summer 2005 and three fish captured from zone 5 of the Gordon River in April 2006. These catch rates are consistent with the low catches of this species recorded from previous surveys.

9.3.2.2 Pouched lampreys (Geotria australis)

Table 9.11 shows CPUE's for *G. australis* between December 2001 and April 2006 in the test and reference zones. With the exception of the latest autumn zone 5 data, catch rates in the test river zones were below average, particularly during the summer sample.

Autumn catches in the Franklin and Birches reference zones were above average, indicating good spawning success in these rivers from previous years.

No adult lampreys were captured in 2005–06. All summer captures were ammocoetes. The vast majority of the autumn catch were ammocoetes, with four macrothamia identified in the surveys.

Table 9.11. Catch per unit effort (standardised to fish per 1200 seconds) for *G. australis* in all river zones between December 2001 and April 2006.

Zone	Dec01	Apr02	Dec02	Mar03	Nov03	Apr04	Dec04	Apr05	Dec05	Apr06
Zone 1 river sites	0	0	0	0	0	0	0	0	0	0
Zone 2 river sites	0	0	0	0.13	0	0	0	1	0	0
Zone 3 river sites	0	4.55	0.64	5.12	1.75	0	0.77	2.10	0	0.78
Zone 4 river sites	0	1.29	0	2.94	4.52	0	0	2.27	0	0
Zone 5 river sites	1.66	2.11	0.23	2.46	0	0.54	0.74	1.94	0	1.76
Zone 7 river sites	0	2.74	0	1.90	0	0	0	–	0	2.59
Zone 8 river sites	0	0	0	2.57	1.69	1.20	0.23	0.7	0.48	1.72
Zone 9 sites	0	1.25	0	4.50	1.31	0	0	0.48	0	1.58
Zone 13–14 sites	0	1.03	1.14	6.86	5.84	0.29	2.78	2.21	2.14	1.45

9.3.2.3 Short-finned eels (Anguilla australis)

Catch rates of short-finned eels (*Anguilla australis*) are shown in Table 9.12. Summer catches were well below average for most zones, with the exception of zone 8 (Franklin u/s Big Fall) and the Henty River zones, where summer catches were above average. Catches from these reference sites accounted for 60 % of the total eel catch for the summer survey. Autumn catches were below average for all zones.

Captured eels ranged in size between 105 mm and 710 mm, with the majority of larger eels captured from reference sites.

Table 9.12. Catch per unit effort (standardised to fish per 1200 seconds) for *A. australis* in all river zones between summer 2001 and autumn 2006.

Zone	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
Zone 1 river	2.22	0.20*	0.25	0.61	0.19	0.24	0	0.24	0	0
Zone 2 river	0.38	0	1.13	0.13*	0	0	0	0	0	0
Zone 3 river	1.99	0.97	2.86	0.73	0.97	0.26	2.12	1.53	0.37	0.2
Zone 4 river	4.05	3.56	0	0.33	2.18	1.86	4.66	1.95	0.38	1.13
Zone 5 river	5.19	6.32	2.26	7.57	3.89	1.25	3.52	2.91	0.23	0.78
Zone 7	0.38	4.52	1.92	0.95	12.93	0	2.79	-	0	0
Zone 8	1.06	3.58	1.98	0.96	1.29	0.72	3.25	0.46	1.93	0.49
Zone 9	1.86	2.19	2.8	3.15	4.81	0.45	8.73	0.48	0	1.58
Zone 13-14	0.88	0.77	0.28	2.39	0.28	0.29	1.11	0	1.34	0.36

9.3.3 Galaxiids and sandys

Table 9.13 to Table 9.16 provide summaries of catch effort data for galaxiids, sandys and grayling captured in the Gordon and Franklin Rivers and their tributaries, Birches Inlet and Henty Rivers between summer 2001 and autumn 2006. Summer catch rates were low in comparison to previous surveys, with little evidence of juvenile recruitment from spring whitebait runs. Grayling and Tasmanian mudfish were not captured during the 2005-06 surveys.

Table 9.13. Catch per unit effort for galaxiids (*G. brevipinnis, G. maculatus, G. truttaceus*) and (*P. urvillii*) captured in the Gordon River between summer 2001 and autumn 2006.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
1 river	*G. brevipinnis*	0	0	0	0.61	0	0	0	0	0	0
2 river	All (galaxiids and sandys)	0	0	0	0	0	0	0	0	0	0
3 river	*G. brevipinnis*	0	0	0	0	0	0	0	0.19	0	0
	P. urvillii	0	0	0	0	0	0	0.19	0	0	0
4 river	*G. truttaceus*	0.81	0.64	0.77	0	0	0	4.3	7.79	0	6.8
	P. urvillii	0	0	0	0.33	0	0.62	0.36	0.65	0.38	0.57
	G. brevipinnis	0	0	0	0	0.31	0	1.08	0	0	0
	G. maculatus	0	0	0	0	0	0	0.72	0	0	0.57
5 river	*G. brevipinnis*	0	0.47	2.71	0.76	4.26	0	12.03	5.04	2.49	0
	G. maculatus	0.42	2.34	0.45	0.57	12.77	5.19	10.18	0	0.45	0
	G. truttaceus	4.98	3.98	3.39	3.03	7.22	1.61	17.39	6.21	0.68	2.55
	P. urvillii	2.91	2.34	1.81	0.76	2.23	1.79	4.44	0.58	1.36	1.37

Table 9.14. Catch per unit effort for galaxiids (*G. brevipinnis, G. maculatus, G. truttaceus*) and (*P. urvillii*) captured in the Gordon River tributaries between December 2001 and April 2006.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
1 tribs	*G. brevipinnis*	8.07	1.75	1.3	2.6	3.12	0.35	3.93	0	0	0
2 tribs	All (galaxiids and sandys)	0	0	0	0	0	0	0	0	0	0
3 tribs	*G. truttaceus*	0	0.12	0	0	0	0	0	0	0	0
	P. urvillii	0.18	0	0	0	0	0	0.19	0	0	0
4 tribs	*G. brevipinnis*	0.28	0	0.38	0	0	0.19	0	0	0.22	0
	G. truttaceus	4.53	1.56	2.26	2.52	0.35	1.53	1.46	2.35	4.64	0.94
	P. urvillii	0.28	0.31	0	0.9	0.17	0	0	0.2	0.88	0.38
	G. maculatus	0	0	0	0	0.17	0	0	0	0	0

Table 9.15. Catch per unit effort for galaxiids (*G. brevipinnis*, *G. maculatus*, *G. truttaceus*) and *P. urvillii* captured in the reference river zones between December 2001 and April 2006.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
7 river	*G. brevipinnis*	3.43	0	3.83	0	5.96	0	12.08	-	1.01	0
	G. maculatus	0	1.51	2.88	0	0.99	0	0	-	0	0.86
	G. truttaceus	1.91	2.51	8.63	3.8	4.96	0	5.58	-	4.03	0.86
	P. urvillii	1.91	3.01	0.96	2.85	3.97	4	2.79	-	3.02	4.32
8 river	*G. brevipinnis*	1.33	0	1.54	0	2.25	0	2.32	0	0.24	0
	G. truttaceus	0.53	0.45	0.44	0	0.32	0	1.39	0.23	0	0
	P. urvillii	0.27	0.45	0.44	1.29	0.32	0	0.23	0	0.48	0.49
9 river	*G. brevipinnis*	0	0.31	0.4	0	0.44	0.45	0	0	0	0
	G. maculatus	1.86	0	7.6	0.45	2.19	0.45	1.09	0	1.31	0
	G. truttaceus	1.24	3.12	7.6	5.41	7.44	4.96	4.37	0.95	3.05	10.28
	P. urvillii	9.31	12.49	6.8	12.16	9.19	5.86	7.64	6.67	6.1	11.87
13-14	*G. brevipinnis*	0.44	0	4.55	0.6	0	0.29	4.17	0	0	0
	G. maculatus	1.32	1.03	0	2.98	0.28	3.24	0.83	0	0	1.09
	G. truttaceus	3.31	5.9	7.68	6.27	6.12	1.18	16.98	14.18	7.23	5.81
	P. urvillii	1.55	1.28	0.28	1.19	0	0.59	0.56	4.1	4.29	5.44
	N. cleaveri	0	0	0	0	0.28	0.29	1.39	0	0	0
	P. maraena	0	0	0	0	0	0	0.28	0	0	0

Table 9.16. Catch per unit effort for galaxiids (*G. brevipinnis*, *G. maculatus*, *G. truttaceus*) and *P. urvillii* captured in the reference tributaries between December 2001 and April 2006.

Zone	Species	Dec-01	Apr-02	Dec-02	Mar-03	Nov-03	Apr-04	Dec-04	Apr-05	Dec-05	Apr-06
8 tribs (Frank. u/s Big Fall)	*G. brevipinnis*	1.61	1.28	2.86	4.54	1.28	1.19	0.95	0.32	0	0.63
	G. truttaceus	4.02	2.87	1.43	0.6	7	2.08	2.53	4.22	1.31	4.12

9.3.3.1 Climbing galaxias (*Galaxias brevipinnis*)

A total of 14 climbing galaxias were captured during the summer survey, and only two fish were captured in autumn. Summer catch rates for this galaxiid species were historically low in both the test and reference sites, particularly in comparison to December 2004, and reflect the absence of a significant migratory run during December 2005. Catches in the Gordon River were confined to G15, Gordon d/s Sprent River and Howards Creek, with sizes ranging between 42mm and 60 mm.

No fish were collected from Indigo Creek, a small zone 1 tributary, during the 2005–06 surveys. Flows were relatively high during both the summer and autumn surveys, and conditions were overcast, reducing the effectiveness of the electrofishing field and visibility. Large rafts of foam also collected in the tail end of the pools, which reduced visibility into the water. One fish shocked during the autumn visit could not be collected due to poor sampling conditions. Conclusions about low catches from this remnant brevipinnis population should be reserved until the site can be fished again under better sampling conditions.

9.3.3.2 Spotted galaxias (Galaxias truttaceus)

Unlike the previous summer, spotted galaxias (*Galaxias truttaceus*) catches were relatively low during the summer 2005 survey. The majority of catch rates for the monitoring zones were below average, with catches in the zone 4 tributary sites and zone 7 river site (Franklin d/s Big Fall) the exception to this trend. Spotted galaxias returned the highest CPUE for all species in the summer sample for the zone 4 tributaries, zone 7 river site (Franklin d/s Big Fall) and lower Henty (zone 13) sites.

Autumn catch rates were generally higher than those collected in summer. Zone 4 river catches were well above average, due to a high catch rate at the Gordon above Sprent site. Conversely zone 4 tributary catches were below average, but this was due to the inability to sample Platypus Creek, which has historically returned good catches of spotted galaxias. Catches in zone 9 were well above average, due to good catches of a range of size classes from the Sorell and Pockacker Rivers.

Analysis of length frequency data, as shown in Figure 9.3, showed little evidence of juvenile recruitment to the test or reference zones during December, with only a handful of juveniles collected from the Henty River in early January 2006. Autumn population structure also showed limited evidence of summer recruitment, which supports the observation that galaxiid recruitment was inhibited by frequent periods of high flows over spring and summer.

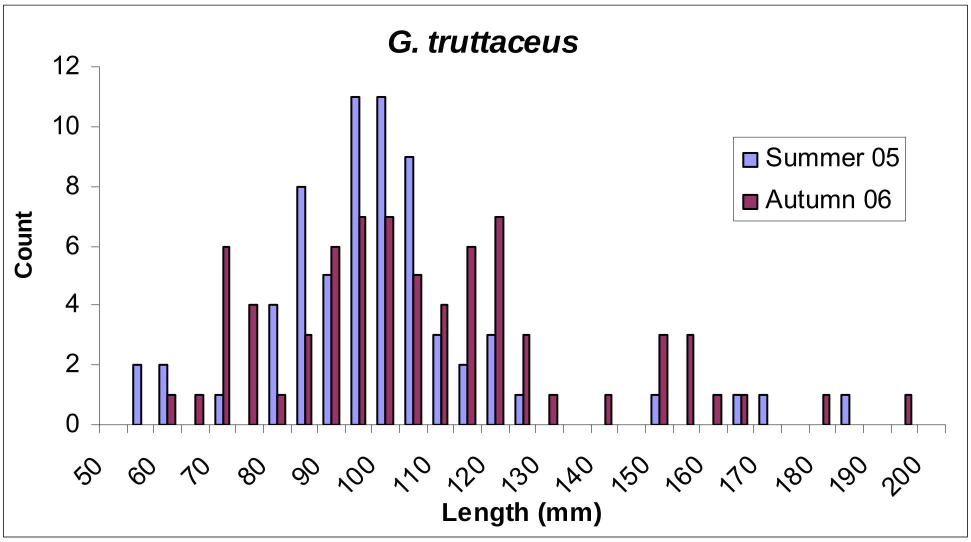


Figure 9.3. Length frequency histogram showing spotted galaxias population structure from all sites for summer 2005 and autumn 2006.

9.3.3.3 Jollytails (Galaxias maculatus)

Only five *Galaxias maculatus* were captured during the summer survey, two from zone 5 and three from zone 9. Autumn catches were also low, with a total of five fish captured from zone 4, 7 and 13. The distribution of the catches was restricted to the downstream zones, which is characteristic of this species.

Catch per unit effort was well below average for both surveys in all monitoring zones where jollytails have previously been collected. The two fish collected from zone 5 in December were juveniles, indicating that a small migration run had occurred prior to the summer sample. However, this low number of juveniles indicates that migration runs were hampered, most likely due to extended periods of high flows in spring and early summer.

9.3.3.4 Tasmanian mudfish (Neochanna cleaveri)

Tasmanian mudfish were not collected during the summer 2005 or autumn 2006 surveys. This species has only been collected from the Henty River on three occasions and appears to be a transient component of the fish fauna at this site.

9.3.3.5 Sandys (Pseudaphritis urvillii)

Forty six sandys were collected during the summer survey, and 47 in the autumn survey. Average catch rates for each zone were generally similar to or higher than previous surveys, returning the highest catch rate of all species from Birches Inlet for the year. Size ranges were similar between the summer and autumn sample, ranging between 25mm and 175mm. Summer catches showed a slight bias towards smaller size classes.

P. urvillii is not diadromous, and the prolonged period of rainfall and associated high flows in the test and reference sites was not detrimental to sandy catch rates. Sandys are ambush predators, and have often been observed associated with detritus beds in shallow backwaters. Freshes tend to disturb these deposits, which may compel sandys to move around making them vulnerable to capture by electrofishing in suitable habitats.

9.3.3.6 Australian grayling (Prototroctes maraena)

Australian grayling were not collected during the summer 2005 or autumn 2006 samples. A single specimen was collected from the Henty River in April 2004 indicating that their presence in catches has been rare during the monitoring program, and their absence from the most recent survey is not unusual.

9.3.4 Hydrological conditions

The Hydrology chapter of this annual report provides a summary of rainfall and flows data for the Gordon River downstream of the Gordon Power Station for the 2005-06 period. The main points of relevance to the fish monitoring program were that December 2005 and April 2006 received higher than average rainfall, receiving 212 % and 155 % of the long-term average respectively. This resulted in increased number of flow events in the catchment, particularly in the unregulated tributaries, and higher than usual post shutdown water levels in the Gordon River during monitoring periods.

The higher than average rainfall and increased flows, during both summer and autumn sampling, is likely to have been responsible to a large extent for the trend of reduced catches and CPUE of most native species. The higher than normal number of freshes appears to have influenced the success of migration of many of these fish. In addition, the preceding high flows conditions may have meant that the sampling areas were marginal fish habitat, and fish may have temporarily moved to more suitable locations as a result.

Power station operation is also distinctly different to previous autumn samples, showing periods of hydro-peaking in April 2006 followed by consistent hydro-peaking in May 2006, marking the start of full time trading into the National Electricity Market. The fact that the autumn samples were collected while the power station was hydro-peaking raises the question of whether the autumn 2006 sample should be used to derive monitoring trigger levels. On balance, the test zones would only have been subjected to a limited period of hydro-peaking, and it is unlikely that the autumn 2006 results would have had significant influence from the altered power station operation regime.

9.4 Conclusion

Catches were low in both summer and autumn, with identical numbers of fish caught in each survey. A total of 342 fish were captured, representing eight species in summer and nine species in autumn.

Catch rates for brown trout in summer was consistent with those recorded for previous surveys, whilst catches in autumn were lower than in previous surveys. It is likely that catch declines are linked to high rainfall in the catchment and sequential freshes proceeding both sampling periods resulting in decreasing fish abundance around channel margins, and also decreased electrofishing efficiency at sites with elevated flows. The presence of brown trout fry in zone 1 has not been observed previously and indicates that successful trout spawning is possible in this zone under suitable conditions.

Redfin perch were absent from the summer 2005 catches, and three fish were captured from zone 2 in autumn. While the reason for their summer absence is not clear, the general decline in redfin abundance supports the hypothesis that this species has probably occurred previously in the river via introduction from the power station but failed to establish a self sustaining population due to lack of suitable habitat, such as unsuitable hydrological conditions and spawning areas. As lake levels increase it is likely that redfin abundance will decrease in zones 1 and 2 due to reduced power station passage.

Lamprey catches from the test zones, particularly *Geotria australis*, were low. While a small number of adults have been captured in previous surveys, catches are generally dominated by ammocoetes. Lampreys are diadromous, but it is unlikely that the unseasonably wet summer and autumn would have affected ammocoete abundance, as they take approximately four years to metamorphose prior to downstream migration. Low catches may be attributed to past recruitment failure, but it is more likely that elevated flows during the summer and autumn sampling periods limited electrofishing access to stable ammocoete habitat (e.g sandy bars).

Short–finned eels were below average for the summer 2005 surveys, particularly in the test zones. This is not likely to be associated with recruitment failure but more likely an artefact of behavioural changes, reduced fishing efficiency, and localised habitat sampling inaccessibility due to elevated flows.

Unseasonably high rainfall and high flow variability in the Gordon River and its tributaries inhibited upstream galaxiid migration in summer 2005. This is evident in low galaxiid catch rates and lack of juveniles in the population structure in summer catches. Small schools of juvenile galaxiids were observed in Lake Fidler, and Gordon River adjacent to Fidler in mid January 2006 following several weeks of low rainfall and flows, and so migration appears to have been reduced in size and delayed until flows stabilised in the catchment.

Sandy catch rates were similar to or marginally higher than mean catch rates from the previous surveys. *P. urvillii* is non migratory and therefore recruitment success is not dependent upon migration success into the catchment. It is interesting to note that while elevated flows were implicated in reductions in electrofishing efficiency and reduced catch rates in several other species, this was not reflected in *P. urvillii* catches.

Tasmanian mudfish and grayling were not captured during the summer 2005 sample. This result is not unexpected as these species have only been captured in very small numbers in past surveys.

In summary, unseasonably high baseflows and sequential flow events preceding and during sampling reduced catch rates in both test and reference sites. Reduced catch rates were recorded for most species, and reductions in electrofishing efficiency due to elevated sampling flows probably contributed to catch reductions.

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10 Pre–Basslink aerial photo analysis

10.1 Introduction

Hydro Tasmania's water licence requires aerial photographs of the middle Gordon River to be taken in the year prior to the commissioning of Basslink. This was completed on 12 December 2004. The licence requires that an analysis of the photos be completed, which compares the 2004 photos with the aerial photo analysis completed during the IIAS investigations in 1999.

In consultation with DPIW, it was formally agreed that visual comparisons of 1999 and 2004 aerial photographs would provide a suitable level of analysis in place of a detailed photogrammetric analysis, as specified in the water licence. This was based on the rationale that current changes in bank are around 30 mm per year in the most active river reaches. This is well below the 1–2m scale of change that is detectable by photogrammetric analysis. The condition applied to this approach was that if any areas were identified as having under gone substantial change, a subsequent analysis using more rigorous digital investigative methods would be undertaken.

This section presents the results of the visual comparison of the 1999 and 2004 aerial photos for all geomorphic zones in the middle Gordon (zones 1–5).

10.2 River conditions during aerial photography

Both the 1999 and 2004 aerial photos were obtained at a scale of 1:5,000, under clear conditions with the power station off. Table 10.1 summarises river levels and flow conditions for the respective days. Water levels were higher in all zones in 1999. In zone 1, the difference was approximately 0.25m at the site 75 level recorder. In the wider alluvial sections of zone 1, the difference would have been less.

In zone 2, the difference was reduced to ~0.15m owing to the generally wider nature of the channel. The difference in river level height increased with distance downstream due to the entrance of tributaries, which in 1999 were higher compared to 2004. In zones 3 and 4 there are no river level data available which cover both days, but in zone 5 in 1999 at site 42, flow was 20–30 $m^3 s^{-1}$ greater compared to 2004, with a difference in river levels of up to 50–60 cm through the day. This is a substantial difference in water level, and led to difficulties in identifying 'new' tree falls and other features in 2004 as compared to newly exposed features, relative to 1999.

Table 10.1. River levels and flow rates for dates on which aerial photos were obtained. Data from Hydro Tasmania's Time Studio data base. Range is provided for Gordon above Franklin gauge site in 1999 as the water level fell through the day.

Zone	Site	1999		2004	
		Level (m) (local datum	Flow ($m^3 s^{-1}$)	Level (m) (local datum)	Flow ($m^3 s^{-1}$)
1	77 (tailrace)	*	<5	0.25	<5
1	75	0.32	Not rated	0.07	Not rated
2	72	0.35	Not rated	0.19	Not rated
3	65	Not installed		10.16	1.9
5	42	0.86–0.70	43–33	0.23	11.3

*Level data not available

10.3 Methods used in qualitative approach

10.3.1 Direct comparison of JPEG images

A direct comparison of 2004 and 1999 photos was completed by projecting jpeg images of the same reach from each photo set (1999, 2004) side-by-side on a computer screen at similar magnification (1 image pixel = 2 screen pixels), and marking notes and changes on a printout of the 1999 GIS image. The jpeg images had sufficient resolution to detect individual trees, tree trunks and logs in the river.

ERDAS viewfinder was used to compare the photos, providing magnification, rotation, and individual image enhancement (brightness, contrast, sharpening of images, outlining of images). The use of an optical computer mouse with a magnification function also assisted in the viewing of photos. Combined, these techniques proved to be a satisfactory method for the qualitative comparison of the two photo sets. Due to differences in water levels, photo angles and shadows, quantitative measurements of channel widths were not undertaken.

Photos were first compared at a relatively low magnification (e.g Photo 10.1, Photo 10.2) to assess potential large-scale changes such as channel morphology or bar shape. Following this, the photos were viewed at high magnification to compare features such as the Plimsoll line, cobble bars, tree fall, woody debris in the channels and landslips.

10.3.2 'Ground truthing' of aerial photos

Where possible, changes identified in the 2004 aerial photos were 'ground truthed' by searching the ground-based photo library of the middle Gordon River (photo-monitoring sites and other field photos) for relevant photos and examining the changes from river level.

10.4 Description of changes by zone

The following sections summarise the findings of the aerial comparisons on a zone by zone basis. Each section contains a summary map showing the location of subsequent photos shown for the zone, and a summary of the changes observed. The raw results of the analysis are contained in appendix 2 (Annotated aerial photography maps), where the 1999 GIS vector maps show changes observed in 2004.

10.4.1 Zone 1

Zone 1 is a 5 km reach between the Serpentine River and Able Gorge (Figure 10.1). The photo analysis found no evidence of large-scale or small-scale channel form change. There was also no evidence in the aerial photos of where bank slumping is known to have occurred, due to the overhanging vegetation. Changes which were observed include:

- modification of one cobble bar (the 'construction' bar);
- approximately five new tree falls dispersed throughout the zone;
- some additional woody debris in the river, which could not be directly linked with a new tree fall; and
- increased vegetation upslope of the power station-controlled water level.

Other differences in the photos, such as greater exposure of cobble bars, are attributable to water level differences between the two dates. There has been no change to the cemented cobble bar during the intervening five years. Some of these aspects are discussed in more detail below.

10.4.1.1 Changes to 'construction' bar

Following construction of the Gordon dam and operation of the power station, a cobble bar formed at the downstream end of the steep bedrock gorge section downstream of the power station tailrace. The exact timing and depositional history of the bar is unknown. It was first documented in the 1999 aerial photos, but was not present in the 1977 photo set. Photo 10.1 shows the bar in 1999 and 2004, with the differences not attributable to water level changes (water level in 1999 was slightly higher). Field observations indicate that this bar has finer sediments at the upstream end, and is located in a high flow eddy. The general morphology of the bar remains similar between the two photos, however in 2004 there appears to be erosion of the coarser material downstream of the contact between the two sediment types. This bar is presumed to consist of construction derived materials, and its reduction in size may indicate the material is slowly being transported through the system.

Another interesting aspect of the photos is that erosion pin monitoring site 1B is located in the small embayment downstream of the construction bar. This site has recorded the highest rates of change of any of the erosion pin sites in zone 1, reflecting the erosion of sediment and organic root mats overlying bedrock. The aerial photos indicate that this level of erosion has not resulted in large-scale changes to this area over the past five years.

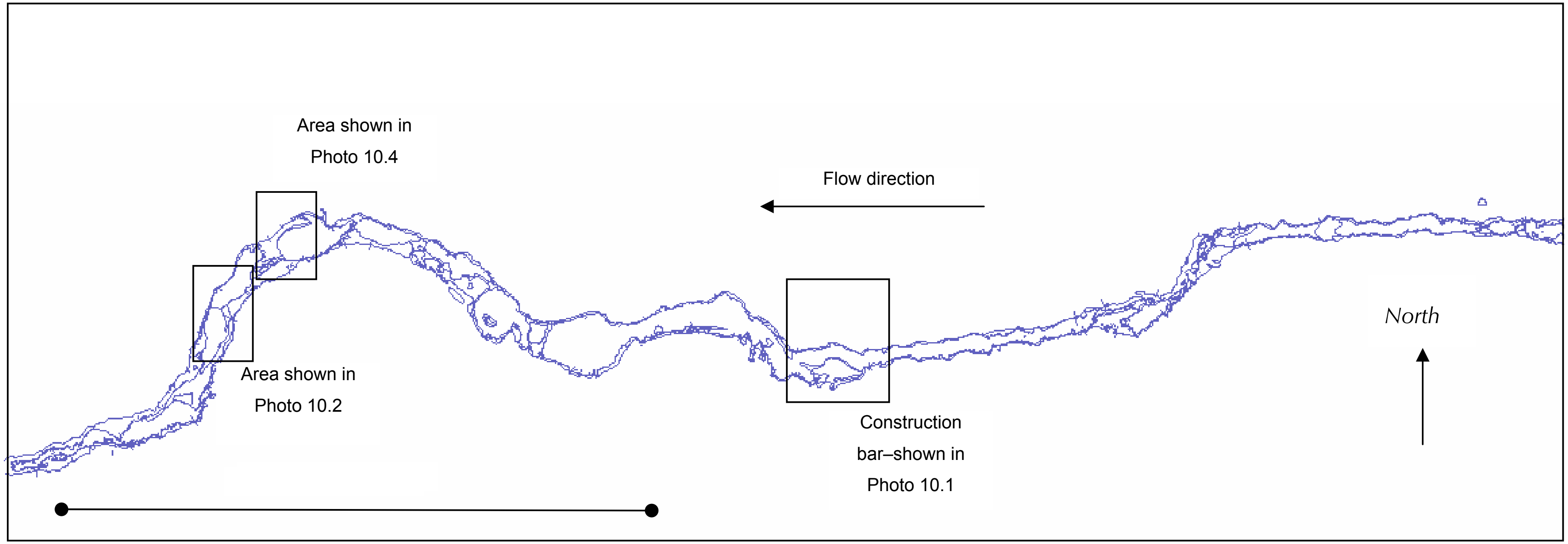


Figure 10.1. Outline of Gordon River in zone 1 as established by aerial photo investigation completed in 1999. The location of photos contained in the discussion are shown.

Photo 10.1. 1999 (top) and 2004 (bottom) aerial photos of 'construction' bar showing changes in morphology. Changes in sediment textures discernible in 2004 photo were also present in 1999 based on field observations, with finer grained sediments present on upstream end of bar (right side of bar in photos, lighter colour in 2004 photo).

10.4.1.2 Additional woody debris and bank slumping

In the lower alluvial reaches of zone 1, bank slumping has been documented by the annual photo-monitoring in a riffle/run section connecting two pools (Photo 10.2, Photo 10.3). The ground-based photos show that bank slumping occurred between 2002 and 2006, although it is not evident on the aerial photos due to the presence of overhanging vegetation. Evidence of this activity is limited in the 2004 aerial photo in the form of a 'new' log in the river deposited downstream of the area of active slumping. The photos also demonstrate the differences in water levels between the two dates.

Photo 10.2. Aerial photos from 1999 (left) and 2004 (right) showing alluvial reach in zone 1 where bank slumping has occurred based on ground–based photo–monitoring. Red circle indicates area shown in Photo 10.3.

Photo 10.3. Photo–monitoring site P1–4a in March 2002 (left) and March 2006 (right) showing changes to area indicated in aerial photo in Photo 10.2.

10.4.1.3 No change to cemented cobble bar

Photo 10.4 shows the aerial photos of a cemented cobble bar in zone 1 from 1999 and 2004, with Photo 10.6 showing ground-based photos of the same bar. Although the cementation of the bar has been breached by the channel, both the aerial and ground-based photos indicate that no major changes have occurred at the site between the two aerial photo-monitoring dates.

Photo 10.4. Aerial photo of cemented cobble bar and channel from 1999 (top) and 2004 (bottom).

Photo 10.5. Photo–monitoring site P1–3 consisting of cemented cobble bar in zone 1. Photos taken from left bank (facing downstream) looking across channel to right bank. Left photo taken March 2002, right photo taken March 2006.

10.4.2 Albert River mouth

The Albert River enters the Gordon at the beginning of zone 2. The aerial photo analysis completed for the Basslink IIAS showed that the mouth of the Albert River had undergone extensive channel widening between 1972 and 1999. Photo 10.6 shows the aerial photos from 1999 and the 2004 for this area of the river. Comparing the two indicates that the Albert is continuing to widen. The general morphology of the mouth in 2004 was similar to 1999, recognising the differences in water level. The main area of erosional activity is the left bank. The 2004 photo in Photo 10.6 (right) has five areas indicated which show changes from the 1999 photos:

1. The vertical cobble bank has continued to erode throughout the pre-Basslink monitoring period. Although water levels make direct comparison difficult, there is an increase in sediment blocks at the base of the bank in the 2004 photo as compared to 1999, and trees have been lost from the top of the bank. Photo 10.7 shows the bank as of March 2006;

2. This area has had additional tree fall since 1999. Ground-based investigations have found that these tree falls have resulted in the river being directed towards the left bank, and has resulted in the migration of the main channel towards the left bank. Photos of the tree falls in the area between #2 and #3 are contained in Photo 10.8;

3. This area shows how the channel has migrated towards the left bank, resulting in additional tree fall in this area as well as upstream. Seepage erosion is very active along this bank of the river;

4. Both field observations and aerial photo indicate that inundation of this area has increased. It is possible that the tree falls described in #2 and #3 have allowed water to enter this area at high flow, but this has not been confirmed; and

5. Additional tree fall is present in the 2004 aerial photo in the Albert River, and the spur separating the two rivers is eroding. In October 2005 a large section of the bank was being supported by roots only, as shown in Photo 10.9. The same slip was observed in June 2006, and the opening in the bank had increased in size.

Upstream of the 'numbered' reach, there are also additional tree falls in the 2004 photos, though due to the difference in angles between the two photos, the number is difficult to establish.

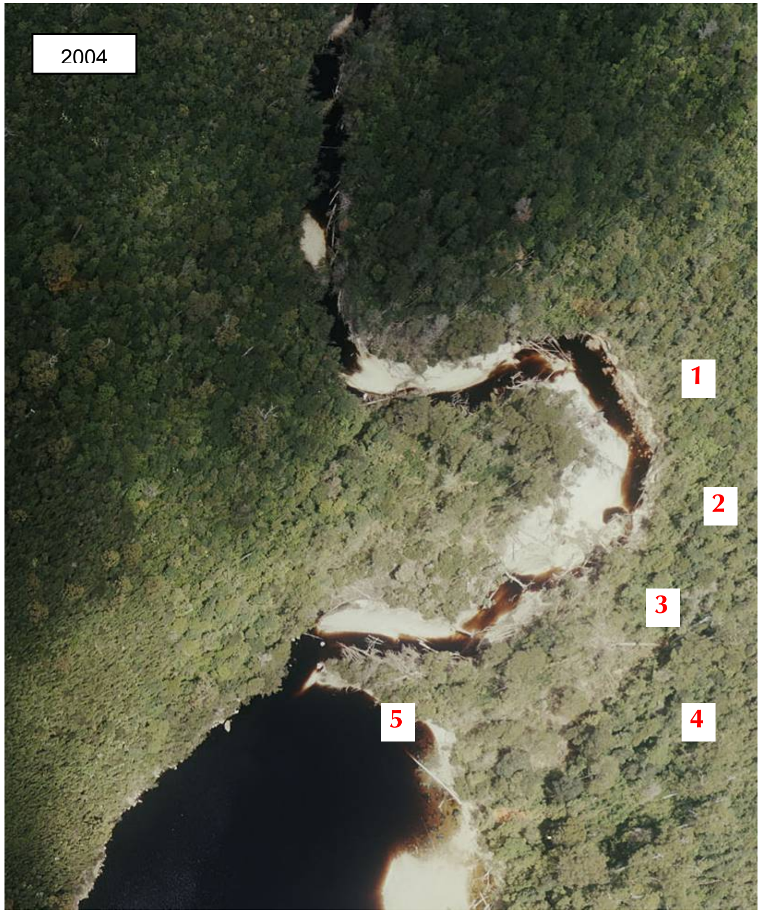


Photo 10.6. Aerial photos of the Albert River at the Gordon confluence in 1999 (left) and 2004 (right). The Albert is flowing from the top of the photo into the Gordon at the bottom of each photograph.

Photo 10.7. Photo mosaic of left bank, lower Albert River showing boulder sized sediment blocks at base of bank.

Photo 10.8. Three photos of the left bank, lower Albert River downstream of bank in previous photo. Photos show recent tree falls along bank which separates the Albert River from the Gordon.

Photo 10.9. Slip in spur separating Albert and Gordon Rivers near the mouth of the Albert. Photo on left from March 2006, photo on right from June 2006.

10.4.3 Zone 2

The GIS vector map of the 1999 aerial photo analysis showing changes found in the 2004 photos is contained in appendix 2.

The photo comparison found no large-scale changes to channel form, with drip lines, cobble bars and the extent of vegetation remaining unchanged within the limits of detection of the qualitative assessment.

Changes in zone 2 included:

- approximately 15 additional tree falls, some of which have modified the banks and a cobble bar;
- generally small changes to existing landslips (the loss of small branches and leaves on existing tree fall);
- the realignment of some woody debris; and
- modification to tributary mouths (including the Albert, previously discussed).

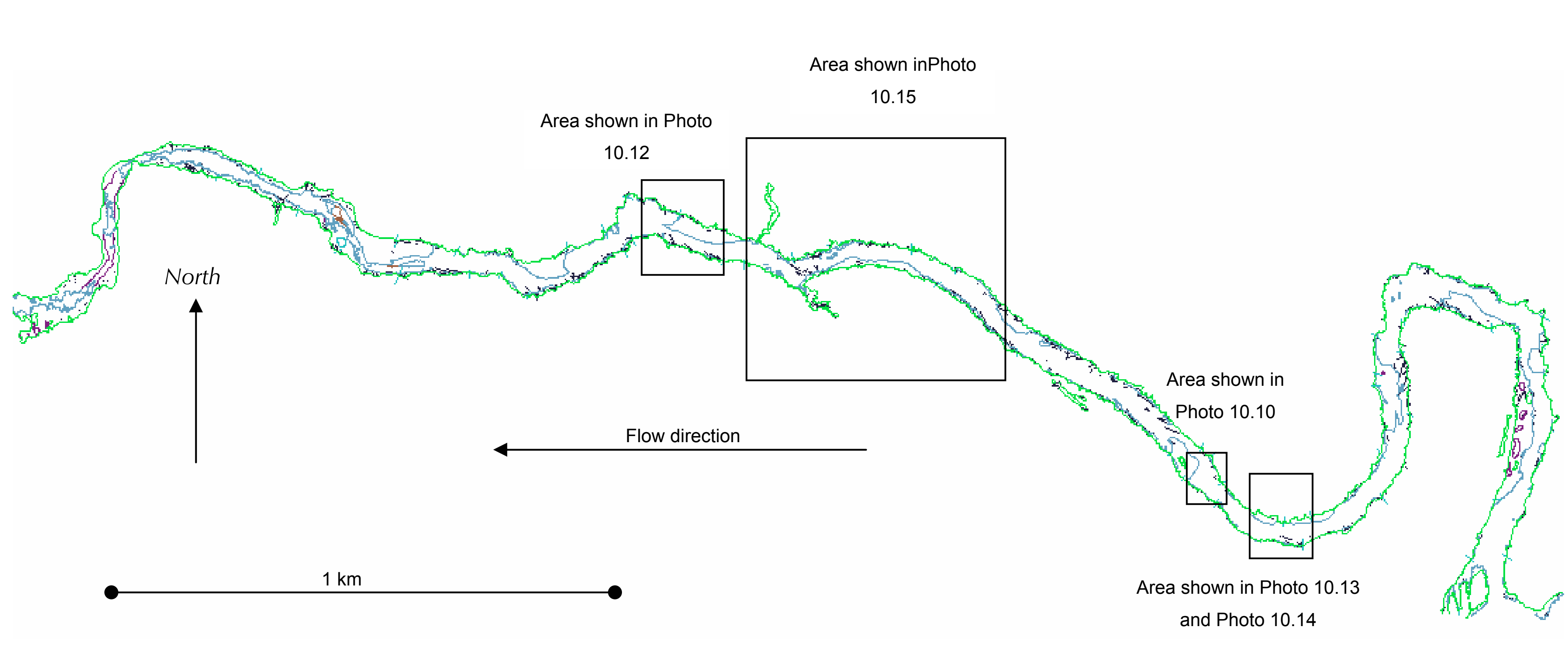


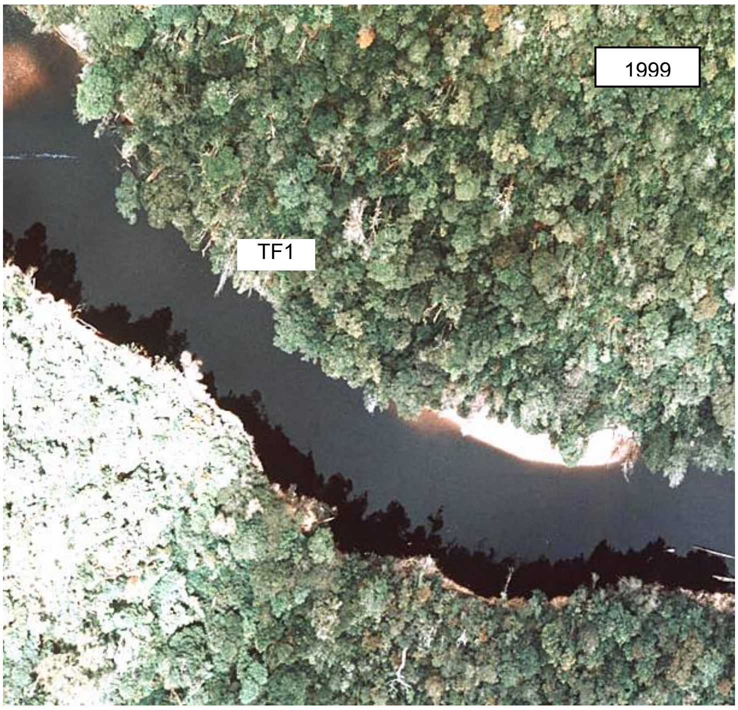
Figure 10.2. Map of zone 2 based on 1999 aerial photo analysis showing locations of photos and examples used in this report.

10.4.3.1 Additional tree falls

Approximately 15 new tree falls were identified in zone 2 in the 2004 photos as compared to the 1999 photos. Tree falls were also identified which were present in both the 1999 and 2004 photos, but not mapped on the GIS layers. The 2004 new tree falls were distributed throughout zone 2, with no one area showing a cluster of new falls. Several of these new tree falls have been documented by the annual photo-monitoring, and during the bi-annual erosion pin monitoring.

Three of the new tree falls have resulted in changes to the bank, due to the large size of the trees and removal of smaller trees by the initial fall. The largest of these is located upstream of the piezometer site and is shown in Photo 10.10, labelled TF1, and in the annotated maps in appendix 2. The area has been visited repeatedly since 1999, as shown in photos in Photo 10.11. The initial disturbance was caused by a large tree fall in late 1999. The area has remained active, with the disturbance propagating upstream through a series of smaller falls. The initial scarp, which continues to be stabilised by a large tree stump, can still be seen in the most recent photos.

The other two large tree falls which have modified the bank are located downstream of the piezometer site, and are labelled TF 2 and TF 3 on the annotated maps in appendix 2. Aerial photos of TF 3 for 1999 and 2004 are shown in Photo 10.12. The position of the tree in relation to the new channel on the bar suggests that the tree has diverted water across the bar at low flow (as river levels were lower in 2004), leading to modifications of the bar.



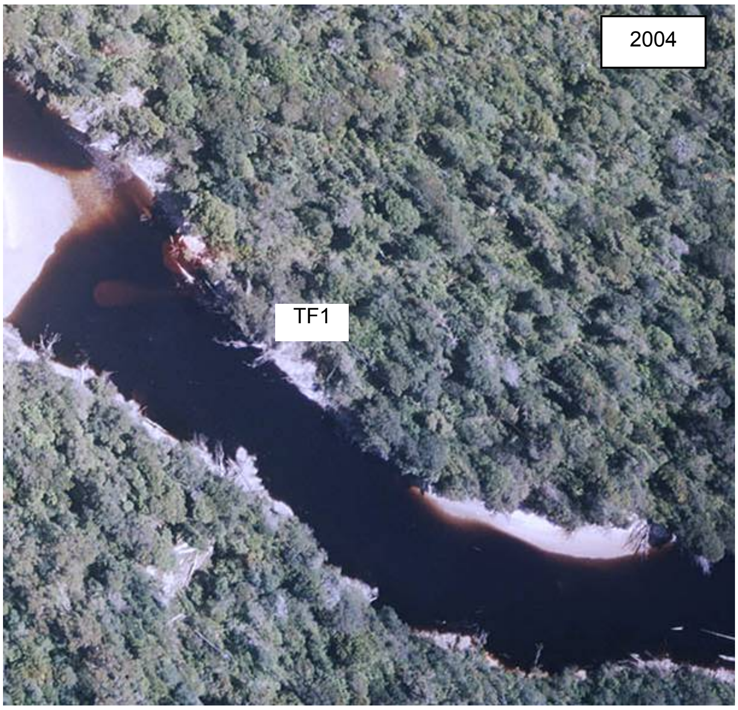


Photo 10.10. Aerial photo of region immediately upstream from piezometer site, showing increased loss of vegetation due to tree fall between 1999 and 2004. Gordon flowing from right to left in photos.

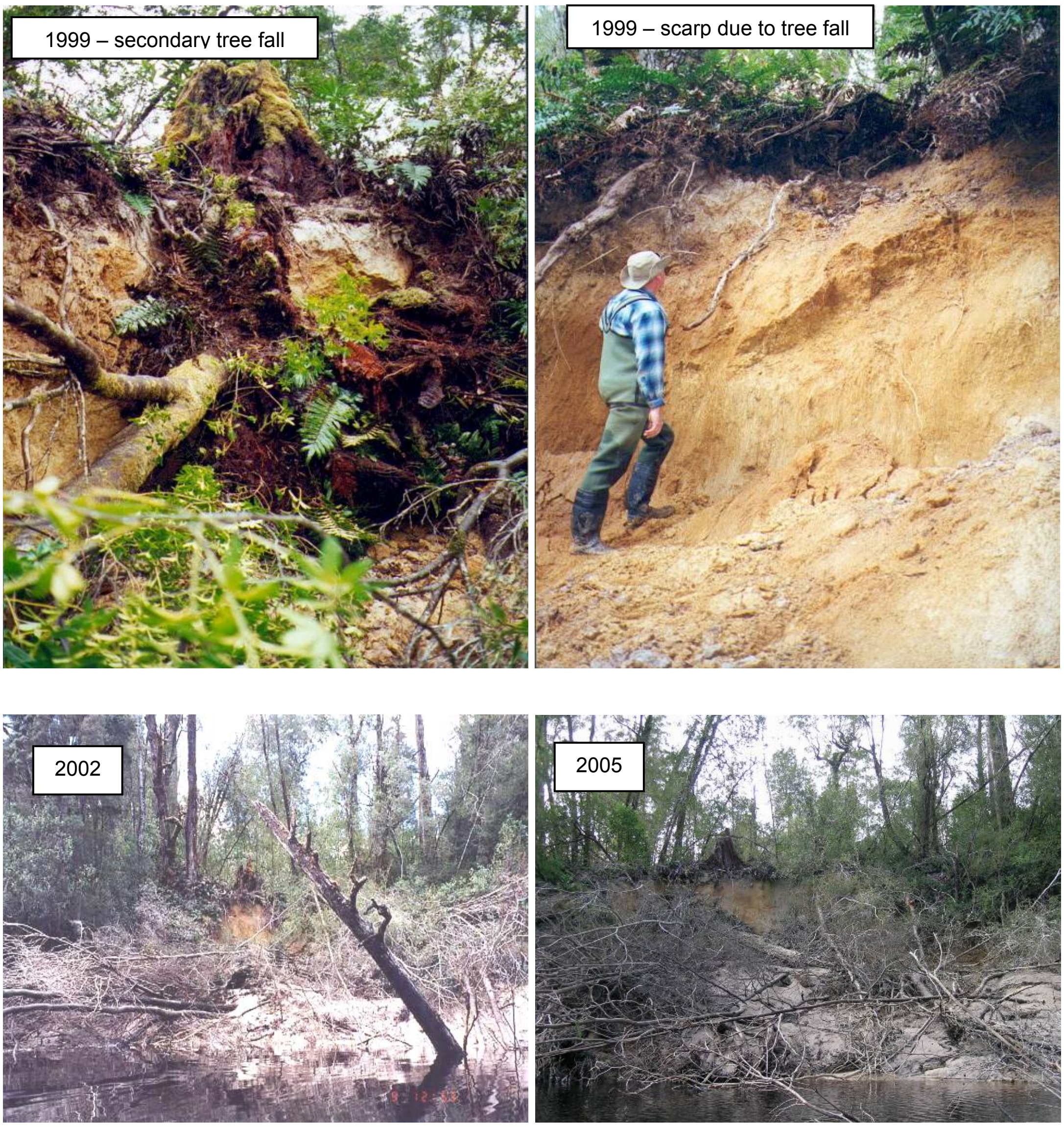


Photo 10.11. Ground–based photos of initial disturbance and subsequent additional tree falls at TF1 site in zone 2.

Photo 10.12. Tree fall (TF3) in lower zone 2 in 1999 and 2004.

10.4.3.2 Changes to landslips

The 2004 aerial photos show minor changes to landslips recorded in 1999. Generally, the loss of leaves and small branches from already collapsed trees were the greatest changes discernible in the photos. Ground-based photography during the five years has shown that changes to the landslips have included the collapse of overhanging vegetation, an additional slip next to an existing one (LS2), and establishment of vegetation on slip faces above the power station-controlled high-water level. Because most of these changes occurred beneath the overhanging vegetation, they are not easily seen on the aerial photos. Examples of aerial photos showing landslips in zone 2 are shown in Photo 10.13, with ground-based photography of the same features in 1999 and 2005 presented in Photo 10.14.

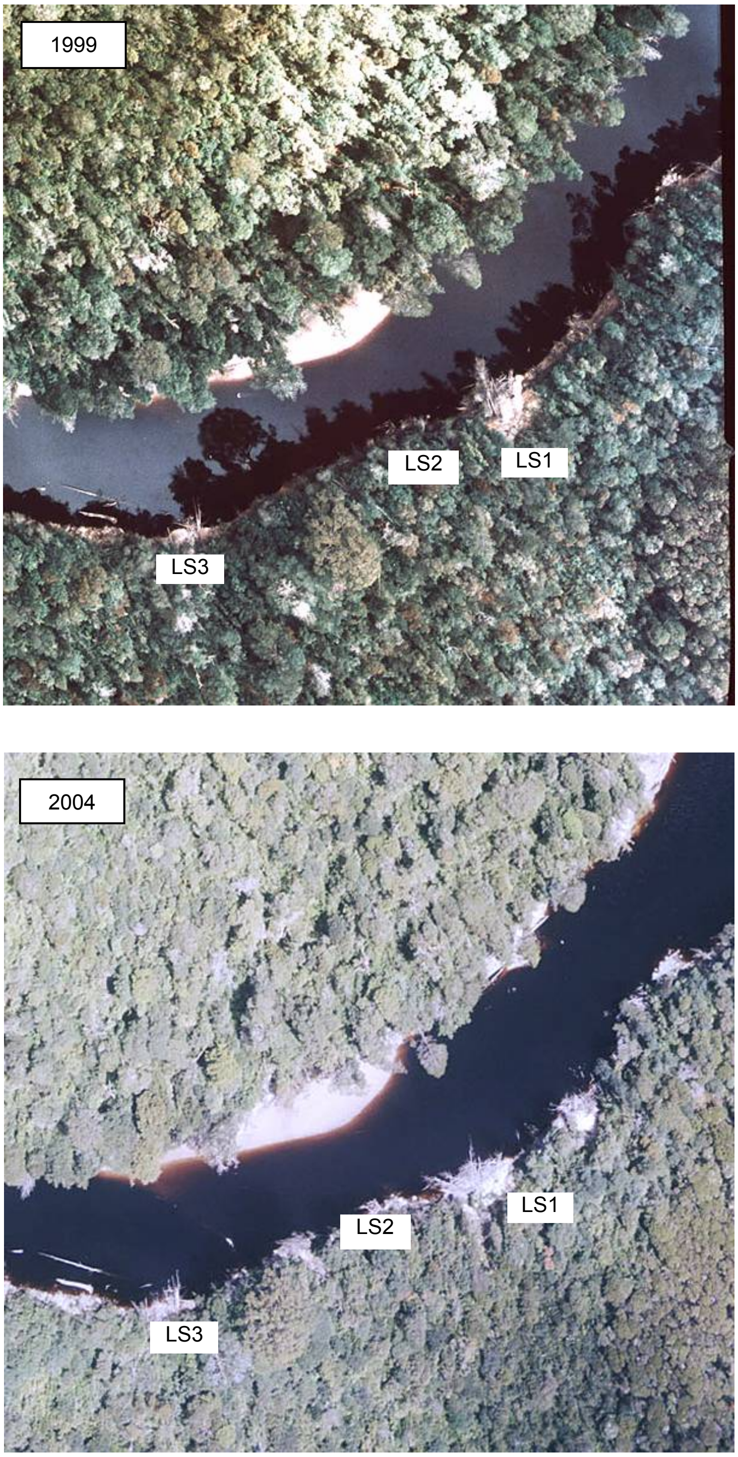


Photo 10.13. Aerial photo of zone 2 showing landslips in vertical cobble banks in 1999 (top) and 2004 (bottom).

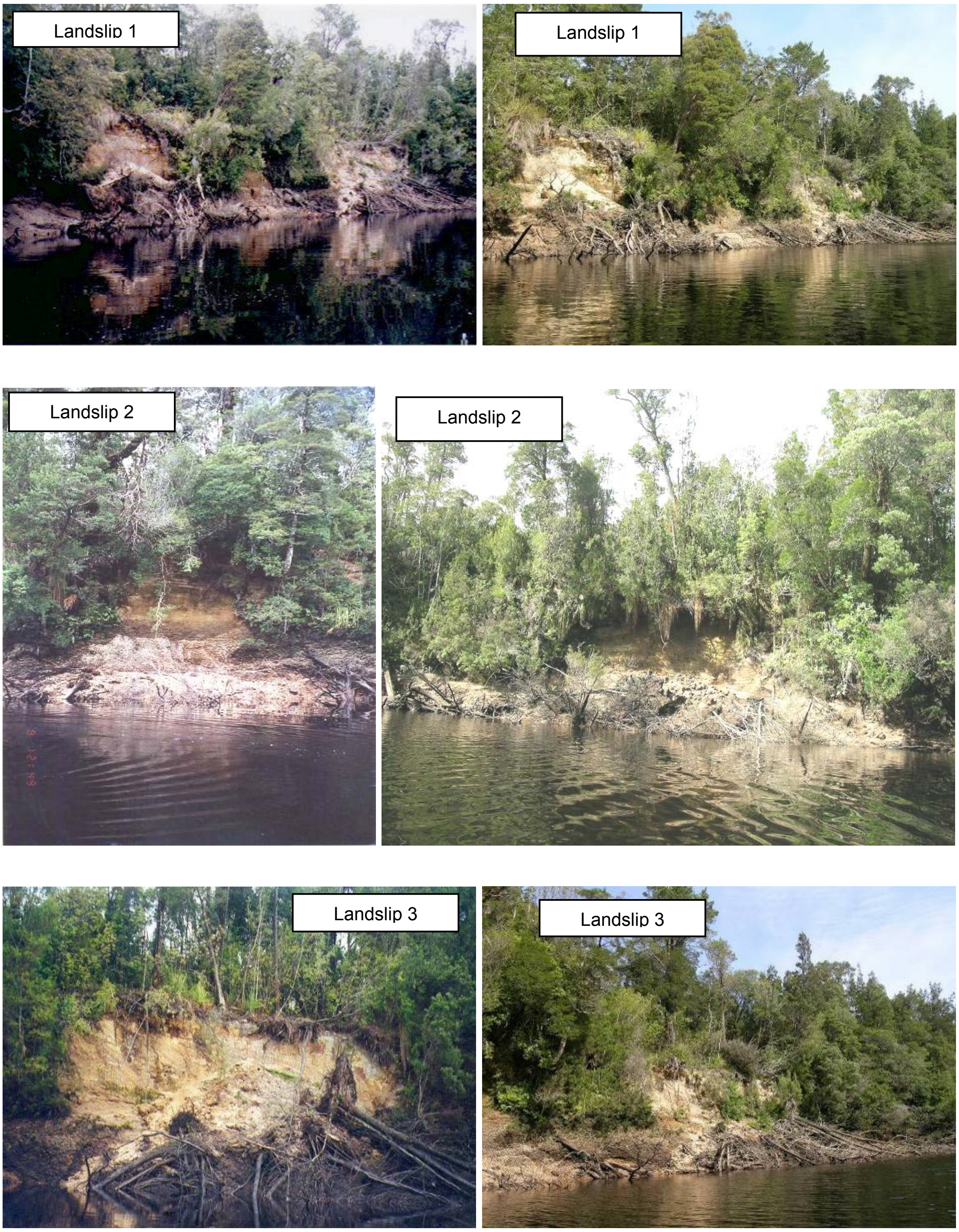


Photo 10.14. Ground–based photography of landslips shown in previous figure, showing changes between 1999 and 2005. Landslips identified by number in the previous figure.

10.4.3.3 Tributary mouths

The two small tributaries which enter in the lower part of zone 2 (the one entering from the left bank commonly referred to as ‘Bathtub Creek’) appear to have lost additional vegetation upstream of the Gordon confluence, although differences in lighting and angles of the photos make interpretation difficult. Examples are shown in Photo 10.15.

Photo 10.15. Aerial photos from 1999 (top) and 2004 (bottom) of small tributaries entering Gordon in lower portion of zone 2.

10.4.4 Zone 3

A general map of zone 3 is presented in Figure 10.3, with the results of the aerial photo analysis presented on the GIS vector maps in appendix 1 (Erosion pin graphs). Very few changes have occurred in zone 3 between 1999 and 2004 based on the aerial photo comparison. There are no large-scale changes to the channel, cobble bars or islands, no major new landslips, and no change to the Plimsoll line. Changes observed include:

- vegetation may have increased in the gorge section upstream of the Orange River;
- three new tree falls are apparent;
- several existing logs appear to have shifted slightly within the channel; and
- changes to the confluences of the Orange and Denison Rivers with the Gordon.

The overall lack of changes to the Gordon in zone 3 is consistent with the photo-monitoring results from the Basslink baseline monitoring program which have not documented major changes at any of the photo sites.

The aerial photo results do not reflect the erosion pin results which have shown relatively high rates of bank erosion (millimetre scale changes in the 1-2 and 2-3 turbine bank level) over the past five years. This is because (1) the area affected by the bank erosion is located below the overhanging vegetation and (2) aerial photo comparisons cannot detect millimetre scale changes. What the aerial photos confirm is that the rate of erosion over the past five years has not lead to widespread tree fall or large-scale changes.

The largest scale changes to zone 3 are at the mouth of the Orange River, the confluence of the Gordon and Denison Rivers (end of zone 3, beginning of zone 4), and at the newly established Basslink compliance site (site 65). These areas are shown in Photo 10.16, Photo 10.17 and Photo 10.18 and discussed in the following sections.

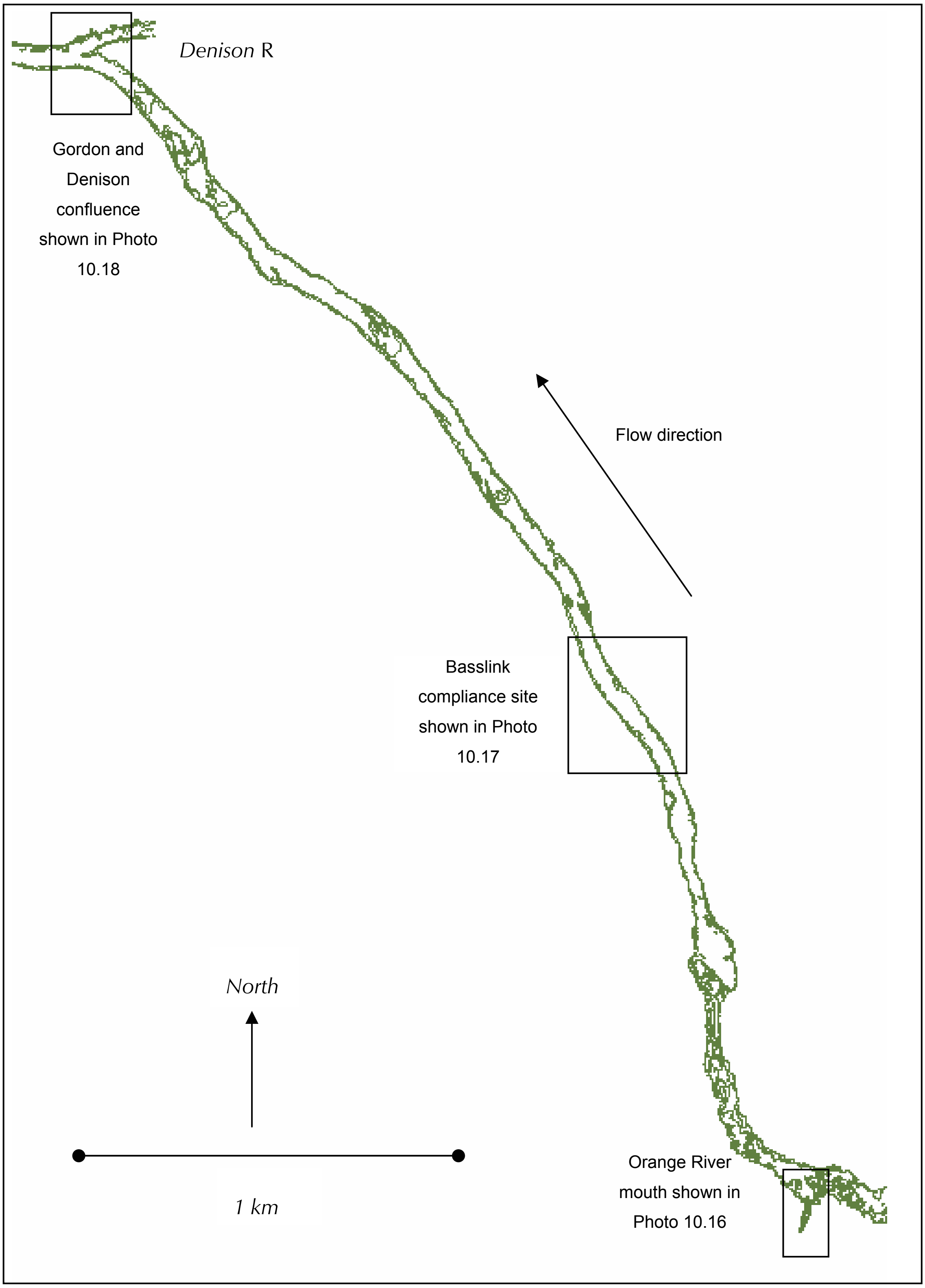


Figure 10.3. Outline of Gordon River in zone 3 as established by aerial photo investigation completed in 1999. The location of photos contained in the discussion are also indicated.

10.4.4.1 Orange River mouth

The Orange River mouth is situated at the upstream end of zone 3, downstream of Snake Rapids (Photo 10.16). At high power station discharge the mouth of the Orange River is a backwater, and is characterised by a Plimsoll line similar to the Gordon River. The 2004 aerial photo shows additional tree fall in the mouth of the Orange River as compared to the 1999 photo, however differences in photo angle and lighting make quantification of the changes difficult. The 2004 photo also shows a sand bar in the Orange River upstream of the mouth, which is not apparent in the 1999 photo, although differences in photo angle and water level may prevent seeing the bar in the 1999 photo.

Photo 10.16. Orange and Gordon confluence. Gordon River flows from right to left in both photos, with the Orange River entering from the bottom, although angle of photos varies somewhat.

10.4.4.2 Basslink compliance site

In 2004, a new gauging site and helipad were established in zone 3 to monitor flow as part of the environmental requirements associated with Basslink. Photo 10.17 shows where the site is located, along with the clearing associated with establishing the gauging station, and the helipad. The photos also show water level differences between 1999 and 2004 photos, and that the 'active' part of the banks (as determined through erosion pin monitoring) are obscured below the overhanging vegetation in the aerial photos.

Photo 10.17. Reach in zone 3 where Basslink compliance site has been established, with helipad and gauging wire apparent. Downstream is towards the left of the photos.

10.4.4.3 Gordon and Denison confluence

Aerial photos of the Gordon and Denison confluence have shown changes between 1999 and 2004 (Photo 10.18). The higher water level in the Denison in 1999 is evident. Most notably, the landslip present in the 1999 photo on the right bank of the Denison at the confluence has extended downstream, resulting in additional tree fall (although some of the additional tree fall visible is due to lower water levels in 2004). There may also be additional tree fall on the left bank of the Gordon River, though differences in water level and angle make quantification difficult.

Photo 10.18. Gordon and Denison confluence. Gordon flowing from right to left in photos with Denison entering from top of photo.

10.4.5 Zone 4

An overview map of zone 4 is presented in Figure 10.4, with the results of the aerial photo comparison between 1999 and 2004 photos contained in appendix 2 (Annotated aerial photography maps).

Similar to zones 1–3, there are no large–scale changes to the channel or bars in the zone. Flow entering the zone from the Denison was considerably lower in 2004 as compared to 1999 which resulted in lower water levels and the exposure of more logs and woody debris. Changes in the zone include:

- possibly six new tree falls in the zone. Identification is difficult due to differences in water level;
- additional large and small woody debris evident in the 2004 photos. Some of the increase in tree fall and woody debris is associated with changes between the photos, and some is attributable to the lower water level;
- additional tree fall and landslip downstream of the Gordon and Denison confluence; and
- a relatively large landslip on the right bank downstream of erosion pin site 4C, and across from erosion pin site 4D.

The additional tree falls and increased woody debris are distributed throughout the zone, and indicated on the maps in appendix 2. The other changes are discussed in the following sections.

10.4.5.1 Downstream of the Gordon and Denison confluence

Photo 10.19 contains the 1999 and 2004 aerial photos of the zone 4 reach immediately downstream of the Gordon and Denison confluence. In the 2004 photo more logs are apparent in the river, which is due to a combination of additional tree fall in the reach, and lower river levels in 2004. Because of the differences in water level, it is not possible to quantify the number of new tree falls in the reach, however compared to the remainder of zone 4, this reach appears to be the most active.

10.4.5.2 Landslip in mid zone 4

The 2004 aerial photo shows a disturbance in vegetation in mid zone 4, as indicated in Photo 10.20. In September 2002, Hydro Tasmania personnel observed the relatively large, new landslip, and the site was investigated and photographed in October 2002 (Photo 10.21). It was found to be caused by a rotational slip of a large tree located above the power station–controlled high–water level, which had dislodged the root mat and shallow rooted trees in the area. As shown in the photos, little sandy substrate was moved during the disturbance.

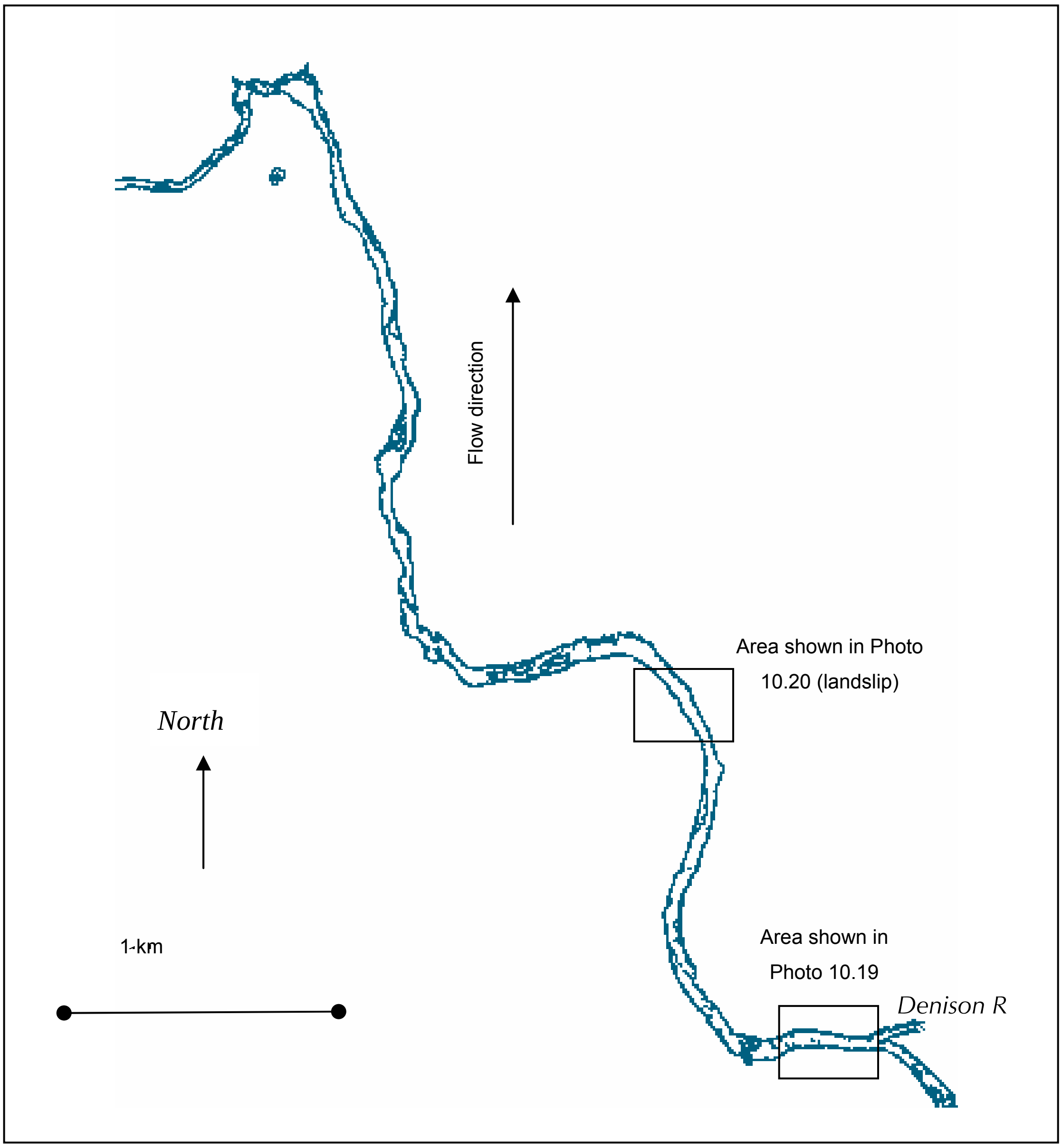


Figure 10.4. Outline of Gordon River in zone 4 as established by aerial photo investigation completed in 1999. The location of photos contained in the discussion are also indicated. Flow is from south to north (bottom to top) with Denison and Gordon confluence at upstream end of zone (bottom of map) and Sunshine Gorge at upstream end (top).

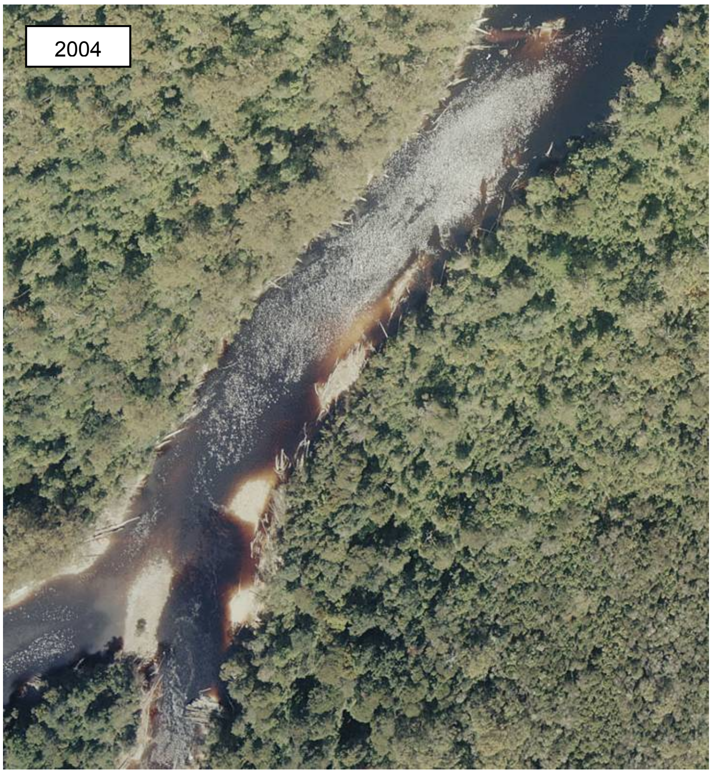


Photo 10.19. Denison and Gordon confluence and reach immediately downstream. Denison enters from bottom of photo, with Gordon entering from the left. River flows towards top of photo.

Photo 10.20. Zone 4 reach downstream of erosion pin site 4C, upstream from Bill Neilson Cave showing landslip on right bank. River flows from top to bottom of photo. Higher water level in 1999 is apparent from cobble bar exposure.

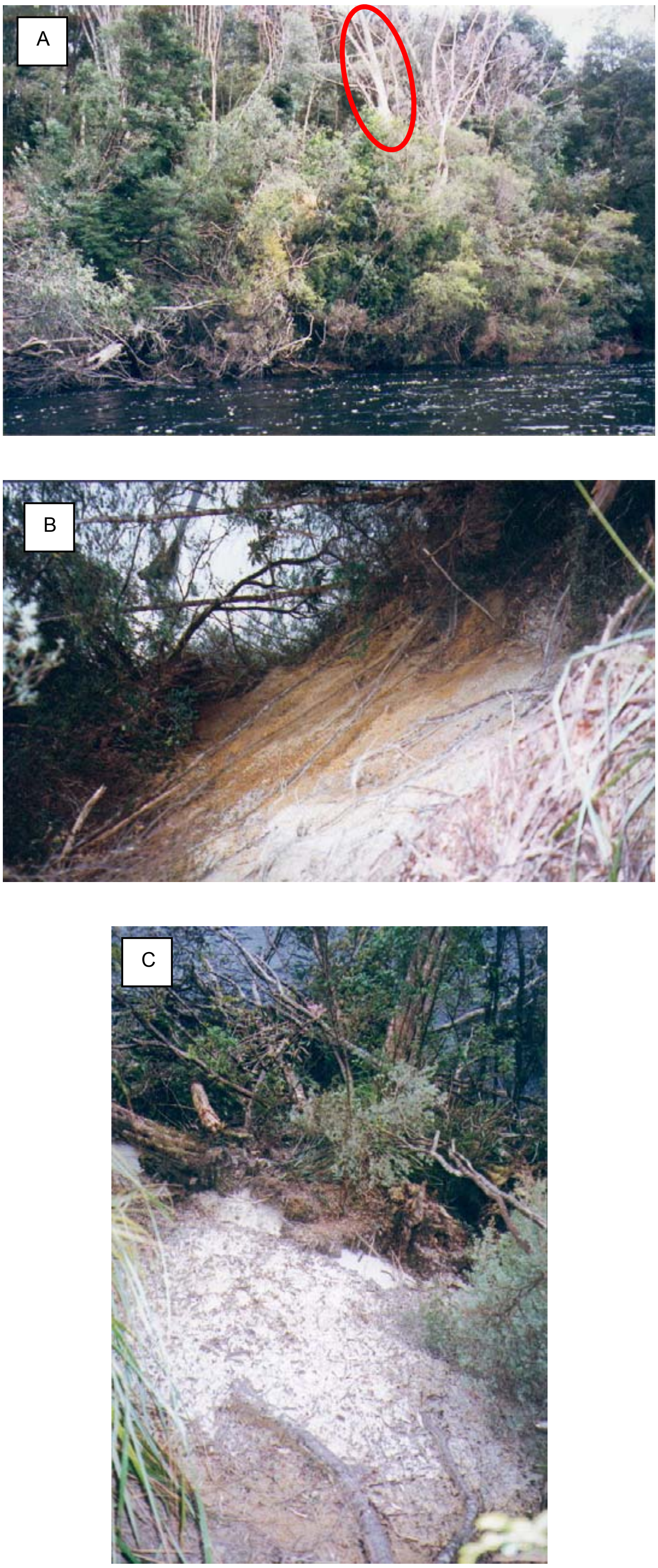


Photo 10.21. October 2002 photos of landslip in zone 4. (A) View of slip from water showing rotational slip of large tree (in circle) which resulted in removal of root mat and other smaller trees in vicinity. (B) Face of slip where root mat material has been removed. (C) Photo is taken from top of slip, looking downslope towards river, showing displaced root mat.

10.4.6 Zone 5

Zone 5 comprises almost half of the middle Gordon River, stretching ~14 km from Sunshine Gorge to the Gordon and Franklin confluence. In the 1999 aerial photos, discharge from the Olga River and other smaller tributaries increased flow levels in the river relative to the 2004 photo conditions, leading to a difference in water level between the two photo sets of ~0.5m. This has resulted in the 2004 photos depicting far more logs, woody debris and banks in general as compared to the 1999 photos, and has limited the ability to identify changes as compared to water level effects. Within these limitations, zone 5 was found to have had no large-scale changes to channels or bars, with vegetation on islands unchanged. The mouths of tributaries showed far fewer changes as compared to the tributary mouths upstream.

Changes in the zone included:

- ~15 new tree falls distributed over the length of the zone;
- shifting logs, especially in depositional locations such as wood pile island, which is not unexpected due to the size and frequency of floods in the zone; and,
- at first appearance, one cobble bar appears altered between the photos, however image enhancement suggests that water level differences are responsible for the differences.

The tree falls, shifted logs and exposed woody debris are indicated on the maps in appendix 2. Water level differences and the tributary mouths are described below.

10.4.6.1 Water level changes

The lower water levels in the 2004 photos resulted in more exposed bars, and more exposure of logs, bedrock and woody debris compared to 1999. Photo 10.23 compares photos from 1999 and 2004 for the same reach in zone 5. The difference in bar exposure is shown at locations labelled A, B, C and D on the photo. At site 'E', which is shown in more detail in Photo 10.24 there is a greater exposure of logs and woody debris in 2004 due to the lower water levels and to a lesser extent, the angle of the photographs. Because of these differences, it was difficult at times to determine whether a 'new' log was actually 'new' since 1999, or just exposed by the lower water levels. In some instances portions of inundated logs were discernible in the 1999 photos, or water flow disturbances (ripples) were present in the 1999 indicating the presence of material sub-surface. In the annotated maps in appendix 2, logs which were readily determined to be 'new' are labelled as such, with others indicated by 'more logs-WL', indicating more logs were visible, but may be attributable to water level changes only.

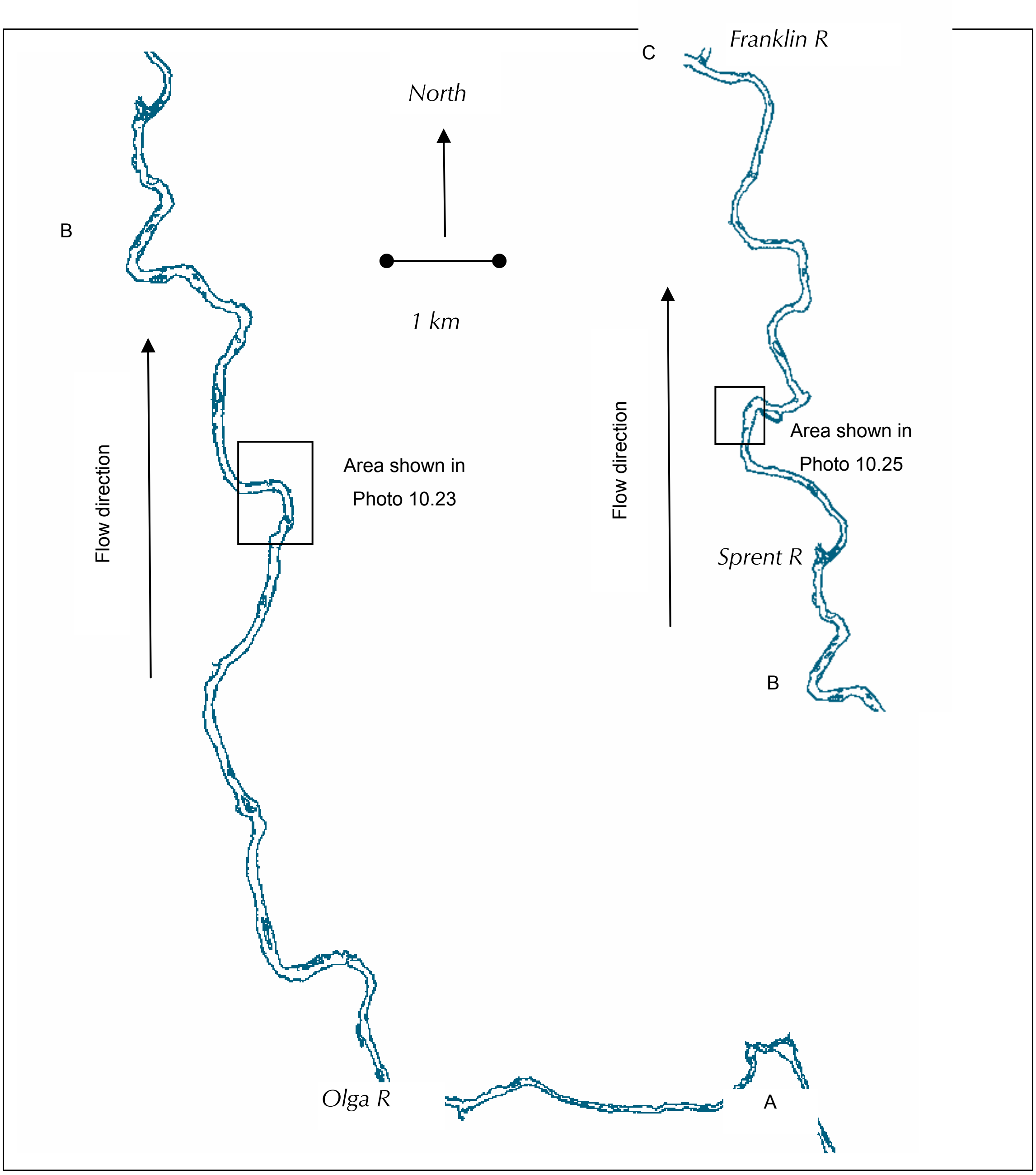
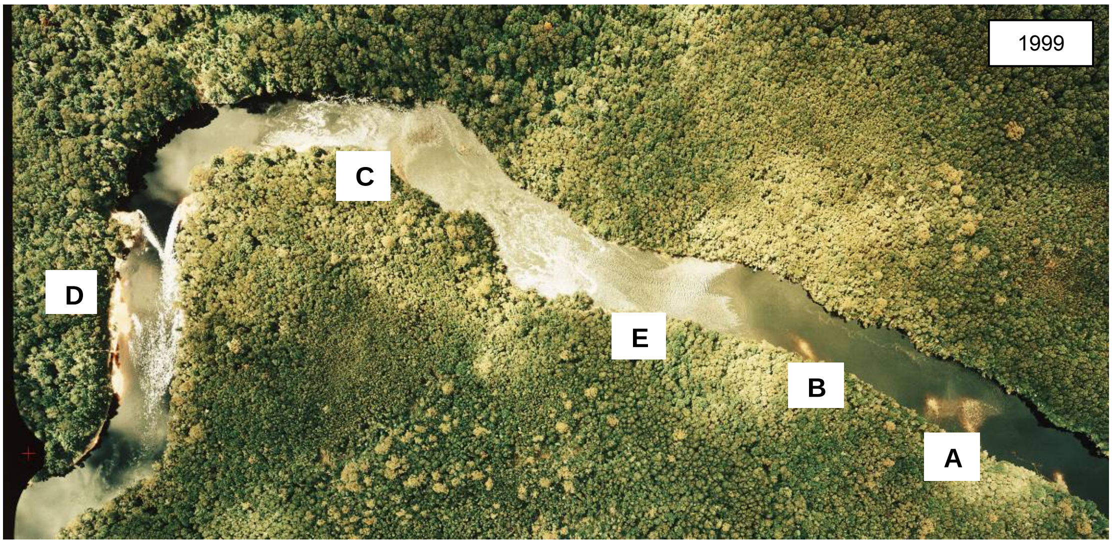


Photo 10.22. Outline of Gordon River in zone 5 as established by aerial photo investigation completed in 1999. Zone starts at Sunshine Gorge ('A') and continues to confluence with Franklin River ('C'). Maps connect at 'B'. Flow is from south to north (bottom to top). The location of photos contained in the discussion are also indicated.



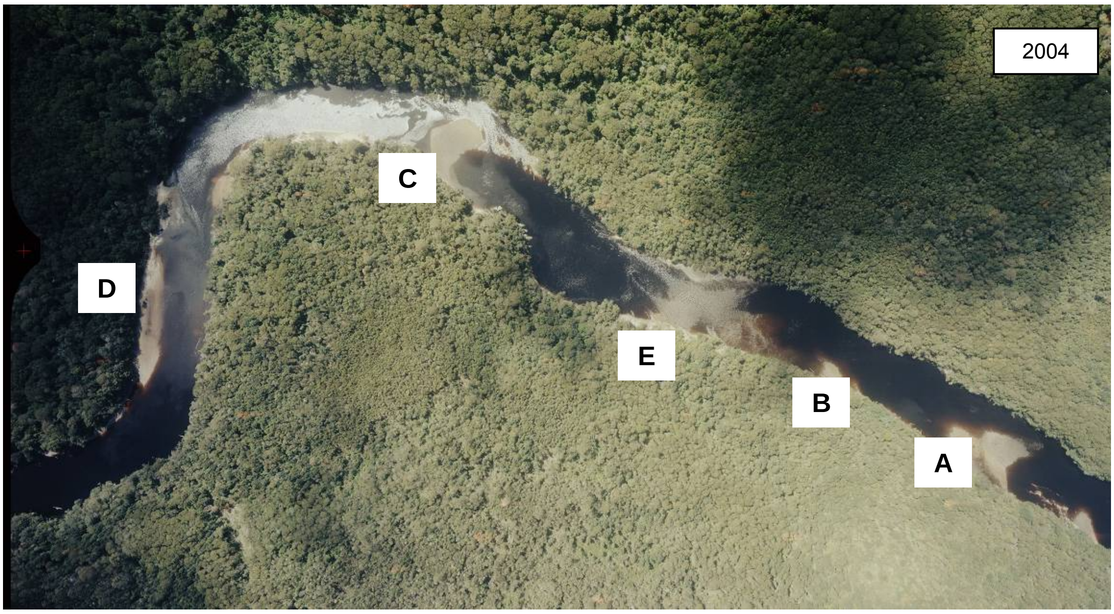


Photo 10.23. Reach in zone 5 downstream of Platypus Creek showing differences between 1999 and 2004 photos due to water level changes. River flows from right to left in photo.

Photo 10.24. Enlarged photo of area 'E' in previous figure showing greater exposure of logs and woody debris in 2004 photos due to changes in water level and minor differences in photo angle.

10.4.6.2 Possible change to cobble bar

There is one exposed cobble bar in zone 5 in the 2004 photos which appears absent in the 1999 photo set. Photo 10.25 compares the photos from 1999 and 2004. The bar on the right side of the photo provides a good indication of the 'typical' differences in bar exposure found between the two sets of photos due to water level changes; the 2004 bar is larger, although the overall shape of the bar is unchanged between the two photos. Photo 10.26 shows enlarged images of the potentially changed site, with the contrast in the 1999 photo reduced to eliminate glare. In the 1999 photo, the outline of the bar is discernible, so it is likely that the bar is very low lying and was obscured by the higher water level in 1999, rather than a new feature. This is consistent with field observations of Hydro Tasmania coxswains who recall the bar being present throughout the pre–Basslink monitoring period (C. McCarthy, pers com).

Photo 10.25. Reach in zone 5 downstream of Sprent River.

Photo 10.26. Comparison of 1999 enlarged photo with 2004 photo. The 1999 image has been sharpened and the contrast reduced to overcome the glare and dark colour of the water. In the 1999 image the outline of the bar is apparent.

10.4.6.3 Mouths of tributaries unchanged

In zone 5, the Olga, Sprent and Franklin Rivers enter the Gordon. These are large tributaries, and increase flow in the Gordon considerably. Unlike the tributary mouths in zones 2–3 (Albert and Orange) which have undergone additional tree fall between 1999 and 2004, the zone 5 tributaries appear to have experienced less change. This is probably attributable to the larger size of the inflowing rivers, and the smaller and slower water level fluctuations associated with power station operations.

Of the three tributaries, the photos of the Olga confluence were the most difficult to interpret due to differences in water levels and photo angles. There may be additional tree fall in the tributary, but it is difficult to confirm.

The mouths of the Sprent and Franklin Rivers are shown in Photo 10.27 and Photo 10.28.

Photo 10.27. Sprent River delta in 1999 (left) and 2004 (right).

Photo 10.28. Gordon and Franklin confluence. Gordon flows from bottom to top in each photo, with the Franklin entering from the right.

10.5 Discussion

The aerial photo analysis of the middle Gordon completed for the IIAS compared 1974 pre–dam photos with 1999 post–dam photos, and established changes associated with damming and flow regulation which occurred over a 25–year period. Between 1974 and 1999, large–scale changes were generally associated with the increase/decrease of vegetation due to:

- increased inundation levels (denudation) or reduced flooding (increased vegetation);
- the elongation of channel bars, presumably due to increased median flows; and
- widening of tributary mouths

These changes reflected the large–scale changes in flow regime (reduced flooding, increased median flows, longer duration high flows) associated with implementation of the dam and river regulation.

The comparison of the 1999 photos with the 2004 photos has not found similar large-scale changes, with drip lines, the Plimsoll line, cobble bars and the extent of vegetation remaining largely unchanged within the limits of detection of the qualitative assessment. The lack of change is not surprising, given that the time between the two photo sets is only five years, and there have not been large-scale changes to the flow regime, with the greatest difference probably relating to the increased duration of 3-turbine discharge from the power station over the whole period. This is a relatively small flow change when compared to the flow changes associated with implementation of the power scheme.

Where the middle Gordon River continues to be active is in the lower reaches of tributaries affected by backwater effects from power station operation, the Gordon and Denison confluence, and zone 2, which is subjected to large fluctuations in water level. The findings of the 1999-2004 aerial photo comparison are summarised as follows:

- although both sets of aerial photos were acquired during summer with no discharge from the power station, flow conditions differed between the two dates, with water level during the 1999 aerial photo run higher than during the 2004 runs. The water level difference was small in the upstream zones, and did not affect the ability to detect changes. With distance downstream, the difference in flow levels increased, reaching a maximum in zone 5 where water levels differed by ~0.5m (1999 higher). In places this hindered the ability to identify 'new' logs in the river as opposed to existing logs which were present, but not visible, in 1999;
- water level differences did not hinder a comparison of major features in the middle Gordon, and no major changes to channel form were observed between the two sets of photos in any of the geomorphic zones;
- features such as existing tree falls showed little change over the five-year period. Common changes included the loss of leaves and small branches, and the realignment of woody debris with respect to current direction; and
- additional tree fall has occurred in all zones. In zones 1 and 3-5, new tree fall 'rates' are approximately one new tree fall per km of zone length, as shown in Table 10.2. Zone 2 has a much higher rate of tree fall, with 15 new falls identified over the 3 km reach. In all of the zones, these additional tree falls have generally occurred as single tree events distributed throughout the zone, with little impact on the surrounding bank evident in the aerial photos. In zone 2, three of the tree falls have lead to modification of the bank which is discernable in the air photos and, in zone 4, one tree fall has lead to bank modification.

Table 10.2. Summary of new tree falls by zone in 2004 aerial photos as compared to 1999 aerial photos

Zone	Length	No. new tree falls
1	5	5
2	3	15
3**	5	3
4**	5	6
5	15	16

*recognising errors probably increase downstream due to differences in water levels

**excluding the Gordon and Denison confluence

- cobble bars showed very few changes through the middle Gordon River. In zone 1, the 'construction bar' has undergone some loss of material, and in lower zone 2, a tree fall has altered flow across one bar. No evidence of erosion of cemented cobble bars was found in the aerial photos;
- vegetation was largely unchanged in the middle Gordon River, with the exception of areas within gorges where vegetation above the power station-controlled high-water level may have increased over the past five years;
- the lower reaches of tributaries entering the Gordon in zones 1-3 have shown additional tree falls in areas inundated by 3-turbine power station operation;
- the Gordon and Denison confluence and the reach immediately below the confluence show additional tree falls and bank slumping over the past five years;
- the aerial photos do not allow detection of bank changes known to occur during the 1999-2004 period due to the small scale of bank erosion (mm $yr^{-}1$) , and the screening of banks by overhanging vegetation; and
- ground-based photo-monitoring has documented most of the changes identified using the aerial photographs.

11 Trigger value reports

The Gordon River Basslink Monitoring Program was set up in order to monitor and document the pre- and post-Basslink condition of the Gordon River such that adjustments in response to Basslink operations could be detected and if necessary, be acted upon.

As part of the licence requirements for Basslink, Hydro Tasmania has conducted baseline environmental monitoring in the middle Gordon River and must identify 'trigger values' against which post-Basslink monitoring results will be compared. The trigger values are to be based on the pre-Basslink range of monitoring results obtained in the Gordon, and used as a basis for identifying potential post-Basslink change.

Draft trigger values were presented in the Basslink Baseline Report (BBR) and the approach to finalise the trigger values was agreed upon at the Scientific Reference Committee (SRC) meeting in April 2006. During the meeting the committee broke into two groups (one for fish, macroinvertebrates and algae and one for geomorphology and riparian vegetation) to review final trigger values for the individual disciplines. The groups considered:

- key indicators;
- significant ecological effects; and
- review of interim trigger values.

They assigned a priority to indicators based on ecological significance, sensitivity to change, and pre-Basslink variability.

The SRC concluded as a whole that water quality and karst geomorphology variables will not be considered as trigger values but should be continued to be monitored to assist interpretation of post-Basslink effects.

This section provides the full set of final trigger value reports for each discipline being monitored as part of the Basslink investigations. These reports provide the trigger values for each discipline, and were prepared by the researchers undertaking the monitoring following the incorporation of final data from spring 2005 and the decisions made at the SRC meeting in April 2006. Each described the method used to develop the trigger values and proposes the action required should a trigger values be exceeded. Should a trigger value be exceeded, an appropriate action will be developed with the Regulator at the time.

For each of the disciplines where formal trigger levels have been required, triggers have been set by compiling the pre-Basslink data sets for the nominated indicator variables, and defining confidence levels around the mean. The studies have either adopted 95 % as the confidence level or set other values as appropriate for the indicator variable in question.

In order to compare post–Basslink data to the trigger levels, it is intended in some disciplines to utilise the average of all post–Basslink data to date to obtain increasing levels of accuracy around the post–Basslink mean as the monitoring program progresses. When these mean values are to be assessed against the trigger levels, the range of the trigger levels are contracted from one year to the next in order to compensate for the increasingly less variable post–Basslink mean. When simple annual averages are compared against the trigger levels, no adjustment to the trigger levels from year to year will be made.

Although it varies between disciplines, there is generally a three stage response to a breach of a trigger level. Initially there is a 'note and explain' response where the exceedence is investigated in the context of other supplementary information. If no suitable explanation for the exceedence can be made or there are consistent breaches of the trigger value, then additional investigation is required to determine the cause. The third level of response dictates that the need for management intervention should be investigated and appropriate mitigation actions implemented. Such actions would be triggered when there was consistent decline in the health of the Gordon River and the change in condition could be attributed to Basslink–related hydrological changes.

11.1 Water quality trigger values report (L Koehnken & G McPherson)

11.1.1 Introduction

In the BBR, the ANZECC/ARMCANZ (2000) approach for establishing water quality guidelines was adopted, with trigger values set at the 20th or 80th percentile of reference site values (pre-Basslink monitoring results). These values have been reviewed during formulation of final trigger values for all disciplines, and changes to the draft trigger values are proposed based on additional statistical analysis. Water quality monitoring in the middle Gordon has identified dissolved oxygen levels and temperature as the parameters most affected by power station operation.

11.1.2 Concept of trigger values for water quality parameters

11.1.2.1 Dissolved oxygen

Dissolved oxygen levels at the power station intake are influenced by lake level, and the dissolved oxygen structure present in the water column. Dissolved oxygen levels can be modified as the water passes through the power station, where air injection can greatly increase levels. Operating rules have been in place at the power station since 2002 which aim to minimise the incidence of low or high dissolved oxygen water being discharged to the river through the managed use of air injection.

Dissolved oxygen levels are also modified immediately downstream of the power where the discharge flows turbulently through a steep, rough gorge. Investigations have shown that this turbulence increases dissolved oxygen concentrations if low, and decreases concentrations if high, so the risk of high or low dissolved oxygen conditions persisting in the middle Gordon River is very low even in the absence of management controls at the power station.

Under Basslink, dissolved oxygen levels will continue to be actively managed at the power station through the rules implemented in 2002. In this sense, dissolved oxygen is not a Basslink-related issue, but rather a present and ongoing management issue. The trigger values derived in the BBR reflect three years prior to implementation of the air injection rules, and the three years since the rules came into effect. Given the management of dissolved oxygen at the power station, it must be recognised that maintaining dissolved oxygen values post-Basslink within these trigger values will be as much (if not more) a measure of the success of management procedures rather than detecting Basslink change.

Recognising that dissolved oxygen is an important parameter, even though the risk of high (>12 mg/L) or low (<6 mg/L) dissolved oxygen levels persisting downstream is very low, it is proposed that it is monitored, with the results reported annually.

11.1.3 Temperature

Trigger values as defined in the BBR are of little relevance with respect to temperature because the temperature regime of the middle Gordon is largely controlled by the patterns of power station discharge. Although the influence of discharge is not uniform throughout the year (as discussed in the following sections) it is a controlling factor which will change post-Basslink, with a more uniform distribution of flow through the year, increased short-term frequency of operation, and the inclusion of a minimum environmental flow.

A compounding factor is that the temperature at the power station intake in Lake Gordon is dependant on the depth of the intake relative to lake level and the water column temperature profile. Temperature profiles within the lake are characterised by seasonal warming and stratification during summer, and uniform temperature profiles during winter. This combination of seasonal temperature cycles and changing lake levels results in the inflow temperature to the power station not being uniform within or between years.

Trigger values for temperature are therefore of little relevance, as it is recognised that the hydrology of the river will change which will inherently lead to a change in the temperature regime. Because temperature cannot be separated from the discharge of the power station, the parameter is better considered an input variable to the downstream environment, similar to hydrology, rather than a response variable such as geomorphology, macroinvertebrates, vegetation or fish. It is recommended that the parameter be monitored, with results analysed, reported in the annual report and provided to other researchers for use in the analysis of biological monitoring results.

Of more use than defining trigger values, is the understanding of processes presently controlling water temperature variability in the middle Gordon River, so that post-Basslink monitoring and analysis can focus on those aspects most likely to change. The following sections of this report present the results of analyses that may assist in understanding the processes controlling water temperature variability.

11.1.4 Analysis of water temperature

11.1.4.1 Available data & limitations

For the pre-Basslink monitoring period (2000-05) water temperature data is available for:

- site 75 in the middle Gordon River which is approximately 1 km downstream of the power station;
- site 62, which is located on the left bank (viewing downstream) of the Gordon and Denison confluence; and
- site 39 situated on the Gordon River downstream of the Franklin River.

These data sets have limitations which have restricted the statistical analysis, including:

- there are substantial gaps in the record from site 75 (downstream of the power station);
- site 75 is a poor surrogate for power station discharge because:
    - There is poor agreement between the water temperatures from lake profiles at the depth of the intake, and the temperature recorded at site 75 on corresponding dates, suggesting there is modification of water temperature between the intake and site 75; and
    - site 75 is subject to rapid warming/cooling during power station shutdowns;
- the temperature record at site 62 (downstream of the Gordon and Denison confluence) strongly reflects the record from site 75, showing little variation due to unregulated inflows, even during winter when the Denison inflow would be expected to dominate flow. This is believed to be due to the positioning of the probe on the southern bank of the Gordon, within ~200m of the confluence of the two rivers. At this site, mixing of the two rivers has probably not occurred, and the probe is located on the 'Gordon' side of the mixing zone;
- there is no suitable temperature or flow data available for the Denison River or other unregulated tributary in the middle Gordon River which prevents comparison of the power station discharge temperature with local conditions; and
- the accuracy of the temperature probes is ±0.5 °C which is greater than the differences in temperatures frequently recorded between sites.

Supplementary information that was considered of potential value in explaining changes in water temperature is provided by:

- hourly flow data from the power station;
- daily and average monthly lake levels in Lake Gordon
- seasonal water temperature profiles in the lake at the input point which together with the lake level provide the seasonal temperature of the water being drawn into the power station,
- monthly average air temperature at the tail race and at Strathgordon,
- monthly average rainfall at Strathgordon. (Rainfall figures were also obtained from Mt Fincham but had too many missing values to be of use.); and
- monthly average water temperature from Huon River at Judbury (DPIW site) which is judged to be the unregulated river with temperature records that most nearly matches what is expected in the tributaries of the Gordon River.

Because most of the supplementary data are available only on a monthly basis, and given that the primary variation is from month-to-month, most analysis is based on monthly figures. In general the monthly summary data comprise average values. However the median, minimum and maximum flow rates were also determined, as was the interquartile range, to reflect the variability in flow across a month which incorporates the on-off frequency.

It is noted that the existing chapter on water quality in the BBR provides a detailed study of short-term changes in water temperature which demonstrate the dominant control of the power station on downstream temperatures. This short-term analysis is not revisited in this report.

11.1.4.2 Factors affecting water temperature

11.1.4.2.1 Temperature profiles in Lake Gordon

The temperature profiles in Lake Gordon (presented in BBR, and reproduced in Figure 11.1) show considerable annual and inter-annual variation due to summer thermal stratification, and winter deep mixing. Superimposed on these seasonal cycles is the effect of lake level, which determines from what depth water will enter the power station via the intake. The intake opening to the Gordon Power Station is approximately 5m high, and during the pre-Basslink monitoring period was situated between ~20–45m below the surface of the lake (depending on lake level). These depths correspond to the region of the thermocline in summer, resulting in the ingress of water with variable temperature during this period. There is also evidence that, during periods of lake stratification (summer) as flow rates increase through the power station, water is drawn preferentially from above the intake level, as compared to below the intake level, due to density differences (the warmer surface water in summer is less dense). This results in warmer water being discharged from the power station as compared to the lake water temperature at the 'elevation' of the intake (254m) used in the analysis. Based on the lake profiles, the range of water temperature entering the power station is ~7 °C to 14 °C, assuming intake depths of 20–45 m.

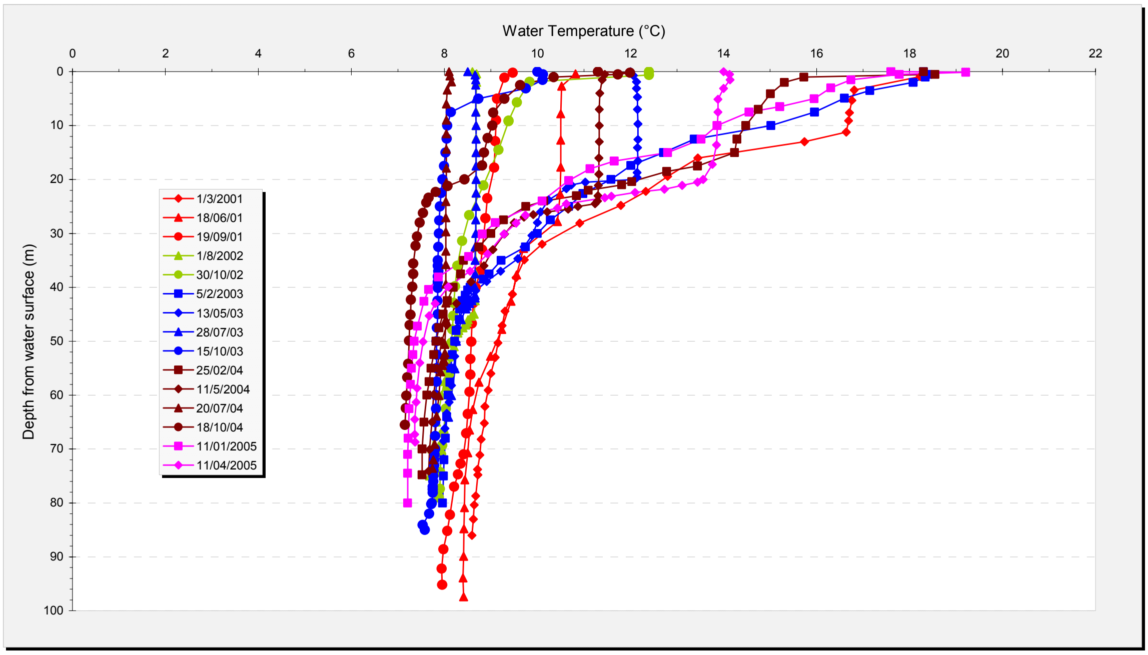


Figure 11.1. Temperature profiles from the Lake Gordon near the intake.

11.1.4.2.2 The annual pattern

There is a strong and well-defined pattern of change in water temperature across a year as is evident in the plots of average monthly water temperatures at the monitored sites (Figure 11.2, Figure 11.3) with a peak around March and a trough around September. Figure 11.2 shows the amplitude of temperature change is not consistent between years. Also shown on the plot is the average monthly temperature record from the Huon River at Judbury, an unregulated river (except for the diversion of water from the headwaters into the Gordon). Although there is limited overlap between the Gordon and Huon records, it is evident that the unregulated Huon River has a larger temperature range, with summer maxima and winter minima occurring one to two months earlier than in the regulated Gordon River. The amplitude of the Huon temperature record is also variable.

A comparison of the Gordon below power station temperature with the Gordon below Denison and Gordon below Franklin temperature records (Figure 11.3) show there is warming as the water flows downstream in summer, and cooling in winter. However, there is no pattern to the seasonal extremes, with summer maxima in 2001 and 2002 at the downstream sites being equivalent to the maxima recorded at the Gordon below power station site, and the 2003 maxima downstream being greater than the below power station site. Similar differences exist for minimum temperatures.

The average monthly water temperature at the Gordon below Denison site is typically higher in summer than the Gordon below power station site but with little difference in winter (Figure 11.4). This is perhaps surprising given that the proportion of water coming from tributaries is expected to be high in the winter when rainfall is high and power station operation is relatively low, and low in the summer when the water is overwhelmingly from the power station. This is probably at least partially attributable to the position of the Gordon below Denison temperature probe on the 'Gordon' side of the river below the confluence, as discussed in section 11.1.4.1.

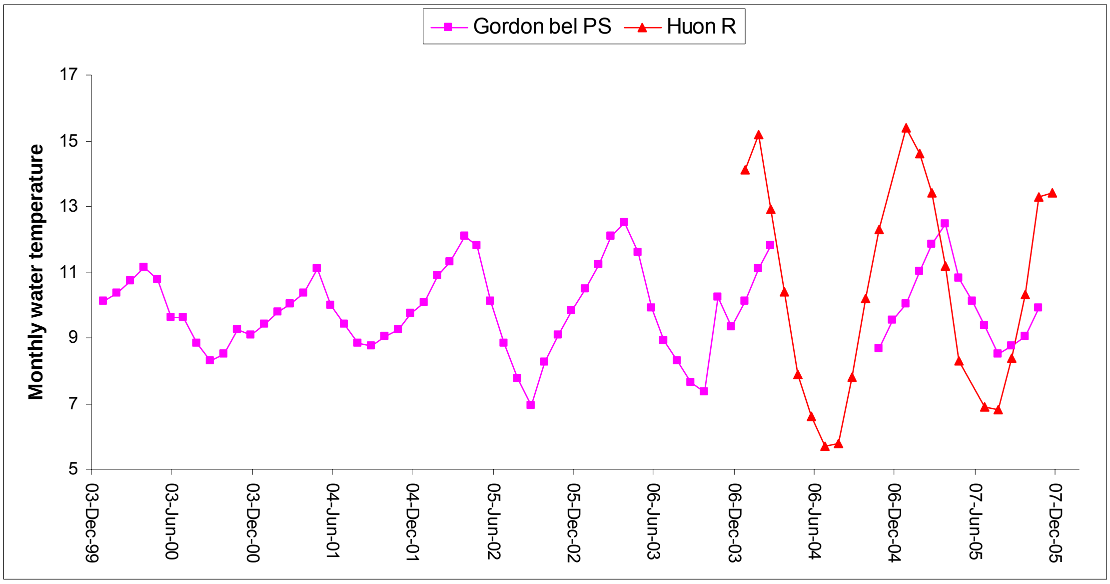


Figure 11.2. The monthly average water temperatures at the Gordon River below the power station, and the unregulated Huon River at Judbury.

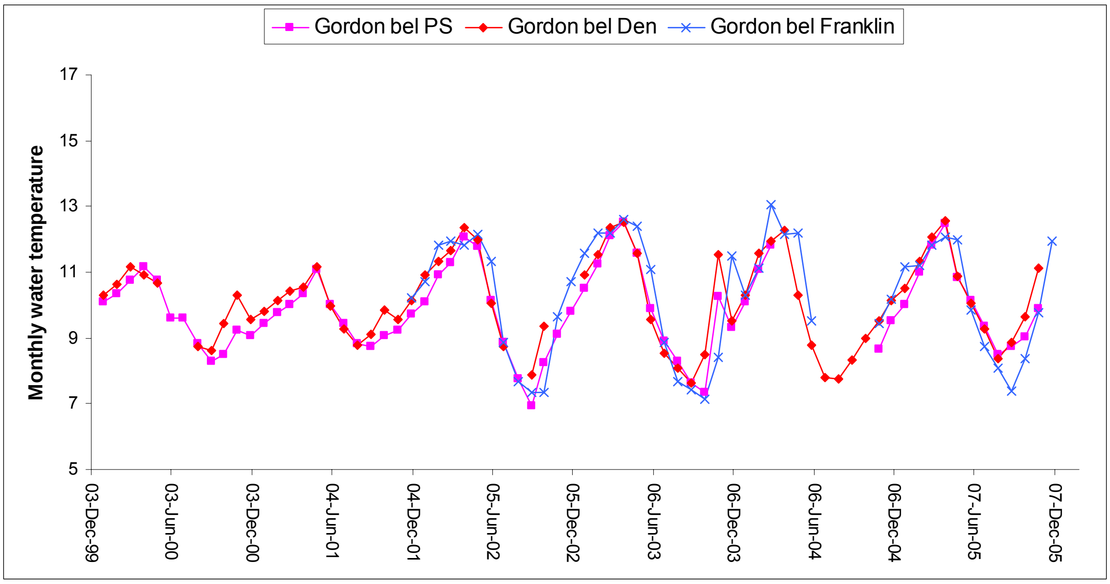


Figure 11.3. The monthly average water temperatures in the Gordon River. Temperature shown for the Gordon River below the power station, the Gordon River below the Denison River and Gordon River below the Franklin River.

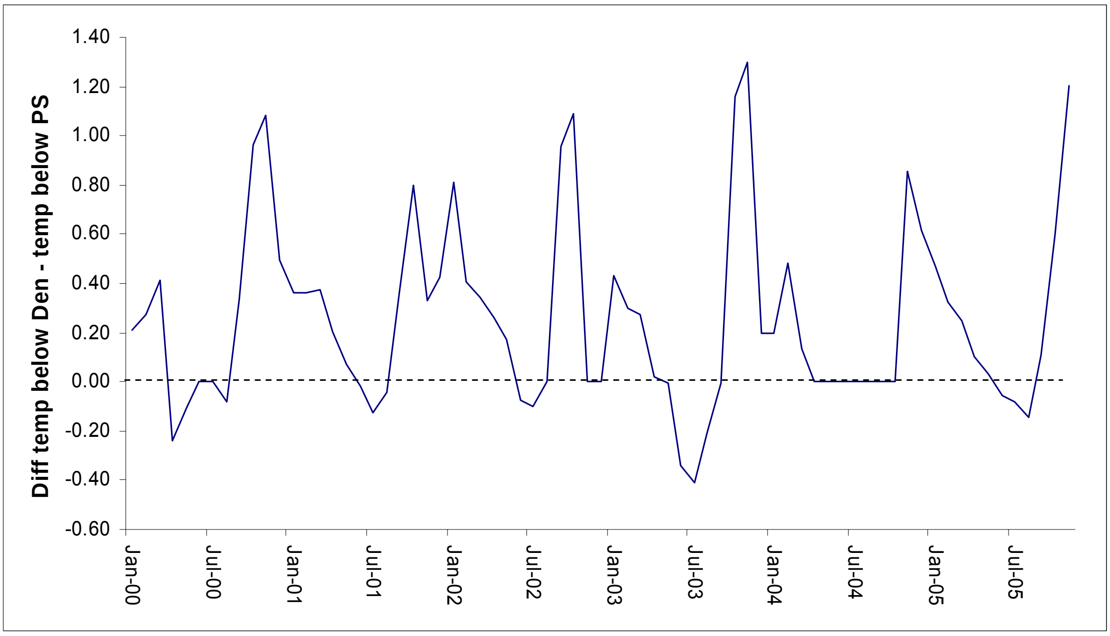


Figure 11.4. Difference in average monthly water temperature at the Gordon below Denison site and the Gordon below power station site. Negative values indicate water below power station is colder than water below Denison.

11.1.4.2.3 Influence of flow rate on water temperature

Figure 11.5 superimposes average monthly flow rate on the water temperature plots for the period from January 2000 to November 2005, showing the general coincidence of temperature and flow patterns. Flow rate is potentially one of the inputs that influences water temperature, and is an input variable that is likely to change substantially in the post-Basslink period, due to the anticipated flow changes (a more consistent flow rate throughout the year; minimum environmental flow rate of 10 $m^3 s^{-1}$.

A compounding factor in identifying the importance of flow magnitude in controlling temperatures in the Gordon is that under the present operating regime of the power station, temperature minima and maxima correspond with flow minima and maxima. That is, temperatures are greatest when flow from the power station is highest, with minimum temperatures coinciding with low power station discharge. This makes separating the impact of flow magnitude from seasonal changes difficult.

An additional complication in determining whether temperature in the river can be determined from changes in outflow temperature from the dam coupled with flow rates is that the influence of power station flow on downstream temperatures varies through the year, depending on the difference between water temperature in Lake Gordon, and the downstream ambient conditions. When the difference in temperature between the intake temperature in the lake and unregulated inflows is high, the amount of flow discharged from the power station exerts a strong influence on temperatures in the middle river (such as in summer, when power station discharges are cooler than unregulated inflows). However, when lake intake temperatures are similar to unregulated inflows, the flow magnitude does not affect downstream temperatures. The lack of information on the temperature of tributary inflows further compounds the analysis.

To overcome these limitations as much as possible, the temperature data at the monitoring sites was divided into seasons, and water temperatures at the monitoring sites were compared with the lake profile temperature corresponding to 254 mASL (level of intake), assuming that based on the trends in Figure 11.3, that higher flow rates would result in a closer correspondence between water temperature in the dam, and at the downstream monitoring sites. The values used in this analysis are contained in Table 11.5 and graphs showing the results of these comparisons are contained in Figure 11.6 and Figure 11.7.

Figure 11.6 shows that during cold months, when discharge from the power station is relatively low and temperature profiles in the lake are uniform, there is little difference between the lake temperature and Gordon below power station temperature. During the warm months, when the lake is stratified and flow rates are high, the temperature below the power station is up to 2 °C higher than the temperature at the intake depth (254 mASL) in Lake Gordon. As the below power station site is only ~1 km downstream, and flow rates are very high, it is highly unlikely the 2 °C difference is due to ambient warming. More probable is that during periods of high discharge from the power station, water is drawn from at and above the intake level in Lake Gordon. During the warmer months, the water that is higher in the water column is warmer than the nominal 254 mASL level water used in this analysis.

The same analysis for the Gordon below Denison site (Figure 11.7) shows that during the colder months, there is greater variability as compared with the below power station site, suggesting that tributary inflows and ambient warming and cooling exert some influence on the temperature of the river during periods of low flow. During the summer months, the difference in water temperature between the lake and the below Denison site is the same as between the lake and the below power station site, indicating very little modification of temperature occurs between the below Power station and below Denison sites, as shown in Figure 11.7.

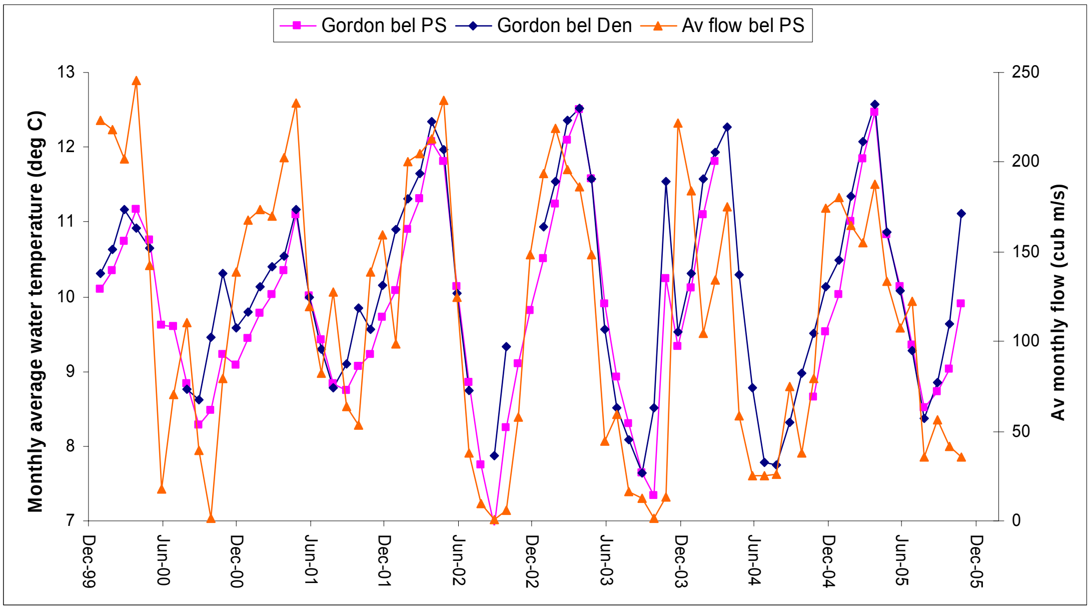


Figure 11.5. Average monthly flow rates superimposed on the water temperature curves.

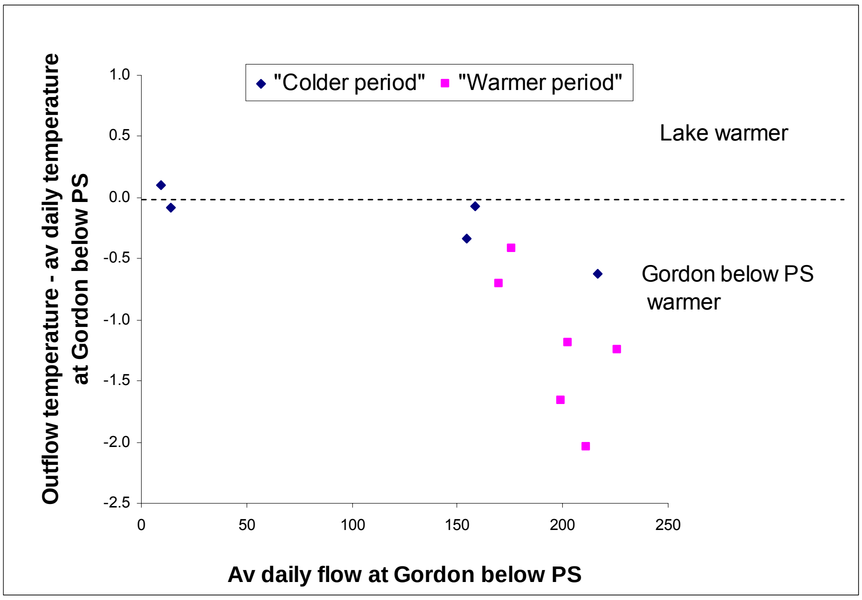


Figure 11.6. Difference between water temperatures at the Gordon below power station monitoring site and water temperature in Lake Gordon at the depth of the intake (254m) compared with flow rates from the power station.

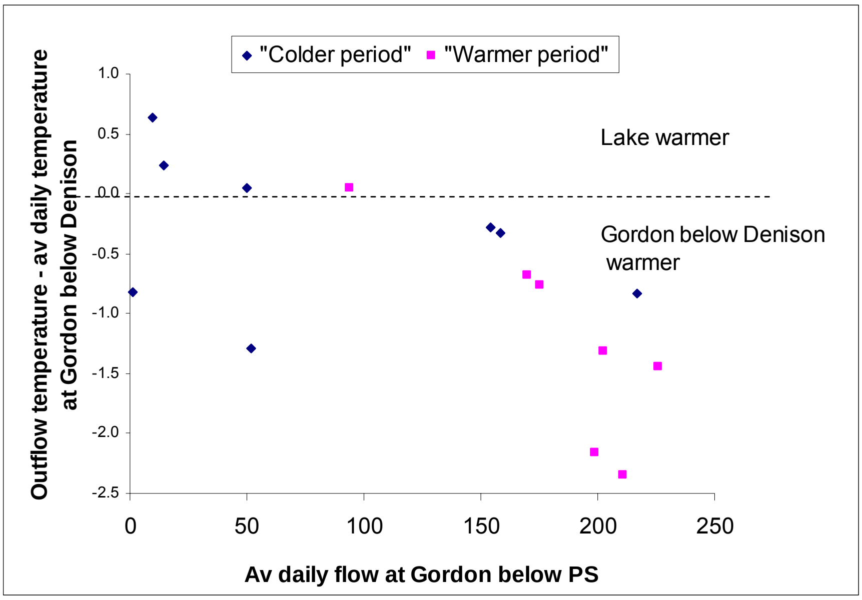


Figure 11.7. Difference between water temperatures at the Gordon below Denison River monitoring site and water temperature in Lake Gordon at the depth of the intake (254m) compared with flow rates from the power station.

Table 11.1. Water temperature for the intake level at the dam, the Gordon below power station and the Gordon below Denison plus the flow at the Gordon below power station. Note that water temperatures and flow rates are interpolated values at the specified dates constructed from monthly averages.

Period	Date	depth to intake	Lake temp at outflow	Temp at G bel PS (interpolated)	Flow at G bel PS (interpolated)	Temp outflow – temp G bel PS	Temp G bel Den (interpolated)	Temp outflow – temp G be Den
Colder	31/08/2000	37.7	8.2	8.8	216.8	–0.62	9.01	–0.83
	19/09/2001	32.2	8.8	8.9	158.7	–0.07	9.1	–0.33
	1/08/2002	21.6	8.7	8.8	14.2	–0.08	8.5	0.24
	28/07/2003	21.5	8.7	8.6	9.4	0.10	8.0	0.64
	15/10/2003	28.4	7.9		1.3		8.7	–0.82
	20/07/2004	26.6	8.0		50.0		8.0	0.05
	18/10/2004	31.1	7.4		51.8		8.7	–1.28
	19/07/2005	22.25	8.9	9.2	154.3	–0.33	9.1	–0.28
Warmer	11/05/2004	36.7	9.5	9.9	175.5	–0.41	10.3	–0.76
	25/02/2004	30.9	9.8	11.0	225.9	–1.24	11.2	–1.45
	13/05/2003	21	11.0	11.7	169.7	–0.70	11.7	–0.68
	1/03/2001	26.3	9.3	11.3	211.0	–2.03	11.6	–2.35
	11/01/2005	22.4	11.2		94.0		11.2	0.05
	11/04/2005	29.4	8.3	10.0	199.0	–1.66	10.5	–2.16
	5/02/2003	23.7	11.3	12.5	202.5	–1.19	12.6	–1.31

11.1.4.2.4 Air temperature and rainfall

The possibility that the unexplained fluctuations in water temperature at either site could be related to air temperature changes was explored but no link was found. The same applies to rainfall variations which do not contribute to an explanation of the pattern of differences between water temperatures at the Gordon below power station site and the Gordon below Denison site.

11.1.4.2.5 Summary of factors controlling temperature in the middle Gordon

The following factors have been found to account for the temperature regime documented in the middle Gordon River:

- the seasonal warming and cooling of Lake Gordon controls the seasonality of water temperature in the middle Gordon. Due to the thermal mass of the lake, winter minima and summer maxima occur later than unregulated tributaries by one to two months, and the magnitude of the extremes is less than that found in unregulated tributaries. Water temperature in the lake in the vicinity of the intake can range between 7 °C to 14 °C;

- during periods of low discharge from the power station, the temperature regime of the river above the Denison reflects the discharge from the power station. Downstream of the Denison, the water temperature of low power station flow can be modified through warming or cooling by inflows from the Denison by up to about 1°C; and
- between the Gordon below Denison River site and Gordon below Franklin River site, the temperature of the power station discharges are heated and cooled seasonally. Although the data is sparse, seasonal maxima and minima may be shifted about one month earlier, similar to patterns observed in unregulated tributaries.

11.1.5 Implications of findings on trigger values

Because water temperature is strongly dependent on systematic variation in flow rate that is determined by electricity demand and management decisions, and lake water levels, there is no meaningful basis on which trigger values can be set. The pattern of flow rate has been constantly changing in the pre-Basslink period in a complex way that makes it very difficult to model the flow/temperature relationship.

The primary assumption in setting trigger values using pre-Basslink data for application in the post-Basslink period is that the post-Basslink conditions are presumed to be the same conditions as applied in the pre-Basslink period. It is known that they will not be the same in respect of flow rate and hence water temperature. Indeed, even if there were no Basslink intervention we can confidently say that the flow rate pattern after April 2006 would not be the same as that seen in the previous period because of the changing circumstances for power requirements, rainfall patterns and water level management.

Logically, water temperature should be considered an **input** variable, similar to hydrology, which will change under Basslink as the flow regime changes. The value in data on water temperature lies in its possible explanatory value of changes in the biota where the trigger values for biota provide evidence of possible post-Basslink change.

The above conclusion relates not only to water temperature at both points of observation but also to the difference in water temperature between the points. As established above, the difference is a function of flow rate. Furthermore, evidence is presented that suggests the placement of the temperature probe below the Denison is not reflecting the input from the tributary, i.e mixing of water from the two sources has not occurred at the site of the probe. Hence the intended aim of determining the difference in water temperature before and after input from the tributary has not been realised.

11.2 Fluvial geomorphology trigger values report (L Koehnken)

11.2.1 Introduction

Draft trigger values were presented in the Basslink Baseline Report (BBR), published in December 2005. Following publication of the BBR, it was determined that additional analyses could be completed for some disciplines, and that more recent monitoring results should be incorporated for all disciplines prior to finalising the trigger values for inclusion in Hydro Tasmania's Special Water Licence. This paper discusses supplementary information considered for fluvial geomorphology and provides a final summary of trigger values and additional qualitative indicators which will be monitored post-Basslink commissioning.

11.2.2 Development of geomorphology trigger values

11.2.2.1 Overview

In the Basslink Monitoring Program, disciplines have identified trigger values based on the present condition of the river as documented by the pre-Basslink monitoring results. Adopting this approach for geomorphology is problematic for the following reasons:

- the banks of the Gordon are not in equilibrium with the pre-Basslink flow regime of the river, and are continuing to respond to the initial damming and flow regulation and/or the increased operation of three turbines since 2000;
- present monitoring results are limited to three to five years, and are inadequate to establish where the river is with respect to final adjustment to the regulated flow regime, i.e is the river nearing dynamic equilibrium with the present flow regime, or is it years or decades away?;
- erosion and deposition are not occurring consistently in each zone. Figure 11.8 shows the mean erosion (+) or deposition (-) trends for the five geomorphic zones. The graph shows that erosion has occurred over the pre-Basslink period in zones 2-4, with zone 1 showing little change, and zone 5 showing a small depositional trend;
- given the limited number of pre-Basslink times of observation plus the potential for correlation among successive responses, there is uncertainty as to the nature of the long-term trend that must be assumed if trigger values are to be applied.

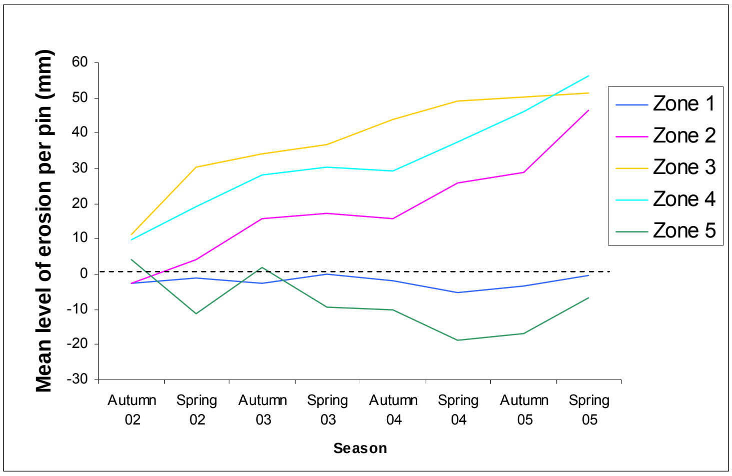


Figure 11.8. Mean erosion in zones 1–5 based on erosion pin results grouped by zone.

- the differences in the mean erosion trends of the zones is underlain by differences in how erosion is occurring in each zone, and suggest that the zones may be at different points in the adjustment process. Zone 1 appears stable with low rates of erosion or deposition. Figure 11.9 and Figure 11.10 show how erosion is occurring in each of the other zones, with the monitoring results grouped by turbine level for zones 2 and 3, and zones 4 and 5, respectively. Figure 11.9 shows that in zones 2 and 3 toe erosion (<1 turbine level) is low, with relatively high rates of erosion in the 1–2 and 2–3 turbine bank levels, which are driving the overall erosion rate. In zones 4 and 5 there is a high rate of toe erosion (<1 turbine level), but low rates of erosion in the 1–2 and 2–3 turbine bank levels. The relative stability of zone 1 combined with the processes depicted in the graphs are consistent with an erosional wave progressing downstream, at an unknown rate; and

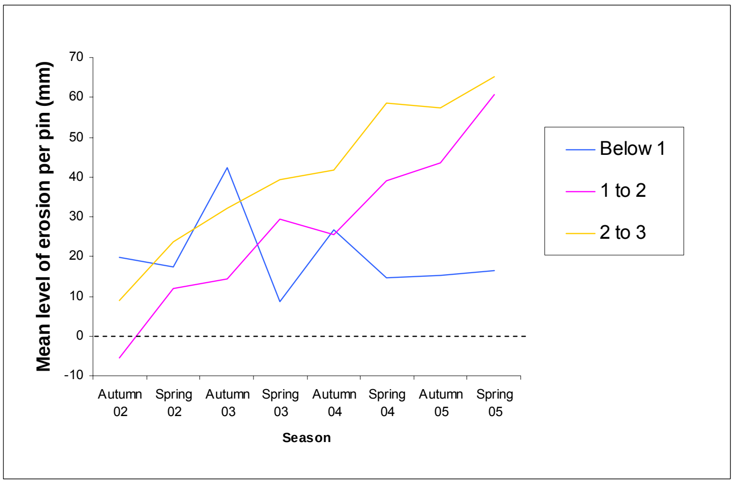


Figure 11.9. Mean erosion (+) or deposition (–) in zones 2 and 3 showing pin results grouped by turbine level.

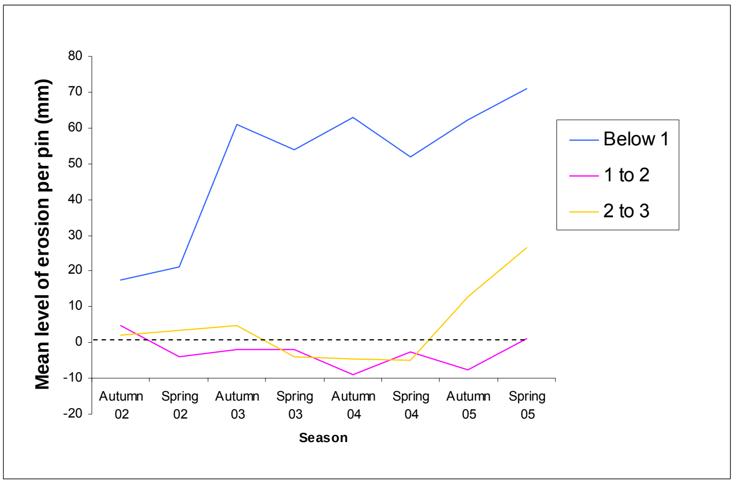


Figure 11.10. Mean erosion (+) and deposition (–) in zones 4 and 5 showing pins results grouped by turbine level.

- given the present understanding of processes and trends in the river, it is recognised that erosion processes *will* change in the future, for example, the erosion of bank toes in zones 4 and 5 cannot continue indefinitely without eventually leading to over-steepening and collapse of the 1-2 and 2-3 turbine zone. In zones 2 and 3, eventually the erosion rate in the 1-2 and 2-3 turbine level will decrease, but following this, there may be renewed erosion in the <1 turbine level.

Because of the non-equilibrium condition of the river at present, there is inherent risk in assuming the present rates of erosion will continue indefinitely into the future. However, the present trends can be assumed to be stable for as long as the underlying trends and processes remain unchanged. That is, for as long as erosion in zones 2 and 3 is predominantly occurring in the 1-2 and 2-3 turbine bank levels, the present net rate of erosion in the zone can be viewed as a reliable trend of bank behaviour. Similarly, as long as the 1-2 and 2-3 turbine levels in zones 4 and 5 show no change, the erosion rates for the zones can be used viewed as a trend.

Based on this approach, the present erosion trends in each zone (Figure 11.8) have been extrapolated and adapted as trigger values to detect post-Basslink change. However the interpretation of monitoring results with respect to trigger values will require a multi-step process with erosion pin and other results (discussed in Section 11.2.3) first interpreted with respect to the underlying trends and processes presently recognised as occurring in each zone. If the findings are consistent with the pre-Basslink understanding of how the river is responding to flow regulation, then a comparison of mean erosion pin rates by zone with predicted values can be made and considered.

11.2.2.2 Geomorphic trigger values

Geomorphic trigger values have been derived by the consulting statistician for Basslink (G McPherson) by applying a linear fit to the pre-Basslink erosion pin results shown in Figure 11.8 and extrapolating six years into the future with a 95th percentile confidence interval. The 95th

percentile confidence interval was agreed upon by the Scientific Reference Committee as a default, as it is consistent with national water quality guidelines and policies. Background information about the statistical analysis and interpretation of these trends is contained in the Basslink Baseline Report, and annual monitoring reports. It is noted that the location of the trigger values is dependent on the assumption that in the absence of a Basslink effect there would be a constant rate of erosion over the period of prediction. There is uncertainty associated with this assumption that cannot be built into the positioning of trigger values because of our lack of knowledge as to how the erosion processes are proceeding.

The graphical results of this statistical analysis are shown in Figure 11.11. Each graph shows the predicted mean erosion value (line), with the dashed lines depicting the minimum and maximum values of the 95th percentile confidence interval. All values are relative to the spring 2001 monitoring results, when pre–Basslink monitoring began. The trigger values are defined as the upper limit of predicted erosion for each zone, with the monitoring results from the autumn (March) sampling used each year for comparison. A summary of these trigger values are presented in Table 11.2 as cumulative erosion relative to spring 2001, and in Table 11.3 as annual rates. The annual rates were derived by dividing the predicted values in Table 11.2 by the number of years of monitoring, assuming monitoring dates of 15 March and 15 October each year.

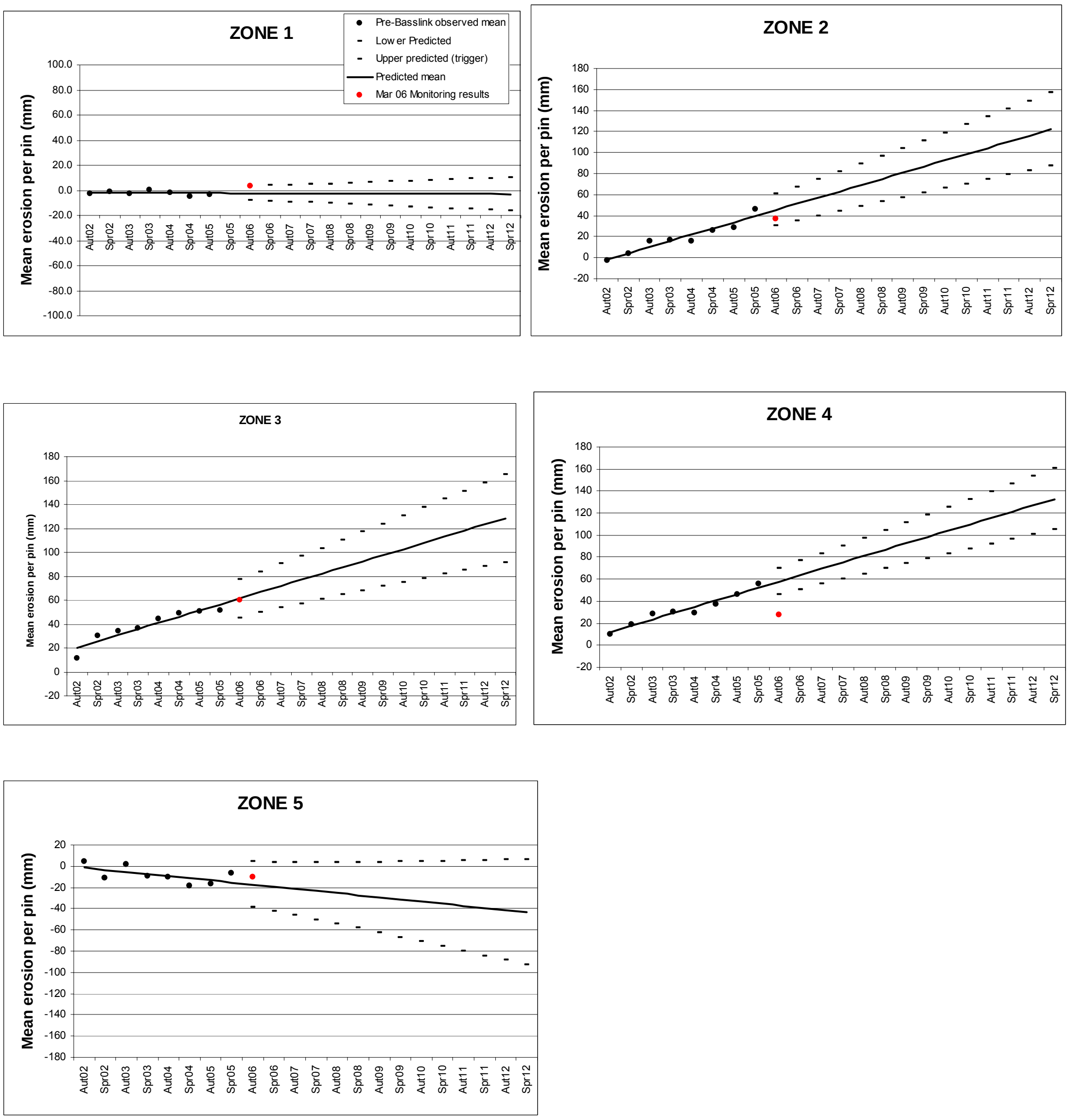


Figure 11.11. Graphical depiction of trigger values, showing linear trend fit to pre–Basslink monitoring results extended six years into the future, along with the 95th percentile confidence limits. The upper limit in each graph are the trigger values for that zone. Also shown are the March 2006 monitoring results. Note upper and lower limit of erosion scales differ, but each axis depicts 200 mm.

Table 11.2. Summary of trigger values for each zone for years March 2007–March 2012 shown as cumulative values relative to spring 2001. Values indicate maximum erosion in mm expected based on present trends. All values in mm.

Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
March 2007	4	75	90	83	4
March 2008	5	89	103	97	3
March 2009	6	104	117	111	4
March 2010	7	119	131	125	4
March 2011	9	134	144	139	5
March 2012	10	149	158	153	6

Table 11.3. Summary of trigger values for each zone for years March 200 –March 2012 shown as annual rates. Values indicate maximum erosion in mm expected based on present trends. All values in mm.

Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
March 2007	0.9	14.9	18.1	16.7	0.7
March 2008	0.8	13.9	16.1	15.1	0.5
March 2009	0.9	14.0	15.8	15.0	0.5
March 2010	0.9	14.1	15.5	14.9	0.5
March 2011	0.9	14.2	15.3	14.8	0.5
March 2012	0.9	14.3	15.2	14.7	0.6

Aside from the uncertainties about future processes and trends with or without Basslink, there is additional uncertainty inherent in the proposed trigger values due to the high variability present in the underlying data set. In Figure 11.11, the width of the 95th percentile envelope is related to the variability of the underlying data, and accounts for the varying confidence intervals between zones. Because the pre-Basslink trend is based on only six data points (three years worth of results), each result exerts a strong influence on the linear trend line and 95th percentile confidence interval. The first data point in zone 3 (autumn 2002), and the last data point in zone 5 (autumn 2006) are good examples of how the predicted trends and confidence intervals have been affected by one monitoring period.

Even in the absence of potential changes to the underlying processes and trends, the length of the post-Basslink projection (six years) relative to the length of the underlying data set (three years) introduces additional uncertainty into the trigger values. The main reason for this is that to date, once an erosion pin record lacks one reading, either through a pin going missing or not able to be located due to inundation, the results from that pin are excluded from the erosion pin analysis. This approach is leading to an ever smaller group of useable erosion pin results. McPherson is examining the erosion pin records and is trying to develop a method for estimating pins which are missing only one value within the record, or for estimating a missing reading due to a pin being lost through disturbance, erosion or deposition, and a new one being installed at the same location.

A final difficulty with the trigger values is that the October 2005-March 2006 (autumn 2006) monitoring period is not considered pre- nor post-Basslink, due to testing of the cable during this period, but not full operation. Therefore, the first set of projections to be used as trigger values (March 2007) are based on a projection 18 months into the future relative to the last pre-Basslink monitoring results (October 2005). Relative to the duration of the underlying data set (26 months) this is a large interval.

For all of these reasons, the application of trigger values cannot be done without consideration for the underlying processes and trends, and quality of the erosion pin data set. To provide an example of how the triggers will be applied in the future, the following section provides an example.

11.2.2.3 Application of trigger values

As highlighted in the above discussion, the application of trigger values involves a multi-step process involving:

- examination of the hydrology during the monitoring period and assessment of how variations in the hydrology might affect monitoring results;
- examination of the underlying processes and trends in the geomorphic zones, and evaluating whether these are consistent with pre-Basslink trends; and
- if appropriate, comparing the mean erosion pin results for each zone to the derived trigger values.

As means of demonstrating how this will occur in the future, the March 2006 monitoring results are interpreted with respect to trigger values in the following section. More information about the hydrology and erosion pin results for the March 2006 period is presented in other chapters of this report.

11.2.2.3.1 March 2006 monitoring results – consideration of hydrology

The March 2006 monitoring period was characterised by an unusual flow regime relative to the pre-Basslink monitoring period, as maximum flow from the power station was limited to 2-turbine discharge due to the refurbishment of a turbine. This hydrologic characteristic needs to be considered when examining the underlying trends and processes, as the lack of 2-3 turbine level flow in the Gordon has been found to be correlated with erosion during the pre-Basslink period (see BBR for discussion).

11.2.2.3.2 March 2006 monitoring results – examination of underlying erosion pin trends and other evidence

Examination of the erosion pin results grouped by turbine level for zones 2 and 3 (Figure 11.12) and zones 4 and 5 (Figure 11.13) provide an indication of whether the underlying trends and processes during the October-March monitoring period were consistent with the pre-Basslink understanding of the river. Figure 11.12 shows that in zones 2 and 3, erosion rates for the 1-2 and 2-3 turbine levels remained consistent with pre-Basslink trends, and the <1 turbine results remained low, suggesting the same processes are underlying bank erosion as during the pre-Basslink period (see chapter 4 Fluvial geomorphology for greater discussion of these results).

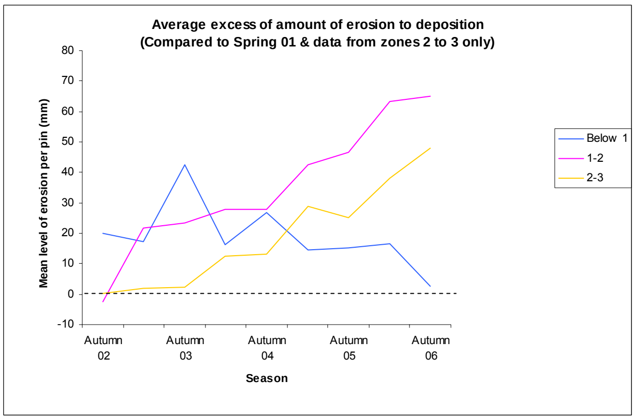


Figure 11.12. Erosion pin results grouped by turbine levels for zones 2 and 3 only showing autumn 2006 results along with pre–Basslink results.

In zones 4 and 5, results for the 1–2 and 2–3 turbine levels are consistent with previous trends, however in the <1 turbine level, erosion results are unusual, with the autumn 2006 results showing a reduction in erosion relative to the previous spring results for the first time. The reasons for this may include reduced shear stress on the bank toe due to reduced discharge from the power station, and/or recent deposition from large storm events. Although the results are unusual, the underlying trend is consistent with the pre–Basslink understanding of the river, that is, erosion is most active in the <1 turbine zone.

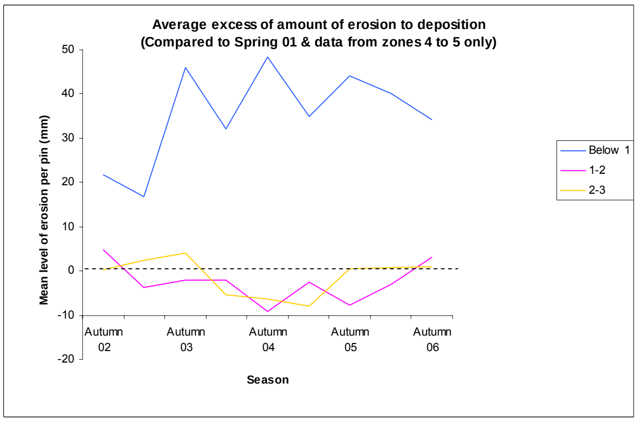


Figure 11.13. Erosion pin results grouped by turbine level for zones 4 and 5 only showing autumn 2006 results along with pre–Basslink results.

Figure 11.13 shows the erosion pin results grouped by pins showing erosion and pins showing deposition for each zone. This graph shows that the erosional and depositional trends for each zone in autumn 2006 are consistent with previous trends, with the exception of zone 4, where the erosion result is below the previous trend, although deposition is consistent with past results. The results grouped in this manner support the view that the underlying processes and trends in the Gordon are the same as during the pre–Basslink period.

Other results, such as photo-monitoring and scour chains also showed no major changes from previous results, and based on this interpretation, it is appropriate to compare the erosion pin results with the trigger values.

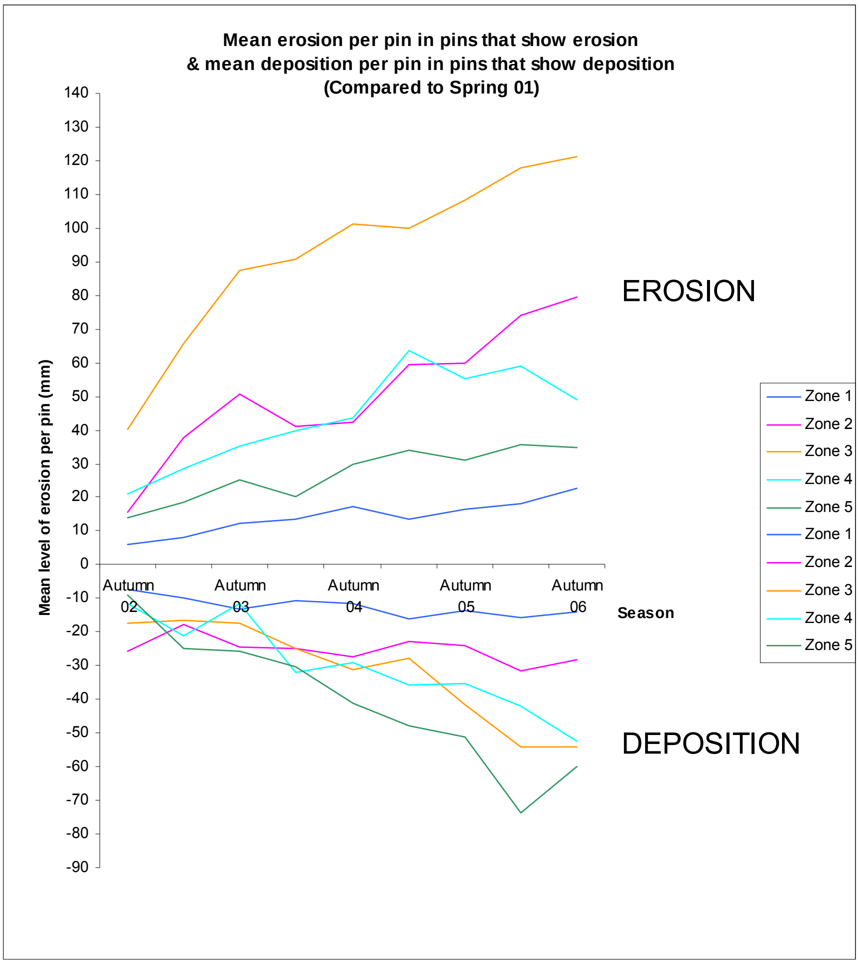


Figure 11.14. Erosion pin results grouped by pins showing erosion and pins showing deposition for each zone. The derivation and analysis of this graph is discussed in more detail in the Gordon Geomorphology chapter.

11.2.2.3.3 March 2006 monitoring results – comparison with trigger values.

The March 2006 monitoring results are shown for each zone in Figure 11.11, and in tabular form in Table 11.4. The mean erosion result for all zones is below the trigger values, with the exception of zone 1, where the value is equivalent to the trigger. In zone 4, the mean erosion result is well below the trigger value, and also below the predicted minimum erosion value, as shown by the dashed line in Figure 11.11. This is likely related to the unusually low result recorded in the <1 turbine level in zones 4 and 5 (Figure 11.13, Figure 11.14 and may be related to the hydrology during the monitoring period.

Table 11.4. Comparison of March 2006 monitoring results with trigger values.

Zone	Trigger value (mm)	March 2006 results Mean erosion in each zone compared to spring 2001 (mm)
1	4	4
2	61	37
3	78	60
4	70	28
5	4	–11

In interpreting the trigger values with respect to the March 2006 results, the conclusion is that it is appropriate to apply the trigger values, and that the monitoring results are within the predicted bounds of the trigger values. The unusually low erosion result in zone 4 may be related to the lower than 'normal' 3-turbine discharge from the power station during the monitoring period.

11.2.2.4 Response to exceeding trigger values

If analysis of the monitoring results (erosion pins and qualitative indicators) indicates it is appropriate to apply trigger values, and the monitoring results exceed the trigger values, then additional analysis of the flow regime (magnitude, duration, frequency, seasonality) and monitoring results should be conducted to try and establish what component of flow or other factors might be related to the elevated erosion values. Correlation analyses were used in the BBR to link flow components to erosion pin trends, and this approach would again be used in the event of the trigger values being exceeded. This approach will allow an evaluation of whether a Basslink flow component (such as increased frequency of on/off operation), a natural flow component (flood event), or a non-Basslink power station related flow component (long-duration 3-turbine operation due to drought condition) is associated with the high erosion value.

If a natural or non-Basslink flow component is linked to the high erosion result, then a watching brief should be maintained, and results discussed with other disciplines.

If there is evidence a Basslink flow component is related to the high erosion result, the results will be reviewed with respect to Basslink operations (e.g was Basslink operating in an atypical manner during the monitoring period, is the operation expected to continue into the future), discussions will be held with other disciplines as to whether the Basslink operation affected other aspects of the Gordon River, the conceptual model will be reviewed with the aim of putting the change in a larger context, and the SRC will be informed. Response to the high erosion result may range from a watching brief, to exploration of management measures at the power station based on the confidence of the analysis and perceived potential impact.

If no reasonable explanation for the monitoring results exceeding trigger values can be gained from the hydrology or other monitoring results, an examination of the individual erosion pins which were grouped to calculate the erosion/deposition rates will be conducted, and other disciplines will be canvassed to see if similar unusual monitoring results were obtained for the period. If this does not yield a satisfactory explanation, then an evaluation will need to be made about whether the exceedence warrants additional field investigation or management intervention.

11.2.2.5 What if trigger values are no longer applicable?

In the event that the underlying processes and trends suggest there has been a fundamental shift from pre-Basslink conditions, such as a decrease in erosion in the <1 turbine bank level and increased erosion in the 1-2 and 2-3 turbine bank levels in zones 4 and 5, then the present trigger values can no longer be considered valid. This decision will need to be made on a zone by zone basis, and it is likely that the triggers may continue to apply to some zones, but not others.

When trigger values are no longer applicable, the erosion pin results and qualitative indicators will be interpreted with respect to the question 'are the observed changes in line with the pre-Basslink understanding of the river, or not?' For example, is increased erosion in the 1-2 and 2-3 turbine level in zones 4 and 5 expected once toe erosion decreases? If the answer is yes, then it is not possible to ascribe the change to Basslink, or determine whether Basslink altered the timing of the change, as the existing data provides no indication of the expected timing of changes. Under these circumstances, the qualitative indicators will continue to be monitored and interpreted, with findings and discussed with other disciplines.

11.2.3 Qualitative indicators to be monitored post-Basslink

As part of the geomorphology monitoring in the Gordon River, a number of additional parameters are measured and observed and will continue to be monitored post-Basslink. These results assist in understanding how the river is changing over time and assist in the interpretation of erosion pin results. As discussed in previous sections, this is of particular importance in the field of geomorphology as it is recognised that the river is not in equilibrium, and is continuing to adjust to the regulated flow regime.

Monitoring results from the qualitative indicators will continue to be summarised and interpreted in the annual monitoring report. These qualitative parameters are outlined below, with an indication of how the information assists in understanding the geomorphology of the middle Gordon River.

11.2.3.1 Sub-groupings of erosion pin measurements

As noted above, the erosion pin results have been grouped and analysed based on zone and bank placement. Although only the zone-groupings have been adopted as 'trigger' values, the other groupings (turbine level on bank, and combination of turbine level on bank and zone, erosion and depositional components of net change) provide useful information about how the banks are responding within each zone, and within each turbine bank level. These analyses will continue to be completed with post-Basslink monitoring results, and will assist with understanding the distribution of erosion and deposition processes in the middle Gordon, and establishing whether the trigger values are relevant.

11.2.3.2 Scour chains

Twenty five scour chains are located at monitoring sites, with most situated between the 1–2 turbine bank level. The scour chain results are difficult to quantify, as frequently deposition recorded by the chain is indicative of the downslope movement of material rather than the fluvial deposition of sediment. The results from the scour chains are useful for interpreting the erosion pin results at the specific site. At most sites, the scour chain results have been very consistent over the pre-Basslink period. Post-Basslink scour chain results will be compared to pre-Basslink results, and used to assist in the interpretation of erosion pin results.

11.2.3.3 Photo-monitoring

Approximately 56 photo-monitoring sites are visited on an annual basis, with results reported in the Basslink Annual Report. Many of the photo-monitoring sites were chosen in 2000 because there had been a recent disturbance to the site. The aim of the monitoring has been to document how the sites have changed over time, and how the bank above and below the power station controlled water levels has responded to the disturbance. The sites will continue to be monitored post-Basslink, with results summarised in the annual report similarly to those presented in the BBR. Several new monitoring sites were added in March 2006 based on the outputs of the recent aerial photo interpretation.

11.2.3.4 Bank profiling

Between October 2004 and March 2005, bank profiles were measured using hand levelling techniques. Profiling of the sites using similar techniques should be repeated every two to three years depending on field access. Additionally, at nine monitoring sites, bank angles at specific locations are measured during each monitoring run. Although these data have only recently been collected, they will assist in understanding how the banks are changing over time, and will provide a context within which the erosion pin results can be interpreted.

11.2.3.5 Bank saturation

Bank saturation in geomorphology zone 2 is monitored using an array of five piezometers which span from the water's edge to 27m 'inland'. The probes record water levels at 15 minute intervals. The resulting data are used to establish in-bank water surface slope, and identify periods of high risk for seepage erosion. These results are used to help interpret field observations and erosion pin results.

Over the past several years, data collected by the probes has been questionable, due to the infiltration of fine sediments into the probe casings. New probes have been installed in close proximity to the existing array, but the new array extends 50m inland with probes located at

~13m intervals. This will provide greater information about bank saturation which will be of use for both geomorphology and vegetation monitoring. The existing array will be maintained for a period to establish a correlation between the data sets.

11.2.3.6 Channel cross-sections

Eight channel cross-sections have been surveyed two to four times between 2000 and 2006 (pre-Basslink). These cross-sections will be re-surveyed every two to three years following the implementation of Basslink. The cross-sections provide information about channel changes during the intervening period, and provide a context within which to interpret erosion pin and aerial photo results.

11.2.3.7 Aerial photo analysis

For the IIAS, a detailed aerial photo comparison between 1974 and 1999 aerial photos was completed by Hydro Tasmania. Additional aerial photos were obtained in December 2004 at a scale of 1:5000. A qualitative comparison of the 2004 photos with the 1999 photos is contained in this annual report. The findings have been used to increase the number of ground-based photo-monitoring sites.

11.2.4 Summary

Final trigger values for fluvial geomorphology have been derived based on erosion pin results from the five geomorphic zones in the middle Gordon. The upper limit of net change for each zone has been predicted for March 2007–March 2012 based on the pre-Basslink monitoring results and 95th percentile confidence interval. Because the triggers are based on predictions of current trends, and it is recognised that these trends will not continue indefinitely, even in the absence of Basslink, each year an assessment will be required as to the applicability of the established trigger values to the monitoring results. With time, if it is found that the underlying processes and trends are changing, the present triggers will no longer be applicable, and alternative management strategies will need to be investigated. The long-term response of the river to a regulated flow regime will continue to be documented through the collection of erosion pin and other qualitative indicator results.

11.3 Karst geomorphology trigger value report (J Deakin)

11.3.1 Background

Changes in sediment movement in the caves and dolines have been identified as the most likely potential significant impact to the karst areas in the Gordon River with the commencement of Basslink (Hydro Tasmania 2005). These changes are currently being monitored using various sets of erosion pins and water level recorders located in the caves and dolines.

The primary indicator variables recommended in the Basslink Baseline Report for assessing potential sediment changes include the current maximum range of change at erosion pins, the current average rate of change, and the long-term trend since the pins were installed. Two additional variables for Bill Neilson Cave were also considered useful:

- the percentage of time that the pins in the dry sediment bank are inundated; and
- the maximum height of inundation in the cave

In the dolines, the sum of the distances between the pins was selected as the most appropriate indicator variable.

The Basslink Baseline Report (BBR) 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. Nonetheless it was accepted that consideration of possible changes in pattern at the erosion pins should take place and an informal basis for alerting to possible changes was proposed. A series of informal trigger values have been determined for the indicator variables which will be used to detect if potentially significant change is occurring. The next step will then be 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.

The BBR recommended that future changes outside the current range of change at the erosion pins in the caves, or which cause the average rate of change to be varied by ±100 %, or to reverse, or which significantly change the long-term trends as shown on the graphs of pin changes, should indicate a need for further investigation. In the dolines, increases in the sum of the distances between the pins in the dolines of more than 20 mm were to be considered, taking into account the potential for the pins to have been disturbed by wildlife.

The purpose of this report is to review the appropriateness of the recommended basis for informally assessing potential Basslink changes in the context of the new monitoring data collected during the October 2005 monitoring trip and subsequent data analysis.

11.3.2 Additional data exploration

The October 2005 monitoring data were added to the primary datasets, the data were reanalysed and the informal trigger values were reviewed. As a validation exercise, the October 2005 data were assessed against the interim informal trigger values for each of the indicator variables, on a pin-by-pin basis, as if they were post-Basslink data. The results showed that there would have been 19 individual 'breaches' of the informal trigger values, despite the fact that the October 2005 data are supposed to be part of the same baseline (see Table 11.5). For instance, the erosion at pin 4 in GA-X1 during the winter 2005 monitoring season was greater than the maximum range of change to date by 1 mm on a season-by-season basis, or by 8 mm since the monitoring began. However, the average rate of change at pin 4 in GA-X1 has not changed significantly over time and the change is clearly consistent with the long-term trend (Figure 11.15). So while the informal trigger value for one of the indicator variables would have been exceeded had this been a post-Basslink assessment, it would have been inappropriate to identify the change as one that is significant. This exercise shows that it is not appropriate to consider the indicator variables as presented in the Basslink Baseline Report in isolation of each other.

Table 11.5. Informal trigger values for the indicator variable 'sediment change at erosion pins'. Shaded boxes indicate those values that were exceeded in the validation exercise.

Location		Pin no.	Change between sampling periods			Change since pin installed		
			Max erosion	Max deposition	Average change	Max erosion	Max deposition	Average change
Channel Cam		1	-9	8	0	-1	8	3
		28	-13	11	0	-11	2	-2
GA-X1 cave		2	-6	11	0	-1	12	5
		3	-4	2	-1	-6	1	-3
		4	-8	4	-3	-22	0	-10
Kayak Kavern		16	-40	1	-17	-50	1	-15
		17	-51	35	-9	-91	9	-31
		18	-15	11	0	-4	15	5
		19	-26	42	4	-22	34	11
		29	n/a	n/a	n/a	n/a	n/a	n/a
		30	n/a	n/a	n/a	n/a	n/a	n/a
Bill Neilson Cave	6A Wet sed bank at entrance	20	-19	8	-2	-19	3	-11
		21	-4	4	-1	-5	1	-2
		22	-3	3	0	0	3	1
	6B Wet sed bank II	25	-7	2	-1	-11	0	-5
		26	-2	2	0	-3	1	0
		27	-2	4	1	-1	7	3
	6C Dry sed bank	23	-3	2	0	-1	2	0
		24	-1	24	3	0	25	19

Figure 11.15. Cumulative sediment changes at karst sites between December 2001 and October 2005.

The indicator variables are based around the records of sediment transport occurring at individual erosion pins, rather than across pins from different sites in different zones as in the geomorphology assessment. The karst monitoring pins need to be considered individually because each measures impacts occurring under a different range of flow conditions and direct comparisons between pins at different sites is not possible. Considering the pins individually however, means that the dataset can be heavily influenced by single extreme events that may not necessarily be representative of general sediment change trends. For example, the pins in the caves can be moved by pieces of floating debris as the waters in the caves rise and fall which can give the impression that there has been significantly more or less erosion than has actually occurred. Clearly some sort of grouping in the analyses is required to increase the likelihood of the informal trigger values identifying actual Basslink changes rather than extreme events.

The indicator variables ‘maximum range of change’, ‘average rate of change’ and ‘the long-term trend since the pins were installed’ should be considered as sub-components of the one indicator variable group, i.e ‘sediment change at erosion pins’. An exceedance of an informal trigger value for one of these sub-components should not be considered significant unless:

- it is accompanied by exceedances for the other indicator variables of the group; and/or
- it is consistently repeated over subsequent monitoring seasons.

Changes between sampling periods and since sampling began should both be considered.

Similarly, the indicator variables 'percentage of time that the pins in the dry sediment bank are inundated' and 'the maximum height of inundation in Bill Neilson Cave' should be considered as sub-components of another indicator variable group: 'inundation of the dry sediment bank'. There is only one indicator variable for the dolines so this will remain as a stand alone.

11.3.3 New trigger values

As previously discussed, there are no formal trigger values for the karst indicator variables. The primary methods by which Basslink change will be determined are described below under each indicator variable. These will be supported by general observations, photo-monitoring and surveying techniques. Note that for two of the three indicator variables, the interim informal trigger values recommended in the BBR have not changed with the addition of the October 2005 monitoring data to the dataset.

The purpose of the informal trigger values is to detect if there is potentially significant change occurring. Further investigation and/or analysis of the data will then be necessary 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.

11.3.3.1 Sediment change at erosion pins

Sediment change at erosion pins will be assessed in three main ways. Firstly, post-Basslink data will be assessed against the current maximum range of change in erosion or deposition between sampling periods and since sampling began (Table 11.5). Secondly, the data will be used to calculate new average rates of change between sampling periods and since sampling began which will then be assessed against the pre-Basslink average rates in Table 11.5. Changes of less than ±100 % of pre-Basslink average change will not be considered significant. Thirdly, any changes in seasonal or long-term trends as shown on the graphs of erosion pin data in Figure 11.15 will be determined. Changes identified through all three methods of analysis will be required in order to trigger the need for further investigation and/or analysis of the data.

11.3.3.2 Inundation of the dry sediment bank

Change to the inundation of the dry sediment bank will be assessed in two main ways. Firstly, the percentage of time in any given season and overall that the pins in the dry sediment bank are inundated will be assessed and compared with the pre-Basslink period. The pins have been inundated just over 1 % of the time since the monitoring program commenced, while on a seasonal basis, the maximum duration of inundation was 3.5 % of the time during the winter 2002 period.

Secondly, the maximum height of the inundation in Bill Neilson Cave will be 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 peak flow level at Gordon below Denison to date has been 6.1m (winter 2002) or approximately RL 3.9m in the cave. Note that the 3.9m RL maximum height was estimated from the gauge and a high-water level mark on the vegetation in the cave.

The inundation pattern of the dry sediment bank during winter 2005 and the maximum inundation level both fell within the range of that recorded to date and therefore there are no changes recommended to the informal trigger values. During the post-Basslink monitoring phase, significant changes to one or both of these indicators will require further assessment to see whether they are attributable to natural high flow levels in the Denison River or are Basslink changes.

11.3.3.3 Distances between pins in the dolines

Changes in the dolines will be monitored by comparing the sum of the distances between the erosion pins during the post-Basslink monitoring phase with the average sum of the distances over the pre-Basslink monitoring period, with an allowance for the level of accuracy of the measuring technique. The average sum of the distances between the pins at site 3 is 4.25m and the informal trigger value is therefore 4.25 ± 0.02 m. The average sum of the distances between the pins at site 4 is 2.95m and the informal trigger value is 2.95 ± 0.02 m. Consideration needs to be given to whether pins could have been interfered with by wildlife.

There were no significant changes to the dolines during the 2005 winter period and there are consequently no changes recommended for the informal trigger values.

11.4 Riparian vegetation trigger values report (A Wild)

11.4.1 Introduction

Following discussions with the Scientific Reference Committee (SRC) meeting, a series of indicator variables and trigger values have been developed to enable detection of riparian vegetation change in the Gordon River. These variables measure a number of components, all of which are considered to be good descriptors of riparian vegetation on the Gordon River. These variables also have essential pre-Basslink baseline data to allow development of trigger values. These quantitative variables, most of which are measures of abundance or density of flora species, seedlings or ground cover conditions are considered to provide a suitable basis for comparison between pre- and post-Basslink periods.

11.4.2 Quantitative indicators

Indicator variables for riparian vegetation include numerous abundance and density variables that are measured either annually or bi-annually. The priority group of indicator variables are those that provide a measure of the integrity of the riparian vegetation communities along the middle Gordon River. Selection criteria for indicator variables and the sites at which they will be monitored are discussed in detail in section 9.9 of the Basslink Baseline Report.

11.4.2.1 Community integrity

The indicator variables monitoring community integrity will highlight changes to the overall community at the species scale. Triggering of these indicators will alert to the changes in species composition and possibly increased abundance of ‘undesirable species’ or predominance of stress tolerators.

Characteristic	Variable measured
Community composition	Comparison of presence–absence data for pairs of years at zone level. Bray–Curtis similarity index for all zones based on annual similarity index calculated on presence–absence data.
Species/taxa richness	An indicator of the number of species/taxa present per site. This will be compared over time.
Species/taxa evenness	An indication of the relative equity or dominance in species abundance. Values can range from 0 to 1 with 1 being perfect evenness in distribution of species abundance. This would show if conditions are changing to favour particular species only from a reduction in others.

11.4.2.2 Community structure

Community structure indicator variables include abundance measures of bare ground, bryophytes, ferns, shrubs and total vegetation cover. Other life form data were excluded due the paucity of data and high variability on the zone level. These variables are measured annually giving four pre-Basslink measures to compare the post-Basslink results. These indicator variables are presented as ratios of values from above the 3-turbine level (‘above’) to:

- (a) corresponding values between the 2- and 3-turbine levels ('high'); and
- (b) corresponding values between the 1- and 2-turbine levels ('low').

Characteristic	Variable measured
% bare ground	Ratio of % cover between 'above and high' quadrats and between 'high and low' quadrats
% bryophyte cover	As above
% fern cover	As above
% shrub cover	As above
% total vegetation	As above

11.4.2.3 Ecologically significant species

A biogeographical study of Tasmanian flora distribution and subsequent community classification has shown that the south-western rivers have distinct flora assemblages to other rivers. This classification showed that four species present on the middle Gordon River are considered to be indicator species that characterise the south-west river systems. Therefore, these species should be given particular attention when considering potential impacts. These species include:

- *Epacris franklinii*;
- *Acradenia franklinii*;
- *Lagarostrobos franklinii*; and
- *Leptospermum riparium*.

The pre-Basslink data set has few records of *Epacris franklinii* as this species occurs predominantly on bedrock outcrops in the middle of the river, areas not frequently sampled. Therefore this species is not included in further analyses.

Characteristic	Variable measured
Changes to ecologically significant species' abundance or density	Changes in seedling recruitment or % cover of ecologically significant species after consideration of mast events etc. Changes in size class density for species. Changes in health or condition of tree density at each site.

11.4.2.4 Population dynamics

The use of seedling counts to determine changes in ecological condition are considered not to be a reliable indicator due to the numerous factors that can influence the variability of seedling recruitment in space and time. Therefore, these triggers need to be interpreted with caution and will be used only as supplementary evidence. The above/below values have been excluded due to concerns about the limited value of assessing the lower quadrats in the river.

Characteristic	Variable measured
Seedling recruitment	Ratio of total seedlings <5cm per quadrat between 'above and high' quadrats
Seedling recruitment	Ratio of total seedlings in all size classes per quadrat between 'above and high' quadrats

11.4.3 Qualitative indicator variables

Numerous diseases and deficiencies that adversely affect vegetation and flora may not result in an immediate change in abundance or cover that will be detected in quantitative measures. An example of this is the presence of *Phytophthora cinnamomi* in the Gordon River. Therefore, in addition to quantitative indicator variables, some additional qualitative indicator variables are proposed.

11.4.3.1 Photo-monitoring

Photo-monitoring occurs annually at 35 sites along the Gordon River in zones 2-5. The analysis of these sequential photographs is a qualitative assessment of increasing or decreasing cover in vegetation strata that is visible on the photographs. These analyses are presented as differences between pairs of photographs between subsequent years. The results are presented as the *proportion of sites* showing a change of at least 10 % in canopy or ground cover vegetation including contraction and expansion; with 10 % being set as the smallest reliably detectable change in strata cover.

11.4.3.2 Broadscale condition and health assessment

Other indicators of change in riparian vegetation along the Gordon River may include visual signs of poor health or stress. Such indicators include:

- visible signs of stress such as yellowing of leaves (chlorosis);
- dieback of leaves; and
- lack of flowering/seed set

These factors are not formally monitored in the program on a large scale, however, they may become apparent during field monitoring. Observations of such anomalies will continue to be presented in the Basslink Annual Report and elicit further investigation if deemed appropriate (category 1 response - see below).

11.4.4 Setting trigger values

Table 11.6. Attributes of indicator variables.

Characteristic	Scale	Exceedance defined by	Implications of exceedance
Community composition	Quadrat type within zones	Lower and upper values outside range of similarity index values of pre–Basslink data. Reducing	Upper: communities converging over time Lower: communities diverging over time
Species/taxa richness	Quadrat type within zones	Lower value outside range of pre–Basslink data	Upper: greater number of taxa present Lower: reduced number of taxa present
Species/taxa evenness	Quadrat type within zones	Lower and upper values outside range of evenness index of pre–Basslink data	Lower: spread of species abundance becoming less equitable Upper: spread of species abundance becoming more equitable
% bare ground	Quadrat type within zones	Upper or lower value outside range of cover values of pre–Basslink data	Lower: increased variable cover in high quadrats compared with above quadrats Upper: reduced variable cover in above quadrats compared with high quadrats
% bryophyte cover	Quadrat type within zones	Upper or lower value outside range of cover values of pre–Basslink data	As above
% fern cover	Quadrat type within zones	Upper or lower value outside range of cover values of pre–Basslink data	As above
% shrub cover	Quadrat type within zones	Upper or lower value outside range of cover values of pre–Basslink data	As above
% total vegetation cover	Quadrat type within zones	Upper or lower value outside range of cover values of pre–Basslink data	As above
Changes to ecologically significant species' abundance or density	Above and below high–water & Quadrat type within zones	Lower value outside range of cover values of pre–Basslink data	Lower: reducing mean of density, cover or seedling recruitment of defined species
Seedling recruitment	Quadrat type within zones	Upper and lower ratio values outside range of pre–Basslink data	Lower: increased seedlings in high quadrats compared with above quadrats Upper: reduced seedlings in above quadrats compared with high quadrats

Potential changes to vegetation over time are likely to be reflected in one or more of the indicator variables that characterise the physical and ecological characteristics of the riparian vegetation along the Gordon River. These characteristics have been measured in the pre–Basslink period to provide a baseline with which to compare post–Basslink data. These data have inherent weaknesses that have been discussed in the BBR. Importantly, these data show a range of temporal and spatial variation that limits the precision to which trigger values can be set. It is within these limits that the following trigger values have been determined.

Frequentist statistics approach whereby a set of characteristics of the population has been determined from the pre–Basslink data. The set value of an indicator variable is recognised to be within the limits of acceptable change if the value lies within an interval defined by the estimated 2.5^{th} and 97.5^{th} percentiles for that variable, where the estimated values are determined from a suitable statistical model applied to the pre–Basslink data for that variable. These trigger values, being values which fall outside of these ranges, have been estimated using a type I error rate of 0.05. This level has been used as an accepted standard for many ecological studies of a similar nature and is therefore applied here. It should be noted that in some cases the risk of making a type 1 error is judged to have serious implications and therefore the alpha level is set to 0.01. This was not considered necessary in the vegetation monitoring.

11.4.4.1 Why not set 'ecological thresholds'?

It is possible that trigger values calculated using a frequentist statistics approach and 'standard' type 1 error rate may fall within or outside the range of variable values which may later be shown to have crossed an ecological threshold. Ideally, trigger values should be able to be set in such a way. However, given the constraints of the data and the limited comparable studies defining such thresholds and the myriad interactions and correlations between vegetation and other discipline variables, this approach has not been taken. As an alternative, a conservative level has been set and the *response* to the triggers has been the focus of the vegetation indicators. The triggers will elicit further investigation and interpretation before management actions are implemented. In this way, exceedances of vegetation variables can be considered within the framework of the conceptual model and after consideration of evidence from the geomorphology at the co-located sites. In addition, mechanisms such as feedback situations and changes to alternative states can be considered. The proposed steps in response to exceeding trigger values are given below.

11.4.5 Response to exceedance of trigger values

Following discussions with the SRC and Regulator it was decided that exceedance of variables is likely to lead to responses of a different scale which is determined by the perceived seriousness of the response. Therefore, a series of categories outlining the response were determined for all disciplines. The state at which a response is elicited for riparian vegetation is presented in Table 11.7.

Table 11.7. Categories of response to exceedance of trigger values and state which leads to a response for riparian vegetation for quantitative and qualitative indicator variables.

Category	Description	Response elicited by
1	Note and explain	*Quantitative* – Any exceedance of pre–Basslink mean values (at the statistical significance level of 0.05) *Qualitative* – Increase in proportion of photographs showing contraction of ground layer or canopy layer vegetation. Localised changes in vegetation health or condition.
2	Investigate	*Quantitative* – Exceedance that cannot be readily explained *Qualitative* – Exceedance that cannot be readily explained or larger–scale changes in vegetation health or condition.
3	Management response required	*Quantitative* – Persistent exceedance of important trigger variables at the whole of zone or river scale AND investigation has shown exceedances are highly likely to be caused by a Basslink –induced change in conditions. *Qualitative* – Dieback at zone or whole–of–river scale that is shown to be highly likely to be caused by a Basslink –induced change in conditions.

For most variables, trigger values have been calculated for individual zones in addition to those for the whole-of-river. Responses may initially be detected at the level of the river or zone. However, it should be noted that due to the reduced data points at the zone level, the degree of confidence or power of the indicators are lower than those calculated at the river level. If a zone effect, or difference in trend between the responses in the zones, is detected further analysis for causal mechanisms will be directed at the zone level.

The investigation of exceedance of a quantitative trigger value is likely to follow the process outlined in the following section. This process includes assessment of the likelihood of the response being a ‘real’ one and the nature of the response on a temporal and spatial scale.

11.4.6 Final values for quantitative trigger values

The following section presents the entire range of trigger values that have been developed for riparian vegetation. These values may have been presented in the BBR and the supplement; others are presented here for the first time.

11.4.6.1 Community integrity variables

11.4.6.1.1 Community composition

Table 11.8. Mean values and 95 % confidence interval range for Bray Curtis similarity index for all zones based on annual similarity values calculated on presence–absence data.

Zone	Quadrat type	Mean	Confidence interval range
2	Above	73.89	64.39–80.08
	Low	65.11	61.79–68.76
	High	66.04	57.43–74.79
3	Above	53.94	51.95–55.17
	Low	59.99	52.43–66.41
	High	59.05	56.42–62.45
4	Above	41.37	37.86–45.52
	Low	38.01	36.13–40.32
	High	35.98	35.59–36.39
5	Above	59.10	53.31–66.35
	Low	61.55	57.33–65.51
	High	59.40	57.18–61.08

11.4.6.1.2 Species/taxa richness

Table 11.9. 95 % confidence intervals for species richness values for each zone and quadrat type calculated from pre–Basslink data.

Zone	Quadrat type	pre–Basslink mean	Confidence interval range
2	Above	3.50	3.06–3.94
	Low	2.88	1.92–3.83
	High	3.33	2.72–3.94
3	Above	5.92	4.94–6.89
	Low	2.50	1.70–3.30
	High	4.63	3.84–5.41
4	Above	8.15	6.48–9.83
	Low	4.54	3.47–5.61
	High	5.58	4.56–6.59
5	Above	5.38	3.89–6.86
	Low	2.42	1.69–3.14
	High	6.46	4.68–8.24

11.4.6.1.3 Species/taxa evenness

Table 11.10. 95 % confidence intervals for species evenness values for each zone and quadrat type calculated from pre–Basslink data.

Zone	Quadrat type	pre – Basslink mean	Confidence interval range
2	Above	0.69	0.58–0.79
	Low	0.53	0.35–0.70
	High	0.62	0.49–0.76
3	Above	0.70	0.61–0.78
	Low	0.36	0.19–0.53
	High	0.62	0.50–0.74
4	Above	0.62	0.51–0.73
	Low	0.57	0.42–0.71
	High	0.58	0.47–0.70
5	Above	0.43	0.30–0.56
	Low	0.31	0.15–0.47
	High	0.52	0.38–0.65

11.4.6.2 Ecologically significant species

Table 11.11. Confidence intervals for % cover values for ecologically significant species for each zone and quadrat type calculated from pre–Basslink data.

Zone	Quadrat	Species	pre – Basslink mean	Confidence interval range
2	Above	*Acradenia franklinii*	4.13	1.79–6.46
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	0.00	0.00–0.00
	Low	*Acradenia franklinii*	0.08	0.00–0.25
		Lagarostrobos franklinii	0.63	0.10–1.15
		Leptospermum riparium	0.00	0.00–0.00
	High	*Acradenia franklinii*	0.58	0.02–1.15
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	0.00	0.00–0.00
3	Above	*Acradenia franklinii*	0.58	0.16–1.01
		Lagarostrobos franklinii	0.08	0.00–0.20
		Leptospermum riparium	0.00	0.00–0.00
	Low	*Acradenia franklinii*	0.67	0.00–1.89
		Lagarostrobos franklinii	0.67	0.03–1.30
		Leptospermum riparium	0.00	0.00–0.00
	High	*Acradenia franklinii*	0.71	0.00–1.59
		Lagarostrobos franklinii	0.50	0.03–0.97
		Leptospermum riparium	0.00	0.00–0.00
4	Above	*Acradenia franklinii*	0.12	0.00–0.28
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	2.50	0.85–4.15
	Low	*Acradenia franklinii*	0.00	0.00–0.01
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	3.81	1.00–6.62
	High	*Acradenia franklinii*	0.35	0.00–0.77
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	3.96	1.13–6.79
5	Above	*Acradenia franklinii*	2.50	0.00–5.21
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	0.04	0.00–0.12
	Low	*Acradenia franklinii*	0.17	0.00–0.49
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	0.25	0.00–0.54
	High	*Acradenia franklinii*	0.00	0.00–0.01
		Lagarostrobos franklinii	0.00	0.00–0.00
		Leptospermum riparium	0.67	0.00–1.67

Table 11.12. Confidence intervals for the sum of density values for ecologically significant species for each zone and total for Gordon River calculated from pre–Basslink data. The 20 % change to trigger further investigation (a category 1 response) for is shown for total values.

Species	Zone				Total	20 % change
	2	3	4	5		
Acradenia frankliniae <5	0	13	4	0	17	3.4
Acradenia frankliniae <10	1	1	1	0	3	0.6
Lagarostrobos franklinii <5	1	2	0	2	5	1
Lagarostrobos franklinii <20	0	0	1	0	1	0.2
Lagarostrobos franklinii >20	0	2	0	0	2	0.4
Leptospermum riparium <5	0	0	11	10	21	4.2
Leptospermum riparium <10	0	0	1	2	3	0.6
Leptospermum riparium <20	0	2	1	1	4	0.8
Leptospermum riparium >20	0	1	1	0	2	0.4

11.4.6.3 Community structure

11.4.6.3.1 Ground cover and vegetation cover data

Table 11.13. The range within which 95 % of values are likely to lie for means of ratios for selected ground cover variables based on monitoring for one year, two years and three years in the post–Basslink period. Note that seasonal figures are not provided because monitoring occurs only once per year.

	Ratio (% above 3–turbines+1) to (% between 2– and 3–turbines+1)					
Post–Basslink	1 year		2 year mean		3 year mean	
	Lower	Upper	Lower	Upper	Lower	Upper
% bare ground:	0.2	0.9	0.2	0.8	0.2	0.7
% bryophyte	1.1	6.1	1.3	5.0	1.4	4.7
% fern	0.5	3.1	0.6	2.5	0.6	2.3
% shrub	0.6	2.0	0.7	1.8	0.7	1.7
% total vegetation	1.0	3.2	1.1	2.8	1.2	2.6
	Ratio (% above 3–turbines+1) to (% between 1– and 2–turbines+1)					
Post–Basslink	**1 year**		**2 year mean**		**3 year mean**	
	Lower	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
% bare ground:	0.1	0.7	0.1	0.5	0.1	0.5
% bryophyte	3.3	9.9	3.7	8.8	3.9	8.3
% fern	1.1	7.8	1.4	6.3	1.5	5.8
% shrub	0.6	4.5	0.7	3.6	0.8	3.3
% total vegetation	3.0	11.6	3.5	10.0	3.7	9.4

11.4.6.4 Ecological processes

11.4.6.4.1 Seedling trigger values

Table 11.14. The range within which 95 % of values are likely to lie for means of ratios for seedlings <5cm based on monitoring in the pre–Basslink period including data collected in December 2005.

Number of seedlings less than 5 cm: Ratio of ABOVE quadrats to HIGH quadrats						
Post–Basslink	**1 year**		**2 year mean**		**3 year mean**	
Whole–of–river	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
autumn	0.76	1.80	0.84	1.63	0.87	1.57
summer	0.72	2.35	0.93	2.06	0.87	1.76
To 1st time in year	0.86	1.78	0.98	1.56	1.01	1.51
To 2nd time in year	0.94	1.62	1.00	1.53	1.02	1.49
Zone 2						
autumn	0.45	3.08	0.56	2.48	0.61	2.27
summer	0.25	6.80	0.51	4.70	0.43	3.03
To 1st time in year	0.51	3.03	0.70	2.20	0.77	2.01
To 2nd time in year	0.64	2.42	0.74	2.08	0.79	1.96
Zone 3						
autumn	0.56	4.32	0.70	3.43	0.77	3.13
summer	0.27	6.24	0.53	4.38	0.45	2.88
To 1st time in year	0.58	3.49	0.80	2.52	0.88	2.30
To 2nd time in year	0.73	2.77	0.85	2.39	0.90	2.24
Zone 4						
autumn	0.10	6.94	0.16	4.31	0.20	3.55
summer	0.40	2.62	0.59	2.12	0.54	1.65
To 1st time in year	0.31	2.78	0.46	1.87	0.51	1.67
To 2nd time in year	0.41	2.10	0.49	1.74	0.53	1.62
Zone 5						
autumn	0.42	2.86	0.52	2.30	0.57	2.11
summer	0.31	7.40	0.60	5.17	0.51	3.38
To 1st time in year	0.50	3.36	0.70	2.38	0.77	2.16
To 2nd time in year	0.63	2.63	0.74	2.24	0.79	2.10

Table 11.15. The range within which 95 % of values are likely to lie for means of ratios for total number of seedlings in all size classes based on monitoring for pre–Basslink period including data collected in December 2005.

Total Number of seedlings: Ratio of ABOVE quadrats to HIGH quadrats						
Post–Basslink	1 year		2 year mean		3 year mean	
Whole–of–river	Lower	Upper	Lower	Upper	Lower	Upper
autumn	0.69	2.08	0.78	1.84	0.82	1.75
summer	0.36	6.87	0.68	4.93	0.58	3.33
To 1st time in year	0.60	3.12	0.81	2.32	0.88	2.13
To 2nd time in year	0.74	2.53	0.85	2.20	0.90	2.08
Zone 2						
autumn	0.34	4.12	0.45	3.11	0.50	2.77
summer	0.13	13.06	0.34	7.75	0.27	4.18
To 1st time in year	0.36	4.18	0.57	2.69	0.64	2.38
To 2nd time in year	0.50	3.06	0.61	2.50	0.66	2.30
Zone 3						
autumn	0.61	4.31	0.77	3.46	0.84	3.16
summer	0.23	6.57	0.46	4.49	0.38	2.86
To 1st time in year	0.53	3.75	0.75	2.63	0.83	2.38
To 2nd time in year	0.68	2.92	0.80	2.48	0.85	2.32
Zone 4						
autumn	0.11	6.02	0.17	3.84	0.21	3.20
summer	0.39	2.58	0.59	2.09	0.53	1.62
To 1st time in year	0.32	2.61	0.46	1.78	0.51	1.60
To 2nd time in year	0.41	1.99	0.49	1.67	0.53	1.55
Zone 5						
autumn	0.57	2.36	0.67	2.01	0.71	1.88
summer	0.31	9.23	0.64	6.30	0.53	4.01
To 1st time in year	0.54	3.72	0.76	2.62	0.84	2.38
To 2nd time in year	0.69	2.91	0.81	2.47	0.86	2.31

11.4.7 Proposed response when quantitative trigger values exceeded

Quantitative indicator variables have trigger values that have upper and lower bounds around a mean value that may vary seasonally (as for seedlings). Following the commissioning of Basslink, further investigation of indicator variables will be triggered if monitoring trip values fall outside the defined range for a specific variable. The following discussion outlines a proposed response to potential scenarios where values have fallen outside the trigger value range.

11.4.7.1.1 Scenario: total vegetation cover for *life form X* or total seedling numbers fall outside defined indicator range

1. Validation of response (is this a 'real' response?)

Due to the low sample sizes, outliers have the potential to skew the response. For example, a tree fall at one site may lead to high bare ground, giving an inflated value. If this is the case, a report detailing the site and implications will be prepared.

2. Location of response

The response in the Gordon River will be compared with any response found in the reference rivers (Denison and Franklin). This will determine if the response is a catchment or regional trend or one that may be attributed to a Basslink effect. Supporting data such as climatic data and hydrological may be used to assist with correlations of environmental variables and the indicator variable.

For example, if there is a detectable decline in the seedling numbers in the high quadrats, this may be due to unseasonal weather that has precluded seed germination. This pattern should also be apparent in the reference rivers, indicating a regional affect.

3. Universality of response

In most cases, data within the middle Gordon River is analysed at the level of the zone, giving four areas that are stratified according to constrictions and inflows from other tributaries. Any response will initially be detected at the level of the river, data exploration will determine if this response is occurring in all zones, and in the same direction. If a zone effect, or difference in trends between the response in the zones is detected, further analysis for causal mechanisms will be directed at the zone level.

For example, some zones are more geomorphically active than others, if one zone was displaying particularly active erosion, this may preclude seedling recruitment. Other zones receive more sediment inflows from tributaries that may smother seedlings and lead to a response. These scenarios will be investigated. This will therefore require correlations of vegetation data with the geomorphic data.

4. Scale/extent of response or multiple responses from different indicator variables

The extent of the response will be assessed to determine if it is localised or if there are multiple responses from one process.

5. Detection of causal mechanisms

Numerous diseases and deficiencies can adversely affect vegetation and flora. An example of this is the detection of *Phytophthora cinnamomi* in the middle Gordon River. Where active, this pathogen may lead to death of many species and lead to a reduction in plant cover or seedling establishment. Factors such as these will be considered in the assessment of the reasons for the detected response.

11.5 Biota trigger values report: macroinvertebrates, instream algae and moss and fish (P E Davies & D Ikedife)

11.5.1 Introduction

A review was conducted of the Basslink monitoring variables for instream biota (benthic macroinvertebrates, instream flora and fish), their relative importance, and approaches to defining trigger values.

The following components were identified as key aspects of the ecological integrity of benthic macroinvertebrates (BMs), instream flora (and fish), listed in order of priority:

1. **Community structure** (taxonomic composition and relative or absolute abundance);
2. **Community composition** (taxonomic assemblage);
3. **Taxon richness** (number of taxa);
4. **Ecologically significant species** (key ecological taxa); and
5. **Biomass and productivity** (abundance and density).

All of these components are addressed by key variables in the Basslink program for benthic macroinvertebrates and fish. Only component 3 is addressed in the instream flora theme.

All indicator variables are to be classified according to:

- priority (as above);
- ecological significance of changes in variable values;
- sensitivity of the variable to Basslink drivers; and
- pre-Basslink temporal variance in variable values (at the appropriate spatial scale).

The following sections discuss the characteristics of the indicator variables, the magnitude or limits of significant environmental change (LOAC), the proposed trigger values, and how actions are to be elicited by trigger exceedances.

11.5.2 Benthic macroinvertebrates

11.5.2.1 Indicator variables

Ten indicator variables are currently reported from the macroinvertebrate data used as the basis for monitoring changes associated with Basslink. The variables described from quantitative samples are:

1. Total density of all macroinvertebrates ('Density'), derived from quantitative samples;
2. Total density of all macroinvertebrates excluding worms (Oligochaeta) and blackfly larvae (Simuliidae) ('Density no ol or sim') – both taxa which can exhibit strong clumped distributions and poor representation in quantitative samples;
3. Number of 'family' level taxa ('Number of families');
4. Number of EPT species ('NEPT sp') – species from the aquatic insect orders Ephemeroptera, Plecoptera and Trichoptera (mayflies, stoneflies and caddisflies);
5. Proportional abundance of EPT species (i.e density EPT vs. total density);
6. Density of Ephemeroptera ('Density Ephem');
7. Density of Asmicridea; and
8. Bray Curtis similarity to Reference sites.

The variables derived from rapid assessment sampling are:

9. O/Epa – derived from single season (autumn and spring) models; and
10. O/Erk – derived from single season (autumn and spring) models.

One new variable has been identified that has not been reported to date, but is readily derived from existing data – the Bray Curtis similarity index based on presence/absence data. This variable reflects the benthic macroinvertebrate assemblage composition of Gordon sites relative to reference sites, and is distinctive from the Bray Curtis similarity value based on abundance data which reflects the overall community composition. One variable that has been reported to date is recommended to be discontinued (Total density less oligochaetes and simuliids – worms and blackflies) as it does not provide information that differentiates it significantly from Total Density. Another variable (Density of Asmicridea) has also been reported to date, but analysis with regard to trigger levels required a gradient approach which proved too complex for ready interpretation. It will continue to be reported for interpretative purposes, but will not, at present, have trigger values associated with it. Total abundance (n per unit stream length), while a desirable variable, is problematic because of uncertainty about the effective wetted habitat area present in the channel over time, and the relative densities of macroinvertebrate at different positions across the channel beyond the permanently wetted centre-line or thalweg. These issues have yet to be resolved, and this variable may be dropped in the future.

The following table identifies the final list of monitoring variables appropriate to each of the five key benthic macroinvertebrate components.

Table 11.16. Mapping of key components to the final list of reported variables for which trigger values are derived.

Component	Variables
Community structure	Bray Curtis similarity to Reference (abundance data) O/Erk
Community composition	Bray Curtis similarity to Reference (presence/absence data) O/Epa
Taxonomic richness	Taxon richness (number of families) N EPT species
Ecologically significant species	Proportional abundance of EPT species Density of Ephemeroptera
Biomass/productivity	Total density (n per unit area) Total abundance (n per unit stream length)

11.5.2.2 Use and interpretation of variables

These variables differ in relation to their ecological significance, their likely sensitivity of response to changes in post-Basslink conditions (flow etc.), and their pre-Basslink magnitude of temporal variation. Each variable has been rated according to these features below, as an aid in defining how exceedances in their trigger values may be used to make management decisions.

11.5.2.3 Ecological significance

The movement of variable values outside trigger and Limits of Acceptable Change (LOAC) ranges (particularly decreases below lower trigger values) is considered to fall in the following order of decreasing ecological significance:

- O/Epa ≈ Number of families ≈ NEPT sp >;
- Bray Curtis similarity to Reference ≈ O/Erk >;
- total density >;
- proportional abundance of EPT species >; and
- density Ephemeroptera ≈ density Asmicridea

11.5.2.4 Sensitivity of response

By contrast, the responses of the variables to declining environmental conditions, especially triggered by changes in flow regime, are likely to fall in the following order of sensitivity:

- proportional abundance EPT species ≈ Density Ephem ≈ Density Asmicridea ≈ Bray Curtis similarity to Reference >;
- NEPT sp ≈ O/Erk ≈ Total abundance >; and
- Number of families ≈ Total Density ≈ O/Epa

Thus, the order of ecological significance is essentially opposite to the sensitivity for these variables. This means that the more sensitive variables with the smallest trigger ranges should be used as early warnings of the potential for more ecologically significant changes.

11.5.2.5 Temporal variance

Following analysis of pre-Basslink data for the period 2001-02 to 2005-06, the variables are considered to fall in the following order of increasing temporal variance or 'noise':

- number of families ≈ O/Epa ≈ O/Erk ≈ Bray Curtis similarity to Reference >;
- NEPT Sp. ≈ Total density ≈ Proportional abundance of EPT species >; and
- total abundance ≈ density Ephemeroptera ≈ density Asmicridea

This information is summarised in Table 11.17. Variables with high sensitivity, low temporal variance and moderate to high ecological significance are designated as early warning variables. Exceedance of trigger values should initiate further investigation. Variables with high ecological significance and low sensitivity, often have low to moderate temporal variance, and are those for which changes are both ecologically important and frequently difficult to recover from. For these, management interventions should be considered as soon as practicable. Other variables with intermediate sensitivity and ecological significance, and/or with high temporal variance, are considered to provide useful diagnostic information.

Table 11.17. Characteristics of benthic macroinvertebrate monitoring variables. Relative order (ranked 1–low to 5–high) is shown against four key characteristics, along with role of variables in decision making when trigger levels are exceeded.

Variables	Component priority	Ecological significance	Sensitivity of response	Temporal variance	Early warning	Supplementary evidence	Management intervention
Bray Curtis similarity to Reference (abundance data)	1	2	1	1	x		
O/Erk	1	2	2	1	x		
Bray Curtis similarity to Reference (presence/absence data)	1	2	2	1	x		
O/Epa	1	1	3	1			x
Taxon richness (number of families)	1	1	3	1			x
N EPT species	1	1	2	2			x
Proportional abundance of EPT species	2	4	1	2	x		
Density of Ephemeroptera	2	5	1	3		x	
Density of Asmicridea (downstream of Denison)	2	5	1	3		x	
Total density (n per unit area)	3	3	3	2			x
Total abundance (n per unit stream length)	3	3	2	3		x	x

11.5.2.6 Spatial and temporal scales of analysis

Variables are reported at three spatial scales as means at 'whole-of-river' and 'zone' scales, and at individual site scale. Two main zones have been defined for benthic macroinvertebrates within the Gordon River:

- zone 1 – consisting of four sites upstream of the Denison confluence; and
- zone 2 – consisting of all four sites downstream of the Denison confluence.

Whole-of-river estimates are derived from observations from all nine Gordon River sites. Note that one site, site 63, though geographically upstream of the Denison confluence, is considered to be highly influenced by both Denison River inflows and benthic macroinvertebrate colonisation, since it is hydraulically influenced (by 'backwater' effects) during high Denison flows and therefore not included in either zone.

Data reporting and trigger value derivation is also conducted at three temporal scales seasonal (summer and autumn), yearly and multi-yearly (two and three years). Not all variables have statistically significant differences between seasonal values of means and/or variances at a particular spatial scale. Where they do, separate trigger values have been derived.

In addition, the potential for deriving trigger values associated with spatial patterns has been explored, particularly with regard to trends downstream for the Gordon Power Station. Fitting curves however results in high levels of variability in parameter estimates and reduces the potential to detect post-Basslink changes. A robust method may be to use the differences in values between above and below site 63, but this requires detailed evaluation before being adopted.

11.5.2.7 Limits of acceptable environmental change and trigger values

The policy position for managing the environmental consequences of Basslink is one of 'no net environmental change'. This is difficult to quantify, as detection of change is dependent on intensity of monitoring effort, sensitivity and background variability of variables, as well as the desired balance of type I and II errors. These considerations are largely logistical and statistical.

In order to provide a quantified context to decision making, the magnitude of changes in each variable which are considered to constitute a substantial and meaningful environmental change (in the context of pre-Basslink environmental conditions), have been scoped for benthic macroinvertebrates, and are shown in Table 11.18. These are also called the 'Limits of Acceptable Change' (LOAC). A substantial and meaningful environmental change is one which would reasonably be expected to represent significant environmental change (and 'harm'), and hence should elicit a management response.

The use of trigger values has been proposed in order to elicit a response (either an investigation or management intervention) prior to significant environmental change occurring. In this way substantial change has not already occurred before triggers are exceeded. This means that a trigger value must be exceeded prior to a change being detected, and therefore implies that the trigger values must fall in the range between the pre–Basslink mean of an indicator variable and the value which represents significant environmental change.

Trigger values were initially estimated using a type I error rate, or alpha level, of 0.05. These are calculated using the 97.5th and 2.5th percentiles of pre–Basslink variable data – the central 95th percentile range of the pre–Basslink data. Trigger values derived in this way may fall within or outside the range of variable values considered to constitute a substantial change environmentally. A comparison of the proposed trigger values, for the pooled 'whole–of–river' and 'whole year' response case, with the nominal change in variable values that represent a substantial change is made in Table 11.18. For a number of macroinvertebrate variables, the alpha = 0.05 trigger values satisfy the requirement of being exceeded before substantial change occurs. However, there are a number of variables for which this is not the case. For these cases, trigger values were derived using an alpha of 0.1 (based on the 95th and 5th percentiles of pre–Basslink variable data values), to ensure they would be elicited before substantial environmental change occurred. The use of triggers based on a 0.1 alpha level potentially raises the risk of trigger value exceedances occurring by chance (type I error), but satisfies the requirement of eliciting action before any significant environmental change occurs.

Examination of relationships between trigger values estimated with the 95th and 90th percentile of pre–Basslink data and the values associated with significant environmental change (the LOAC values) for variables at zone and site spatial scales, and for individual seasons, confirmed the conclusions from the analysis for the 'whole–of–river' and whole year' case shown in Table 11.18. Thus the same alpha level was adopted to derive trigger values for each variable at all spatial and temporal scales.

The magnitudes of change in the macroinvertebrate variables which represent an ecologically meaningful effect shown in Table 11.18 were based on expert interpretation of changes in the variables, as they pertain to loss of taxa and/or changes in relative abundance of dominant taxa, observed during inspection of differences between Gordon and reference site macroinvertebrate communities. They represent a best approximation of what constitutes a threshold for ecologically meaningful change in community composition and hence the response variables.

Final trigger values are shown in Table 11.19 to Table 11.23, for the nine variables which address the five key benthic macroinvertebrate components. The type I error rate (alpha level) has been indicated for each variable. Seasonal values are shown only for those variables for which a statistically significant difference (at either 0.05 or 0.1 alpha level) was observed between seasons in the pre–Basslink observation period data set. Zone values are always shown separately as mean zone values were always significantly different during the pre–Basslink period. Site values are also shown for each variable. Their use is discussed briefly in section 0.

Trigger levels have both statistically defined upper and lower bounds (i.e above and below the pre–Basslink mean). Only the lower bounds are used here, as the primary environmental change of concern in relation to likely effects of post–Basslink conditions for all the benthic macroinvertebrate variables is a decline (e.g in diversity, density similarity to reference community composition etc). Declines below these bounds will be considered ‘exceedances’ of trigger values.

Multivariate triggers, derived from confidence contours within ordination space, will also be used in combination with Bray Curtis variable trigger values. These will be defined on an annual basis, within the non–metric hybrid multi–dimensional scaling ordination space defined by the relevant pre– and post–Basslink data. The 90, 95 and 99 % confidence ellipses will be derived from pre–Basslink data, separately for zones 1 and 2, and excursions outside those limits (equivalent to trigger exceedances) post–Basslink data points will be reported.

Table 11.18. Estimated size of meaningful ecological effect of Basslink for each macroinvertebrate variable ('whole–of–river' means), along with its current pre–Basslink mean value, declines associated with exceedances of the current (alpha = 0.05) trigger.

Component	Variables	Pre–Basslink mean	Meaningful effect	Trigger values	
		'Whole–of–river'	Decline in mean by:	Decline from pre–Basslink mean by:	Appropriate alpha level for trigger
Community structure	Bray Curtis similarity to Reference (abundance data)	26.60	≥ 20%	14%	0.05
	O/Erk	0.85	≥ 0.2	0.09	0.05
Community composition	Bray Curtis similarity to Reference (presence/absence data)	36.96	≥ 20%	12%	0.05
	O/Epa	0.92	≥ 0.2	0.12	0.05
Taxonomic richness	Taxon richness (number of families)	14.53	≥ 3	2	0.05
	N EPT species	8.74	≥ 3	1.9	0.05
Ecologically significant species	Proportional abundance of EPT species	0.25	≥ 0.1	0.07	0.1
	Density of Ephemeroptera	6.15	≥ 30%	40%	0.1
Biomass/productivity	Total density (n per unit area)	123.19	≥ 30%	30%	0.1

Table 11.19. Trigger values for benthic macroinvertebrate community structure variables, for whole–of–river, zones, seasons and sites, for each year of a three–year monitoring cycle. Seasonal values are shown only where statistically significant differences.

Variable Alpha	Post–Basslink	Trigger bounds (lower)		
		1 year	2 years	3 years
Bray Curtis (abundance) alpha 0.05	**Whole–of–River**			
	Av (all times)	21.4	22.6	23.1
	Zone group 1			
	Av (all times)	9.0	10.8	11.5
	Spring	0.9	5.4	5.7
	Autumn	13.8	14.8	15.3
	Zone group 2			
	Av (all times)	27.1	29.3	30.1
	Spring	34.8	36.4	36.5
	Autumn	17.7	21.0	22.3
	Sites			
	Site 42	23.1	25.7	26.7
	Site 48	25.0	27.6	28.6
	Site 57	32.1	33.4	33.9
	Site 60	16.0	21.1	23.2
	Site 63	18.5	21.1	22.2
	Site 69	0.0	2.5	4.1
	Site 72	15.5	17.4	18.2
	Site 74	9.0	10.8	11.5
O/Erk Alpha 0.05	**Whole–of–River**			
	Av (all times)	0.71	0.75	0.76
	Spring	0.84	0.86	0.86
	Autumn	0.62	0.66	0.67
	Zone group 1			
	Av (all times)	0.57	0.60	0.61
	Zone group 2			
	Av (all times)	0.81	0.85	0.87
	Sites			
	Site 42	0.80	0.84	0.86
	Site 48	0.76	0.82	0.84
	Site 57	0.82	0.86	0.88
	Site 60	0.64	0.71	0.75
	Site 63	0.71	0.78	0.80
	Site 69	0.56	0.61	0.63
	Site 72	0.66	0.70	0.71
	Site 74	0.45	0.50	0.53
	Site 75	0.46	0.49	0.50

Table 11.20. Trigger values for benthic macroinvertebrate community composition variables, for whole–of–river, zones, seasons and sites, for each year of a three year monitoring cycle. Seasonal values are shown only where statistically significant differences between seasonal pre–Basslink values were detected. Alpha levels indicated.

Variable Alpha	Post–Basslink	Trigger bounds (lower)		
		1 year	2 years	3 years
Bray Curtis (pres/abs data) alpha 0.05	Whole–of–River			
	Av (all times)	30.8	32.2	32.8
	Zone group 1			
	Av (all times)	13.3	16.4	17.7
	Zone group 2			
	Av (all times)	28.3	30.2	31.0
	Sites			
	Site 42	30.7	33.8	35.0
	Site 48	39.5	41.7	42.5
	Site 57	38.2	40.3	41.1
	Site 60	29.0	33.5	35.3
	Site 63	28.8	33.1	34.9
	Site 69	0.9	6.9	9.3
	Site 72	20.6	23.8	25.2
	Site 74	13.7	16.8	18.1
O/Epa Alpha 0.05	Whole–of–River			
	Av (all times)	0.74	0.78	0.80
	Spring	0.72	0.76	0.76
	Autumn	0.86	0.89	0.91
	Zone group 1			
	Av (all times)	0.60	0.63	0.65
	Zone group 2			
	Av (all times)	0.86	0.92	0.94
	Sites			
	Site 42	0.75	0.82	0.85
	Site 48	0.88	0.93	0.95
	Site 57	0.77	0.85	0.89
	Site 60	0.72	0.80	0.83
	Site 63	0.68	0.77	0.80
	Site 69	0.58	0.63	0.65
	Site 72	0.62	0.68	0.70
	Site 74	0.54	0.59	0.61
	Site 75	0.37	0.41	0.42

Table 11.21. Trigger values for benthic macroinvertebrate taxonomic richness variables, for whole–of–river, zones, seasons and sites, for each year of a three–year monitoring cycle. Seasonal values are shown only where statistically significant differences.

Variable Alpha	**Post–Basslink**	**Trigger bounds (lower)**		
		1 year	**2 years**	**3 years**
Number of families alpha 0.05	**Whole–of–River**			
	Av (all times)	12	12	13
	Spring	11	12	12
	Autumn	13	13	13
	Zone group 1			
	Av (all times)	7	8	8
	Zone group 2			
	Av (all times)	15	15	16
	Sites			
	Site 42	12	13	13
	Site 48	14	14	15
	Site 57	14	15	15
	Site 60	11	12	13
	Site 63	12	13	14
	Site 69	6	7	7
	Site 72	8	9	9
	Site 74	8	9	9
	Site 75	3	4	4
NEPT Sp. Alpha 0.05	**Whole–of–River**			
	Av (all times)	6.0	6.5	6.8
	Zone group 1			
	Av (all times)	3.1	3.6	3.9
	Zone group 2			
	Av (all times)	8.1	8.9	9.3
	Sites			
	Site 42	7.3	8.3	8.7
	Site 48	6.7	7.5	7.8
	Site 57	6.5	7.5	8.0
	Site 60	3.9	5.1	5.8
	Site 63	6.0	7.4	8.1
	Site 69	2.7	3.4	3.7
	Site 72	3.4	4.3	4.7
	Site 74	3.2	3.7	4.0
	Site 75	1.3	1.7	1.9

Table 11.22. Trigger values for benthic macroinvertebrate ecologically significant species variables, for whole–of–river, zones, seasons and sites, for each year of a three–year monitoring cycle. Seasonal values are shown only where statistically significant.

Variable Alpha	Post–Basslink	Trigger bounds (lower)		
		1 year	2 years	3 years
	Whole–of–River			
	Av (all times)	0.17	0.19	0.19
	Zone group 1			
	Av (all times)	0.14	0.16	0.16
	Zone group 2			
	Av (all times)	0.11	0.15	0.16
	Sites			
Proportional abund EPT species alpha 0.1	Site 42	0.13	0.15	0.16
	Site 48	0.04	0.06	0.07
	Site 57	0.02	0.09	0.11
	Site 60	0.07	0.16	0.19
	Site 63	0.22	0.30	0.34
	Site 69	0.07	0.10	0.12
	Site 72	0.10	0.15	0.17
	Site 74	0.09	0.11	0.12
	Site 75	0.07	0.09	0.10
	Whole–of–River			
	Av (all times)	2.9	3.5	3.8
	Spring	3.7	4.5	4.5
	Autumn	0.4	1.0	1.3
	Zone group 1			
	Av (all times)	0.7	1.0	1.11
	Zone group 2			
	Av (all times)	4.2	5.5	6.1
	Spring	14.2	15.5	15.6
Abundance Ephemeroptera Alpha 0.05	Autumn	0.5	1.3	1.7
	Sites			
	Site 42	9.9	11.27	11.9
	Site 48	5.1	5.94	6.3
	Site 57	3.0	4.12	4.7
	Site 60	0.2	1.22	1.8
	Site 63	1.6	2.25	2.6
	Site 69	0.0	0.00	0.1
	Site 72	2.2	3.06	3.5
	Site 74	0.0	0.00	0.0
	Site 75	0.0	0.00	0.1

Table 11.23. Trigger values for benthic macroinvertebrate biomass/productivity variables, for whole–of–river, zones, seasons and sites, for each year of a three–year monitoring cycle. Seasonal values are shown only where statistically significant difference.

Variable Alpha	Post–Basslink	Trigger bounds (lower)		
		1 year	2 years	3 years
Total benthic macroinvertebrate density alpha 0.1	Whole–of–River			
	Av (all times)	80	88	92
	Zone group 1			
	Av (all times)	26	32	35
	Zone group 2			
	Av (all times)	130	147	155
	Sites			
	Site 42	96	114	122
	Site 48	118	131	137
	Site 57	94	113	123
	Site 60	109	140	156
	Site 63	78	98	107
	Site 69	12	18	21
	Site 72	29	38	42
	Site 74	25	33	37
	Site 75	14	18	21

11.5.2.8 Actions associated with trigger exceedances

Three categories of actions which may result from exceedance of trigger values have been developed. These are matched with a trigger formulation for benthic macroinvertebrates in Table 11.24.

Table 11.24. Decision points that elicit post–Basslink actions for benthic macroinvertebrates.

Category	Action	Elicited by
1	Note and explain	Low proportion (two in a zone) of sites exceed trigger levels for one or more variables on one or two sampling occasions
2	Investigate	Persistent (three or more consecutive seasonal sampling occasions) exceedance of trigger values for two or more sites in a zone for one or more variables.
3	Management response : Propose & evaluate actions, instigate as required	Persistent exceedance of trigger values for whole of zone or whole–of–river; and Investigation indicates trigger exceedances are highly likely to be caused by a Basslink–induced change in conditions.

Site level trigger exceedances are to be used, along with zonal values in assessing the need for category 1 and 2 actions. Triggers at all three spatial scales will be evaluated for category 3 actions.

Investigations will depend on which triggers are exceeded, but may include:

- more detailed evaluation of existing samples and data from the theme and covariates (e.g flow);

- additional sampling at specific sites; and
- investigation of causal mechanisms by additional measurement (e.g temperature/DO, stable isotopes, diet, size frequency for specific taxa etc).

Management responses will be identified following review of investigation results, the nature, magnitude and rate of the trigger exceedance, consideration of type I and II error rates in monitoring data, and what management options are most relevant and practical.

11.5.3 Instream algae and moss

11.5.3.1 Indicator variables

Two indicator variables are derived from the instream algae and moss data and used as the basis for monitoring changes associated with Basslink. These are:

- % filamentous algal cover; and
- % moss cover.

As for benthic macroinvertebrates, these trigger levels have upper and lower bounds, with yearly, seasonal (summer, autumn), all-of-river and (two) zonal values. In addition, trigger values associated with spatial patterns are being explored. These values are shown in the recent trigger and LOAC section of the Basslink Baseline Report, and have been updated to include data from spring 2005.

Either exceedances above or decreases below trigger bounds are possible post-Basslink. Decreases below the lower bounds are considered the most likely scenario for filamentous algae, especially upstream of Denison, if environmental flows have a substantial shading effect on the stream bed. This will not be considered a negative environmental management issue, as it represents a shift toward a more natural light climate for the algal community, and will either favour or have a neutral effect on benthic macroinvertebrates.

Following discussions after the release of the BBR, it was agreed that:

- these two variables address a key biomass/productivity and trophic component of the instream ecosystem;
- the current trigger values could include a spatial gradient component, especially for upstream of Denison;
- exceedance of triggers should stimulate investigation and interpretation but would not result in management action in their own right.

Thus algae and moss data are largely to provide a supportive, interpretive role to the other instream faunal themes (see below and Table 11.24).

Both algal and moss cover have a high priority and the ecological significance of changes in variable values is also rated as high. The sensitivity of the variables to Basslink drivers is likely to be high for algae upstream of the Denison River, and moderate to low for moss. The pre-Basslink temporal variance in algal and moss cover is high, though lowest in spring. These variables have the potential to provide early warning of significant change, if spatial variability can be better accounted for in trigger formulation.

11.5.3.2 Limits of environmental change and trigger values

Exceedances above existing upper trigger bounds for either algae or moss, defined with an alpha of 0.05, will be regarded as declines in environmental condition. Consistent changes in % cover above or below trigger bounds over two or more years should initiate a more detailed evaluation of the nature of the change in cover, notably to assess:

- shifts in the physical location of remnant algae across the fixed transects ('bath tub ring' vs. 'bottom scum' scenarios) by examination of presence of peak algal and moss cover and shifts in the extent and location of transect zones;
- changes in dominant species composition, by examination of the taxonomy of the dominant species within each transect's zones from collections made pre-Basslink and comparison with those made post-Basslink; and
- evaluate changes in benthic macroinvertebrates (especially grazers) that may relate to algal changes.

Pre-Basslink mean values for algal and moss cover for the two zones are shown in Table 11.25 (for the 'whole-of-river' case), with the trigger values estimated for both alpha levels 0.05 and 0.1. The differences from the pre-Basslink means that these trigger values represent are shown alongside the initial estimate of what constitutes a significant environmental change (a > 50 % negative or a 100 % positive change in cover). Triggers derived using an alpha of 0.1 have lower and upper bound values generally falling between the values for the pre-Basslink mean and those for a significant environmental change. It is recommended that triggers based on alpha of 0.1 are used.

The magnitudes of change in the algal and moss cover which represent an ecologically meaningful effect shown in Table 11.25 were based on expert interpretation of differences in the variables, as they pertain to change in plant dominance, food resource and habitat quality for benthic macroinvertebrates, observed during inspection of differences between Gordon and reference site algal and moss cover and spatial arrangement. They represent a best approximation of what constitutes a threshold for ecologically meaningful change.

Final trigger values are shown in Table 11.26.

Table 11.25. Estimated size of meaningful ecological effect of Basslink for instream flora cover variables ('whole–of–river' means), along with current pre–Basslink mean values, declines associated with exceedances of trigger values (alpha = 0.05, 0.1; both lower and upper bounds).

Component	Zone	Pre–Basslink mean	Meaningful effect	Trigger values			
		'Whole–of–river'	Change in mean by	Alpha 0.05	Alpha 0.1	Alpha 0.05	Alpha 0.1
				Values		Change from pre–Basslink mean by	
Filamentous algae (% cover)	1 (upstream of Denison)	5.2	–50 % to –75%	2.2	2.6	–57.7%	–50.0%
			+100%	11.0	9.5	111.5%	82.7%
	2 (downstream of Denison)	0.6	–50 % to –75%	0.1	0.2	–83.3%	–66.7%
			+100%	1.5	1.3	150.0%	116.7%
Moss (% cover)	1 (upstream of Denison)	2.5	–50% to –75 %	1.24	1.45	–50.4 %	–42.0 %
			+100 %	4.63	4.15	85.2 %	66.0 %
	2 (downstream of Denison)	0.9	–50 % to –75 %	0.23	0.32	–74.4 %	–64.4 %
			+100 %	1.69	1.49	87.8 %	65.6 %

Table 11.26. Trigger values for benthic filamentous algae and moss cover (all set at alpha 0.1).

Variable Alpha	Post–Basslink	Trigger bounds (lower)					
		1 year		2 years		3 years	
		Lower	Upper	Lower	Upper	Lower	Upper
Algal cover Alpha 0.1	Whole–of–river						
	Av (all times)	0.84	4.48	1.09	3.83	1.20	3.59
	Spring	1.23	5.12	1.58	4.43	1.63	4.04
	Autumn	0.00	7.51	0.06	5.54	0.18	4.87
	Zone group 1						
	Av (all times)	1.82	12.62	2.39	10.35	2.65	9.54
	Spring	4.84	11.44	5.53	10.38	5.62	9.76
	Autumn	0.06	15.33	0.45	11.00	0.64	9.59
	Zone group 2						
	Av (all times)	0.00	1.73	0.10	1.42	0.15	1.31
	Sites						
	Site 42	0.00	5.07	0.23	3.92	0.34	3.52
	Site 48	0.00	3.20	0.01	2.48	0.09	2.23
	Site 57	0.00	1.08	0.00	0.84	0.00	0.75
	Site 60	0.00	1.44	0.00	1.10	0.00	0.97
	Site 63	0.00	15.23	0.07	10.37	0.24	8.83
	Site 69	0.00	10.75	0.18	7.69	0.33	6.69
	Site 72	0.80	5.80	1.10	4.83	1.24	4.48
	Site 74	2.90	45.28	4.19	33.77	4.84	29.93
	Site 75	1.90	32.22	2.85	24.06	3.32	21.33
Moss cover Alpha 0.1	Whole–of–river						
	Av (all times)	0.80	2.58	0.95	2.31	1.01	2.20
	Spring	0.46	2.69	0.67	2.30	0.70	2.08
	Autumn	0.67	3.85	0.88	3.30	0.98	3.09
	Zone group 1						
	Av (all times)	1.05	5.16	1.32	4.42	1.45	4.15
	Zone group 2						
	Av (all times)	0.14	1.90	0.27	1.61	0.32	1.49
	Sites						
	Site 42	0.00	3.74	0.00	2.83	0.01	2.51
	Site 48	0.00	3.61	0.08	2.81	0.16	2.53
	Site 57	0.14	1.08	0.22	0.94	0.26	0.89
	Site 60	0.00	2.78	0.08	2.21	0.15	2.00
	Site 63	0.45	3.66	0.65	3.07	0.75	2.85
	Site 69	0.59	4.44	0.83	3.72	0.94	3.45
	Site 72	0.00	2.42	0.00	1.86	0.00	1.65
	Site 74	2.42	19.39	3.20	15.59	3.57	14.24
	Site 75	0.90	7.86	1.27	6.42	1.44	5.90

11.5.3.3 Actions associated with trigger exceedances

If values fall persistently outside trigger level bounds (Table 11.27), more detailed sampling and interpretation of algal and moss cover and composition will be required across a gradient of benthic conditions in order to identify the primary driver of the change. This should focus on relationships between algal and moss cover and depth and near-bed velocity, so as to clearly assess the role of the changed flow regime in the observed changes in algae and moss.

In addition, the implication of the observed algal and moss changes for the instream ecosystem should be re-assessed using stable isotope analysis of selected macroinvertebrate taxa and fish, coupled with inspection of changes in benthic macroinvertebrate community composition.

Table 11.27. Decision points that elicit actions for moss and algae.

Category	Description	Elicited by
1	Note and explain	Low proportion (2 in a zone) of sites exceed trigger levels for either variable on one or two sampling occasions
2	Investigate	Persistent (three or more consecutive seasonal sampling occasions) exceedance of trigger values for two or more sites in a zone for either variable.
3	Management response required	Only if persistent trigger exceedances are accompanied by category 3 responses for benthic macroinvertebrates.

11.5.4 Fish

11.5.4.1 Indicator variables

Five indicator variables have been reported annually to date from the fish data used as the basis for monitoring changes associated with Basslink. The variables described from fish sampling are relative abundance (as indicated by catch per unit effort) of:

- all fish species;
- native species;
- galaxiids;
- exotic fish (trout and redfin); and
- ratio of exotic fish to natives.

Proposed trigger levels for these variables were included in the BBR. They have upper and lower bounds, with yearly, seasonal (autumn), all-of-river and grouped zonal values. Seasonal values exclude summer triggers due to the high variability of the summer data, which is related to the variability in the size and species composition of annual native fish migration runs.

Following discussion and review of the proposed triggers, the feasibility of revising the set of indicator variables to include community composition and taxon richness was explored using Bray Curtis similarity to Reference sites on pre-Basslink abundance data and presence/absence data. Ordination of the square root transformed abundance data showed good zone grouping clustering in ordination space which was independent of season and year, with the lower Gordon

River zones grouping in the proximity of the reference rivers. In order to investigate the applicability of setting trigger levels for the abundance similarity data, a series of scenarios were run to determine the sensitivity of the analysis to detect significant declines in native fish abundance, and large increases in exotic fish in the test zones. The resulting changes in similarity were used to determine whether this variable had sufficient statistical power to detect ecologically significant changes to the fish fauna of the Gordon River test zones. Power analysis indicated that when alpha was adjusted between 0.05–0.3, the statistical power of the similarity variables was insufficient to have a reasonable chance of detecting ecologically significant changes. While it was expected that flow regulation effects in the test zones would effect similarity with the reference zones, pre–Basslink differences in natural variability between the test and reference zones resulted in different effects on species diversity and relative abundance in these zones. Additionally, the relatively small number of fish taxa and low abundances mean that any natural variability in the reference sites has a large effect on inter–reference zone similarity which in turn confounds the ability to separate post–Basslink Bray Curtis similarity changes between test and reference zones.

The suitability of applying the Shannon–Wiener index to assess pre versus post–Basslink changes in species diversity was also assessed. The limitations that the data posed to the use of Bray Curtis approach also apply to the Shannon–Wiener index, which was not unexpected as both methods rely on:

- the number of species; and
- the number of individual in each species to derive similarity (Bray Curtis) and species diversity (Shannon Weiner) comparisons between sites.

Table 11.28 identifies the fish monitoring variables than are suitable for addressing the key assessment components; community composition, ecologically significant species and biomass/productivity. Each component is associated with one or more variables which have sufficient statistical power to provide a meaningful assessment of the data. It should be noted that while trout and redfin have little environmental value in the World Heritage Area, they have been included as an ecologically significant species due to their potential to impact upon native fish populations and general indicator of environmental change. Hence a decline in the numbers or proportion of these exotic species can be regarded as positive for the Gordon River environment due to the decreased potential for competition with and predation on native species. However a decline in exotics abundance, particularly in the upper zones subject to the greatest influence of flow regulation, may also indicate that post–Basslink operation at the power station is having a negative effect on broadscale fish habitat requirement. Given that there is potential for conflicting interpreting of this indicator variable, it should be assessed in conjunction with other native fish indicators such as the native to exotic ratio indicator variable to determine whether:

- an increase in exotics abundance is indicative of net environmental improvement;

- is implicated with declining native fish abundance; or
- a decrease in exotics abundance is indicative of a general declining environmental conditions.

Table 11.28. Mapping of key components to monitored variables.

Component	Variables
Community composition	Ratio of exotic to native species
Ecologically significant species	Relative abundance of native fish species Relative abundance of exotic fish Relative abundance of galaxiids
Biomass/productivity	Relative abundance of all fish

11.5.4.2 Ecological significance

The movement of variable values outside trigger and LOAC ranges (particularly decreases below lower trigger values for all variables except native to exotic ratio, and exotic species abundance) is considered to fall in the following order of decreasing ecological significance:

- native species abundance >;
- galaxiid abundance >;
- ratio of native species to exotics (trout and redfin) abundance≈;
- all fish species abundance >; and
- exotic species abundance

11.5.4.3 Sensitivity of response

By contrast, the responses of the variables to declining post-Basslink environmental conditions in the Gordon River context, especially triggered by flow, fall within the following order of sensitivity:

- exotic species abundance;
- all fish species abundance >;
- ratio of native species to exotics (trout and redfin) abundance >;
- native species abundance >; and
- galaxiid abundance >

It is important to note that the sensitivity ordering listed above is applicable only to the Gordon River Basslink context, and that this ordering is not an ecological assessment that is intended to apply to other situations. While native species are likely to be more sensitive to flow regulation in a general context, pre-Basslink data has shown that they are found in low abundances in the upstream Gordon River zones that are subjected to the highest flow variability, which limits their sensitivity as Basslink indicator variables. By contrast, introduced species are relatively common in the upper zones, and as such are likely to show an earlier response to hydro-peaking in comparison to native fish based indicator variables.

11.5.4.4 Temporal variance

Analysis of pre-Basslink data for the period summer 2001 to autumn 2006 has shown that the indicator variables fall in the following order of increasing temporal variance or 'noise':

- exotic species abundance;
- all fish species abundance >;
- ratio of native species to exotics (trout and redfin) abundance >;
- native species abundance >; and
- galaxiid abundance >

This information is summarised in Table 11.29. Variables with high sensitivity, low temporal variance are designated as early warning variables. Exceedance of trigger values should initiate further investigation. Variables with high ecological significance and low sensitivity, and low to moderate temporal variance, are those for which changes are ecologically important. For these, management interventions should be considered as soon as practicable. Other variables with intermediate sensitivity and ecological significance, and/or with high temporal variance, are considered to provide useful diagnostic information.

It is noteworthy that no fish indicator variables have been marked as suitable for directly initiating immediate management intervention. Parameters that are of the highest ecological importance show moderate sensitivity and a high degree of temporal variability, and as such are only suitable for flagging a requirement for further investigation into the cause of the trigger. Further investigation may lead to a management response if additional evidence supports an appropriate course of intervention.

11.5.5 Substantial environmental change and trigger values

The philosophy behind managing the environmental consequences of Basslink is one of 'no net environmental change'. This is difficult to quantify, as detection of change is dependent on intensity of monitoring effort, sensitivity and background variability of variables, and the balance of type I and II errors. These considerations are largely statistical.

In order to provide a quantified context to decision making, the magnitude of changes in each variable which are considered to constitute a substantial and meaningful environmental change (in the context of the pre-Basslink environmental status), have been estimated for fish, and are shown in Table 11.30. A substantial and meaningful environmental change is one which would reasonably be expected to represent environmental degradation, and warrant an appropriate response.

Table 11.29. Characteristics of fish monitoring variables. Relative order (from 1–low to 3–high) is shown against four key characteristics, along with role of variables in decision making when trigger levels are exceeded. Arrows indicate that supplementary evidence may lead to a management intervention.

Variables	Ecological significance	Sensitivity of response	Temporal variance	Early warning	Supplementary evidence	Management intervention
All species relative abundance	3	1	1	x		
Exotic species relative abundance	3	1	1	x		
Galaxiid relative abundance	1	3	3		x →	
Native species relative abundance	1	3	3		x →	
Native to exotic ratio	2	2	2		x →	

11.5.6 Selection of appropriate spatial and temporal scales

While there was no evidence of a seasonal effect in the pre-Basslink data, variance of the summer data was substantially higher than that shown in autumn, particularly for indicator variables with a native fish component. This result was expected for a number of reasons. Annual migration runs of juvenile eels, juvenile galaxiids and adult lampreys occur over spring and summer. Their abundance can differ substantially over a broad range of timescales within the seasonal migration period, varying from significant daily variation to large annual variation in the timing and size of migration runs. Local factors such as flow events contribute to spatial and temporal variability of run abundance. Emergence of brown trout fry occurs in early summer, which also contributes to summer data variability. Summer catch variability is reflected across a range of species, and as a result the exclusion of species specific size classes (e.g juvenile galaxiids) to reduce variance is not appropriate for the summer data.

The large variability of the summer data has implications for the application of trigger levels. Summer trigger values have not been recommended due to its high variability. This limitation does not apply to the application of triggers to the autumn only or all season's (annual) data, the former shows less variance and the summer variance in the latter is offset by increased replication. While the summer data increases variance of the annual data, it conveys valuable information about annual recruitment trends and should continue to be collected during the post-Basslink period.

Selective data analysis of the Gordon River downstream zones (zones 4 and 5) has previously been attempted to increase sensitivity to detect change, based on the hypothesis that higher CPUE's and low number of zero catches typically recorded from the lower zones would increase statistical power. However, this approach was abandoned as statistical power was reduced in comparison to whole-of-river triggers due to decreased replication. Further investigation of the ability of a lower zone subset (zones 4–5) to detect meaningful environmental change has shown that even when type 1 error level is increased to 0.2, the probability of detecting meaningful change across the full range of indicator variables is very low. The rationale of focusing analysis on the lower zones was to target areas where native species are more abundant, however the high variance of the data undermines the ability to detect ecologically meaningful changes. The lower zones are also less influenced by flow regulation in comparison to the upper zones, and as a result are more likely to be influenced by natural factors which make them less sensitive as indicators of Basslink-related change. This raises serious questions about the reliability of the lower zone subsets as indicator variables, and so for these reasons, specific lower zone trigger levels have not been recommended or developed.

11.5.7 Application of the principle of acceptable environmental change to development of trigger levels

Trigger values were initially estimated using a type I error rate, or alpha level, of 0.05. These are calculated using the 97.5^{th} and 2.5^{th} percentiles of pre-Basslink variable data. It is possible that trigger values derived in this way may fall within or outside the range of variable values considered to constitute a substantial change environmentally. It is desirable for trigger values, whose role is to elicit further investigation and interpretation before management actions are elicited, to fall within the range of change considered to be substantial. In this way triggers are exceeded before substantial change occurs before triggers are exceeded.

A comparison of the proposed trigger values, for the pooled 'whole-of-river' (zones 1–5) response case, with the estimated change in variable values that represent a substantial change is made in Table 11.30. It is important to note that these are *estimates* of what constitutes ecologically significant change each indicator variable based on expert opinion. Fish stocks in the Gordon River are probably still in a state of post-dam oscillating equilibrium which is influenced by immigration, juvenile recruitment, growth, natural mortality and emigration. The uncertainty of natural variability induced by these factors is reflected in the size of the meaningful effect estimates. Introduced species show a reduced meaningful effect size in comparison to native species-based indicator variables as they are non migratory (with the exception of a low percentage of trout that become sea run), have low immigration and emigration rates, and adults are less prone to inter-specific predation.

For all the fish indicator variables, an alpha of 0.05 results in a low probability that the limits of acceptable change will be triggered before substantial change occurs. The fish trigger values have been re-evaluated to assess the level of alpha which will increase the probability of detecting a meaningful environmental effect; however, it is important to be aware that in taking this approach there is an increased risk of falsely declaring that significant environmental change has occurred. This trade off between ability to detect a meaningful effect at the expense of increasing the risk of false triggering means that the fish indicator variables with an increased type 1 error level are not suitable for triggering an immediate management response, but should be used as an alert to indicate that an investigation into the cause and implications of the trigger is required. A decision on the appropriate course of action, which may include management intervention, can then be made.

Table 11.30. Estimated size of meaningful ecological effect of Basslink for each fish variable, along with its current pre–Basslink mean value, probability of detecting meaningful ecological change at the current (alpha = 0.05), and whether there is a need to increase the type I error rate to increase the probability of detecting substantial change.

Component	**Variables**	**Pre–Basslink mean (whole river)**	**Estimated meaningful effect size** **Decline in mean by (x %)**	**Initial trigger values** **Probability of detecting x % change, based on 0.05 alpha**	**Revise alpha to; (resulting probability)**
Community composition	Ratio of native to exotic species relative abundance	0.99	≥40 % swing towards trout	0.56	0.15 (0.79)
Ecologically significant species	native fish relative abundance	4.8	≥40 % decline	0.39	0.2 (0.71)
	exotic fish relative abundance	4.86	≥30 % change	0.65	0.1 (0.78)
	galaxiid relative abundance	2.9	≥40 % decline	0.45	0.2 (0.76)
Biomass/productivity	Relative abundance of all fish	7.71	≥40 % decline	0.53	0.15 (0.77)

Table 11.31. Community composition trigger values based on the ratio of native fish to exotic fish species abundance, with lower bounds based on both annual and autumn data and an alpha of 0.15.

CPUE ratio natives to exotics		Limits of acceptable change (CPUE)	
Post–Basslink	1 year	2 years	3 years
Zones 1 to 5			
Annual	0.65	0.72	0.75
Autumn	0.61	0.67	0.69

Table 11.32. Ecologically significant species trigger levels based on native fish relative abundance, with lower bounds based on both annual and autumn data and an alpha of 0.20.

CPUE natives	Limits of acceptable change (CPUE)		
Post–Basslink	1 year	2 years	3 years
Zones 1 to 5			
Annual	2.2	2.5	2.6
Autumn	2.1	2.4	2.5

Table 11.33. Ecologically significant species trigger levels based on exotic fish relative abundance, with upper and lower bounds based on both annual and autumn data and an alpha of 0.10.

CPUE exotics	Limits of acceptable change(CPUE)					
Post–Basslink	1 year		2 years		3 years	
Zones 1 to 5						
Annual	2.78	5.25	3.01	4.90	3.11	4.76
Autumn	2.88	5.80	3.14	5.38	3.24	5.22

Table 11.34. Ecologically significant species trigger levels based on galaxiid relative abundance, with lower bounds based on both annual and autumn data and an alpha of 0.20.

CPUE galaxiids	Limits of acceptable change (CPUE)		
Post–Basslink	1 year	2 years	3 years
Zones 1 to 5			
Annual	0.84	1.04	1.13
Autumn	0.67	0.82	0.88

Table 11.35. Biomass/productivity trigger levels based on all species relative abundance, with lower bounds based on both annual and autumn data and an alpha of 0.15.

CPUE all species	Limits of acceptable change (CPUE)		
Post–Basslink	1 year	2 years	3 years
Zones 1 to 5			
Summer–autumn mean	5.2	5.7	5.9
Autumn	5.2	5.7	5.9

11.5.8 Actions associated with trigger exceedances

Three categories of actions were identified which may result from exceedance of trigger values. For the most part, these are matched with a trigger formulation for fish in Table 11.29, however no indicator variables have been deemed appropriate as direct management response triggers due to the higher risk of false positives associated with increased type 1 error levels, and the high variability of the fish data. For example, using a type 1 error level of 0.05 will result in a 1 in 20 chance of falsely declaring a trigger, whilst an alpha of 0.10 will result in a 1 in 10 chance of false trigger declaration.

Evaluation of management responses would be triggered if the investigations carried out under a category 2 (investigate) action implicated Basslink operations as a causal factor.

Table 11.36. Decision points that elicit actions for fish.

Category	Description	Elicited by:
1	Note and explain	Exceedance of one or more fish variable triggers in any one sample (pooled zone).
2	Investigate	Exceedance of one or more fish variable triggers persisting for two or more pooled samples.
3	Management response required	Investigation from a category 2 trigger indicates trigger exceedances are highly likely to be caused by a Basslink–induced change in conditions.

A category 1 (note and explain) trigger would involve additional assessment of existing monitoring data. For example, this may include assessment of population size structure (length frequency) to determine whether a change in an indicator variable has only occurred in the Gordon River, or whether the change is reflected in the reference rivers indicating a regional effect or natural temporal variability. Assessment of community structure using multivariate analysis may also be undertaken to assess trends in changes relative to the reference sites. Existing hydrological data would also be analysed to determine whether natural flow events could be implicated in category 1 triggers.

Category 2 (investigate) triggers would involve assessment of existing data in addition to collection of additional data to assess and understand the causes and implication of the trigger. This may involve sampling additional sites, investigation of cause and effect by additional physical and biological assessment i.e water quality, dietary analysis, linking to other covariates such as macroinvertebrate abundance, distribution, community composition. The specific scope and nature of the investigations will depend on the triggers exceeded. Category 2 triggers may, depending upon their findings, lead to the development of and recommendation to implement a management response.

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Appendix 1: Erosion pin graphs

Abbreviations used in graphs

b/slope – backslope; slope behind crest of bank

b/water – backwater

cave – bank cavity

cob – vertical cobble bank

col – vertical colluvial bank

crest – crest of bank

flow – sediment flow

HW – power station-controlled high-water marker

pipe – casing for piezometer measured as erosion pin

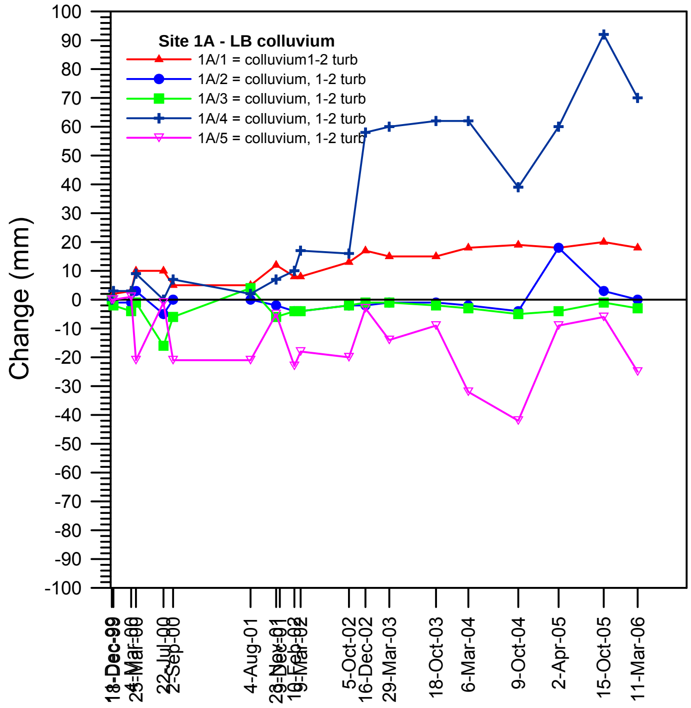
slope – sandy bank slope

toe – sandy bank toe

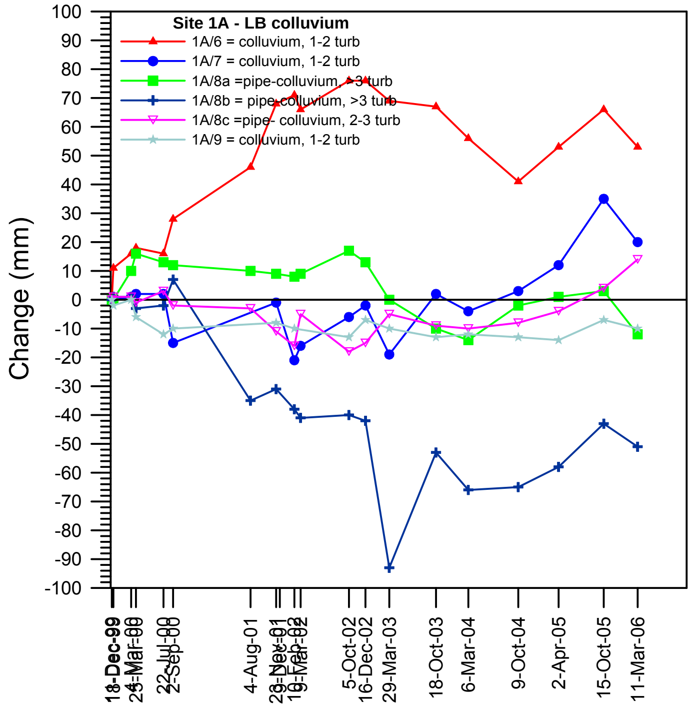
top – top of bank

Zone 1

Site 1A



Site 1A continued



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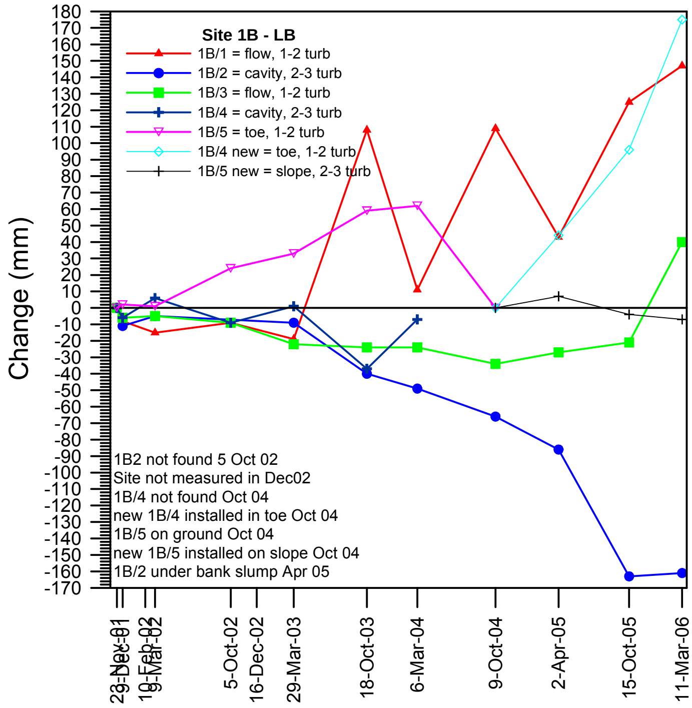

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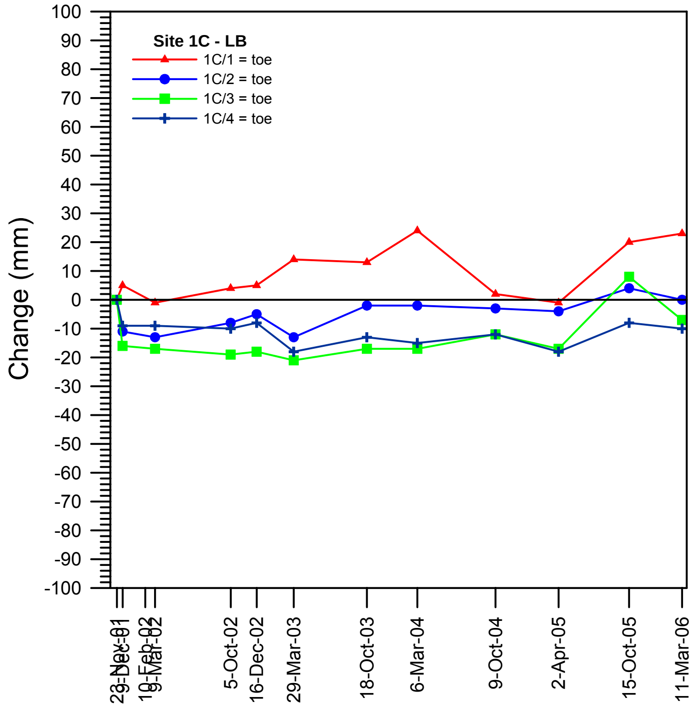
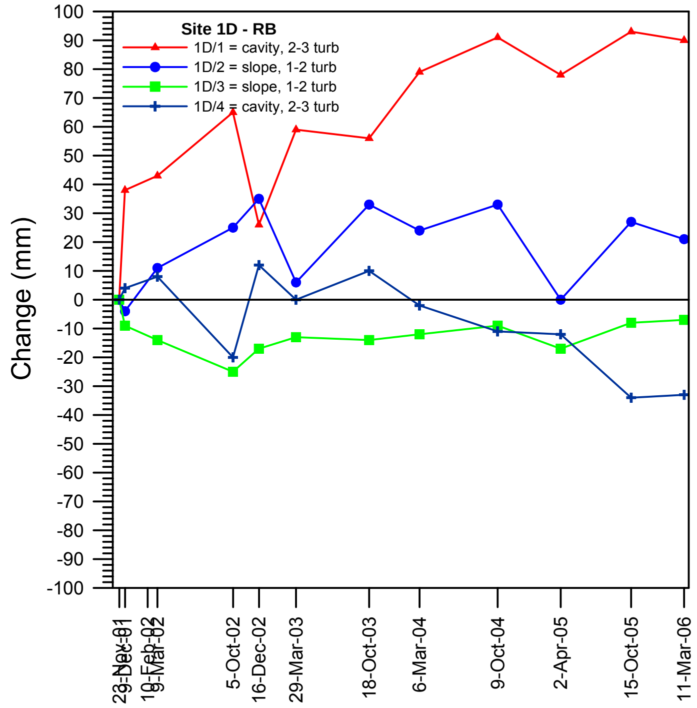


Site 1D



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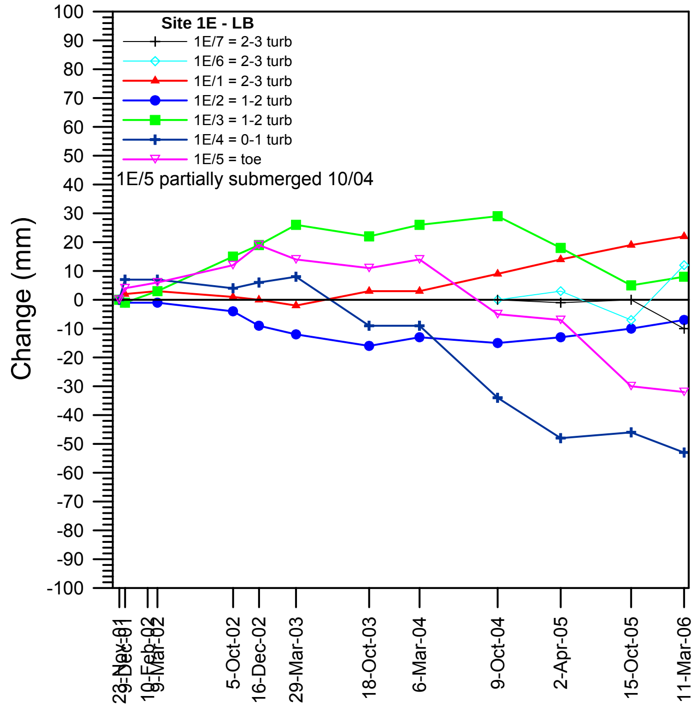
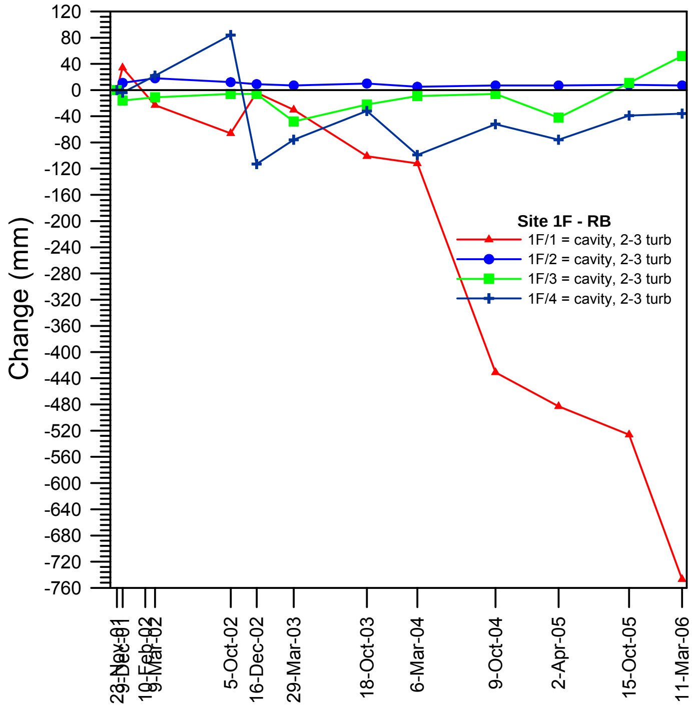
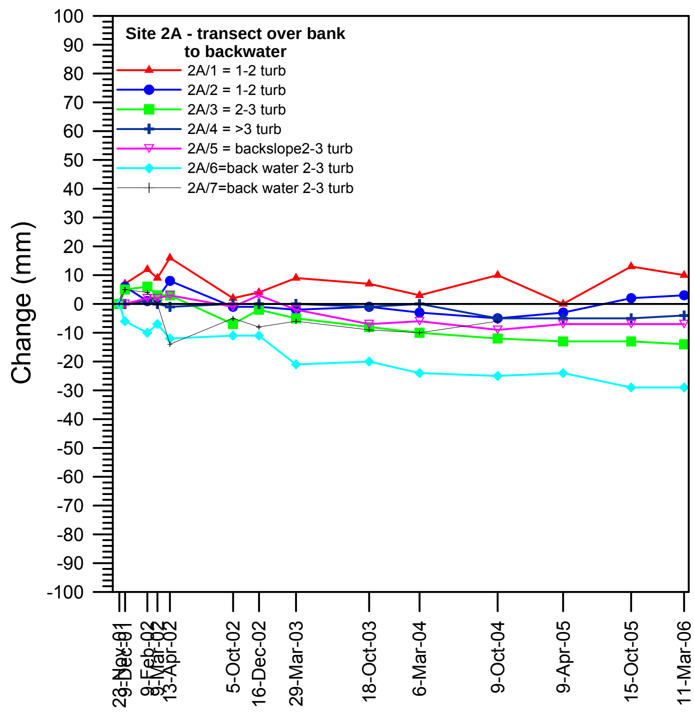


Site 1F


Change (mm)
Site 1F - RB
1F/1 = cavity, 2-3 turb
1F/2 = cavity, 2-3 turb
1F/3 = cavity, 2-3 turb
1F/4 = cavity, 2-3 turb
23-Nov-01
3-Dec-01
10-Feb-02
9-Mar-02
5-Oct-02
16-Dec-02
29-Mar-03
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05
15-Oct-05
11-Mar-06

Zone 2

Site 2A



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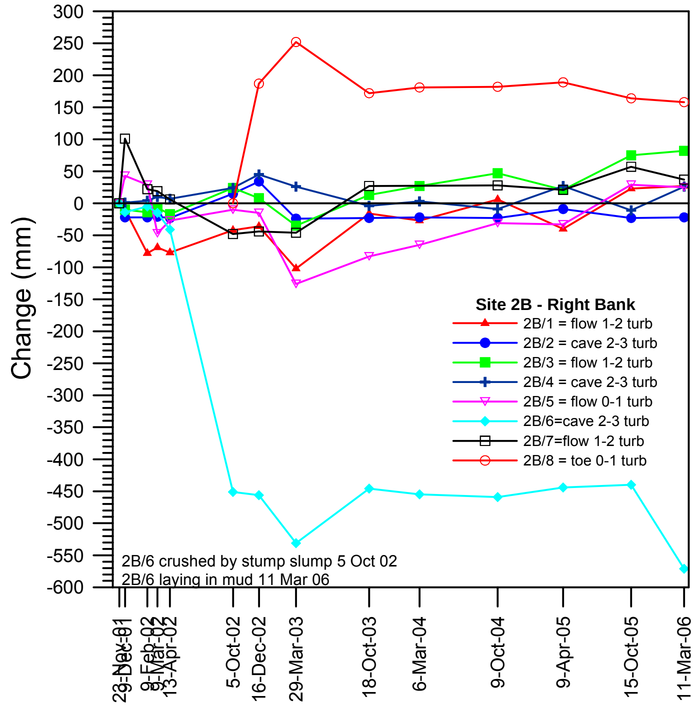

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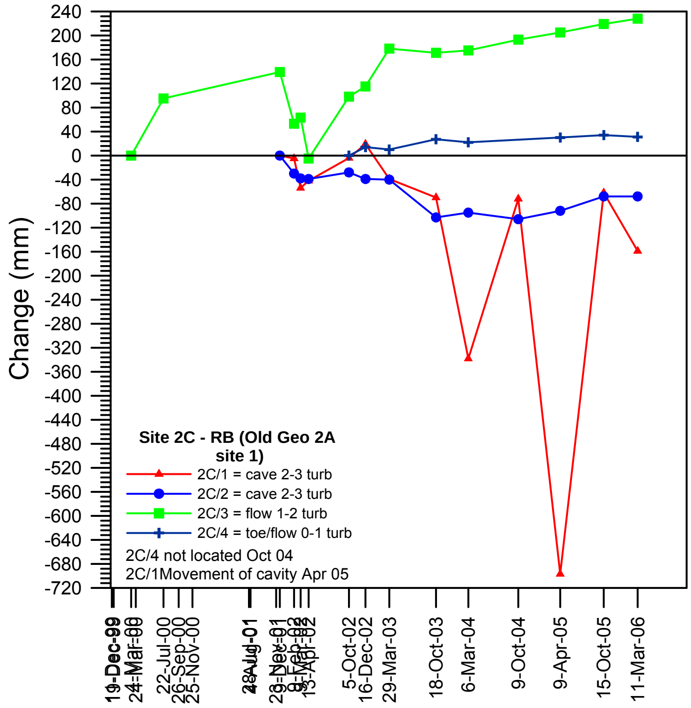

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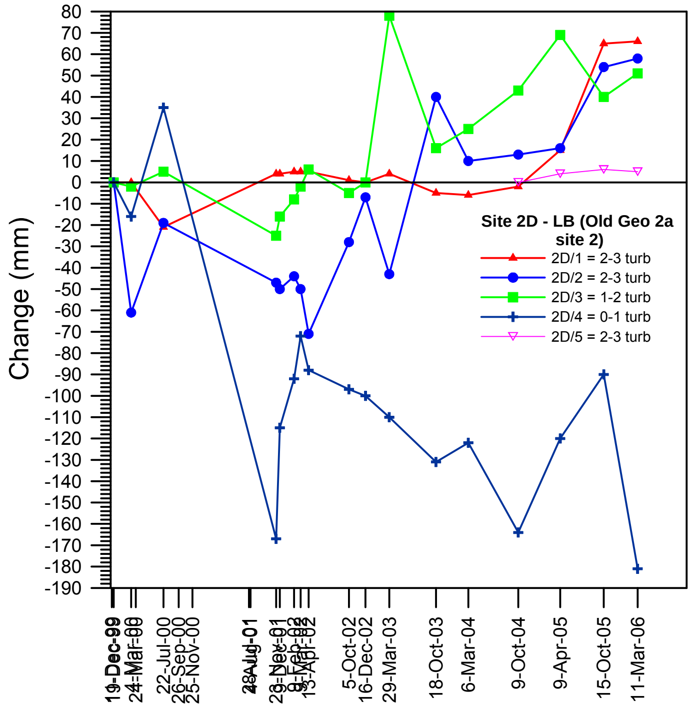

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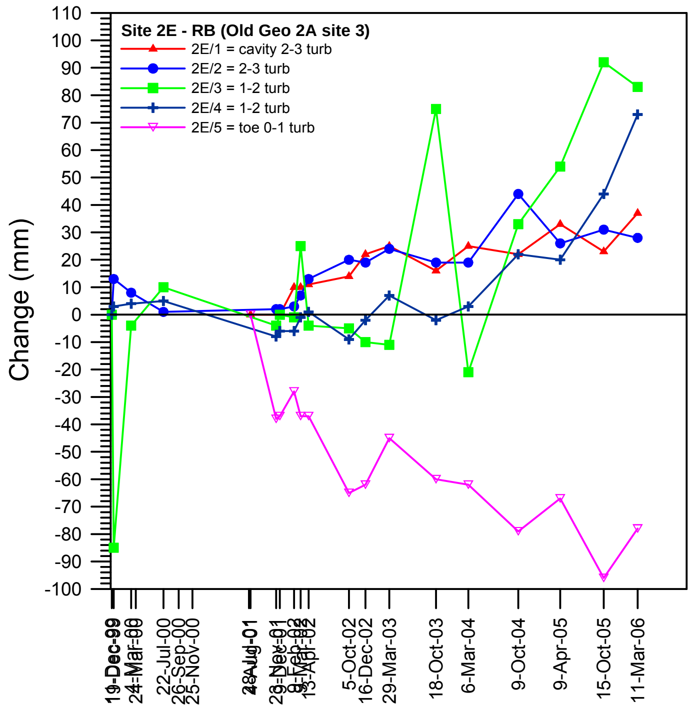

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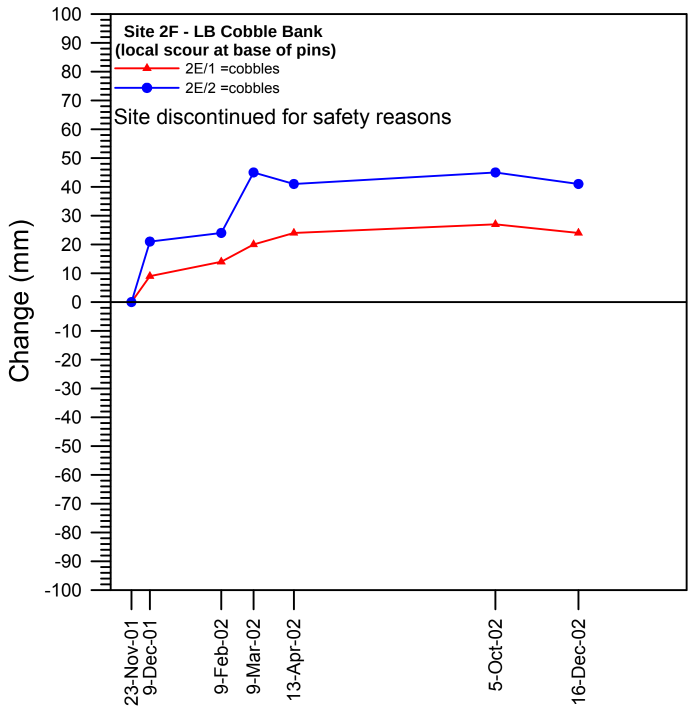

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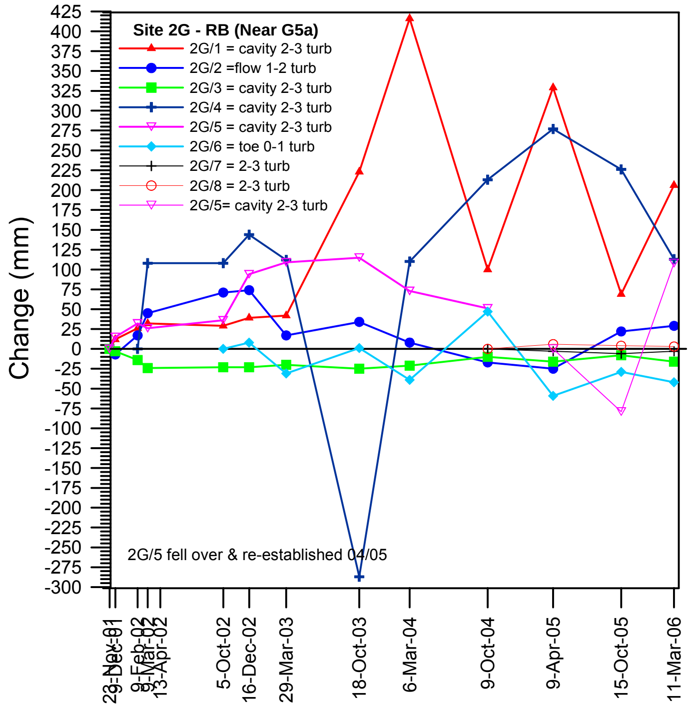
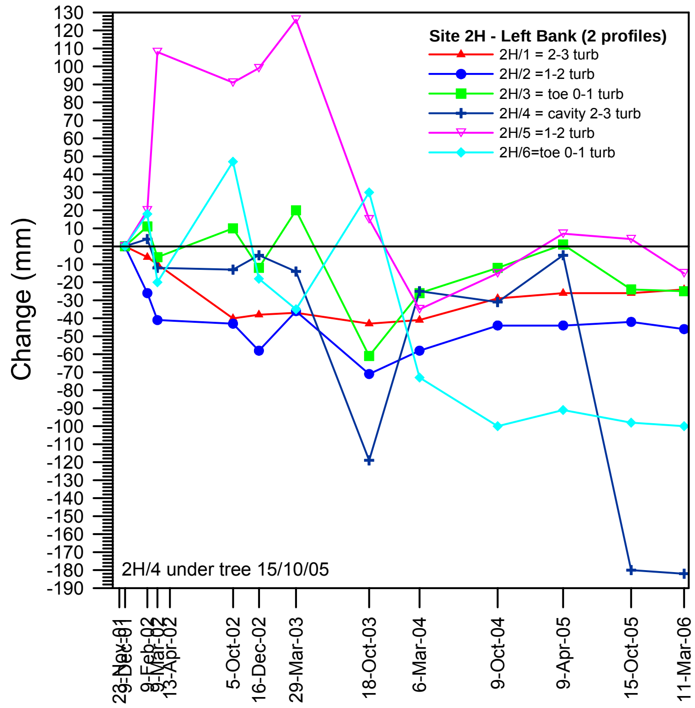
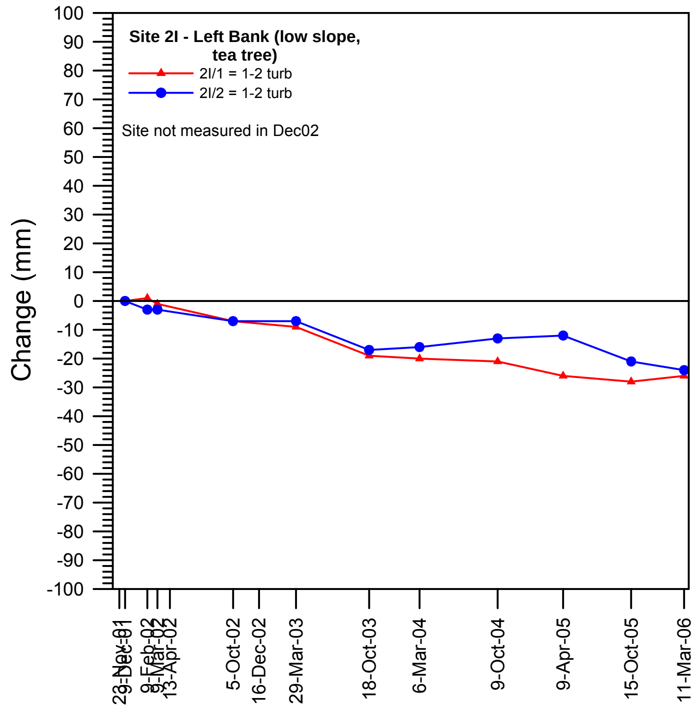


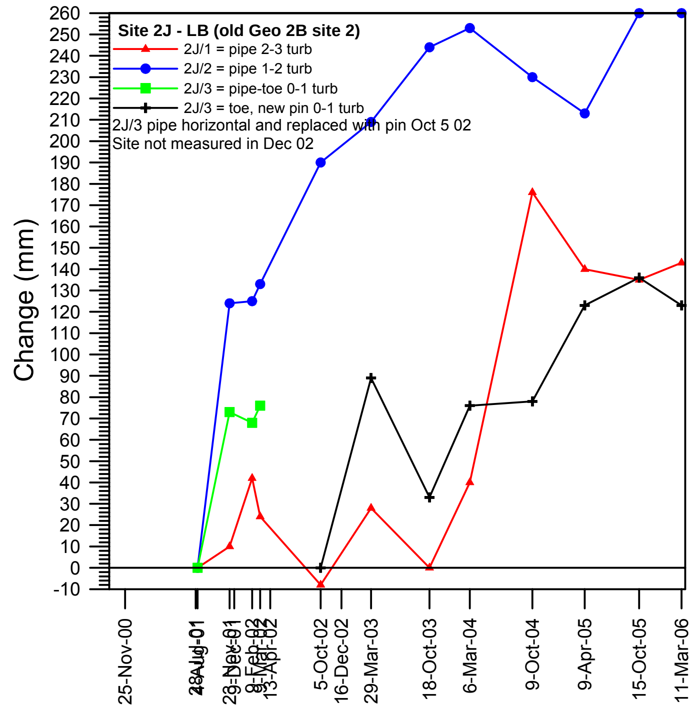
Site 2H



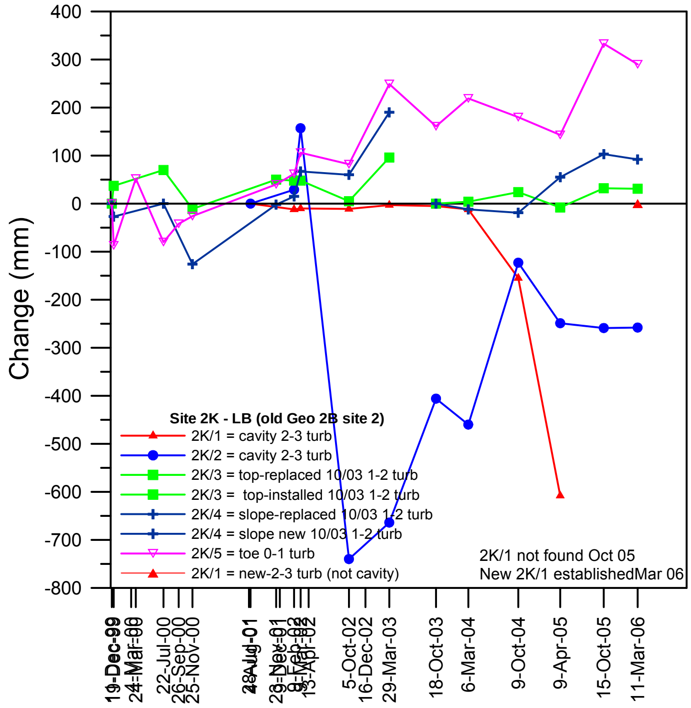
Site 2I



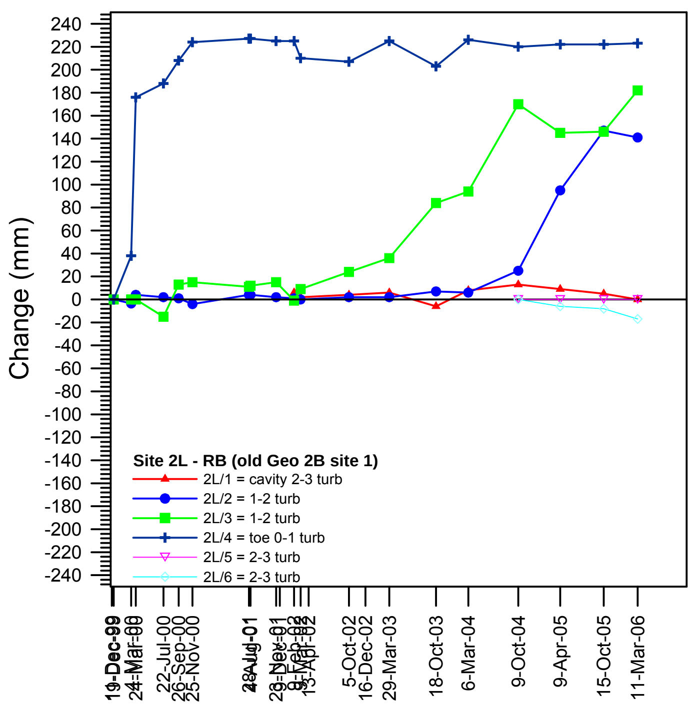
Site 2J



Site 2K

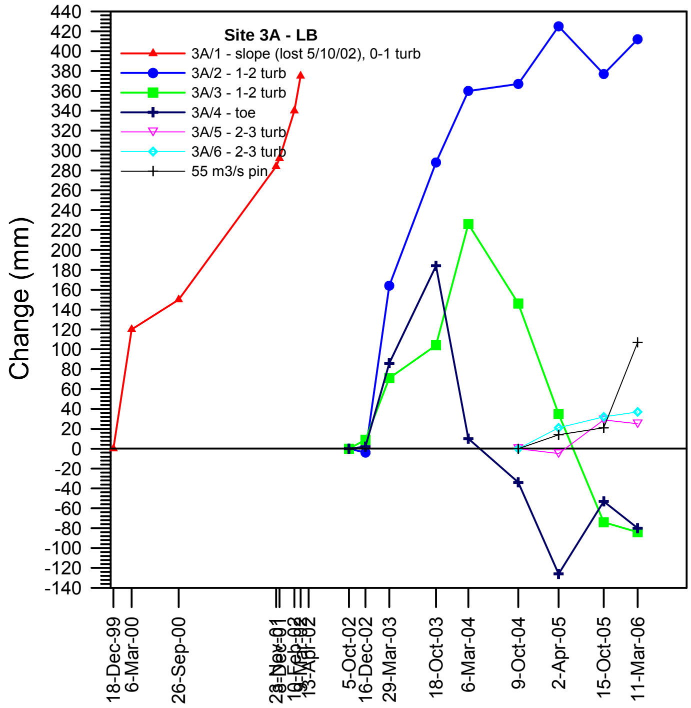


Site 2L

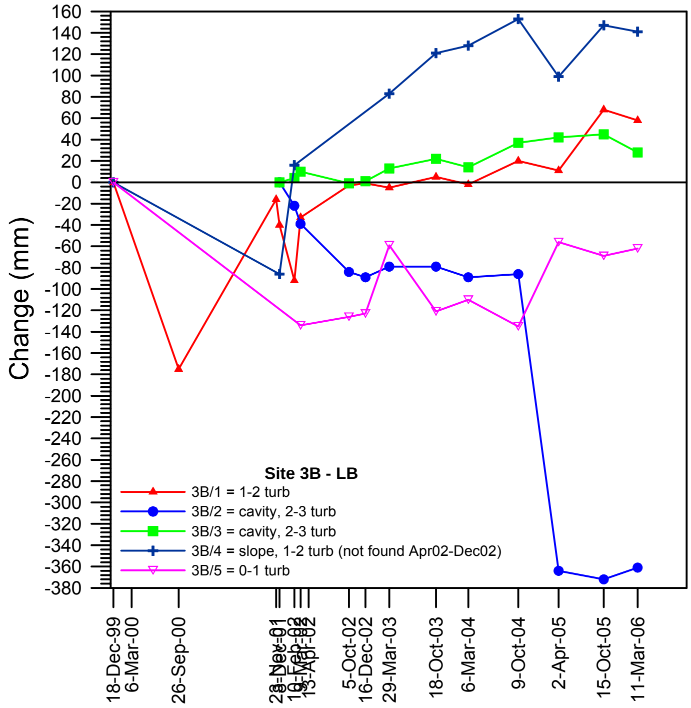


Zone 3

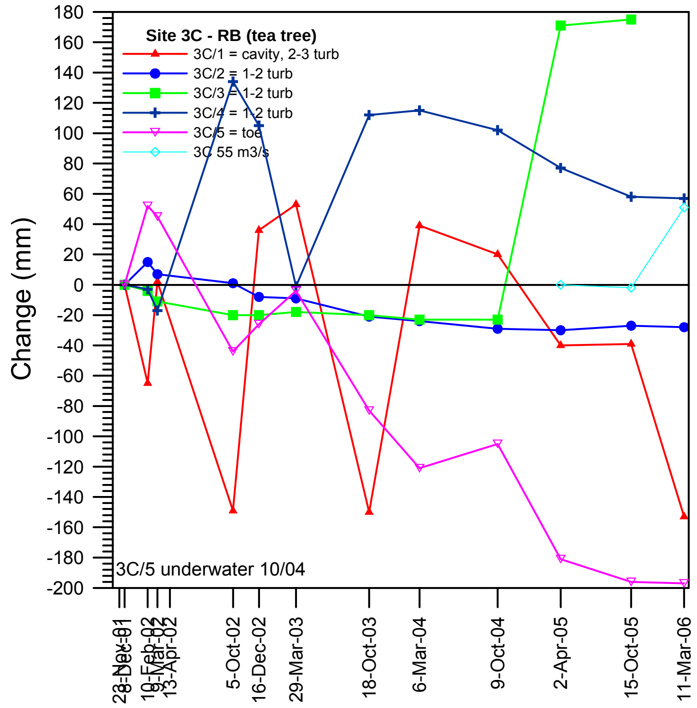
Site 3A



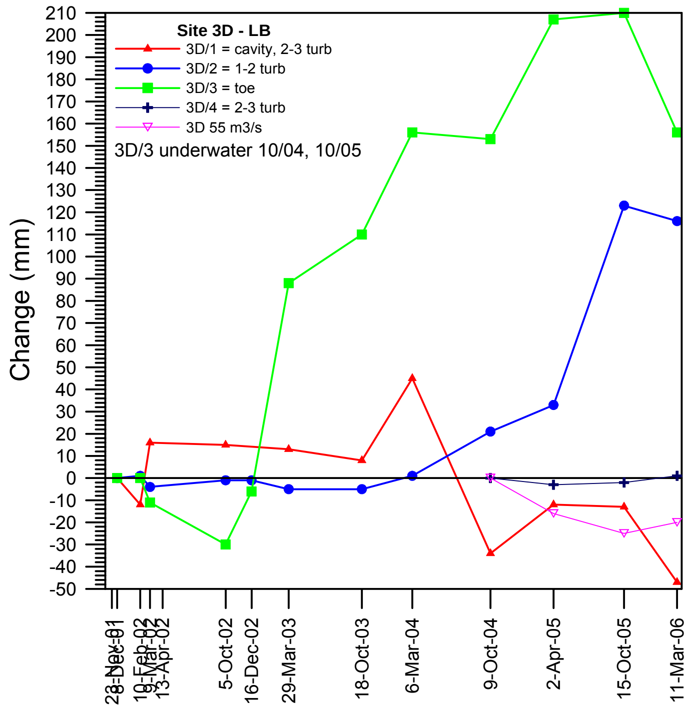
Site 3B



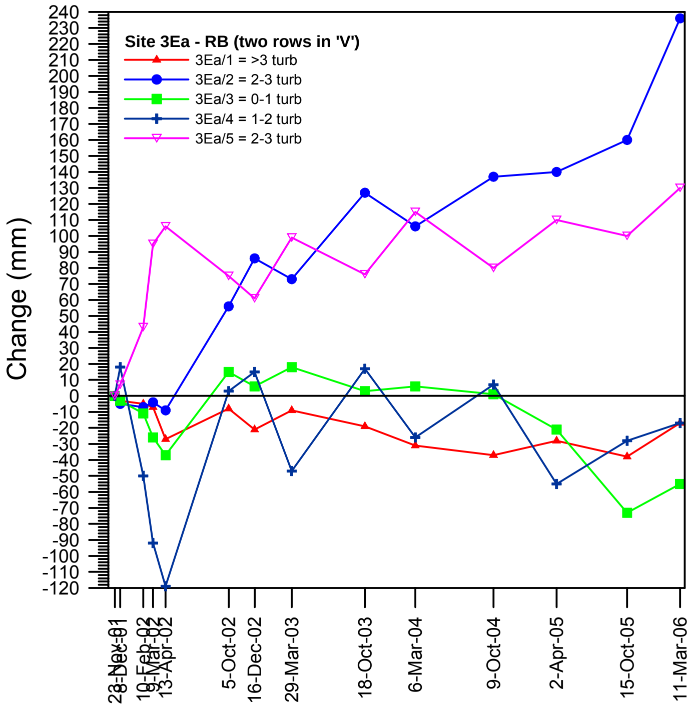
Site 3C



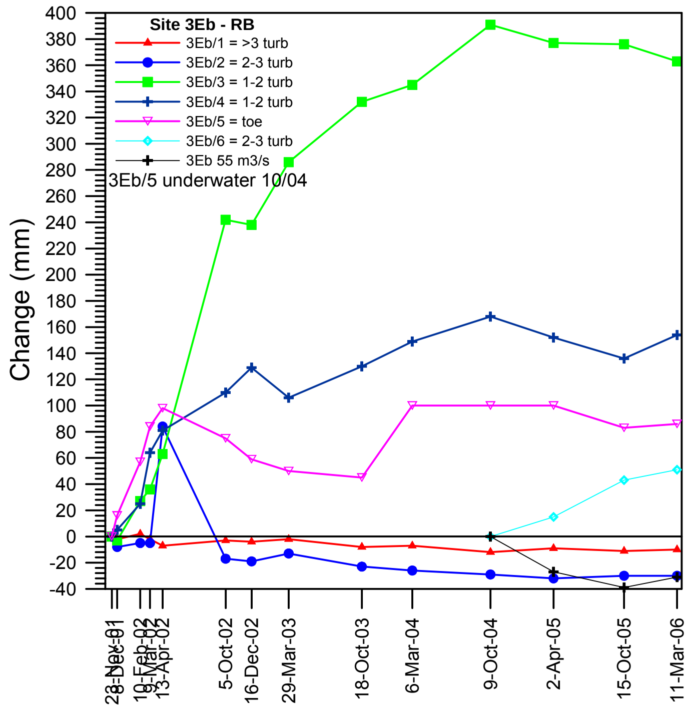
Site 3D



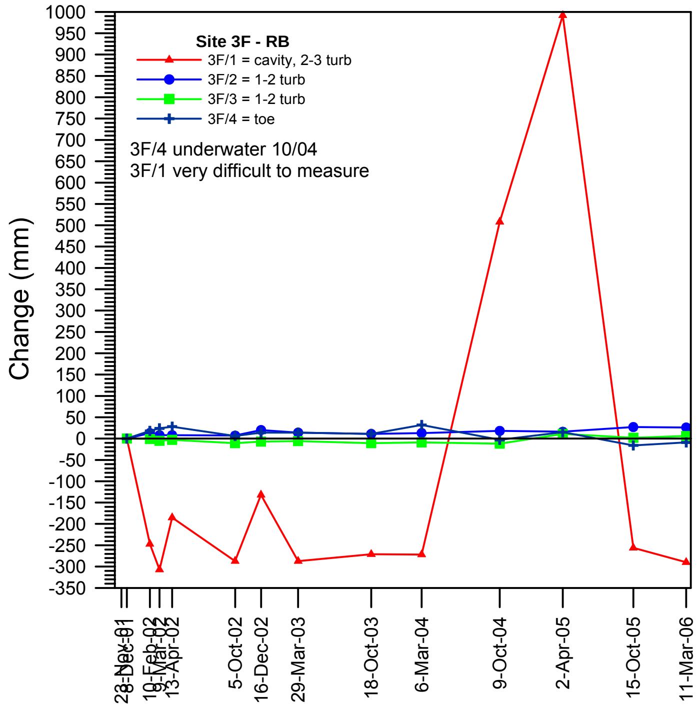
Site 3Ea



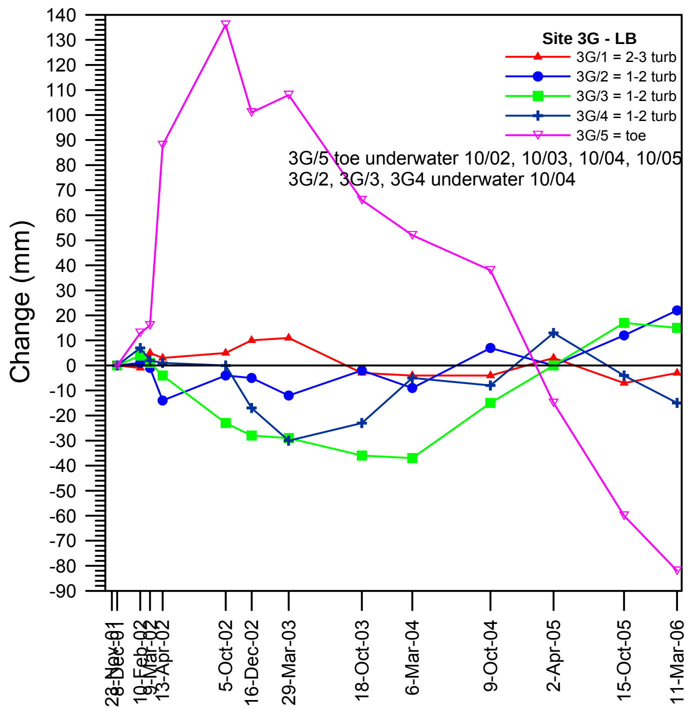
Site 3Eb



Site 3F

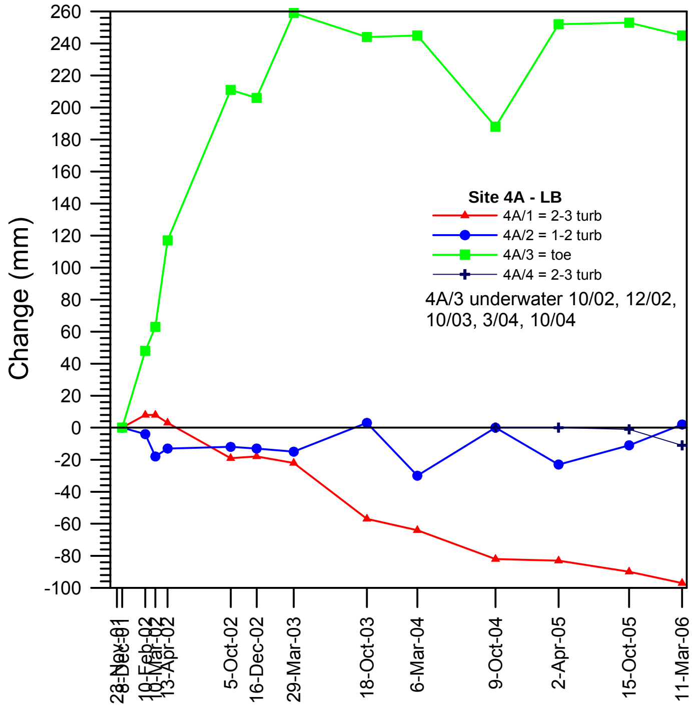


Site 3G

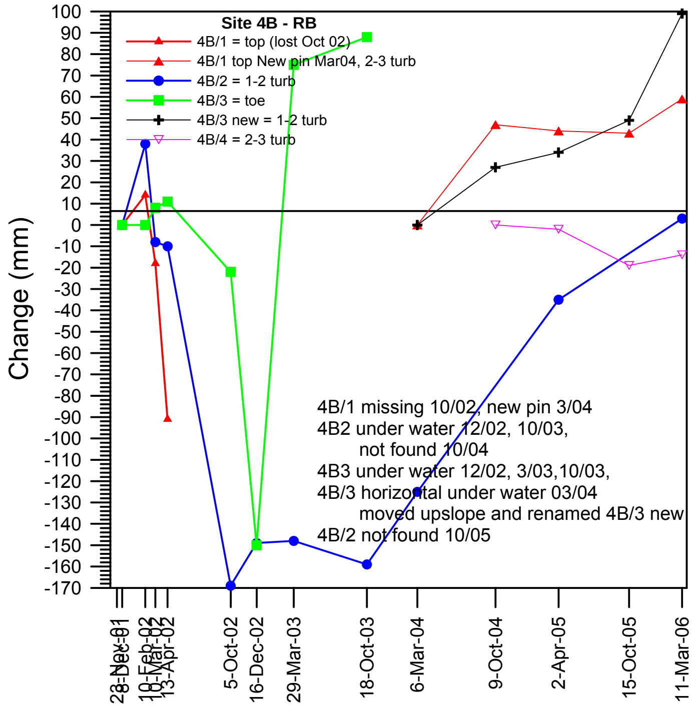


Zone 4

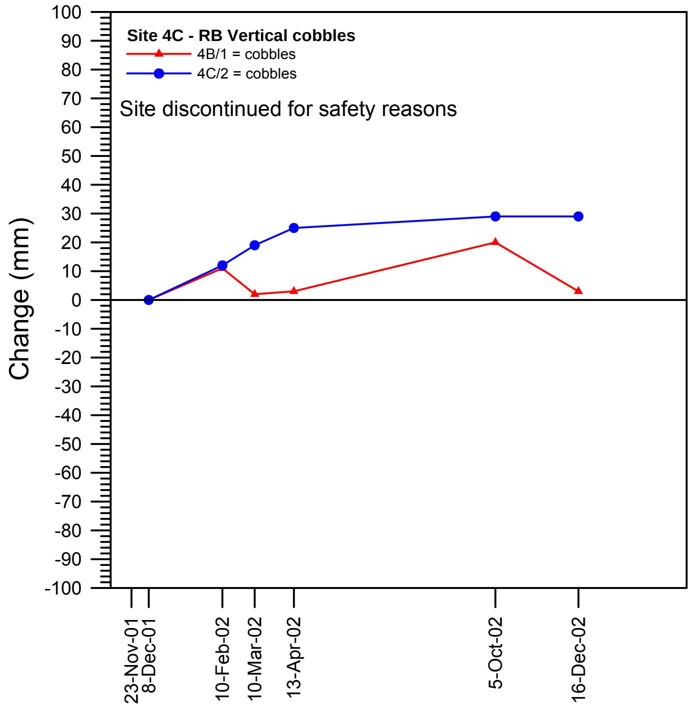
Site 4A



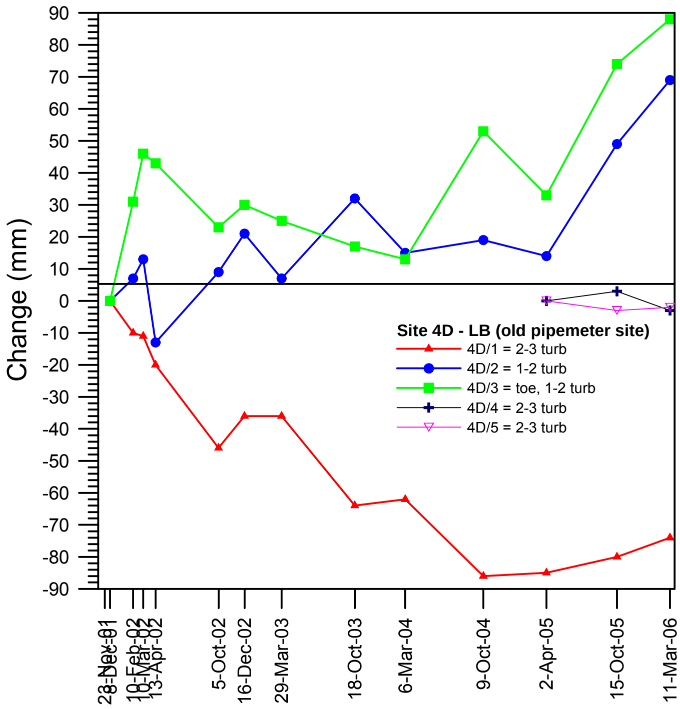
Site 4B



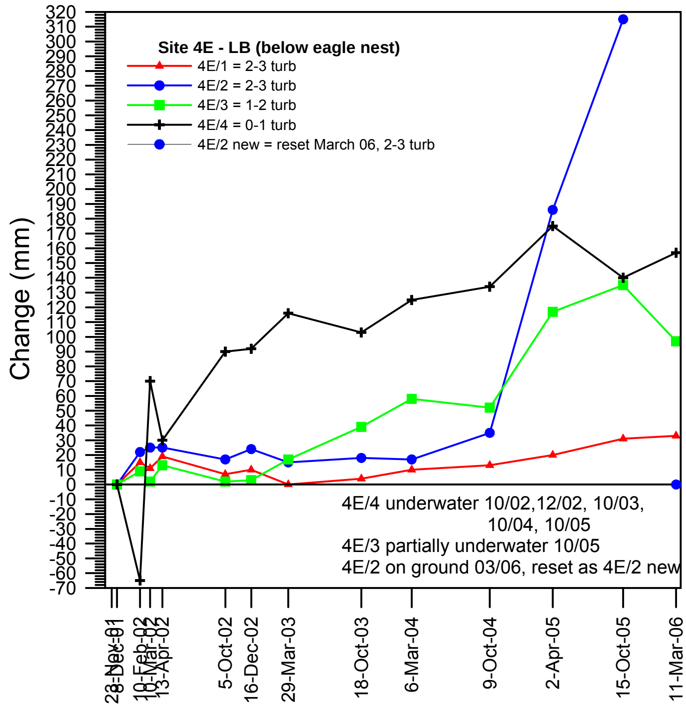
Site 4C



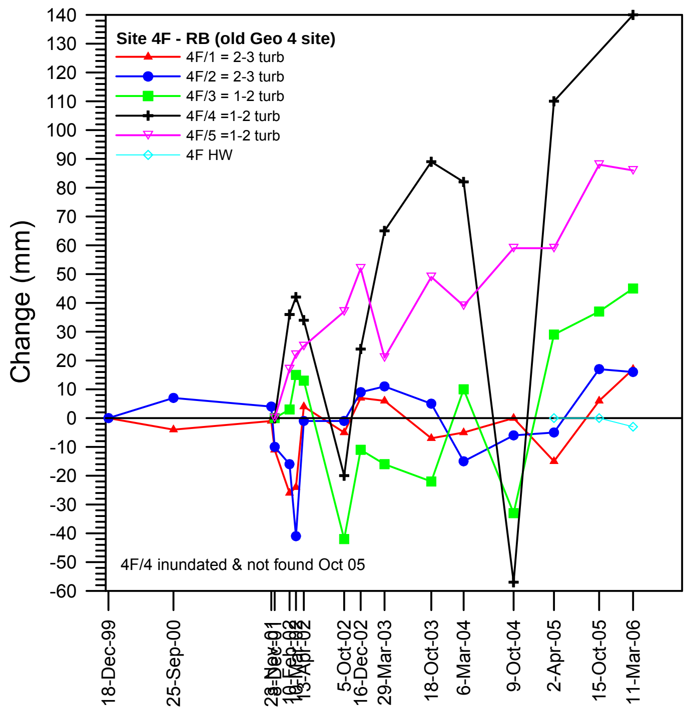
Site 4D



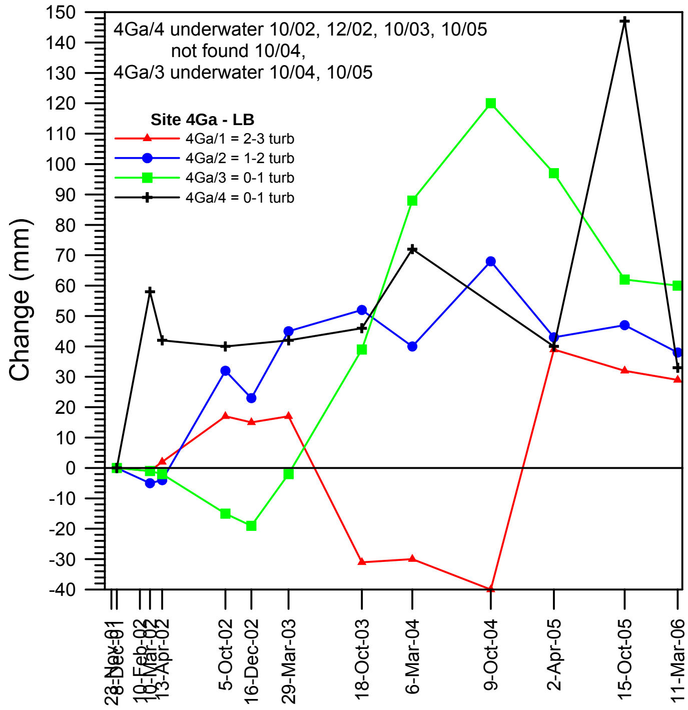
Site 4E



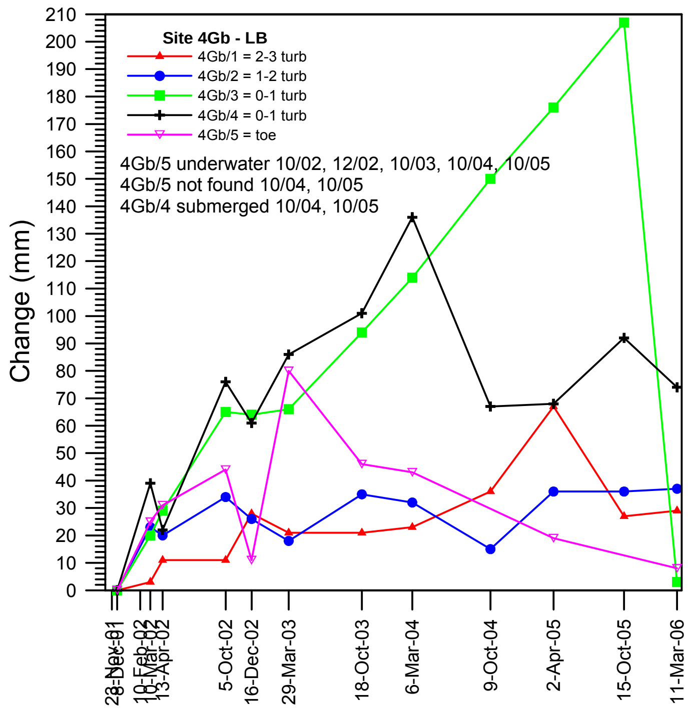
Site 4F



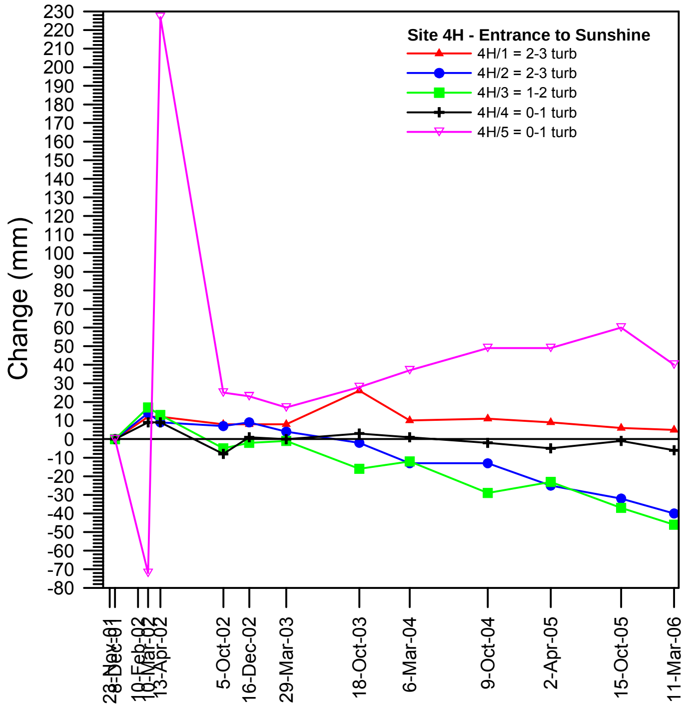
Site 4Ga



Site 4Gb

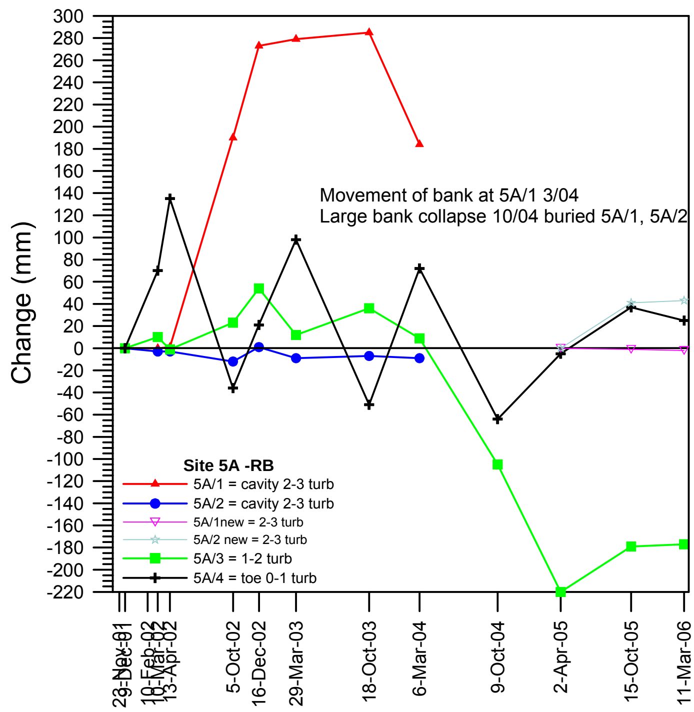


Site 4H

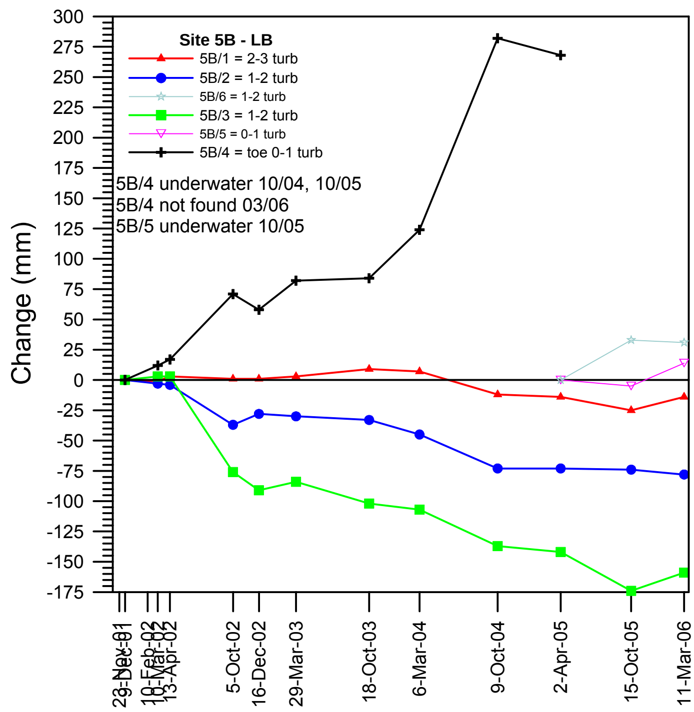

Site 4H - Entrance to Sunshine
4H/1 = 2-3 turb
4H/2 = 2-3 turb
4H/3 = 1-2 turb
4H/4 = 0-1 turb
4H/5 = 0-1 turb
Change (mm)
5-Oct-02
16-Dec-02
29-Mar-03
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05
15-Oct-05
11-Mar-06

Zone 5

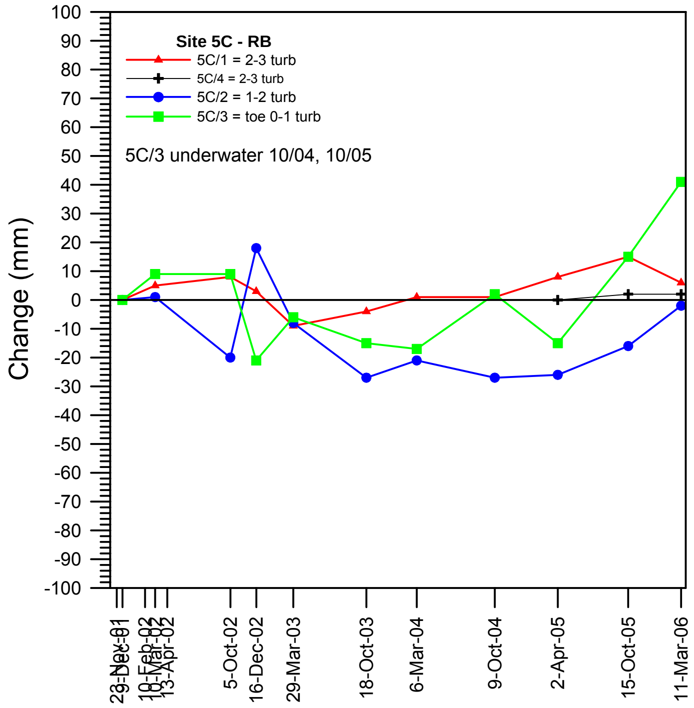
Site 5A



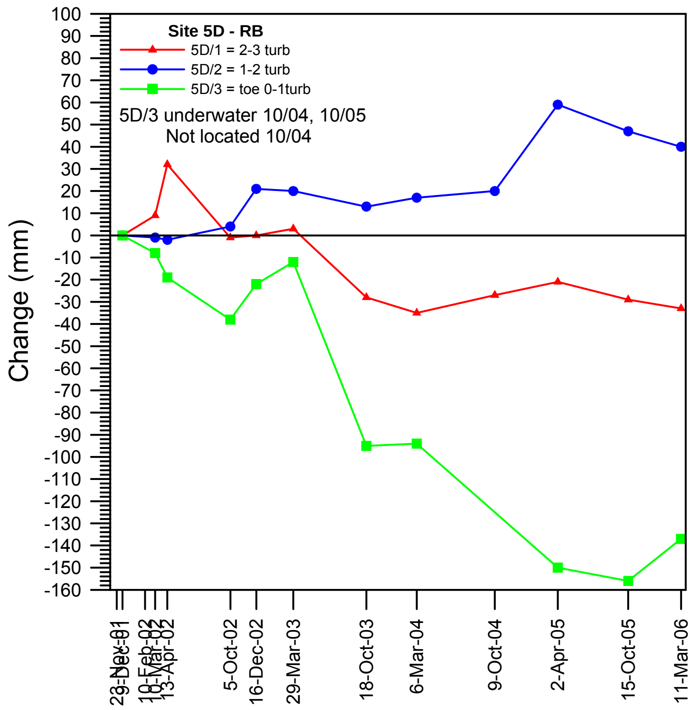
Site 5B



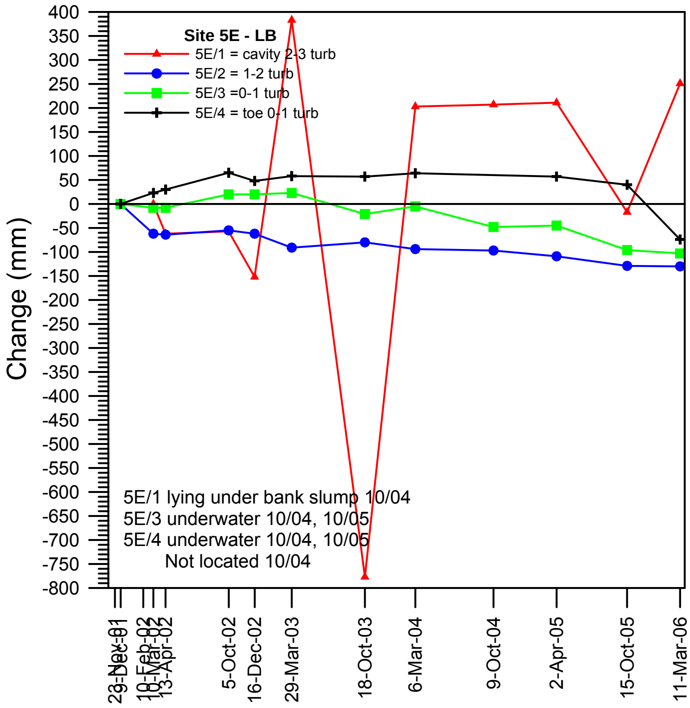
Site 5C



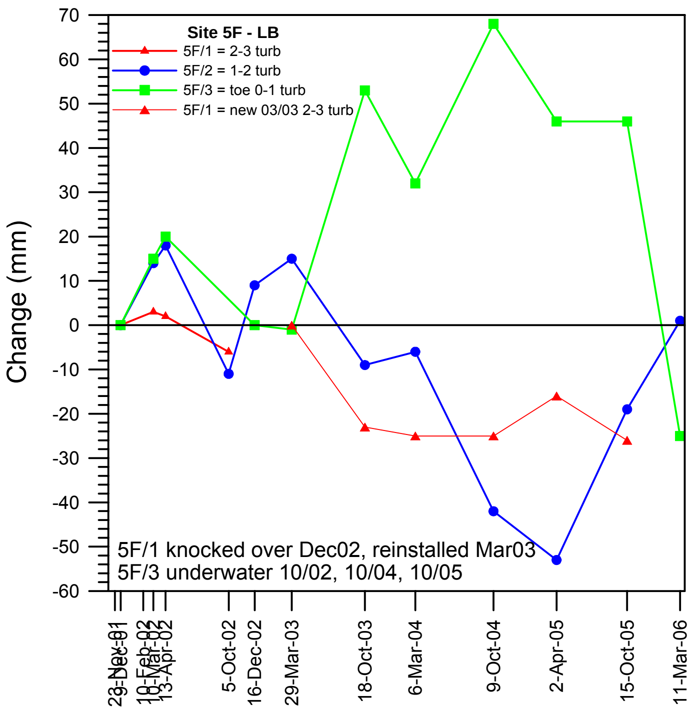
Site 5D



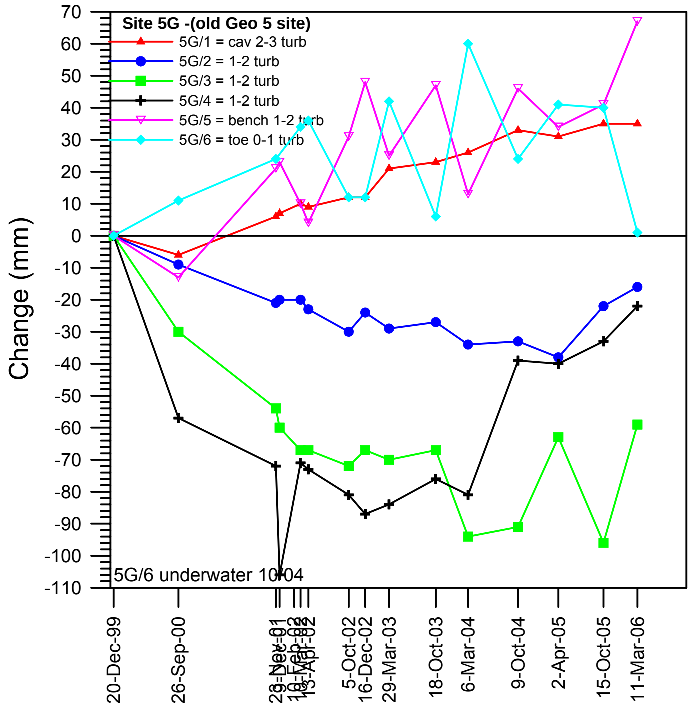
Site 5E



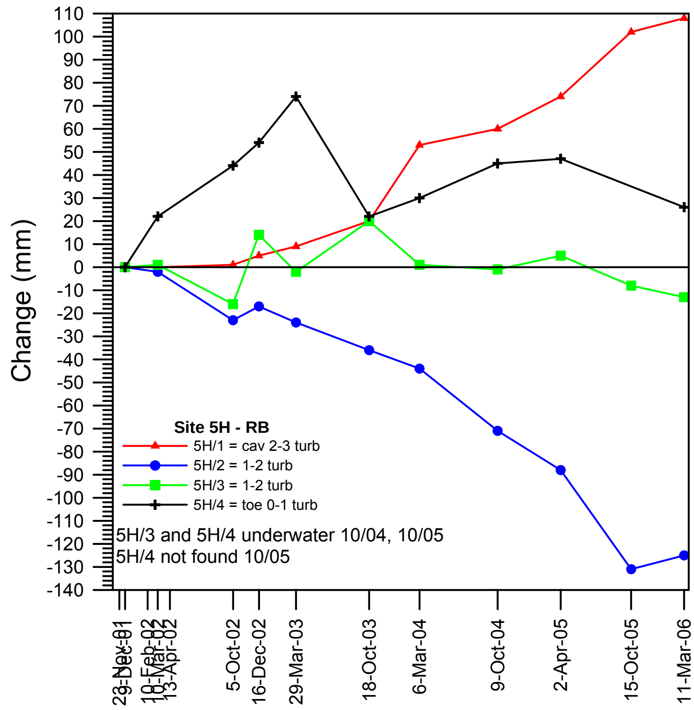
Site 5F



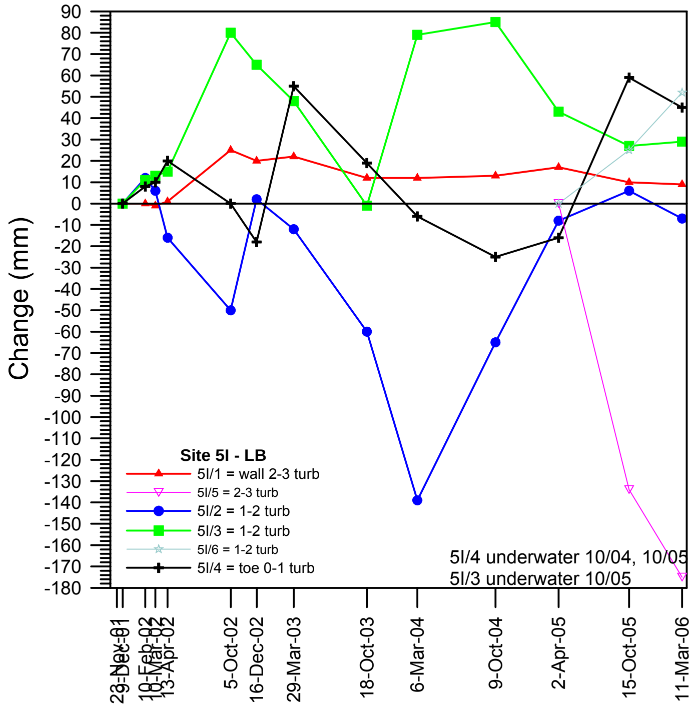
Site 5G



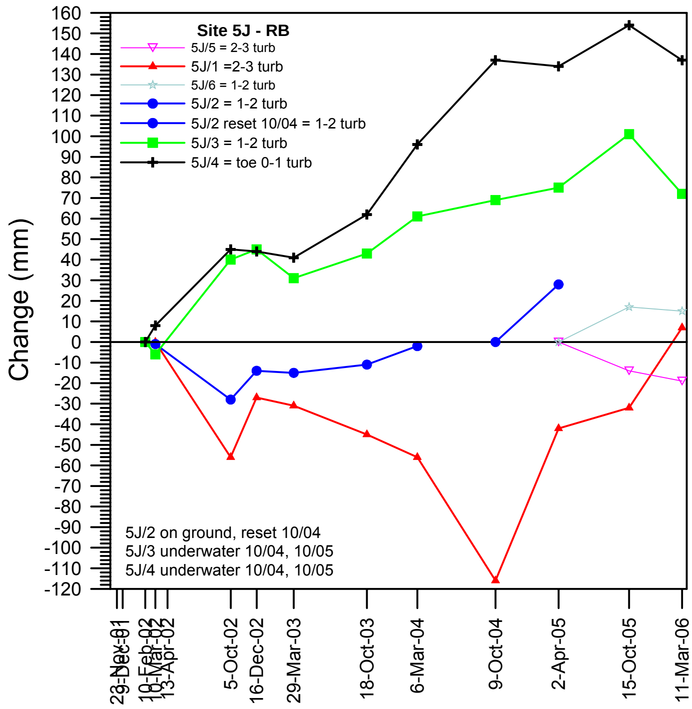
Site 5H



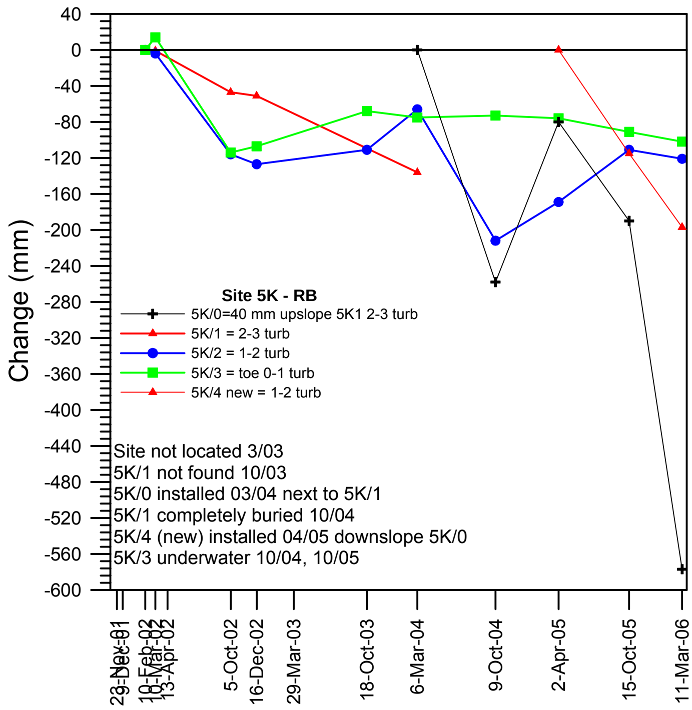
Site 5I



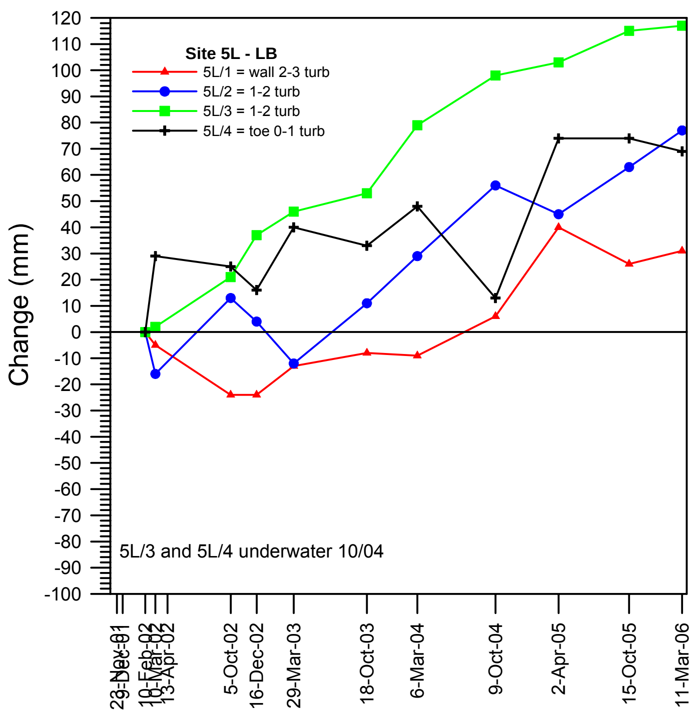
Site 5J



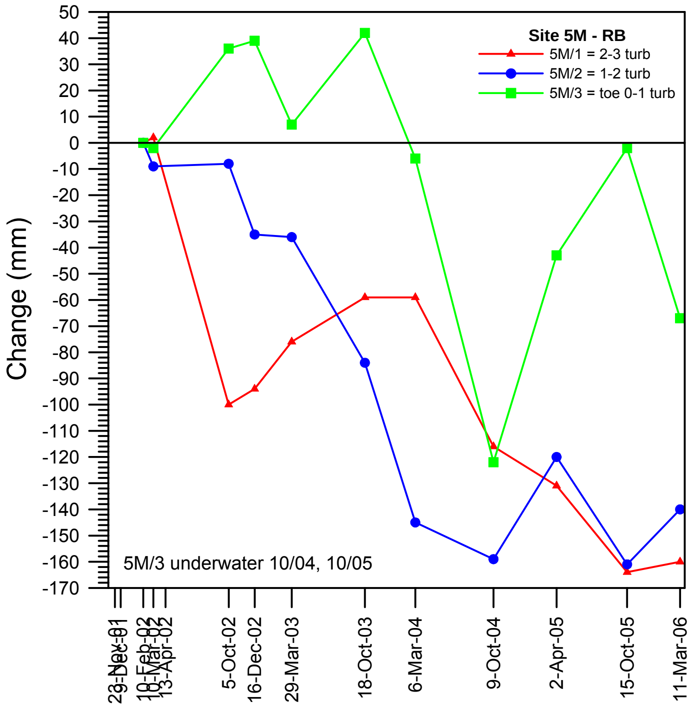
Site 5K



Site 5L



Site 5M


Site 5M - RB
5M/1 = 2-3 turb
5M/2 = 1-2 turb
5M/3 = toe 0-1 turb
Change (mm)
5M/3 underwater 10/04, 10/05
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
5-Oct-02
16-Dec-02
29-Mar-03
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05
15-Oct-05
11-Mar-06

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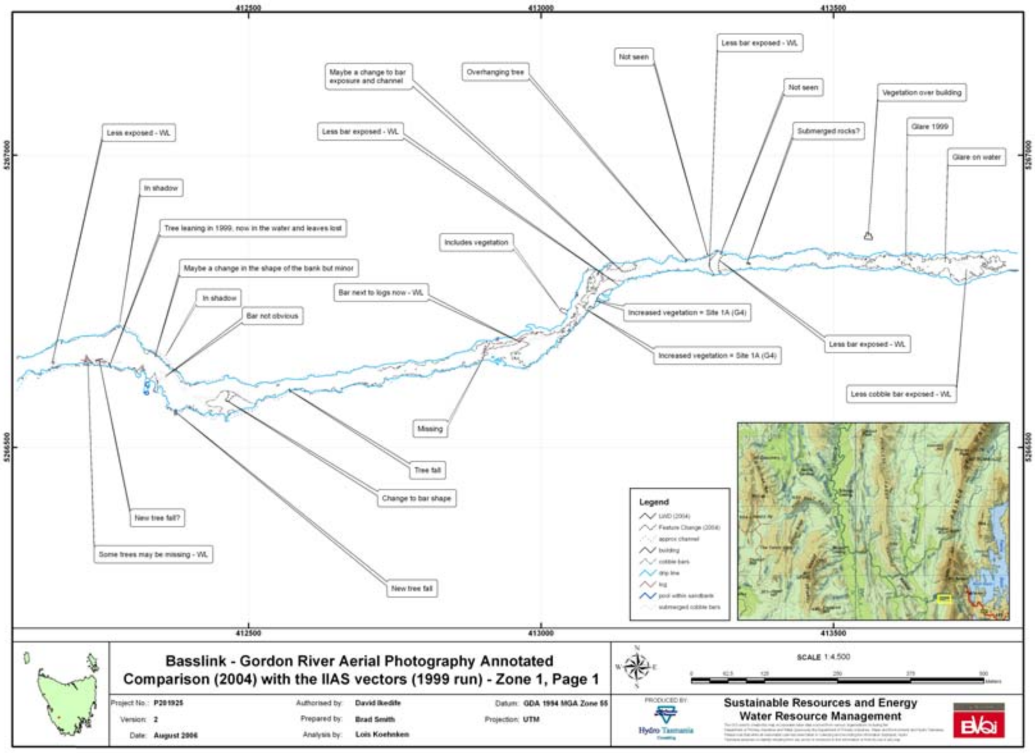
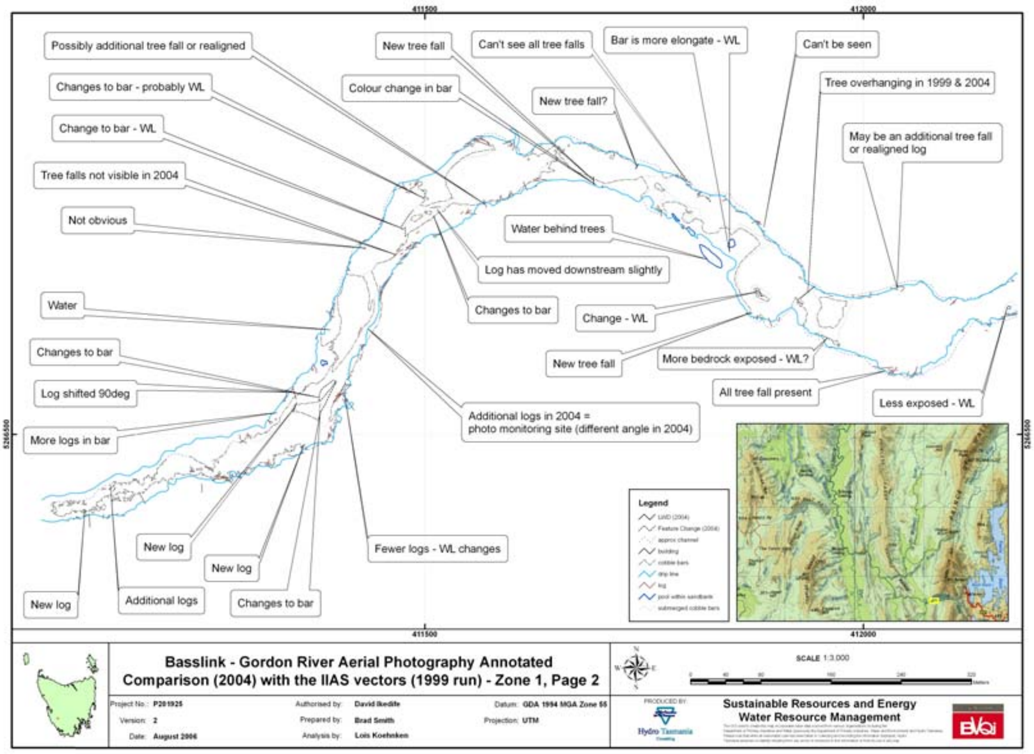
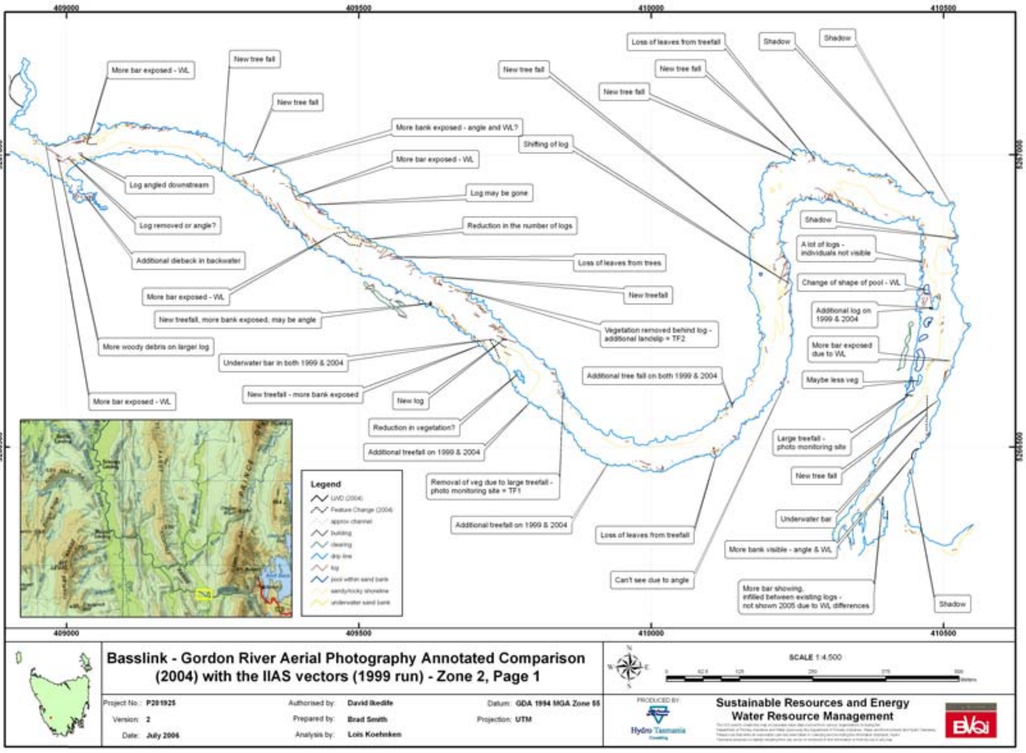
Appendix 2: Annotated aerial photography maps

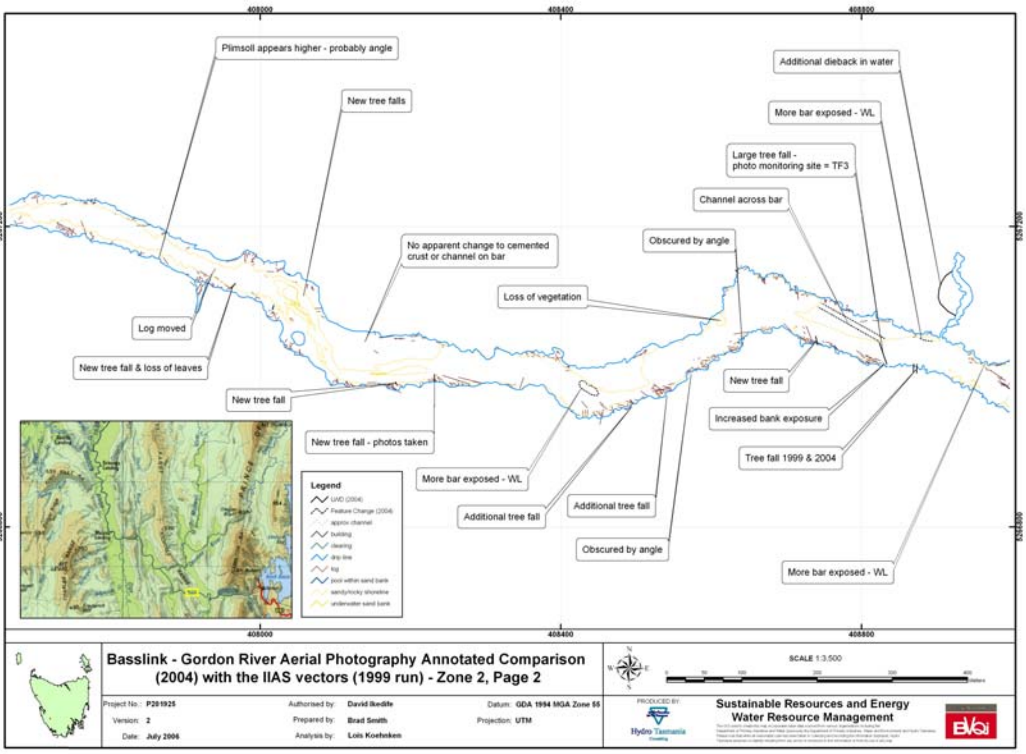
Zone 1

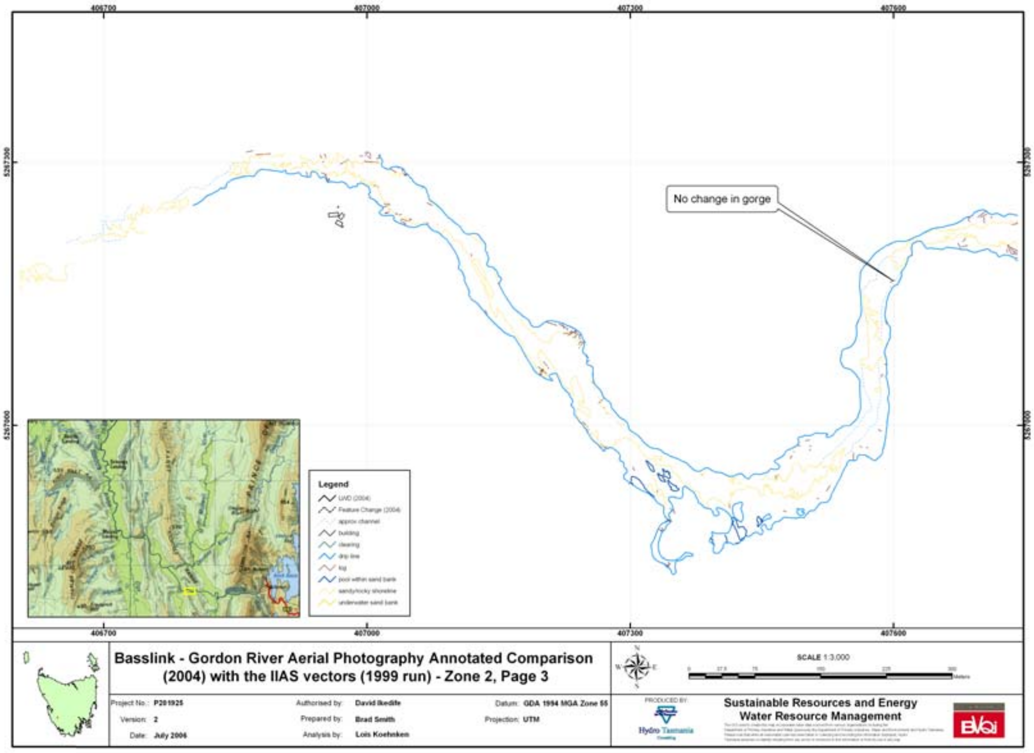




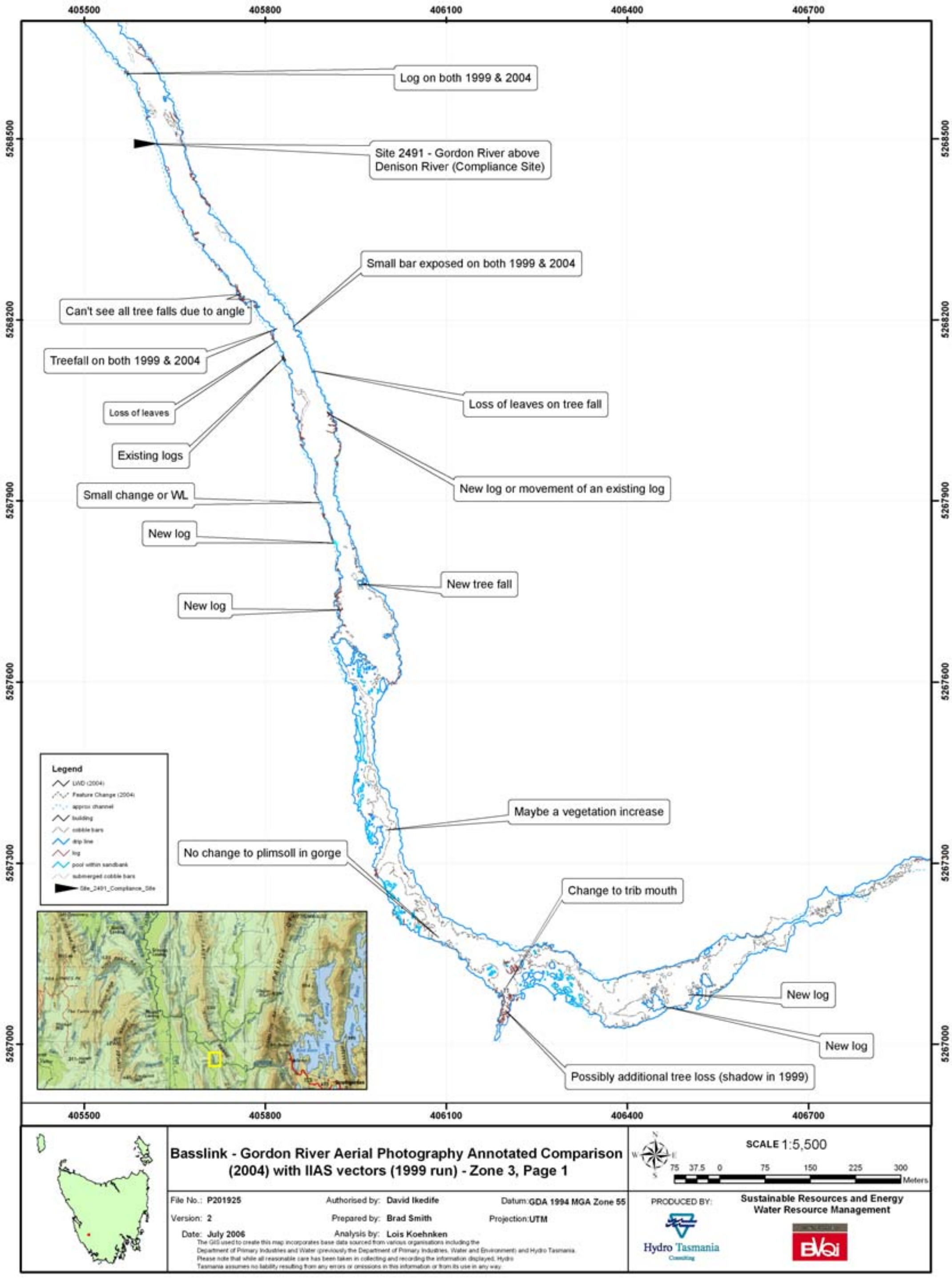
Zone 2

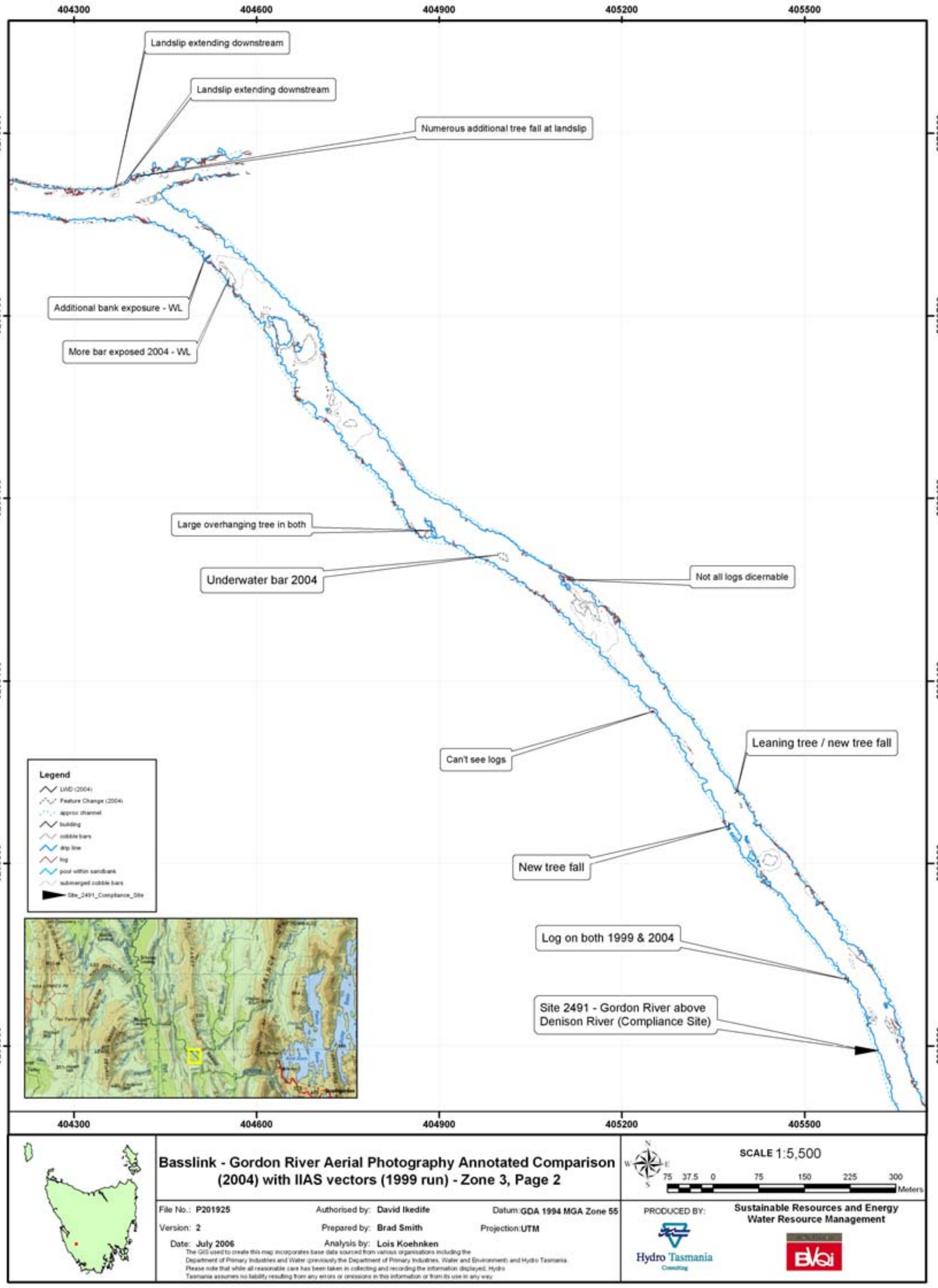

Loss of leaves from treefall
Shadow
Shadow
More bar exposed - WL
New tree fall
New tree fall
New tree fall
New tree fall
New tree fall
More bank exposed - angle and WL?
Shifting of log
More bar exposed - WL
Log angled downstream
Log may be gone
Log removed or angle?
Reduction in the number of logs
Additional dieback in backwater
Loss of leaves from trees
More bar exposed - WL
New treefall
New treefall, more bank exposed, may be angle
Vegetation removed behind log - additional landslip = TF2
More woody debris on larger log
Underwater bar in both 1999 & 2004
Additional tree fall on both 1999 & 2004
New treefall - more bank exposed
New log
More bar exposed - WL
Reduction in vegetation?
Additional treefall on 1999 & 2004
Removal of veg due to large treefall - photo monitoring site = TF1
Additional treefall on 1999 & 2004
Loss of leaves from treefall
Can't see due to angle
Shadow
A lot of logs - individuals not visible
Change of shape of pool - WL
Additional log on 1999 & 2004
More bar exposed due to WL
Maybe less veg
Large treefall - photo monitoring site
New tree fall
Underwater bar
More bank visible - angle & WL
More bar showing, infilled between existing logs - not shown 2005 due to WL differences
Shadow
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with the IIAS vectors (1999 run) - Zone 2, Page 1
Project No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
SCALE 1:4,500
Sustainable Resources and Energy
Water Resource Management


Plimsoll appears higher - probably angle
New tree falls
Additional dieback in water
More bar exposed - WL
Large tree fall - photo monitoring site = TF3
Channel across bar
No apparent change to cemented crust or channel on bar
Obscured by angle
Loss of vegetation
Log moved
New tree fall & loss of leaves
New tree fall
New tree fall
Increased bank exposure
New tree fall - photos taken
Tree fall 1999 & 2004
More bar exposed - WL
Additional tree fall
Additional tree fall
Obscured by angle
More bar exposed - WL
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with the IIAS vectors (1999 run) - Zone 2, Page 2
Project No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
SCALE 1:3,500
Sustainable Resources and Energy
Water Resource Management

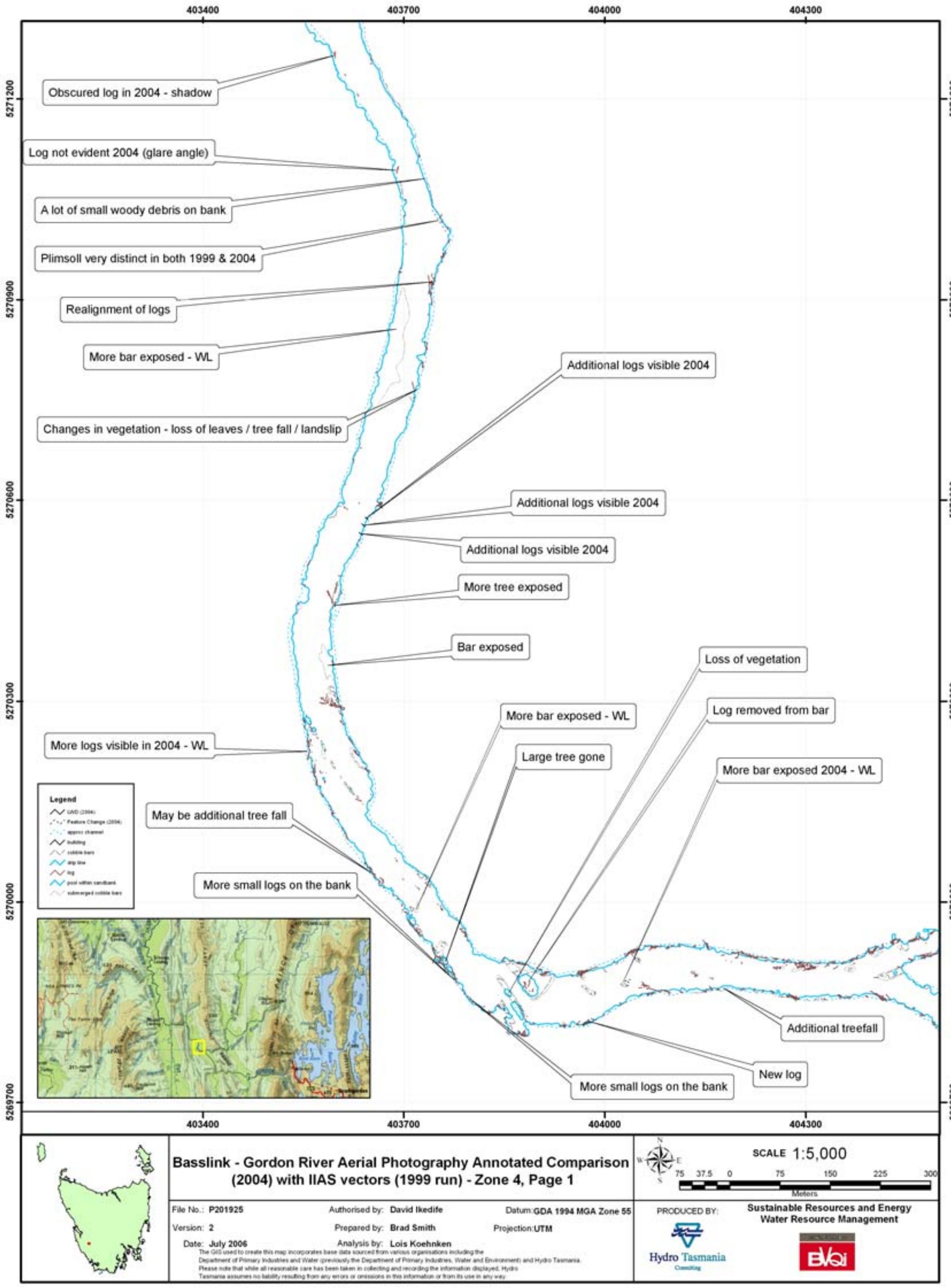

406700
407000
407300
407600
5267300
5267000
No change in gorge
Legend
Feature Change (2004)
approx channel
building
clearing
drip line
log
pool within sand bank
sandy/rocky shoreline
underwater sand bank
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with the IIAS vectors (1999 run) - Zone 2, Page 3
Project No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
SCALE 1:3,000
PRODUCED BY:
Hydro Tasmania
Sustainable Resources and Energy
Water Resource Management

Zone 3


405500
405800
406100
406400
406700
5268500
5268200
5267900
5267600
5267300
5267000
Log on both 1999 & 2004
Site 2491 - Gordon River above Denison River (Compliance Site)
Small bar exposed on both 1999 & 2004
Can't see all tree falls due to angle
Treefall on both 1999 & 2004
Loss of leaves
Loss of leaves on tree fall
Existing logs
New log or movement of an existing log
Small change or WL
New log
New tree fall
New log
Maybe a vegetation increase
No change to plimsoll in gorge
Change to trib mouth
New log
New log
Possibly additional tree loss (shadow in 1999)
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 3, Page 1
SCALE 1:5,500
75 37.5 0 75 150 225 300
Meters
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
PRODUCED BY:
Sustainable Resources and Energy
Water Resource Management
Hydro Tasmania


Landslip extending downstream
Landslip extending downstream
Numerous additional tree fall at landslip
Additional bank exposure - WL
More bar exposed 2004 - WL
Large overhanging tree in both
Underwater bar 2004
Not all logs dicernable
Can't see logs
Leaning tree / new tree fall
New tree fall
Log on both 1999 & 2004
Site 2491 - Gordon River above Denison River (Compliance Site)
Legend
404300
404600
404900
405200
405500
5270000
5269700
5269400
5269100
5268800
5268500
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 3, Page 2
SCALE 1:5,500
75 37.5 0 75 150 225 300
Meters
File No.: P201925
Authorised by: David Ikedife
Datum: GDA 1994 MGA Zone 55
Version: 2
Prepared by: Brad Smith
Projection: UTM
Date: July 2006
Analysis by: Lois Koehnken
The GIS used to create this map incorporates base data sourced from various organisations including the Department of Primary Industries and Water (previously the Department of Primary Industries, Water and Environment) and Hydro Tasmania. Please note that while all reasonable care has been taken in collecting and recording the information displayed, Hydro Tasmania assumes no liability resulting from any errors or omissions in this information or from its use in any way.
PRODUCED BY:
Hydro Tasmania
Consulting
Sustainable Resources and Energy
Water Resource Management

Zone 4


403400
403700
404000
404300
5271200
5270900
5270600
5270300
5270000
5269700
Obscured log in 2004 - shadow
Log not evident 2004 (glare angle)
A lot of small woody debris on bank
Plimsoll very distinct in both 1999 & 2004
Realignment of logs
More bar exposed - WL
Changes in vegetation - loss of leaves / tree fall / landslip
Additional logs visible 2004
Additional logs visible 2004
Additional logs visible 2004
More tree exposed
Bar exposed
Loss of vegetation
Log removed from bar
More bar exposed - WL
Large tree gone
More bar exposed 2004 - WL
More logs visible in 2004 - WL
Legend
May be additional tree fall
More small logs on the bank
Additional treefall
New log
More small logs on the bank
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 4, Page 1
SCALE 1:5,000
75 37.5 0 75 150 225 300
Meters
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
The GIS used to create this map incorporates base data sourced from various organisations including the Department of Primary Industries and Water (previously the Department of Primary Industries, Water and Environment) and Hydro Tasmania. Please note that while all reasonable care has been taken in collecting and recording the information displayed, Hydro Tasmania assumes no liability resulting from any errors or omissions in this information or from its use in any way.
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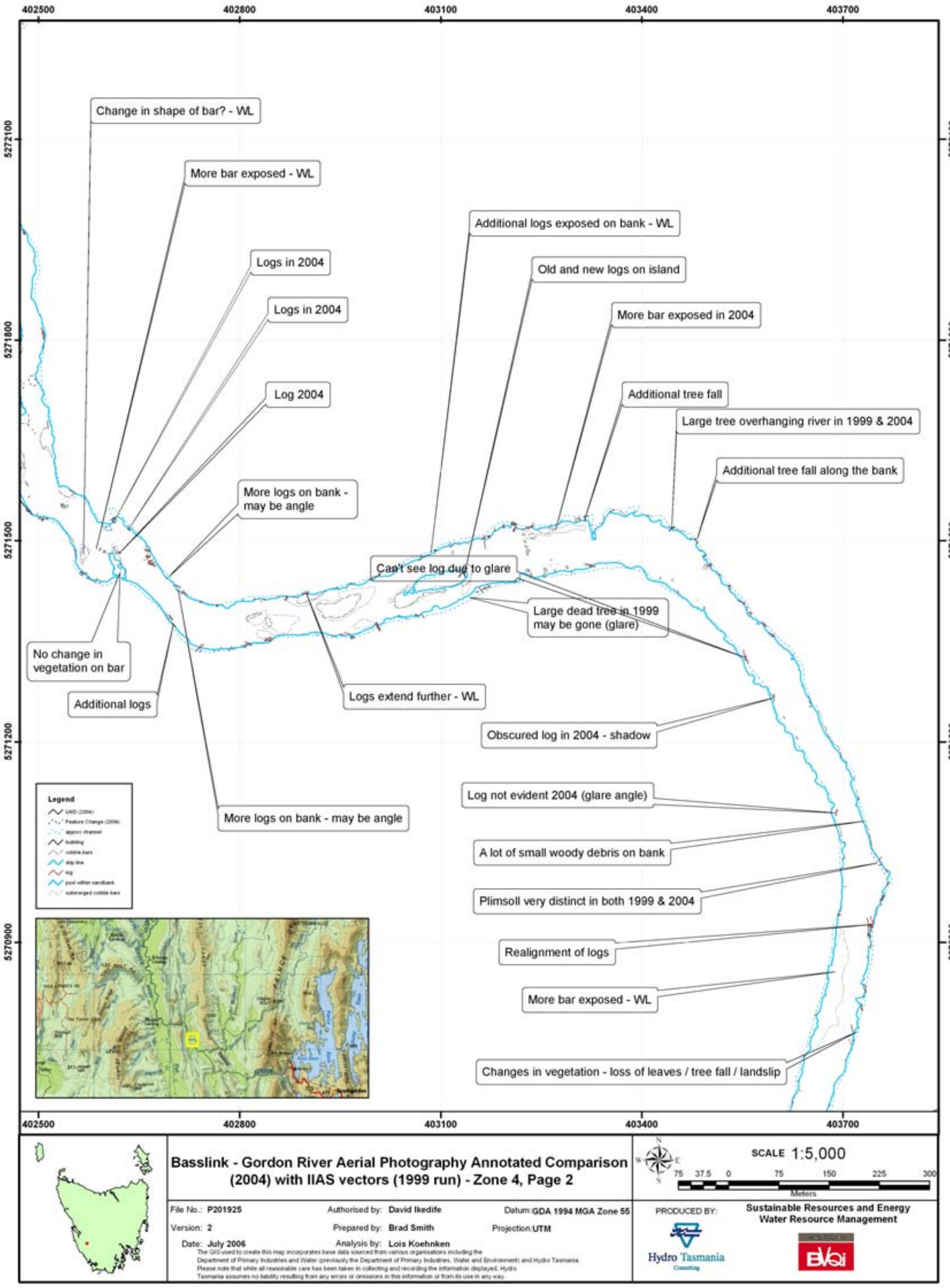
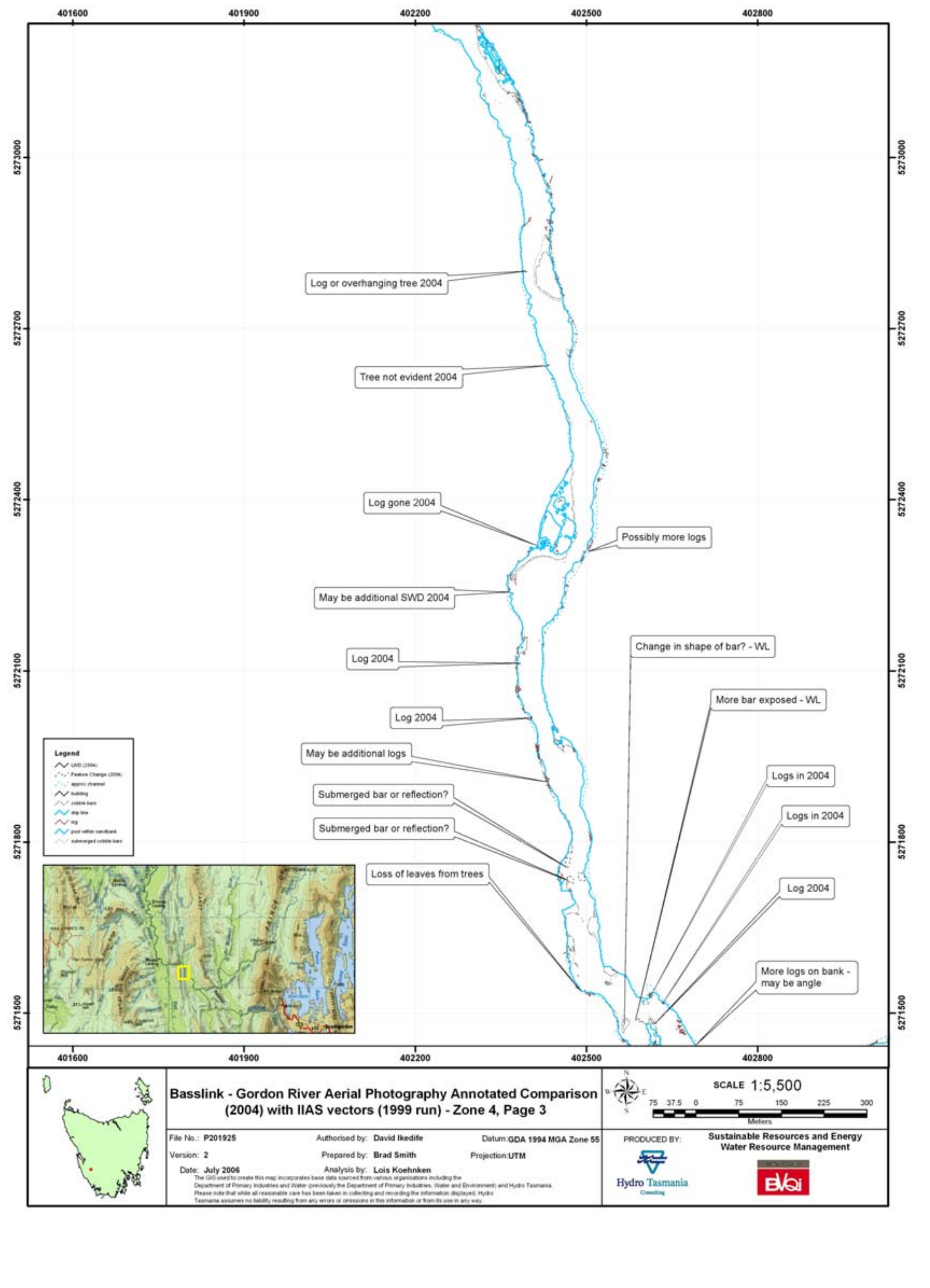
Sustainable Resources and Energy
Water Resource Management


402500
402800
403100
403400
403700
5272100
5271800
5271500
5271200
5270900
Change in shape of bar? - WL
More bar exposed - WL
Logs in 2004
Logs in 2004
Log 2004
More logs on bank - may be angle
No change in vegetation on bar
Additional logs
More logs on bank - may be angle
Additional logs exposed on bank - WL
Old and new logs on island
More bar exposed in 2004
Additional tree fall
Large tree overhanging river in 1999 & 2004
Additional tree fall along the bank
Can't see log due to glare
Large dead tree in 1999 may be gone (glare)
Logs extend further - WL
Obscured log in 2004 - shadow
Log not evident 2004 (glare angle)
A lot of small woody debris on bank
Plimsoll very distinct in both 1999 & 2004
Realignment of logs
More bar exposed - WL
Changes in vegetation - loss of leaves / tree fall / landslip
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 4, Page 2
SCALE 1:5,000
75 37.5 0 75 150 225 300
Meters
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
PRODUCED BY:
Hydro Tasmania Consulting
Sustainable Resources and Energy
Water Resource Management


401600
401900
402200
402500
402800
5273000
5272700
5272400
5272100
5271800
5271500
Log or overhanging tree 2004
Tree not evident 2004
Log gone 2004
Possibly more logs
May be additional SWD 2004
Change in shape of bar? - WL
Log 2004
More bar exposed - WL
Log 2004
May be additional logs
Logs in 2004
Submerged bar or reflection?
Logs in 2004
Submerged bar or reflection?
Loss of leaves from trees
Log 2004
More logs on bank - may be angle
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 4, Page 3
SCALE 1:5,500
75 37.5 0 75 150 225 300
Meters
File No.: P201925
Authorised by: David Ikedife
Datum: GDA 1994 MGA Zone 55
Version: 2
Prepared by: Brad Smith
Projection: UTM
Date: July 2006
Analysis by: Lois Koehnken
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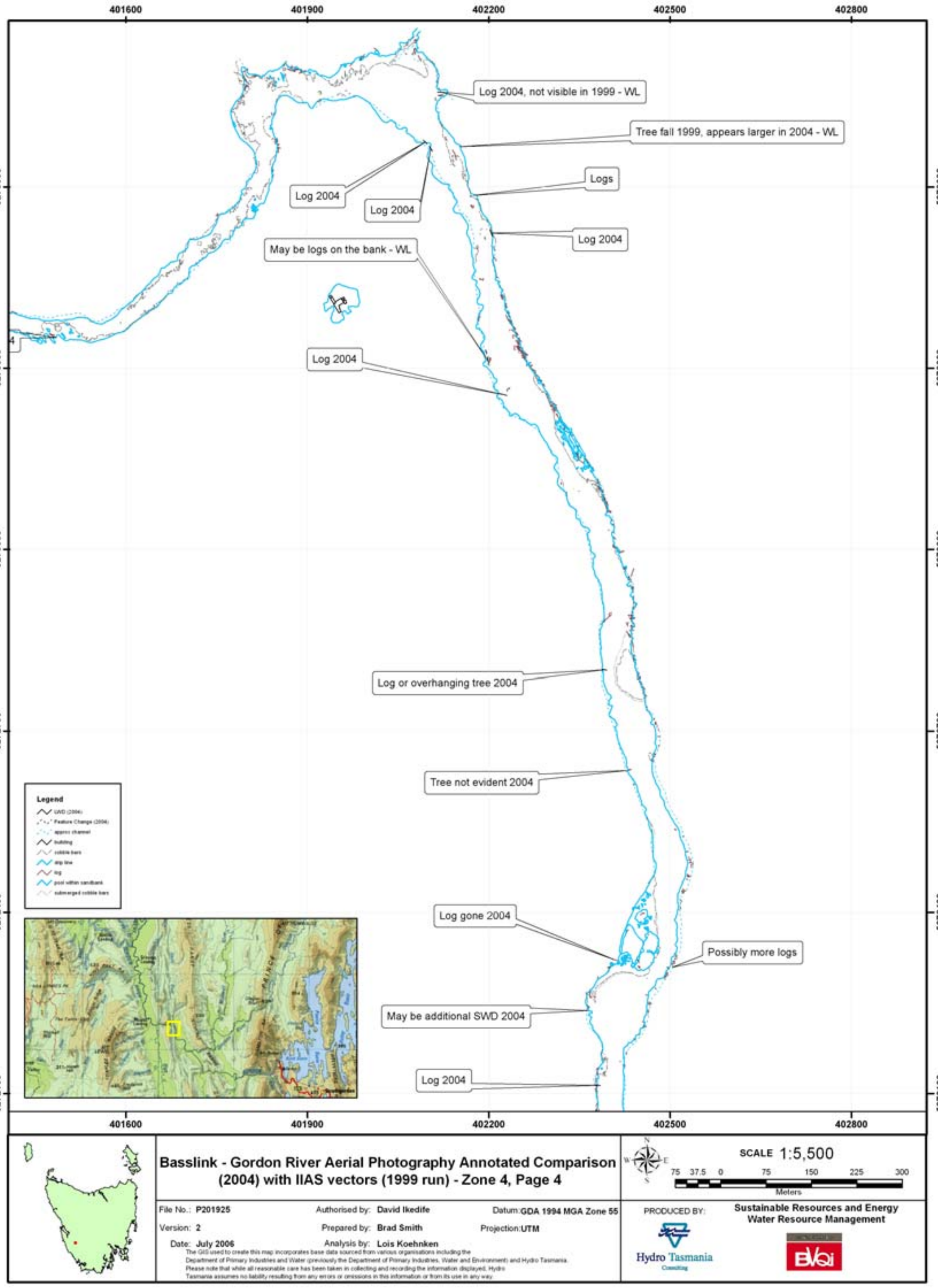
Log 2004, not visible in 1999 - WL
Tree fall 1999, appears larger in 2004 - WL
Logs
Log 2004
Log 2004
Log 2004
May be logs on the bank - WL
Log 2004
Log or overhanging tree 2004
Tree not evident 2004
Log gone 2004
Possibly more logs
May be additional SWD 2004
Log 2004
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 4, Page 4
SCALE 1:5,500
Meters
File No.: P201925
Authorised by: David Ikedife
Datum: GDA 1994 MGA Zone 55
Version: 2
Prepared by: Brad Smith
Projection: UTM
Date: July 2006
Analysis by: Lois Koehnken
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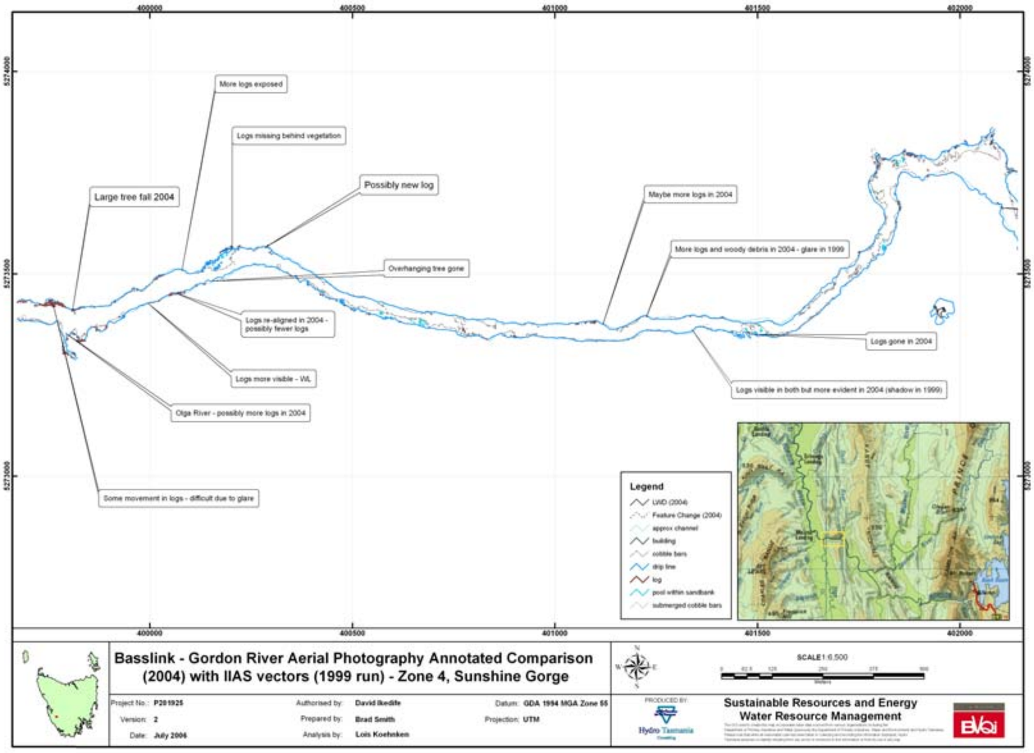
400000
400500
401000
401500
402000
5274000
5273500
5273000
More logs exposed
Logs missing behind vegetation
Possibly new log
Large tree fall 2004
Overhanging tree gone
Logs re-aligned in 2004 - possibly fewer logs
Logs more visible - WL
Olga River - possibly more logs in 2004
Some movement in logs - difficult due to glare
Maybe more logs in 2004
More logs and woody debris in 2004 - glare in 1999
Logs gone in 2004
Logs visible in both but more evident in 2004 (shadow in 1999)
Legend
LWD (2004)
Feature Change (2004)
approx channel
building
cobble bars
drip line
log
pool within sandbank
submerged cobble bars
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 4, Sunshine Gorge
Project No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
N
W
E
S
SCALE 1:6,500
PRODUCED BY
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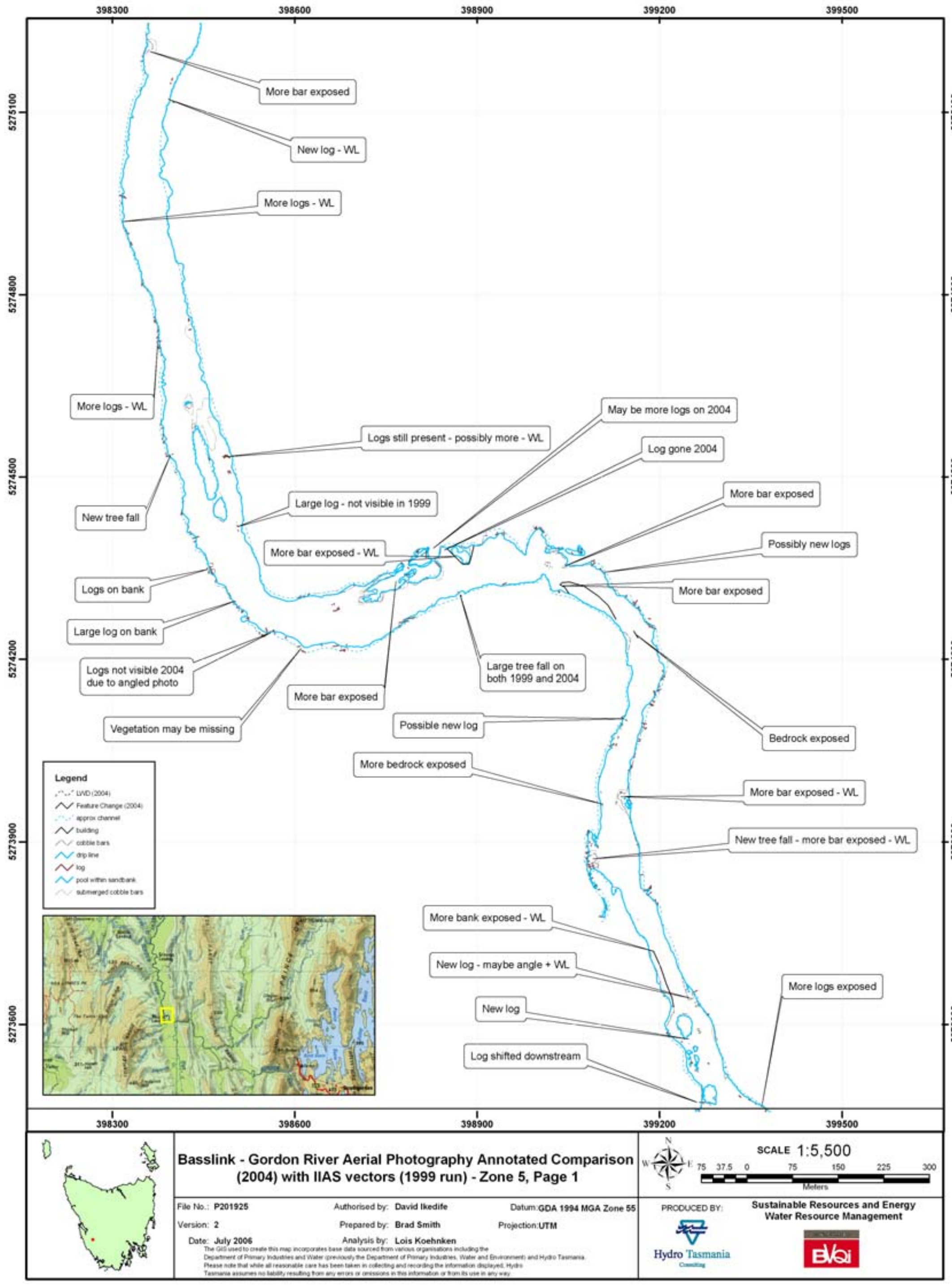
Zone 5


398300
398600
398900
399200
399500
5275100
5274800
5274500
5274200
5273900
5273600
More bar exposed
New log - WL
More logs - WL
More logs - WL
Logs still present - possibly more - WL
May be more logs on 2004
Log gone 2004
New tree fall
Large log - not visible in 1999
More bar exposed
Possibly new logs
More bar exposed - WL
Logs on bank
More bar exposed
Large log on bank
Logs not visible 2004 due to angled photo
Large tree fall on both 1999 and 2004
More bar exposed
Vegetation may be missing
Possible new log
Bedrock exposed
More bedrock exposed
More bar exposed - WL
New tree fall - more bar exposed - WL
Legend
LWD (2004)
Feature Change (2004)
approx channel
building
cobble bars
drip line
log
pool within sandbank
submerged cobble bars
More bank exposed - WL
New log - maybe angle + WL
More logs exposed
New log
Log shifted downstream
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 1
SCALE 1:5,500
75 37.5 0 75 150 225 300
Meters
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
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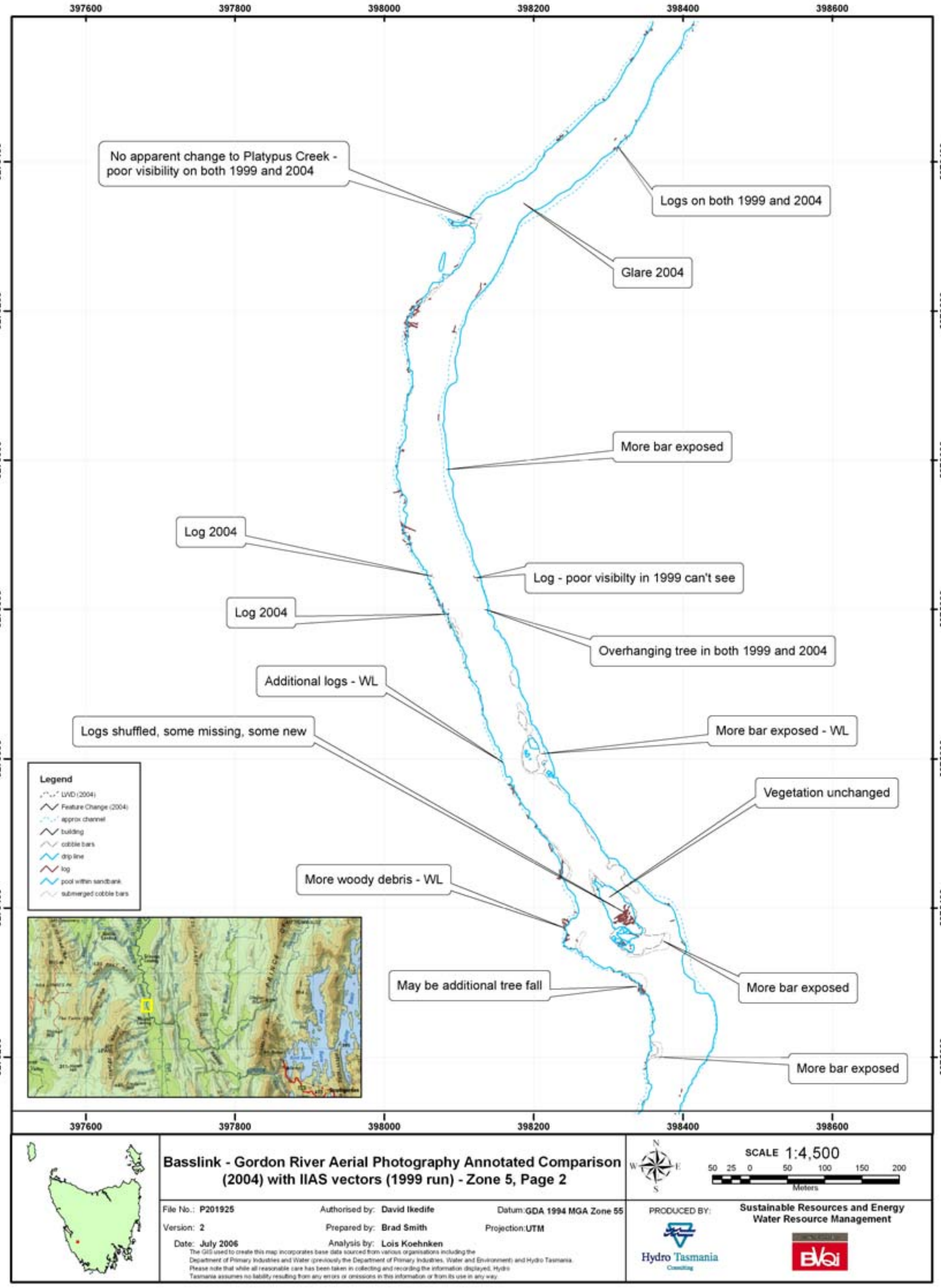
397600
397800
398000
398200
398400
398600
5276400
5276200
5276000
5275800
5275600
5275400
5275200
No apparent change to Platypus Creek - poor visibility on both 1999 and 2004
Logs on both 1999 and 2004
Glare 2004
More bar exposed
Log 2004
Log - poor visibilty in 1999 can't see
Log 2004
Overhanging tree in both 1999 and 2004
Additional logs - WL
More bar exposed - WL
Logs shuffled, some missing, some new
Vegetation unchanged
More woody debris - WL
More bar exposed
May be additional tree fall
More bar exposed
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 2
File No.: P201925
Authorised by: David Ikedife
Datum: GDA 1994 MGA Zone 55
Version: 2
Prepared by: Brad Smith
Projection: UTM
Date: July 2006
Analysis by: Lois Koehnken
SCALE 1:4,500
Meters
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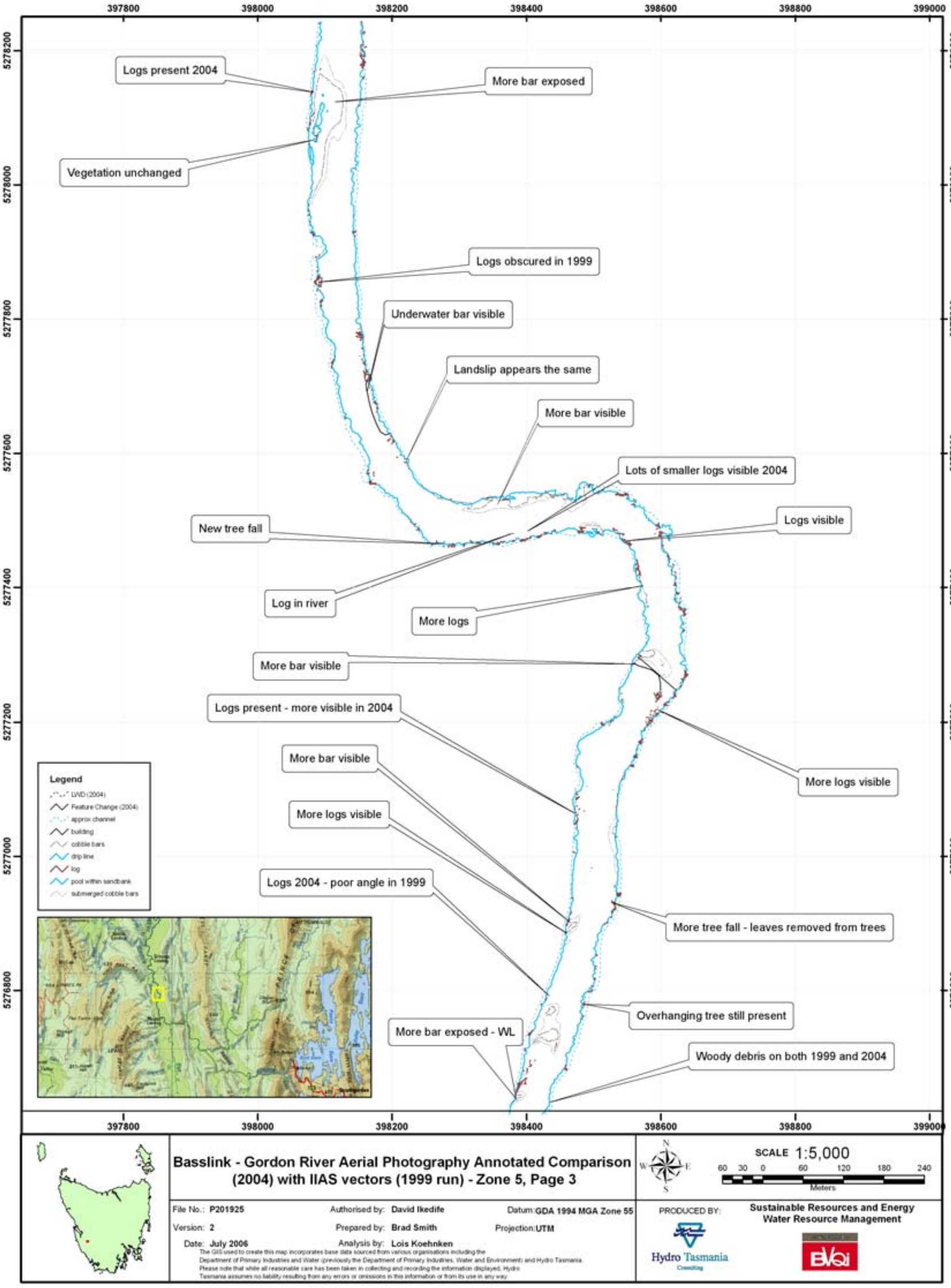
Logs present 2004
More bar exposed
Vegetation unchanged
Logs obscured in 1999
Underwater bar visible
Landslip appears the same
More bar visible
Lots of smaller logs visible 2004
Logs visible
New tree fall
Log in river
More logs
More bar visible
Logs present - more visible in 2004
More bar visible
More logs visible
More logs visible
Logs 2004 - poor angle in 1999
More tree fall - leaves removed from trees
Overhanging tree still present
More bar exposed - WL
Woody debris on both 1999 and 2004
Legend
LWD (2004)
Feature Change (2004)
approx channel
building
cobble bars
drip line
log
pool within sandbank
submerged cobble bars
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 3
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
SCALE 1:5,000
Meters
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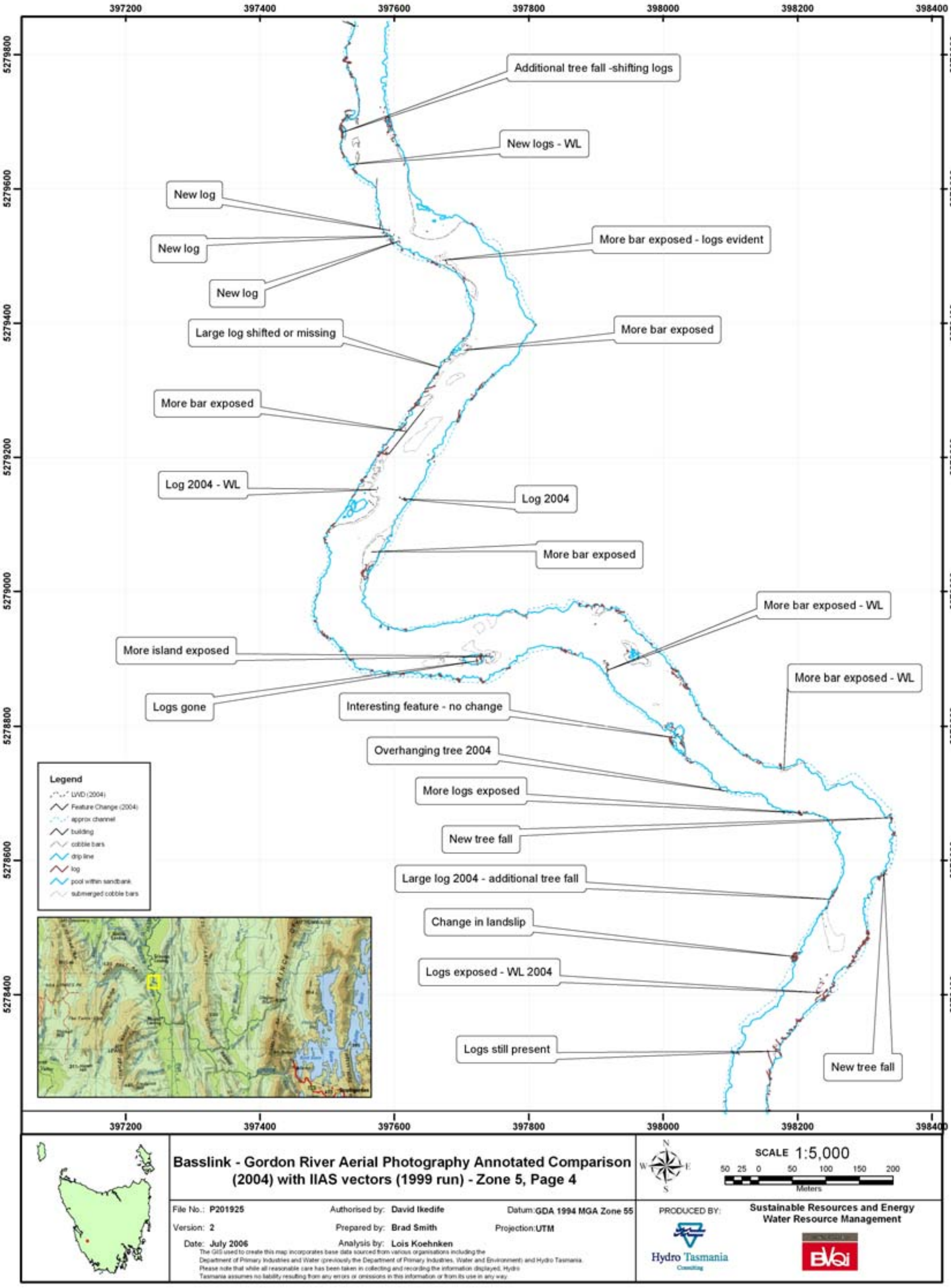
Additional tree fall -shifting logs
New logs - WL
New log
New log
New log
More bar exposed - logs evident
Large log shifted or missing
More bar exposed
More bar exposed
Log 2004 - WL
Log 2004
More bar exposed
More bar exposed - WL
More island exposed
Logs gone
Interesting feature - no change
More bar exposed - WL
Overhanging tree 2004
More logs exposed
New tree fall
Large log 2004 - additional tree fall
Change in landslip
Logs exposed - WL 2004
Logs still present
New tree fall
Legend
LWD (2004)
Feature Change (2004)
approx channel
building
cobble bars
drip line
log
pool within sandbank
submerged cobble bars
397200
397400
397600
397800
398000
398200
398400
5279800
5279600
5279400
5279200
5279000
5278800
5278600
5278400
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 4
SCALE 1:5,000
50 25 0 50 100 150 200
Meters
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
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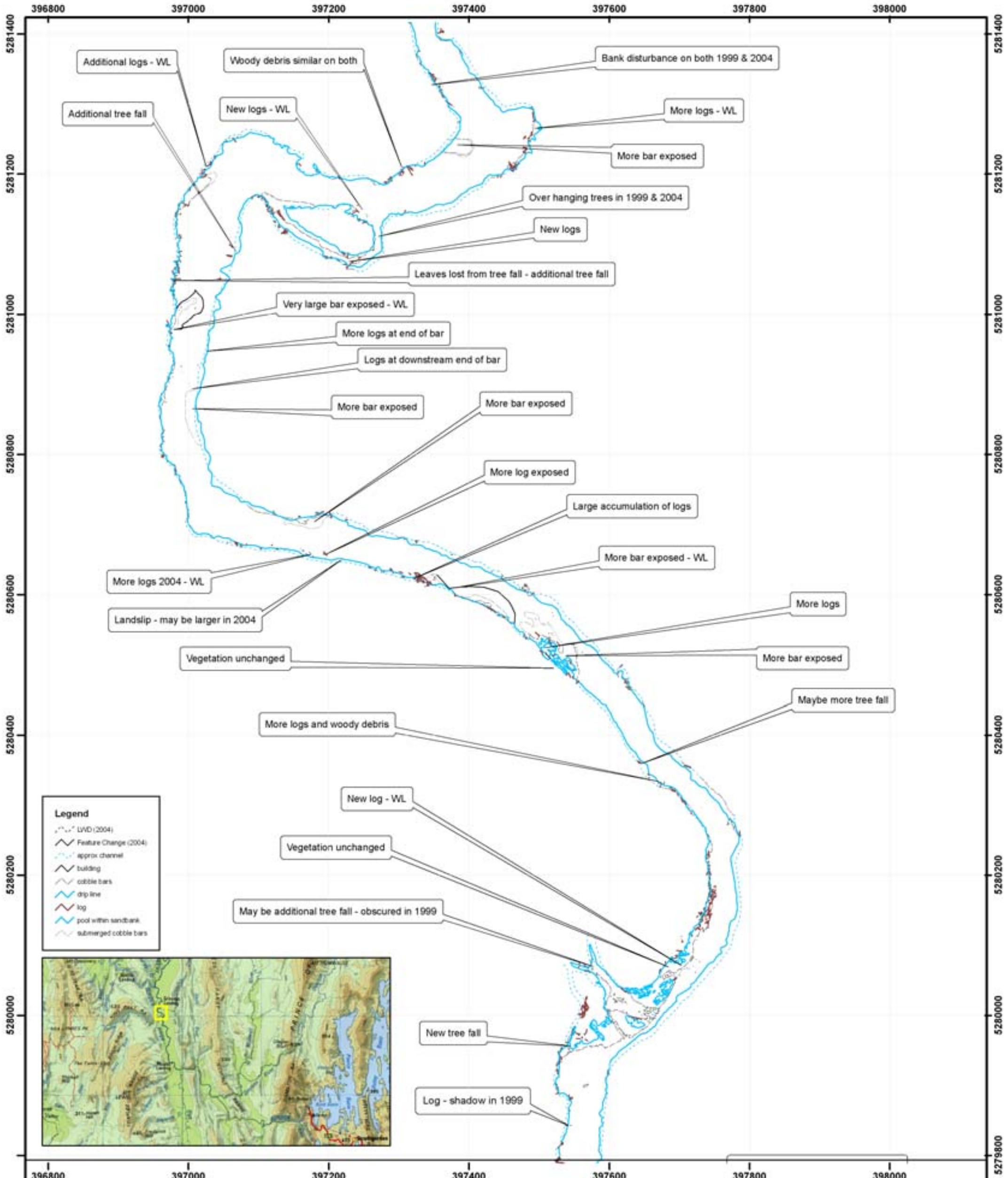

Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 5

SCALE 1:5,000

50 25 0 50 100 150 200 Meters

File No.: P201925 Authorised by: David Ikedife Datum: GDA 1994 MGA Zone 55

Version: 2 Prepared by: Brad Smith Projection: UTM

Date: July 2006 Analysis by: Lois Koehnken

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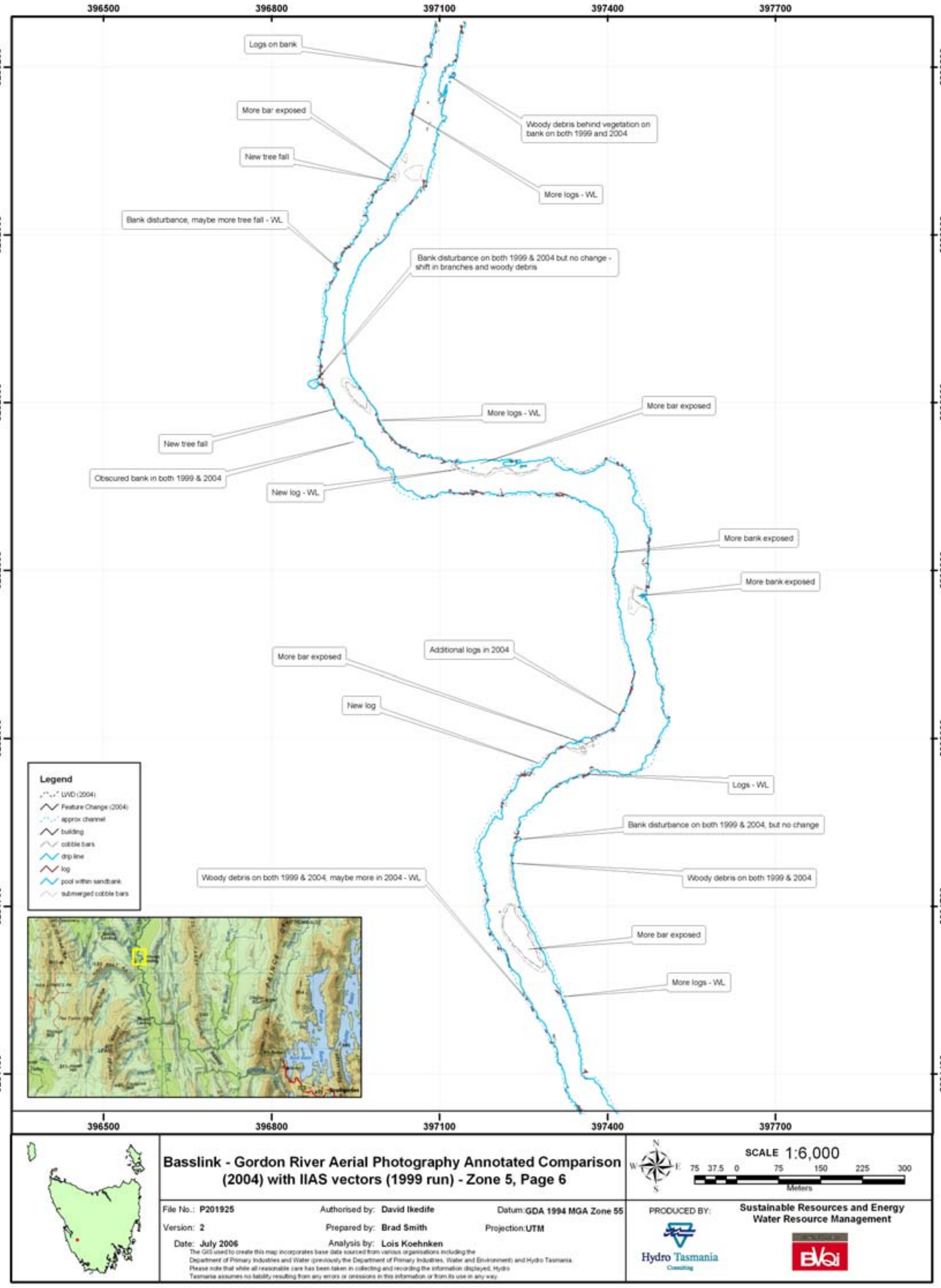
Logs on bank
More bar exposed
Woody debris behind vegetation on bank on both 1999 and 2004
New tree fall
More logs - WL
Bank disturbance, maybe more tree fall - WL
Bank disturbance on both 1999 & 2004 but no change - shift in branches and woody debris
More logs - WL
More bar exposed
New tree fall
Obscured bank in both 1999 & 2004
New log - WL
More bank exposed
More bank exposed
Additional logs in 2004
More bar exposed
New log
Logs - WL
Bank disturbance on both 1999 & 2004, but no change
Woody debris on both 1999 & 2004; maybe more in 2004 - WL
Woody debris on both 1999 & 2004
More bar exposed
More logs - WL
Legend
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 6
SCALE 1:6,000
Meters
File No.: P201925
Version: 2
Date: July 2006
Authorised by: David Ikedife
Prepared by: Brad Smith
Analysis by: Lois Koehnken
Datum: GDA 1994 MGA Zone 55
Projection: UTM
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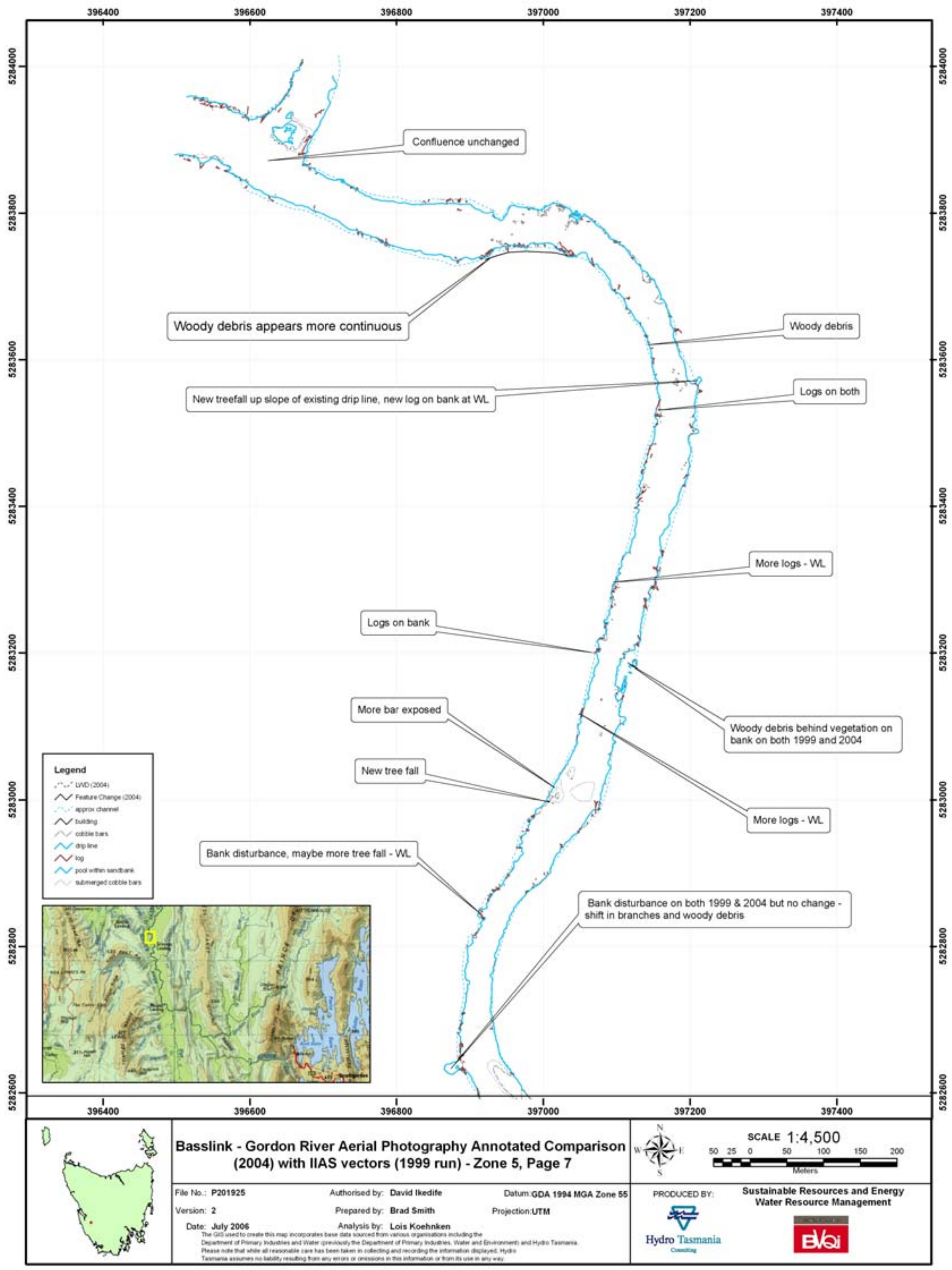
Confluence unchanged
Woody debris appears more continuous
Woody debris
New treefall up slope of existing drip line, new log on bank at WL
Logs on both
More logs - WL
Logs on bank
More bar exposed
Woody debris behind vegetation on bank on both 1999 and 2004
New tree fall
More logs - WL
Bank disturbance, maybe more tree fall - WL
Bank disturbance on both 1999 & 2004 but no change - shift in branches and woody debris
Legend
LWD (2004)
Feature Change (2004)
approx channel
building
cobble bars
drip line
log
pool within sandbank
submerged cobble bars
396400
396600
396800
397000
397200
397400
5284000
5283800
5283600
5283400
5283200
5283000
5282800
5282600
Basslink - Gordon River Aerial Photography Annotated Comparison (2004) with IIAS vectors (1999 run) - Zone 5, Page 7
SCALE 1:4,500
50 25 0 50 100 150 200
Meters
File No.: P201925
Authorised by: David Ikedife
Datum: GDA 1994 MGA Zone 55
Version: 2
Prepared by: Brad Smith
Projection: UTM
Date: July 2006
Analysis by: Lois Koehnken
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