BASSLINK INTEGRATED IMPACT ASSESSMENT STATEMENT

POTENTIAL EFFECTS OF CHANGES TO HYDRO POWER GENERATION

APPENDIX 7:

GORDON RIVER MACROINVERTEBRATE AND AQUATIC MAMMAL ASSESSMENT

P.E. Davies[1] and L.S.J. Cook[1]

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1. Consultant - Freshwater Systems, 82 Waimea Avenue, Sandy Bay, Tas 7005

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1 INTRODUCTION

This report addresses environmental issues associated with instream aquatic fauna of the Gordon River as they pertain to Basslink, focusing on macroinvertebrates and platypus. It describes the current condition of the aquatic fauna of the Gordon River, as well as management issues pertaining to the aquatic ecosystem which result from current operations of the Gordon Dam and power station, and potential future operational conditions that may result under a Basslink 480 MW cable scenario. It then describes possible mitigation measures and their potential to reduce risks to instream biota and habitats under Basslink.

The Gordon River is the single largest river drainage in the Tasmanian World Heritage Area, with a total catchment area of 7,220 km^2. In this report, the Gordon is divided into three broad stretches - the lower Gordon (downstream of the Franklin River junction), the middle Gordon (downstream of the Gordon dam) and the upper Gordon (upstream of the Lake Gordon impoundment). This report is focused on the middle Gordon (Figure 1).

The middle Gordon receives water from a 1768 km^2 catchment area, now supplemented by 261 km^2 supplied by the diversion of water from the Huon-Serpentine ('Lake Pedder') impoundment. These inflows have been regulated by the Gordon power station since 1977. Between the power station and the Franklin River junction, the river has an additional catchment area of 1213 km^2. Major tributaries of the middle Gordon River include the Franklin (catchment area 1676 km^2), Denison (catchment area 664 km^2, or 54.7% of the total 'unregulated' middle Gordon catchment area downstream of the power station) and Olga Rivers (catchment area 180 km^2, or 15% of the total unregulated middle Gordon catchment). A series of smaller tributaries also enter the middle Gordon and include the Albert, Orange, Smith and Sprent Rivers, each contributing between 3 and 7% to the total catchment area of the unregulated middle Gordon.

Thus, the catchment yield, and hence the flow regime, changes substantially in three locations – at the Gordon dam and power station, at the Denison River junction and at the Franklin River junction. For the purposes of this report, the middle Gordon has therefore been divided into two broad sections (Figure 1):

- Section 1 **-** between the Gordon power station and the Denison River junction: 63 – 77 km from the mouth of the Gordon River;
- Section 2 **-** between the Denison River and Franklin River junctions: 40 – 63 km from the mouth of the Gordon River.

The Gordon River and its tributaries form a core geomorphological setting for much of the key biological values identified within the Tasmanian World Heritage Area (see Appendix 14 of this report series – Gordon River World Heritage Area Values Assessment (Kriwoken 2001)). Key aquatic faunal values of the middle Gordon include:

- a diverse macroinvertebrate fauna, predominantly aquatic insects and crustaceans, with a substantial component of Gondwanan origin;
- a native fish fauna of unknown diversity, size and extent;
- platypus and Australian water rat populations of unknown size and extent.

The tidal lower Gordon also supports a limited brown trout recreational fishery.

Only a limited amount is known about the status of the instream ecosystem of the middle Gordon and how it has responded to the impacts of hydroelectric development (see Davies *et al.* 1999). No faunal sampling or survey work was conducted in the Gordon River prior to the presence of hydroelectric infrastructure. A survey of macroinvertebrates was conducted in 1977 and 1978 by Coleman (1978) (also see Richardson and Swain 1978) after dam construction, but the middle Gordon was not sampled again until 1995/96 (Davies *et al.* 1999). No fish or platypus surveys of the middle Gordon River or tributaries have been conducted to date. One of the major tasks of this project was therefore to increase the state of knowledge by re-assessing previous data and conducting additional survey work as required.

This report is primarily focused on the issue of biological impacts of hydropeaking, as they pertain to macroinvertebrates and platypus. Discussion of flow mitigation includes fish, but see Howland *et al.* (2001) for background information on the status of fish populations in the middle Gordon.

Hydropeaking is a term used in the international technical and scientific literature to describe hydroelectric operations in peak load generation mode. These hydroelectric operations are characterised by frequent, rapid changes in discharge at hourly to daily intervals.

Downstream environmental impacts of hydropeaking (e.g see Sear 1995) include:

- erosional and other channel adjustments to rapidly varying water levels;
- loss or reductions in habitat availability and quality for biota due to rapidly fluctuating velocities and extent of inundation and exposure;
- changes in water quality conditions;
- changes in substrate characteristics, often associated with bed 'armouring';
- localised changes at tributary junctions associated with tributary erosion and channel adjustment.

Downstream biological impacts of hydropeaking have been documented periodically for over 25 years (Fisher and LaVoy 1972, Cushman 1985, Gore 1994, Power *et al.* 1996). They include:

- overall loss of biodiversity through loss of species, and reductions in abundance of fish, macroinvertebrates, macrophytes and algae (Troelstrup and Hergenrader 1990, Moog 1993, Munn and Brusven 1991, De Jalon *et al.* 1994, Blinn *et al.* 1995, Ojutkangas *et al.* 1995, Valentin *et al.* 1995, Englund and Malmqvist 1996, Lauters *et al.* 1996, Cereghino *et al.* 1997, Benenati *et al.* 1998, Cereghino and Lavandier 1998, Pardo *et al.* 1998);
- partial or complete recruitment failure in fish populations (Stanford and Hauer 1992, Moog 1993, De Jalon *et al.* 1994, Ojutkangas *et al.* 1995, Liebig *et al.* 1999);
- shifts in community composition toward taxa more tolerant of variable flow environments (Brittain and Saltveit 1989, Trolestrup and Hergenrader 1990, De Jalon *et al.* 1994);
- behavioural responses to varying velocities and habitat conditions including catastrophic drift and localised movement (Perry and Perry 1986, Layzer *et al.* 1989, Lauters *et al.* 1996);
- stranding and associated mortality of fish and macroinvertebrates (Hvidsten 1985, Hunter 1992, Bradford *et al.* 1995, Bradford 1997).

The changes experienced in the middle Gordon River associated with the current Hydro Tasmania management regime and the forecast regime under a Basslink scenario are typical of those associated with hydropeaking or 'stepload' operations, accompanied by the effects of the construction and presence of the Gordon dam. The aquatic biological aspects of these changes are assessed in detail in this report by comparing natural, current and Basslink conditions.

The primary questions addressed in this report are:

1. What is the current status of the instream biota of the middle Gordon?
2. How has the biota and its habitats been affected by hydroelectric operations to date?
3. What changes in habitat and water quality are predicted under a Basslink flow regime?
4. What risks do they present to the instream biota?
5. What mitigation options are available under Basslink and how effective would they be at reducing these risks?

The approaches taken to addressing these questions are described in the following section.

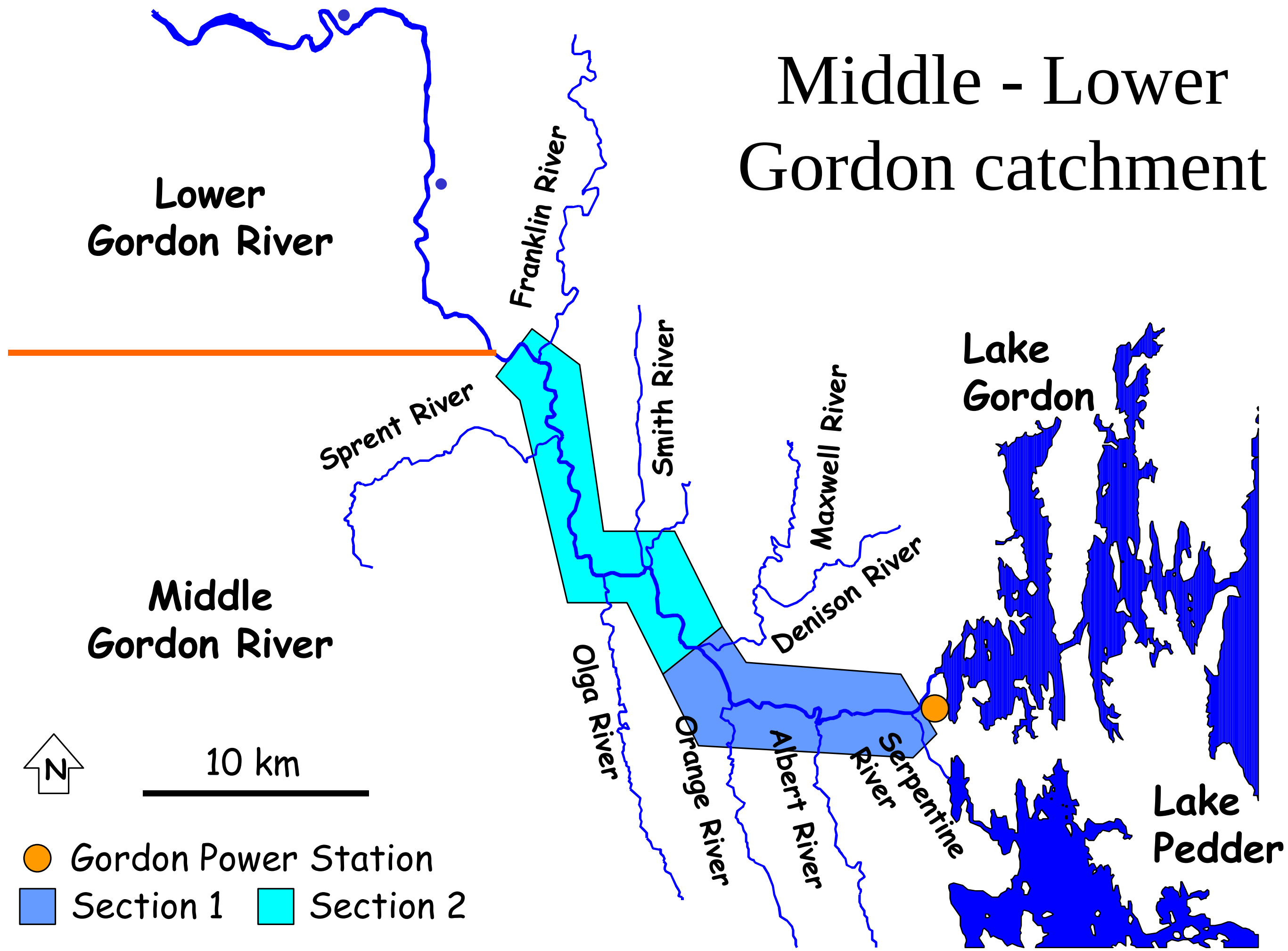


Figure 1. Map of middle-lower Gordon River catchment showing location of the two major study sections, the Gordon power station and all major tributaries.

2 METHODOLOGY

2.1 Overall study approach

The approach taken in this study was based on the conceptual model illustrated in Figure 2. In this model, we see modifications to the flow regime having been being the primary 'driver' of biological changes in the middle Gordon River over the last 20 years, dictated by the presence of the dam and the operations of the power station. These changes act both directly and indirectly on the biota, primarily by modifying the availability and quality of instream habitat, by causing localised bank erosion which in turn affects habitat quality, and by reducing passage between river reaches by enhancing the barrier effects of a number of gorges and rapids for platypus and fish. We believe that modifications to water quality, including dissolved oxygen and temperature regimes, are secondary effects, being of potential biological significance only within 1 - 2 km immediately downstream of the power station (see Appendix 3 of this report series – Gordon River Water Quality Assessment (Koehnken 2001)). Both Koehnken (2001) and Christian and Sharp-Paul (1979) have described a trend of increasing temperature with distance downstream from a minimum at the Gordon power station tailrace. Water quality is generally good to excellent, with no evidence of marked declines in dissolved oxygen, despite the risk of occasional releases of low DO water associated with low lake levels (Koehnken 2001), and relatively minor declines in temperature associated with power station discharges.

The study approach based on the conceptual framework in Figure 2, was as follows:

A) Identify current status and threats

1. describe the current status of instream faunal communities in the middle Gordon in comparison with those in similar 'reference' rivers;
2. compare flow regimes under natural and current scenarios;
3. identify key flow variables which affect the instream fauna in the Gordon or similar rivers;
4. develop empirical relationships between habitat availability (area and/or quality) for key taxa or taxon groups and discharge at a range of sites throughout the middle Gordon;
5. compare flow regimes under natural and current flow scenarios;
6. compare habitat availability under these scenarios and identify any critical 'habitat events' which may significantly limit or impact on instream taxa.

B) Identify potential impacts under Basslink

1. evaluate the incremental changes in flow regime under Basslink by comparison with current and natural flow regimes;
2. identify changes in any key flow elements which may impact on instream fauna;
3. compare habitat availability under these scenarios and identify any new critical 'habitat events' which may significantly limit or impact on instream fauna under Basslink;
4. attempt to quantify risks associated with the Basslink scenario.

C) Mitigation and/or Management options under Basslink

1. identify management options to minimise or reduce risks to instream fauna under Basslink;
2. provide recommendations on flow management for mitigation of any additional environmental impact associated with Basslink.

Assessment of potential impacts of Basslink were conducted by comparison with those observed under current conditions, using the difference between current and natural conditions to put Basslink-induced changes into context. Thus, a first step was to characterise the current conditions relative to natural conditions.

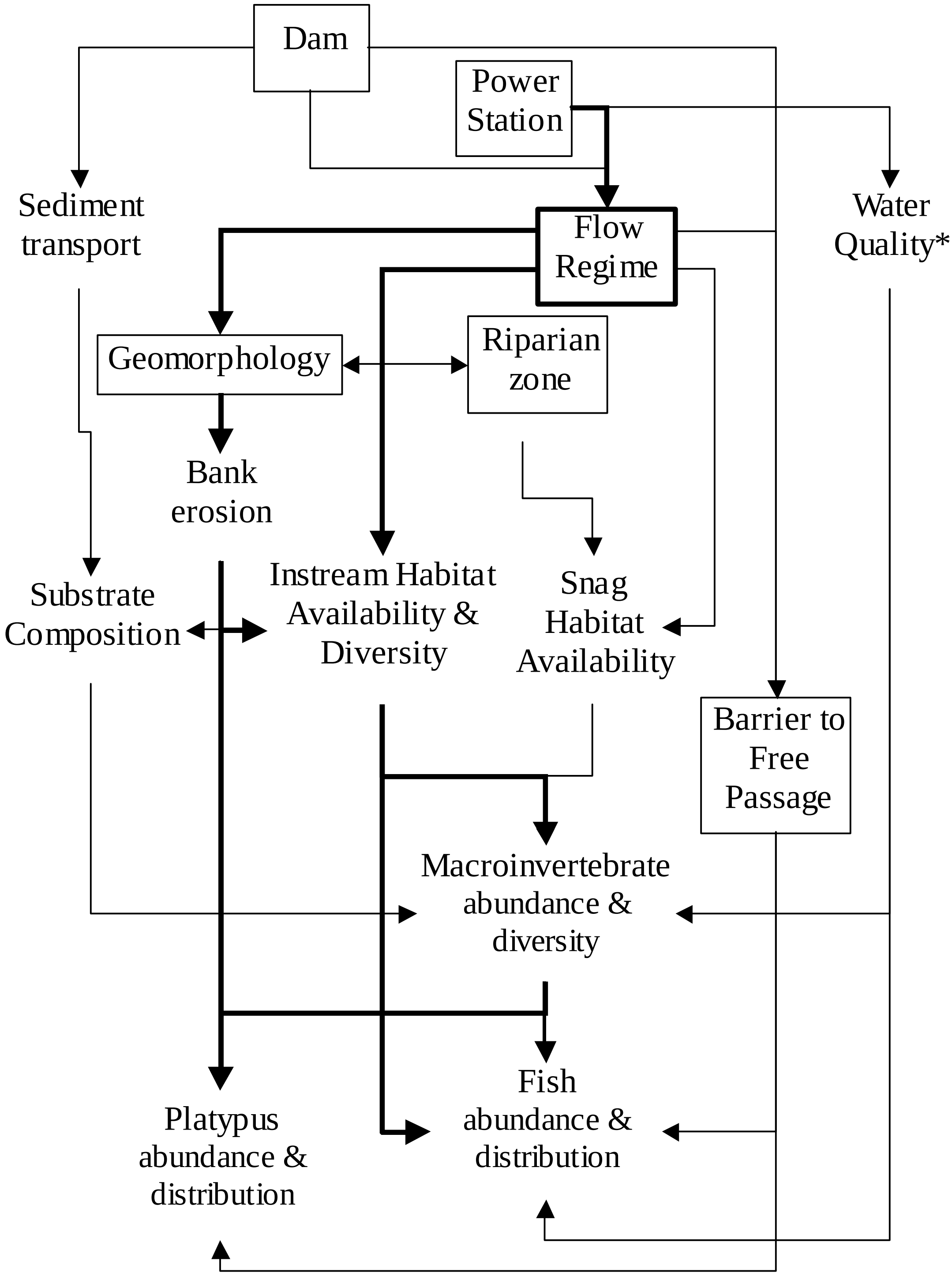


Figure 2. Conceptual diagram of dominant impacts of hydroelectric development on the Gordon River stream ecosystem and their linkages.

Bold lines show perceived dominant connections under a Basslink scenario. * includes temperature; suspended solid, nutrient and gas concentrations.

2.2 Instream Faunal Assessment - Methods

In order to address issues under A and B above, we reviewed existing data and/or published material on instream fauna in the Gordon River. We collected new data from the middle Gordon on the community composition, diversity and status of fish and macroinvertebrate populations in order to assess their conservation status and condition. We also collected new quantitative and semi quantitative (rapid assessment protocol or 'RAP') data on the status of river health in the middle Gordon by repeating sampling for macroinvertebrate bioassessment (as in Davies *et al.* 1999) at sites sampled by both Davies *et al.* (1999) and Coleman (1978) - see Figures 3 and 4 and Table 1. We also re-evaluated the macroinvertebrate data presented in Coleman (1978) and Davies *et al.* (1999). Fish populations were assessed and are reported on by Howland *et al.* (2001).

2.3 Macroinvertebrate sampling and data analysis

2.3.1 Macroinvertebrate survey

Additional macroinvertebrate sampling was required to confirm the downstream trend in community composition described by Davies *et al.* (1999). The rapid assessment protocol (RAP) sampling conducted by them was repeated using the same techniques and sampling sites in spring 1999 (November-December) and autumn 2000 (March). In addition, kick-sample residues were kept from this sampling to provide quantitative ('whole sample estimate' or WSE) data as well as live-pick 'rapid assessment' (RAP) data.

All sites were sampled in the same manner, using the NRHP sampling protocol described by Davies (1994). RAP sampling was conducted once in spring (November – December) 1999 and once in autumn (March) 2000. Sites were accessed by helicopter, with sampling of middle Gordon sites requiring power station shut-downs. Site locations are shown in Figures 3 and 4, and details are provided in Table 1.

The convention of numbering sites as distance in km from the Gordon River mouth was adopted in line with other Appendices in this report series. Thus Section 1 of the middle Gordon (upstream of the Denison River) was characterised by sampling at sites 63 – 76, and Section 2 by sampling at sites 42 – 62.

At each site we selected a mid-channel riffle on a bar and took a 10 m kick-sample in an upstream direction with a 250 micron mesh kick net (dimensions 35 * 35 * 45 cm). Each sample was picked, un-preserved, on-site for 30 minutes, attempting to recover the maximum number of taxa while maintaining the rank abundance of dominant taxa. All individuals collected were stored in 90% ethanol in a vial prior to being returned to the laboratory. Sample residues (the fraction remaining after live-picking) were preserved in 90% ethanol prior to processing in the laboratory. Each residue was sub-sampled to 20% using the grid-cell box sub-sampler described by Marchant (1989), after flotation in a saturated calcium chloride solution, and sub-samples preserved in 90% ethanol. Individuals from all samples were enumerated and identified to family level for all taxa except oligochaetes, Hydracarina and flatworms, consistent with Davies *et al.* (1999).

Quantitative WSE data were also prepared by combining live-pick data from the 1995-96 survey with data from the corresponding 20% sub-sampled residues (which were processed specifically for this study). Macroinvertebrate abundance data from the live-pick fractions were sub-sampled to 20% using the 'Virtual Marchant Sub-sampler' developed by Walsh (1997), prior to combining with the data from the corresponding sample residue.

2.3.2 Macroinvertebrate habitat associations

Quantitative 'surber' samples of macroinvertebrates were also collected from the lower Franklin River in order to establish relationships between macroinvertebrate densities and three key variables - depth, velocity and substrate composition – for use in habitat-flow analyses. The lower Franklin River upstream of Big Fall was selected as it is the largest unregulated, pristine river within the Gordon catchment that contains reaches of similar channel dimensions and slope to the middle Gordon River in both Sections 1 and 2. It is therefore as representative of the unimpacted middle Gordon as possible. Two adjacent sites were sampled in the Franklin upstream of Big Fall, each with similar gradients and proportions of run-pools and bars to that in the middle Gordon upstream and downstream of the Denison River. Field observations of substrates at transect sites in the middle Gordon were used to define the range of dominant substrate types for sampling in the Franklin River. Initial hydraulic modelling of Gordon transects (see below) also indicated that depths and velocities ranged between 0 and 5 m and 0 and 3.5 m/s, respectively, on bars. Sampling was conducted in April 2000 after a period of prolonged, steady flow. 85 quantitative macroinvertebrate ('surber') samples were therefore collected by hand (wading or diving), with sampling stratified over a range of depths (0 – 4.5 m), velocities (0 – 2 m/s) and substrate types (from silt to boulders and bedrock). Samples could not be collected at velocities > 2 m/s due to practical limitations, and depths > 5 m were not encountered in the lower Franklin River sites during sampling. Efforts were made to ensure surber sampling efficiency was standardised over the diversity of depths and velocities encountered.

Individual samples were taken by hand-disturbance of the river bed using a standard Surber sampler (sampled area 30 x 30 cm, 0.5 mm mesh size). Depth and % substrate composition were recorded at each sampling location, as well as velocity immediately above the bed and at 0.4 of the depth of the water column. An index of shear stress was also measured at most sampling locations, using FST hemispheres (see below). Surber samples were preserved and processed as described above. Mayfly (Ephemeroptera) larvae from the samples were subsequently identified to species.

2.3.3 Assessment of macroinvertebrate stranding

Sampling was also conducted to assess the significance of macroinvertebrate stranding following power station shut-downs. Two, 0.1 m^2 areas of channel substrate, located 0.5 m apart, were sampled at each of five equidistant locations between the lower margin of lateral sand/silt deposits at the toe of the bank and the waters edge, at sites 72, 63 and 60 on 19/8/2000, within 9 hr of a shut-down commencing. At each location, the substrate was progressively removed with a trowel to a depth of 20 cm. Each portion of substrate was gently washed three times in a bucket of water, allowed to settle and the supernatant suspension poured through a 500 micron mesh net. The combined, sieved material from each sampling location was preserved (10% formalin), prior to being hand-sorted and identified in the laboratory, as above.

This sampling of the exposed bed was repeated at sites 74 and 72 on 19/9/2000, 9 hr after a second Gordon power station shut-down, and again at these same sites four weeks after the same shutdown commenced (on 15/10/2000). Other sites were not accessed due to high river levels on these dates.

2.3.4 Conservation status

In order to assess the conservation status of the macroinvertebrate fauna of the middle Gordon, samples collected in 1995/96 and 1999/2000 were identified to species level for those groups which have species listed under the Threatened Species Protection Act (1995). Three sites in the middle Gordon were selected, based on the analyses of Davies *et al.* (1999) as having macroinvertebrate fauna that is broadly representative of Section 1 immediately downstream of the power station, Section 1 downstream of the Orange River, and of Section 2 (i.e. downstream of the Denison River), respectively. They were: 75, in the Albert gorge downstream of the power station; 63 in Section 1 immediately upstream of the Denison River, and 50, downstream of the Olga River. Five reference sites in major tributary rivers of the Gordon catchment were selected for comparison and samples identified to species level, as for the three Gordon sites. They were the lower Franklin at Shingle Island (Fr1), the lower Denison River (De7), the Maxwell River (Ma7), the Jane River (Ja7), and the upper Gordon River (U58). These corresponded to sites G18, G22, M1, J1, and G27 of Davies *et al.* (1999). See Figure 4 and Table 1 for their locations.

Data from the middle Gordon samples were:

- examined for the presence of any species listed under the Threatened Species Protection Act (1995);
- compared with data from the five reference sites by statistical comparison (ANOVA) of macroinvertebrate total abundance and species richness.

2.3.5 Data analyses

A variety of data analyses were conducted using these data, including:

- bioassessment using the RAP data and the RIVPACS (River Invertebrate Prediction and Classification Scheme) models developed by Davies *et al.* (1999) for rivers in Tasmanian 'Hydro catchments';
- plotting trends in the 1995-96 WSE data and comparing them with those developed following re-analysis of Coleman's (1978) data;
- conducting multivariate analyses of patterns in the 1977-78, 1995-96 and 1999-2000 macroinvertebrate community compositional data with MDS ordination on 4^{th} root transformed abundance data, using the PRIMER analysis package (Clarke and Warwick 1994, Carr 1996);
- comparisons of macroinvertebrate abundance and diversity between sets of WSE's, using analysis of variance and covariance (ANOVA, ANCOVA) and t-tests conducted with SYSTAT (8.1).

Comparative analyses were conducted of macroinvertebrate survey data collected in 1977-78 and 1995-96. Care was taken to ensure standardisation of taxonomic descriptions prior to these analyses, by inspection of archived material from the 1977-78 surveys. Family level taxonomy was deemed satisfactory for assessing community compositional changes with time and position in the middle Gordon, as the dominant patterns are demonstrated as well at family as at species taxonomic level (Marchant *et al.* 1995, Davies *et al*. 1999).

Data from RAP kick samples collected from each site in spring and autumn were combined (summed) and analysed using the two 'combined season' RIVPAC models developed by Davies et al. (1999) after transformation to either presence/absence or rank abundance. Combination of the two seasonal samples is aimed at controlling for inter-seasonal and inter-operator differences in community and sample composition, respectively.

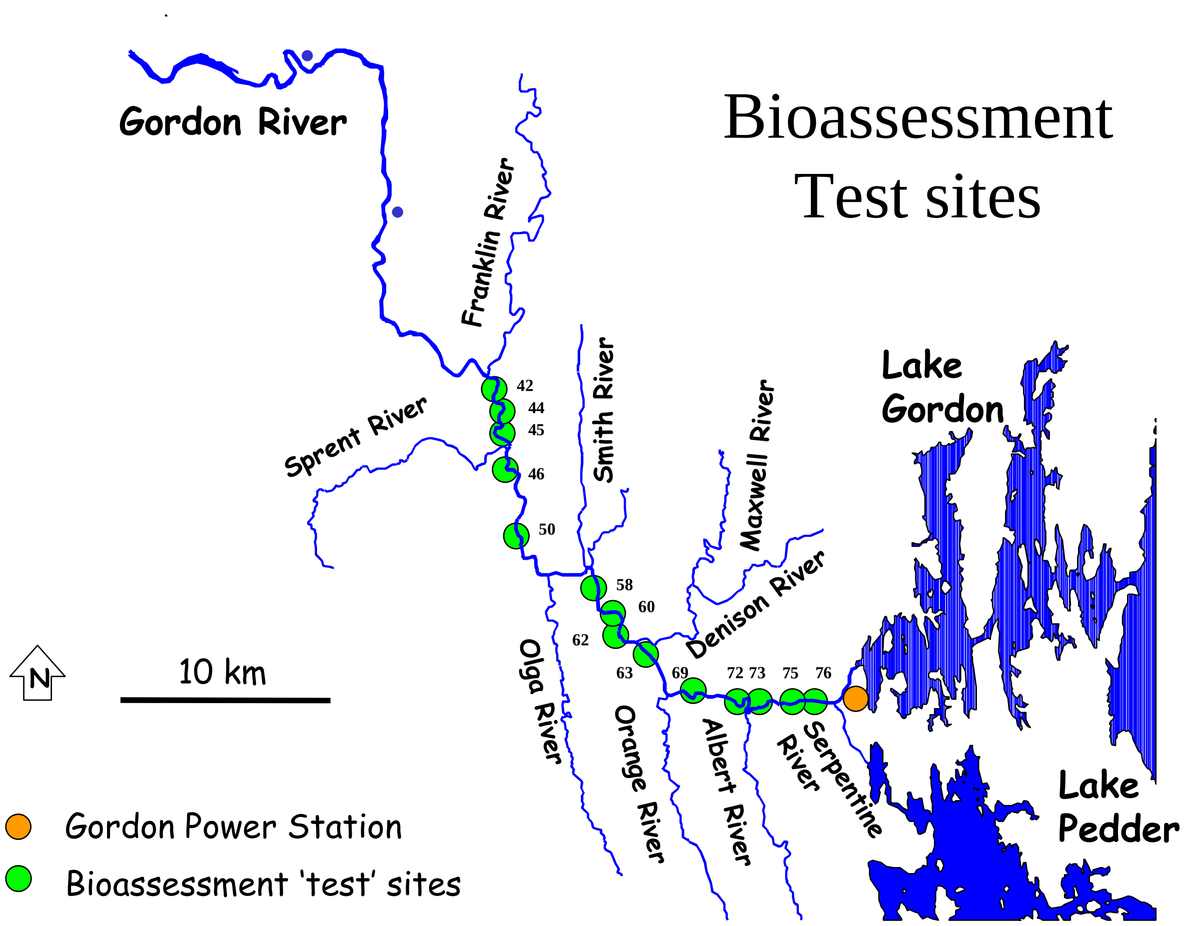


Figure 3. Map of Gordon River showing locations of 'test' bioassessment sites within the middle Gordon River. Numbers indicate distance in km from the Gordon River mouth and are used as site names. See Table 1 for site details.

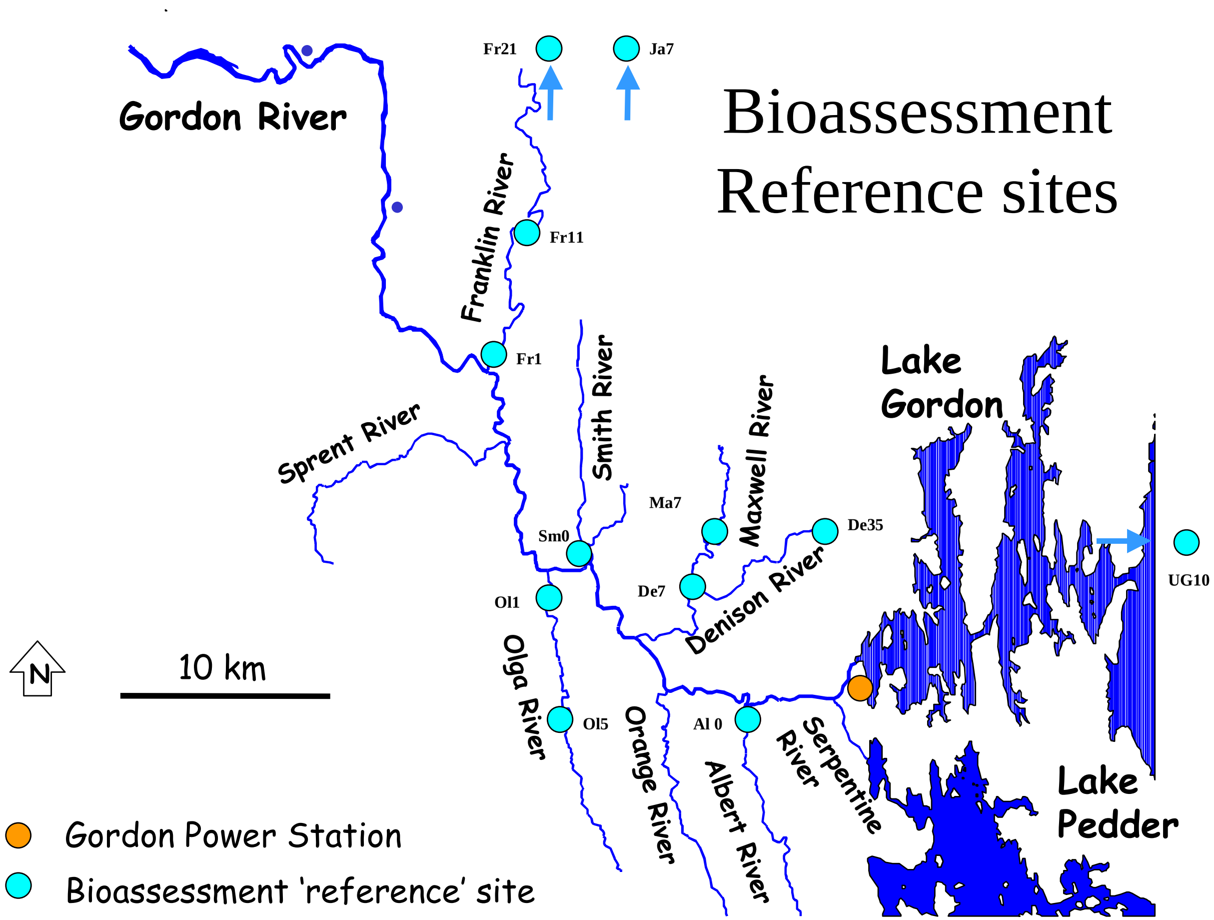


Figure 4. Map of Gordon River showing locations of 'reference' bioassessment sites located within the Gordon catchment. Numbers indicate distance in km from the confluence with the Gordon and are used as site names. See Table 1 for site details.

Table 1. Details of locations and names of sites sampled or modelled hydraulically in this study.

r, b = run-pool and bar. X indicates that site macroinvertebrate samples were also processed to species level (all others processed to family level). Note that site code numbers indicate the distance in km from mouth of Gordon River.

Site code (this study)	Name	Easting	Northing	Distance ds of power station (km)	RAP sampling (1999-00)	Quant. Sampling (1995-96, RAP-WSE)	IFIM transect
Test Sites							
Section 1							
78	Gordon R ds Gordon Dam	415400	5267200	-1	X	X	
76	Gordon R ds Gordon PSt	413875	5266684	1	X	X	
75	Gordon R ds Albert Gorge	412980	5266630	2	X	X	r,b
73	Gordon R ds Gordon PSt	411299	5266519	4	X	X	b
74	Gordon R ds Piguenit R	412311	5266383	3			b
72	Gordon R in Albert Gorge	410355	5266524	5	X	X	b
71	Gordon R ds Albert R	410090	5266789	6			b
70	Gordon R ds Albert R	409032	5266855	8			r,b
69	Gordon R us Second Split	408005	5266815	8	X	X	b
65	Gordon R @ Snake Rapids	405739	5267871	12			r
64	Gordon R ds Orange R	405550	5268000	13			r,b
63	Gordon R us Denison R	404584	5269469	14	X	X	r,b
Section 2							
62	Gordon R ds Denison R	403816	5269713	15	X	X	b
60	Gordon R ds Denison R	402896	5271211	17	X	X	b
58	Gordon R us Smith R	402083	5273405	20	X	X	b
50	Gordon R ds Platypus Ck	398273	5276373	27	X	X	
48	Gordon R ds Olga R	398178	5278476	29	X	X	
47	Gordon R ds Olga R	398450	5277275	30			r,b
46	Gordon R us Sprent R	397503	5279791	31	X	X	
45.7	Gordon R ds Sprent R	396881	5280602	32		X	
44	Gordon R us Grinings Landing	397207	5281277	34		X	
42	Gordon R @ Devil's Teapot	396804	5282486	35	X	X	r,b
Reference	**Sites**						
Sm0	Smith R us Gordon	401956	5273609		X	X	
Ol1	Olga R us Gordon R	399900	5271700		X	X	
Ol 5	Olga R us Stranger Ck	400100	5268800		X	X	
Fr1	Franklin @ Shingle Island	396904	5284540		X	X	
Fr11	Franklin R ds Blackman's bend	398562	5291239		X	X	
Fr21	Franklin R @ Flat Is	397939	5296733		X	X	
De7	Denison ds Maxwell R	407206	5272718		X	X	
De35	Denison R us Truchanas Reserve	417400	5282900		X		
Al0	Albert R	410258	5265975		X	X	
UG 10	Gordon R us Gordon Gorge	447600	5276500		X	X	
Ma7	Maxwell R	409011	5276009		X	X	
Ja 7	Jane R	408100	5300400		X	X	
Se0	Serpentine R	415019	5266274		X	X	

2.4 Flow analyses

Characterisation of river flows in the middle Gordon was conducted by using simulated flow records under three scenarios:

- natural, 'no-Hydro' conditions (simulated records, see Appendix 2 of this report series – Gordon River Hydrology Assessment (Palmer *et al*., 2001) for methods);
- 'current' conditions with existing hydroelectric infrastructure and power station management (actual historical records of power station discharges);
- a Basslink hydroelectric management scenario with a 480 MW cable (simulated records, see Palmer *et al*., (2001) for methods).

Since the majority of flow changes dictated by current and forecast Basslink scenarios occur at short (less than daily) time intervals, and since it is these short interval changes which dominate biological responses to the altered flow regimes (Davies *et al.* 1999), we required flow data sets which reflected hourly changes in flow. Only two years of record were suitable for detailed analysis – 1997 and 1998. These were the only years in which hourly records of power station outputs had been recorded. Data was provided for analysis based on these two years of record for a range of study sites downstream of the power station to the Franklin River junction.

In this report, much of the discussion is illustrated using the 1998 year as an example of real and simulated flow records. This year was an 'average' year in terms of water yield and seasonal behaviour (see Palmer *et al*., 2001). It was also the only complete year of hourly record available, as there were significant gaps in the 1997 year hourly record.

We also required flow data for assessing changes in patterns of mean daily and monthly flows, the latter being used to assess any changes in flow seasonality. Simulated mean daily flow records were available for the natural and Basslink scenarios or comparison with the historical power station discharge record for the period 1977 to 1999. However, comparisons were sought which used as close to 'current' operations as possible. Changes in the number of turbines and in the magnitude and pattern of power production at the Gordon power station over that period were substantial. As a result, we used the historical records for the period 1990-1999 to assess the implications of changes in daily and seasonal flow patterns, in comparison with simulated records for natural and Basslink scenarios for the same years.

Flow records were generated for a number of sites downstream of the power station, using a flow model developed by Hydro Tasmania which incorporated real and simulated tributary inflows and flow routing and attenuation parameters derived empirically from temporary stage recording stations (Palmer *et al*., 2001). On inspection of modelled flow outputs for several of these sites, and comparison with real records, we were satisfied that the simulated records produced by the model were reasonably accurate in terms of timing, duration and frequency of flow variations within the middle Gordon.

2.5 Assessment methods

There is no significant published Australian information on the effects of the type of flow regulation associated with peak hydroelectric power production or 'hydropeaking'. We therefore accessed the international literature on the effects of hydroelectric flow regulation on downstream river ecosystems.

Three major approaches were therefore taken to assessing the status of and risks to biological communities and habitat availability and quality in this report:

- *a predictive modelling approach* to bioassessment using macroinvertebrates called RIVPACS (River Invertebrate Prediction and Classification Scheme), with models developed and used by

Davies *et al.* (1999), for assessing the biological condition of Tasmanian rivers downstream of Hydro power stations and dams;

- *habitat-flow analyses* incorporating a method which links habitat preferences of instream fauna with hydraulic information from river transects to produce relationships between suitable habitat area and discharge. We used habitat availability as a surrogate for biological condition in assessing the likely future impacts of Basslink on the middle Gordon, and in assessing mitigation options. We evaluated changes in habitat availability under the differing flow regimes, and to derive relative risks to the fauna associated with changes in habitat availability at low flows (as used by Davies and Humphries (1995) for the South Esk River basin); and

- *assessment of changes in shear stress* on the river bed associated with power station discharges using 'FST' hemispheres in order to assess the relationship between power-station releases and changes in hydraulic conditions for benthic fauna.

These approaches are described in more detail in the following sections.

2.5.1 Predictive modelling - RIVPACS

The River Invertebrate Prediction and Classification Scheme was developed in the UK by Wright *et al.* (1984) and Moss *et al.* (1987), and is summarised by Wright (1995) and in Davies *et al.* (1999). It now forms the basis of the Australian national river bioassessment framework established under the National River Health Program (AUSRIVAS, Schofield and Davies 1996). The approach uses a predictive model based on macroinvertebrate and environmental data collected from a set of unimpacted 'reference' river sites in order to assess and quantify the departure of a new site's macroinvertebrate community from the reference condition. Davies *et al.* (1999) developed two RIVPACS models specifically for the assessment of Tasmanian river sites downstream of Hydro power stations and dams. The outputs of these two models are used in the following sections to report on the biological condition of sites in the middle Gordon.

Key aspects to this approach are:

- the use and appropriate selection of regional reference sites;
- use of a 'rapid assessment protocol' (RAP) kick-net sampling method, which results in reliable estimates of taxonomic composition and relative (rank) abundance *within* samples, but not reliable total abundance estimates *between* samples;
- the use of environmental variables for prediction which are minimally affected by human impact;
- use of single habitats in sampling (e.g. riffles) rather than proportional sampling of all habitats in a reach;
- use of two, seasonal, samples per year;
- use of family rather than species level of taxonomic identification.

Attachment 1 illustrates how the RIVPACS models were developed for Tasmanian 'Hydro' rivers and how they are used. Details of methods used in the development and use of RIVPACS models for the bioassessment of Tasmanian rivers affected by hydroelectric development are provided in Davies *et al.* (1999). Locations of 'test' and 'reference' sites sampled in 1999-2000 are shown in Figures 4 and 5.

Macroinvertebrate sampling was conducted in November-December 1999 and in February-March 2000 by kick-sampling 10 m sections of riffle habitat at all test and reference sites with a 250 μm mesh net as described in report section 2.3.1. Macroinvertebrate abundance data from the two seasonal samples collected at each site were combined. This data set was then analysed using the RIVPACS models developed by Davies *et al.* (1999).

The RIVPACS approach results in assessments of 'test' sites with the following outputs:

- a biological index (O/E, or the 'observed to expected' ratio) which describes the proportion of taxa predicted to be at a site under undisturbed conditions that are actually found at that site. O/E scores range between 0, with no predicted taxa occurring at the site, to around 1, with all expected taxa being observed (i.e. a community composition equivalent to reference condition). This is an index of biological impact benchmarked against natural conditions, and which accounts for natural spatial variations in community composition;
- a band category (X, A – D) with a standard description of the degree of impact, whose bounds are based on statistically defined ranges of the O/E scores.

Davies *et al.* (1999) reported on the condition of Tasmanian rivers downstream of hydroelectric infrastructure using two indices –

1. O/Epa – the O/E value calculated using a RIVPACS model based on presence-absence data; and
2. O/Erk – the O/E value calculated using a RIVPACS model based on rank abundance category data.

O/Erk is more sensitive to flow changes than O/Epa. Both indices are used in this report.

The O/E bands used to report the condition of macroinvertebrate communities are shown in Table 2, along with the O/E relevant to each band in the two Hydro RIVPACS models developed by Davies *et al.*(1999).

Table 2. Bands for the Hydro PA (presence/absence) and RK (rank abundance) RIVPACS models developed by Davies *et al.* (1999).

Band	Bounds PA model	Bounds RK model	Description
X	> 1.15	> 1.11	More diverse than reference*
A	0.79 – 1.15	0.78 – 1.11	Equivalent to reference. *Unimpacted.*
B	0.43 – 0.79	0.44 – 0.78	Less diverse than reference. *Significantly Impacted.*
C	0.07 – 0.43	0.10 – 0.44	Much less diverse than reference. *Highly Impacted.*
D	0.000 – 0.07	0.000 – 0.10	Extremely less diverse than reference. *Extremely impacted.*

* may occur for sites of exceptional natural diversity, or due to slight nutrient enrichment.

2.5.2 Habitat-flow analyses

2.5.2.1 Habitat-discharge relationships for macroinvertebrates and platypus

In order to assess risks to biota through changes in habitat conditions and availability, a study which incorporated technical components of the Instream Flow Incremental Methodology (IFIM) was conducted. The Instream Flow Incremental Methodology was developed in the late 1970's and early 1980's in the USA (Bovee 1982, Gore 1987, Stalnaker *et al.* 1995). The unthinking use of IFIM for making predictions of biological responses to changes in flow regimes has been criticised, and the success of the techniques within IFIM explored and debated (Orth and Maughan 1982, Orth and Maughan 1986, Petts and Maddock 1996, Jowett 1997). However, IFIM has a core element – physical habitat simulation – which can validly be used to develop relationships between an index of habitat availability for key species or target biota (weighted useable area, WUA) and discharge, and explore flow management options in relation to changes in habitat availability, and hence biological suitability

(Petts and Maddock 1996, Jowett 1997). Physical habitat analysis using IFIM type approaches, has also been recommended for assessing instream flow requirements for platypus (Grant and Bishop 1998).

Two sets of data are used to develop the habitat – discharge (WUA-Q) relationships for key biota:

1. A cell-by-cell set of velocities, depths and substrate descriptors for a representative set of transects in a study reach, repeated over a range of discharges;
2. A set of ‘habitat preference’ criteria, formulated as ‘curves’, describing the relative abundance or occurrence of the target species or biota over ranges of velocity, depth and substrate types.

The process of using these data sets is illustrated in Figure 5.

Weighted useable area of habitat (WUA, in m^2/m) is usually calculated by summing geometrically combined normalised preference scores for depth, velocity and substrate for each cell, centred on the verticals across site transects, for all cells in the entire study reach.

The latter data are usually collected by establishing cross-sectional transects at representative habitat types in study reaches of interest and collecting depth, velocity and substrate data at verticals along each transect, in the same manner of a stream gauging. In order to collect such data at each vertical (which represents the centre of a cell stretching between the upstream and downstream transects) over several discharges, the measurements may be repeated at each required discharge or, (where access is restricted, as in the middle Gordon) may be simulated. Typical practice is to collect one set of field data and use these for calibration in a hydraulic simulation based either on a water surface profile model or, if rating curves are developed for each transect, by direct volumetric estimation. Standard software routines exist to perform such simulations include the IF75 and WSP (water surface profiling) routines used in the PHABSIM component of IFIM, or the RHYHAB package developed by Jowett (1992).

The IFIM-type approach has been criticised for its inability to result in relationships between measures of biological abundance or biomass and habitat availability (as WUA) as well as the relatively simplistic model of habitat suitability and its conversion to WUA (e.g. see discussions in Orth and Maughan 1986, Humphries *et al.* 1996, Growns 1998, Pusey 1998). In this study, WUA outputs were only used in comparative analyses to assess relative changes in habitat availability under natural, current and Basslink flow regimes, and in order to assess minimum flows which would maintain adequate habitat availability for biota during periods when the power station is not discharging.

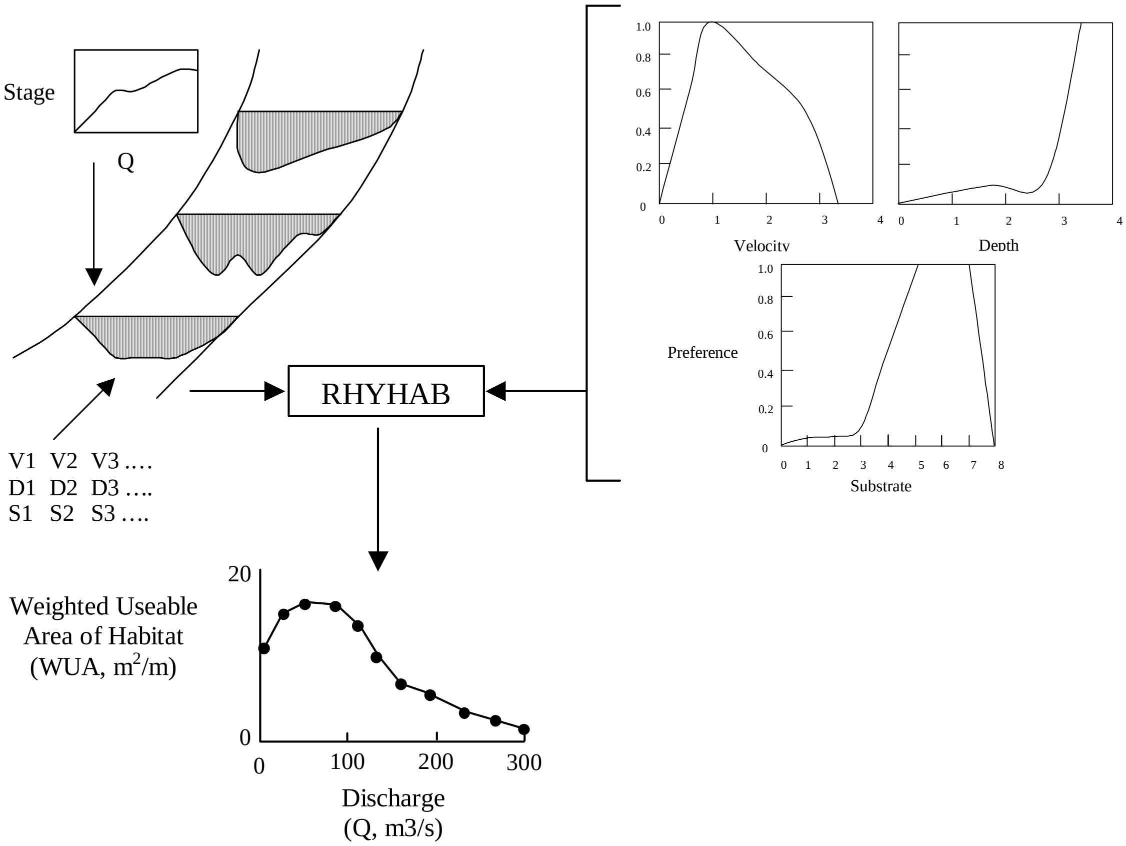


Figure 5. The basis of IFIM habitat modelling;

showing the collection and integration of field hydraulic and habitat data (consisting of data on velocity (V), depth (D) and substrate composition (S), collected at sets of verticals across representative transects for which state-discharge relationships are also developed) with habitat preference criteria (developed from field data on faunal distributions over a range of velocity, depth and substrate compositional values) using the RHYHAB package in order to define the relationship between useable area of habitat (WUA)and discharge (Q) for the study reach.

An IFIM-type study was conducted in which:

1. Data on instream habitat were collected from 15 sites downstream of the Gordon power station (Figure 6) by –
   - establishing IFIM study sites (single transects) which were representative of reaches downstream of the Gordon power station, located so as to adequately sample the two dominant macrohabitats evident at low flows – bars and pool-runs;
   - calibrating all sites by measurement of mean velocity, depth and substrate composition at between up to 90 verticals across the transect;
   - development of rating curves for transects over a wide range of discharges across the power station's operational discharge range;
   - simulation of velocities and depths over those discharges.

2. Data on biological habitat preferences were derived –
   - from existing data/literature/technical information (fish, platypus); or
   - by sampling within the Gordon catchment (macroinvertebrates).

3. Habitat area (WUA) – discharge (Q) relationships were developed for a set of key biological variables by using habitat preference curves, transect data and the RHYHAB flow-habitat

modelling package (Jowett 1992). Simulation was conducted for all bar and pool-run habitat transects separately. Overall WUA-Q curves for 'study reaches' were derived by summing WUA values for bar and pool-run transects in proportion to the length of each habitat within each reach.

4. *For assessing current and projected Basslink habitat conditions* - we converted 'current' and 'natural' flow records to WUA-time series using fitted WUA-Q relationships. We then calculated differences in the median, 10th percentile and coefficient of variation of WUA between 'operational' and 'natural' conditions. These were used as indices of change in habitat availability at median and low flows, and of variability in habitat availability.

5. *For assessing mitigation minimum flows* - we conducted a risk assessment using the approach described by Davies *et al.* (1999), where habitat losses for all taxa were minimised relevant to a reference flow (see report section 2.5.2.8).

Adequate simulations of hydraulic conditions, and hence habitat, could not be conducted without ratings (water level – discharge relationships) that covered the full range of discharges experienced during power station operations. Due to difficulties in obtaining transect ratings at high discharge (due to safety considerations), we were only able to obtain satisfactory rating curves for 5 of the 15 sites.

We therefore conducted the analyses under items 4 and 5 above for three 'study reaches':

- **study reach 03** - 3 km of pool-run and bar habitat within the upper end of Section 1, from 0.2 to 3 km downstream of the power station, represented by transects at site 73;
- **study reach 1215** - representing approx. 3 km of pool-run and bar habitat within the lower end of Section 1, from 12 to 15 km downstream of the power station, represented by transects at sites 63 and 64;
- **study reach 2940** - representing approx. 11 km of pool-run and bar habitat within the lower end of Section 2, from 29 to 40 km downstream of the power station, represented by transects at sites 42 and 47.

The locations of these reaches are shown in Figure 7. These reaches include 43 and 48% of the total length of Sections 1 and 2, respectively, of the middle Gordon (whose total length is approximately 35 km). We were satisfied that they adequately represented channel conditions throughout the upstream and downstream ends of Section 1 and the downstream end of Section 2, and that they were broadly representative of the middle Gordon as a whole.

The only habitats not represented within these study reaches were the larger boulder rapids and gorges. These do not constitute a large proportion of riverine habitat (< 10% overall). Assessment of habitat availability in these habitats would be a major undertaking, and require specialised hydraulic modelling, as well as biological and data collection.

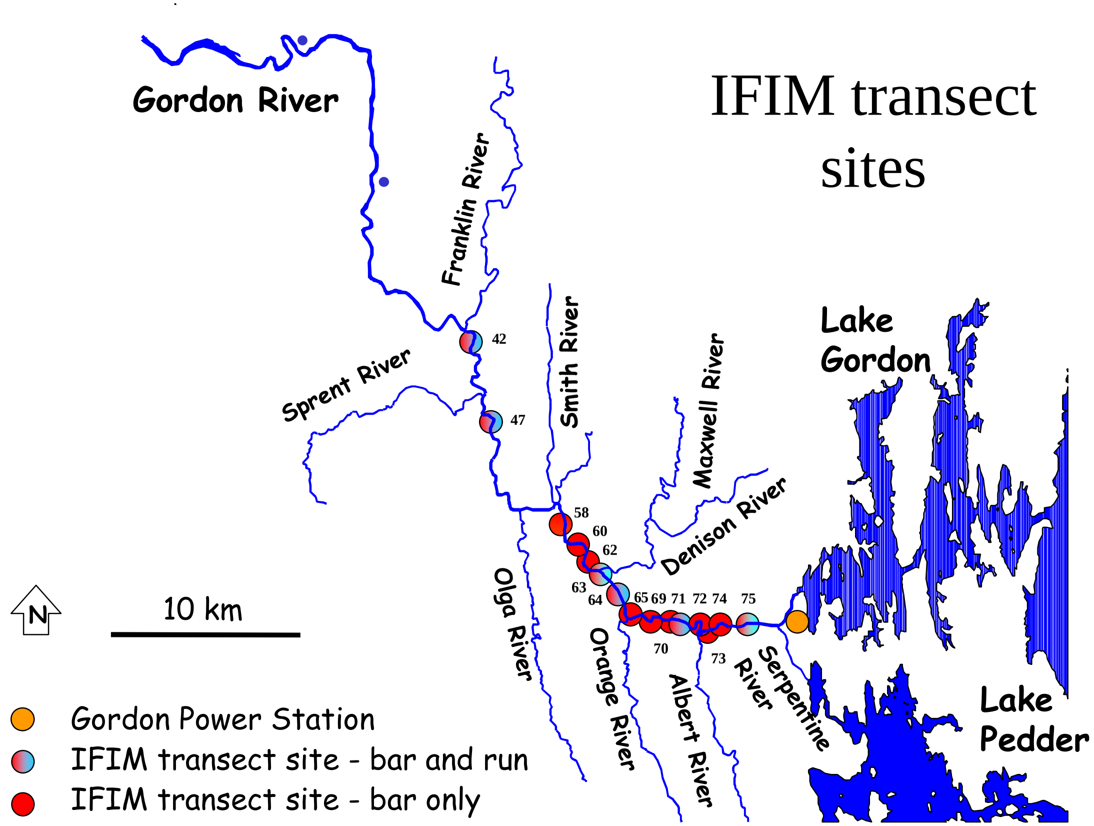


Figure 6. Map of Gordon River showing habitat assessment ('IFIM') transect sites. Sites with transects on bars and/or runs are indicated. Numbers indicate distance in km from the Gordon River mouth and are used as site names. See Table 1 for site details.

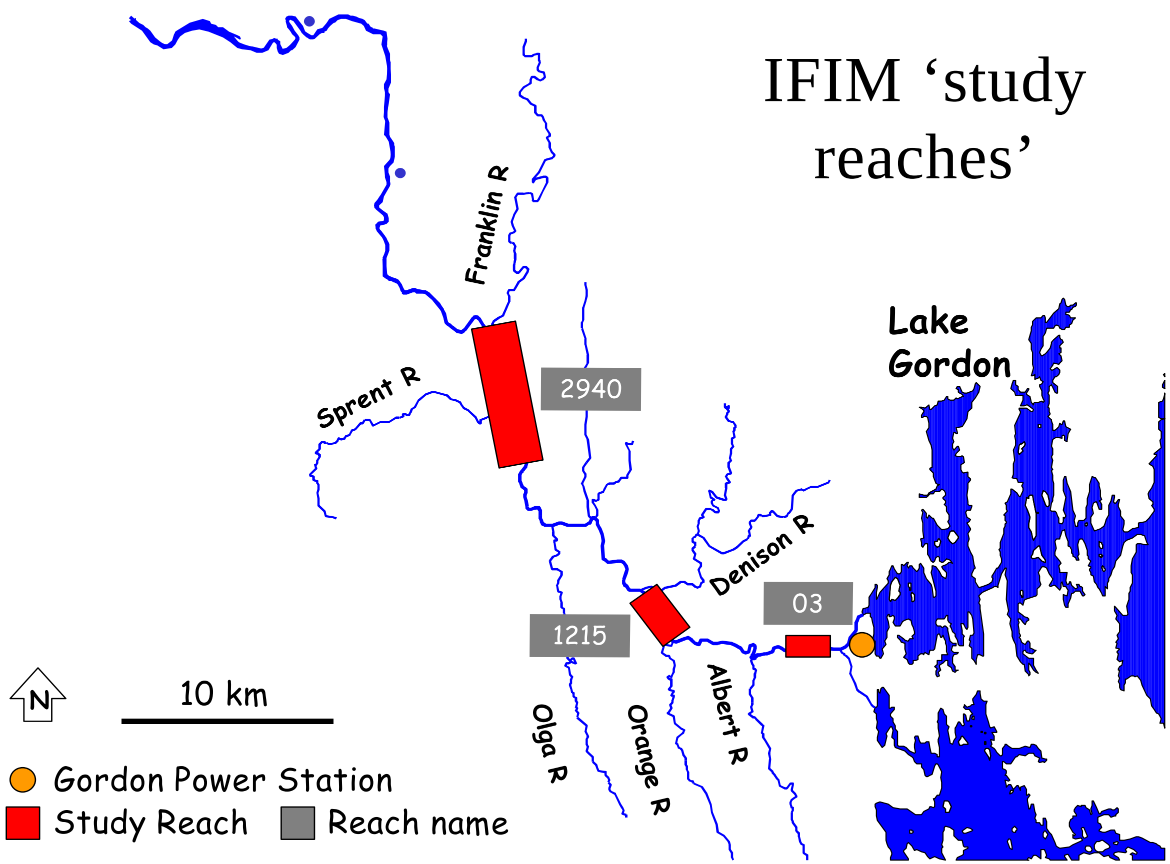


Figure 7. Map of Gordon River showing habitat study reaches, based on selected IFIM transect sites for which reliable rating curves could be determined for both bar and pool-run habitats. See text for details.

2.5.2.2 IFIM sites

A total of 15 sites were selected between the power station and the Franklin River junction as being representative of both bar/rapid and pool-run habitats in the various reaches of the middle Gordon. The location of these sites is indicated in Figure 6 and Table 1. No gorge sites were selected due to access difficulties and the fact that they represented only a small proportion (approx. 5%) of the overall length of the middle Gordon.

A single transect was established across the river at each of these sites, with the transect located across the centre of a bar or rapid, and running perpendicular to the channel. At six of these sites, an additional transect was located in the centre of the pool-run immediately upstream of the bar transect. These sites are also indicated in Table 1 and Figure 6.

2.5.2.3 Site rating

Each transect was established with a permanent datum consisting of a short steel stake inserted into the bank at a position within the riparian forest and at least 4 m above the river bed. At each transect, the profile of the channel was surveyed using a builders level, staff and tape. Between December 1999 and February 2000, a single set of observations was then made at each transect of substrate composition, water depth and mid-water column velocity at between 27 and 89 intervals (‘offsets’) from the datum peg across the channel. These observations were made at very low, residual baseflows, when the power station was shut down. Observations were also made of water surface slope at both very low flows, and at very high flows (using estimated positions of the distinct ‘Plimsoll line’ at the base of the riparian vegetation). Approval for conducting gaugings at high flows (in the range 150 – 250 cumec, with the power station operational) was not obtained from Hydro Tasmania (due to OHS concerns) until late May 2000, when boat-mounted flow-gauging equipment was used to provide a single observation of discharge and water level over the bar and pool-run transects at four of the sites (sites 64, 63, 47, 42).

2.5.2.4 Hydraulic modelling

Hydraulic modelling of transect sites was conducted using the RHYHAB package (Jowett 1992). Modelling was conducted using estimated stage (water level) - discharge relationships (‘rating curves’) for each site based on three points – observed stage at zero flow (assumed to be the lowest point in the channel profile for the downstream bar transect), stage at very low flows (which ranged between 2 and 21 cumec), and stage at high flows (measured in the field for sites 64, 63, 47, 42). Field observations of stage at high flows could not be made for sites upstream of the Splits due to safety concerns and the absence of boat and helicopter access at high river levels. High flow stage values were therefore estimated for site 75 from a combination of modelled stage-discharge relationships based on channel profiles, water surface slope estimates and Manning’s equation, and from the field observations of the Plimsoll and debris lines.

As indicated, detailed modelling and habitat simulation was only conducted for sites 75, 64, 63, 47 and 42, due to uncertainty of estimated high flow water levels at the remaining sites. For the modelled sites, simulations were conducted over the range 2 – 300 cumec. Internal checks were conducted as follows:

- velocity distribution factors were first corrected across the entire channel profile to accord with the field-derived high and low flow observed velocity distributions;
- simulated velocity profiles were inspected for all discharge intervals and velocity values compared with field observations under high flows by regression.

2.5.2.5 Target biological variables

A list of taxa and variables for habitat simulation was developed based on the desire to include:

- habitat suitability and availability for all dominant macroinvertebrate taxa from the middle Gordon;
- a general measure of wetted habitat (wetted area);
- habitat suitability for high macroinvertebrate abundance and diversity;
- habitat suitability and availability for platypus.

There were insufficient data on instream habitat requirements of Australian water rat (*Hydromys chrysogaster*) to conduct an analysis for that species.

Habitat simulation was then conducted on each modelled transect using RHYHAB in order to generate weighted useable area (WUA) – discharge (Q) relationships for the following nine taxa or variables:

- Wetted area;
- Platypus (*Ornithorhynchus anatinus*) abundance;
- Total macroinvertebrate abundance (also a numerical index of benthic fish and platypus food standing crop);
- Number of macroinvertebrate taxa (at family level, an index of macroinvertebrate diversity);
- Caddisflies of the family Hydrobiosidae;
- Mayflies of the family Leptophlebiidae, including the dominant mayfly species *Tilyardophlebia* sp AV2, *Nousia* sp AV6 and Baetid Genus 2 MV sp 3;
- the janirid isopod *Heterias pusilla*;
- Non-biting midges of the family Simuliidae;
- Midges of the sub-families Orthocladiinae and Chironominae.

2.5.2.6 Habitat preference curves

There are few published habitat preference data for platypus which can be used to define substrate, depth and velocity preferences, although some key instream and riparian habitat variables have been identified (Grant and Bishop 1998, Ellem *et al.* 1998). A number of sources were accessed to further define these preferences, including published literature (Kruuk 1993, Gust and Handersyde 1995, Fish *et al.* 1997, Serena *et al.* 1998, Bryant *et al.* 1999, Grant and McDonald 1998, Bethge *et al.* 2000), and discussions with platypus biologists (S. Munks, M. Serena, P. Bethge pers. comm.). These allowed initial assessment of habitat preferences to be made, based largely on the following observations:

- platypus are known to feed actively in very shallow water and up to depths of ca 1 - 3 m. Despite being observed to dive to 11.5 m in lakes (Bethge and Munks unpub. data), foraging is optimal at depths < 2 m due to the greater relative energetic cost of diving at greater depths.
- platypus have been observed swimming and feeding at velocities ranging between 0 and 0.5 m/s, and have been observed to swim for brief periods against current speeds of up to 1 m/s. Water velocities > 1 m/s are not deemed suitable for platypus swimming or foraging.
- platypus actively feed in silt, sands and finer gravel substrates, and are known to forage on coarse gravel to smaller cobble substrate. Feeding activity is not deemed to be efficient or to frequently occur on coarse cobble, boulder or bedrock substrates.
- key instream factors for riverine platypus include the presence of riffle areas for macroinvertebrate food production and foraging, while larger pool areas, and greater habitat diversity are positively correlated with greater platypus abundance (Grant and Bishop 1998).
- key riparian factors identified for riverine platypus include the presence of overhanging riparian vegetation, the area and height of consolidated earth banks (Ellem *et al.* 1998, Grant and Bishop 1998).

We used standard habitat preference curves approach for modelling instream habitat availability for platypus, incorporating depth, velocity and substrate preference data. Habitat preference curves for total macroinvertebrate abundance were used as an index of macroinvertebrate food availability (as used by Jowett 1992, and recommended for platypus by Grant and Bishop 1998).

No habitat preference data existed for macroinvertebrates occurring in the Gordon catchment prior to this study. These data had to be derived from field sampling, which was conducted between February and March 2000 in the lower Franklin River (see report section 2.3 above). Samples were not collected from within the Gordon River due to the known impact from the power station, and the inability to sample when the power station was operating. Habitat preference curves were then prepared from the entire set of Surber sample data in a standard manner (Bovee 1986, Stalnaker *et al.* 1995, Humphries *et al.* 1996) for those taxa with sufficient data to prepare curves (those occurring in > 25% of samples (21 samples) and with total abundances across all samples of > 50 individuals.

Habitat preference curves were then selected for further habitat analysis for those macroinvertebrate taxa known to be dominant or characteristic of middle Gordon sites (see list above).

2.5.2.7 Habitat-flow analysis

Habitat-discharge (WUA-Q) curves were developed for all biological variables for the three study reaches 03, 1215 and 2940 by hydraulic simulation over the flow range 2 - 300 cumec using RHYHAB. Curves were then fitted to these relationships, typically in Excel. Flow series for 1997-1998 were used to make comparisons between habitat availability (measured as WUA) under current conditions and under natural flows. Time series of WUA were deve*l*oped by converting discharge to WUA using the curve equations fitted to the WUA-Q curves. The WUA time-series under current, natural and Basslink (480 MW) flow scenarios were then plotted and compared.

2.5.2.8 Minimum flow risk analysis

In order to derive a minimum environmental flow for the middle Gordon, we used the approach described by Davies and Humphries (1995) for the Macquarie, South Esk and Meander Rivers. This involved a risk assessment of habitat loss for key taxa, relative to a reference flow.

Results of habitat simulations for all taxa and variables listed above (report section 2.5.2.5) were stored as values of weighted usable area (WUA) of habitat for a range of discharges from 2 to 300 cumec for the study reaches 03,1215 and 2940.

Further simulations could be conducted for the reaches between the Abel and Splits Gorges, and between the Denison and Olga Rivers when high flow gauging data becomes available. However, the data from the three reaches above were deemed sufficient to allow a reasonably comprehensive assessment of minimum flow requirements.

For the risk assessment, a ‘reference’ flow was required against which to assess changes in habitat and hence risks to biota. With the aim of maintaining instream habitat at modified, but closer to natural levels during periods between power station discharge peaks, a reference discharge was selected which represented natural ‘baseflows’ during summer-autumn (December – May) and winter-spring (June – November) in an average year. ‘Baseflow’ is used here to describe the discharges occurring between significant rain events. Inspection of discharge plots for the middle Gordon at sites 75, 63 and 42 revealed the baseflows shown in Table 3 for an average year, and allowed selection of median values as reference flows.

Table 3. Natural baseflows (cumec) occurring at key sites, and central (median) values used as reference flows (see below).

Site	Season	Range	Central value
75	summer - autumn	21 – 30	25
	winter - spring	38 – 61	50
63	summer - autumn	22 – 42	28
	winter - spring	30 – 71	55
42	summer - autumn	38 – 60	60
	winter - spring	62 – 141	95

Using the approach described by Davies and Humphries (1995), the following analysis was conducted for each of the three study reaches (see report sections 2.2 and 2.5.2 for details on the flow and habitat simulation methodology):

1) Reference flow selection

The reference flow was selected for each season (see Table 3 above).

2) Habitat change

A series of nominal flows between 2 cumec and the reference discharge value were selected for simulation. Simulation was generally only successful down to 2 cumec. The % deviation of habitat availability (WUA) at the nominal flow from the WUA at the reference flow for that season was then calculated using the following formula:

$$\mathbf{\%\Delta HA = 100*(^{WUAQnom}/_{WUAref})}$$

where $WUAQ_{nom}$ = WUA at nominal discharge, WUA_{ref} = WUA at reference flow.

This was done for all biological ‘values’ listed above (report section 2.5.2.5), including fish variables (using habitat preference data for *Galaxias truttaceus*, *G. brevipinnis*, *Anguilla australis*, *Geotria australis* ammocoetes, and brown trout - see Howland *et al.* 2001).

Separate sets of %ΔHA values were calculated for the two seasonal periods, summer-autumn and winter spring.

3) Risk categories

Each value of habitat deviation (%ΔHA) was converted to a risk category, according to the criteria established by Davies and Humphries (1995), as shown in Table 4. For this analysis, the risk being assessed is the risk of failure to maintain biota due to loss of habitat availability relative to reference conditions (i.e. at natural baseflows). Unlike the approach reported in Davies and Humphries (1995), the results for individual taxa were kept separate.

Table 4. Risk categorisation criteria for biological values in the Gordon River and values for %ΔHA i.e. % remaining WUA under nominal flow cf reference flow (baseflow under natural conditions).

Risk category			
I	**II**	**III**	**IV**
No risk or beneficial	**Moderate risk**	**High risk**	**Very high risk**
> 85% of habitat under natural baseflows	60 – 85% of habitat under natural baseflows	30 - 60% of habitat under natural baseflows	< 30% of habitat under natural baseflows

4) Overall risks and recommended minimum flows

A final risk assessment for each nominal discharge was conducted by taking the lowest risk score (lowest value of %ΔHA) across all biological variables, as the overall risk. The lowest discharge associated with that risk is then the recommended minimum mean hourly flow in each season for that site. This is an inherently conservative approach, in order to minimise risk to the biota. All biological variables were treated equally in this approach with the exception of brown trout which, being regarded as an exotic species in the Gordon, was not included in the final assessment. Trade-off between risk levels for different biological values in the absence of specific management targets favouring particular species/biotic groups is an inherently subjective and semi-arbitrary process and should be avoided. However, plots of %ΔHA for the taxa with the lowest %ΔHA values were made to illustrate their relative contribution to the overall risk assessment.

Study reach 03 experiences the full effect of the power station discharge, with only small residual flows from inputs from the catchment downstream of the Gordon Dam and from the Serpentine River. Analysis of flows at this site was thus uncomplicated by the potential for errors in estimating tributary input flows. In addition, this reach experiences the most severe impacts from the power station discharge regime. Reach 03 (combined bar and pool-run) was therefore taken as the key reach for determining minimum flow releases from the power station.

2.5.3 Shear stress

A key factor in assessing the impact of flow variations on fish and benthic fauna is the relationship between discharge and shear stress at the stream bed. Shear stress is a measure of the force applied to the stream bed (and the biota associated with it) by stream flow. In open channels average shear stress across the channel is broadly related to water depth (hydraulic radius) and water-surface slope, and this relationship has been described as follows:

$$\tau = \gamma .\ R\ .\ S$$

where γ = constant (the specific weight of water), R = hydraulic radius of channel, and S = water surface slope (Chow 1959). It should be noted that in the Gordon, channel widths are much greater than bankfull depths, so that R approximates to depth. The equation implies a trade-off between increasing depth and decreasing water slope during rising limbs of discharge events in constrained channels like the middle Gordon. The exact pattern of shear stress forces on various bed elements is however, influenced by local site characteristics, particularly channel form, substrate composition and patchiness, and the nature of downstream hydraulic controls at various discharges (Jorde and Bratrich 1998). In addition, it is the nature of the hydraulic and shear stress environment at the spatial scale of individual bed elements that is a significant determinant of community composition and patchiness of benthic macroinvertebrates (Statzner 1981, Statzner and Higler 1986).

High shear stress is associated with faunal displacement (Perry and Perry 1986, Lauters *et al.* 1996) and eventually, bed movement. Large fluctuations in shear stress have been reported downstream of hydroelectric power stations (Gore *et al.* 1994), and it was considered important to assess shear stresses associated with power station 'pulses' in the middle Gordon.

A large data set was therefore collected in the Gordon and Franklin Rivers, in order to explore the relationship between shear stress, bed velocity, water column velocity, depth and substrate type. Shear stress was measured using the technique described by Statzner and Muller (1989), by placing 'FST' ("Fischstammtisch") hemispheres on levelled plates on the stream bed and assessing the maximum density of hemispheres moved by the flow at that location. Data on near-bed water velocity, mean water-column velocity, depth and substrate type was also collected from each location. Collection of these data required diving (see frontispiece illustration). Water surface slope was also measured at a selection of sites. Regressions between these variables were then evaluated in order to assess the variables most related to shear stress.

The 'FST' technique has been debated in the literature (Frutiger and Schib 1993, Statzner 1993), but is believed to provide valid comparative measures of shear stress under certain conditions. It measures the force applied to individual substrate elements within the near-bed hydraulic environment, provided the hemispheres are of appropriate scale and placed within the correct position in the bed profile. We used this technique to assess broad relationships between macroinvertebrate densities, water velocity, depth and shear stress, and to evaluate temporal changes in shear stress at fixed locations in the river during fluctuations in river height associated with power station operations.

A key issue was whether bed shear stress rose and fell uniformly with rising and falling water levels during a discharge peak associated with power station operations. Two major flow phases may potentially occur during the rising and falling limbs of discharge peaks:

- a phase of 'chaotic' flow during which there is considerable localised turbulence associated with individual bed elements (cobble and boulders); and
- a phase of 'skimming' flow in which there is a less turbulent layer associated with the bed overlain by more uniform flow conditions.

These two flow environments were described by Davis and Barmuta (1989), and typically occur when depths are approximately less than and more than three times the magnitude of the major bed elements, respectively.

We hypothesised that these two phases may have distinctly different shear stress conditions associated with them in the middle Gordon. We were therefore concerned that changes in the relative duration of these phases during peaking pulses, for example associated with ramping of power station discharge (see report section 5), may lead to prolonged periods of higher shear stress. This may in turn affect the degree of impact experienced by the bed fauna during pulses.

We planned to measure shear stress, bed and mean water column velocity and substrate composition at selected IFIM transect sites in the middle Gordon during rising and falling river levels associated with stepload 'pulses' (on-off power station sequences deemed characteristic of Basslink operations). However, large current speeds (> 2 m/s) and depths (> 3 m) made this impractical and dangerous. We therefore examined shear stress during stepload pulses in a smaller river system with similar general channel characteristics to the middle Gordon – the King River downstream of the John Butters power station, upstream of the Queen River junction.

A series of FST, velocity and depth observations were made at 2 – 5 minute intervals during the rising and falling limbs of two separate peaking discharges from the John Butters power station in the King River on 18 and 19 July 2000. It was not possible to make FST observations in mid-channel due to excessive velocities and the need to use diving equipment to make all observations. A series of observations were made successfully near the channel margins in depths ranging up to 1.3 m, and mean water column velocities ranging up to 1.6 m/s.

3 CURRENT STATUS OF INSTREAM ECOSYSTEM

3.1 The flow regime and Hydro infrastructure

Overall, the river has experienced multiple impacts associated with the development and operation of Hydro infrastructure:

1967 – 1974: Construction of the Gordon dam. Construction of the dam was associated with substantial sediment delivery to the middle Gordon River. Although unquantified, the river between the damsite and the Albert River was observed as having substantial quantities of fine sediment deposited over and between natural river bed materials (e.g. Coleman 1978). In addition, residual pools were observed to be polluted with oil, hydraulic fluids and other organic and solid waste. This period was accompanied by low to zero flows in the section immediately downstream of the damsite.

1974 – 1977: Dam filling. This period was characterised by zero flow release from the dam and the power station (still under construction). There was also a greatly reduced input from the Serpentine River. The upper reaches of Section 1 (Figure 1) experienced very low to no flows, other than minor inflows from small tributaries. Residual sediment was observed overlying or infilling the river bed between the damsite and the Denison River (Coleman 1978). Low flows were also associated with excessive growth of filamentous green algae in the reach immediately upstream and downstream of the Denison River junction, and summer water temperatures were enhanced.

1977 – early 1980's: Commencement of power station operations. The Gordon power station commenced discharge in November 1977, with one turbine operating until a second turbine commenced operation in 1979. Flooding of the Gordon impoundment led to development of a highly stratified water column (Steane and Tyler 1978, 1982). Low dissolved oxygen, sulphide – rich waters were occasionally drawn into the power station intake, affecting water quality downstream. Consequently, flows in the middle Gordon were highly regulated, and water quality was modified substantially with low summer temperatures and frequent to occasional release of sulphide-rich water (presumably associated with low dissolved oxygen). Observations in February 1978 (Coleman 1978) indicate minor flushing of fine sediment from several locations in Section 1, and loss of moss and algal growth on the substrate due to re-commencement of flows.

1980's – 2000: Increasing power station discharge regulation. The Gordon power station was fitted with a third turbine during this period (in 1989), and along with increased power demand, this resulted in a highly modified flow regime with an increase in the reversal of the natural seasonal pattern of flows. Water quality probably improved during this period (though unmonitored), as the degree of chemical stratification of the lake declined (Koehnken 2001). It is highly likely that power station releases had a modified temperature regime (with reduced temperature variation and lower summer temperatures), with at least occasional low dissolved oxygen (see Koehnken 2001). Appendix 4 of this report series – Gordon River Fluvial Geomorphology Assessment (Koehnken *et al*., 2001) reports that bank erosion probably commenced during this period, with ongoing effects on bank stability, riparian vegetation and the quality of instream habitats.

The Gordon dam and power station have markedly altered the flow regime of the middle Gordon River (Palmer *et al*., 2001) by:

- reducing peak flows;
- changing the 'seasonality' of flow (the monthly pattern of flows);
- maintaining flows at specific, high levels for longer periods of time;
- causing water levels to rise and drop at rates that are much more rapid than occur under natural conditions (e.g. floods).

Figures 8 to 11 show the flow sequence in the middle Gordon River for 1998 that illustrates the change in flow regime which has occurred under typical current hydroelectric operations for sites 75 and 63 (at the upstream and downstream end of Section 1, Figure 1), and sites 60 and 42 (at the upstream and downstream end of Section 2). There are distinct differences between wet and dry periods, with a reversal of natural responses to rain events overlying changeable, short-term fluctuations. The sequence for February 1998 (at site 75 in Section 1 upstream of the Albert River, Figure 8), shows a simulated natural sequence of flood peaks preceded and followed by low ('base') flows. It also shows the sequence of flows that actually occurred as a result of power station operations, which are frequently high (150 – 220 cumec) but interspersed with rapid increases and decreases of between 50 and 150 cumec over a few hours. In addition, high rainfall periods are associated with low discharges, reversing the natural response.

The pattern during prolonged wet periods, more typical of winter – spring months, is also shown in Figures 8 to 11 (for October in 1998). Power station discharges are well below what would be expected under natural conditions, and the river experiences very low to zero flows at sites 75 and 63, with much of the river bed exposed in the upper reaches of Section 1.

Part of the natural pattern in flows is restored downstream of the Denison River, particularly in the reaches close to the Franklin River junction (Figures 10 and 11). This is largely due to unregulated inflows from the Denison River, as well as other tributaries. Larger flood peaks are observed in these sections following significant rain events. The natural pattern of summer low flows is not restored however, and, although attenuated, falls in river level associated with power station shutdowns are still more rapid than would occur naturally.

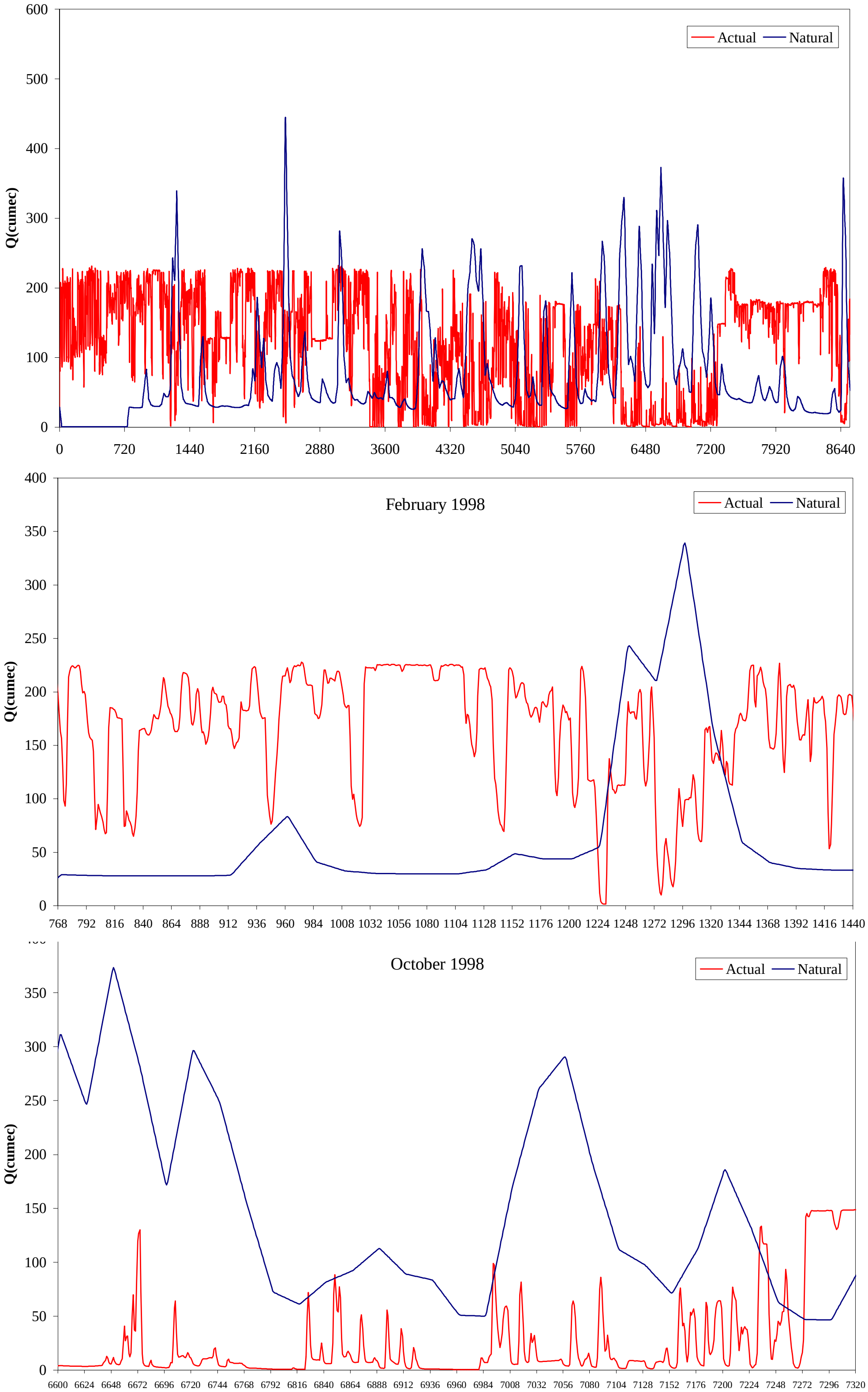


Figure 8. Discharge at site 75 (upstream end of Section 1 of the middle Gordon) for the 1998 example year, under simulated natural and actual (current) conditions with details for February and October.

X axes in hourly time scale, with monthly or daily ticks. Note absence of natural record during January due to lack of data.

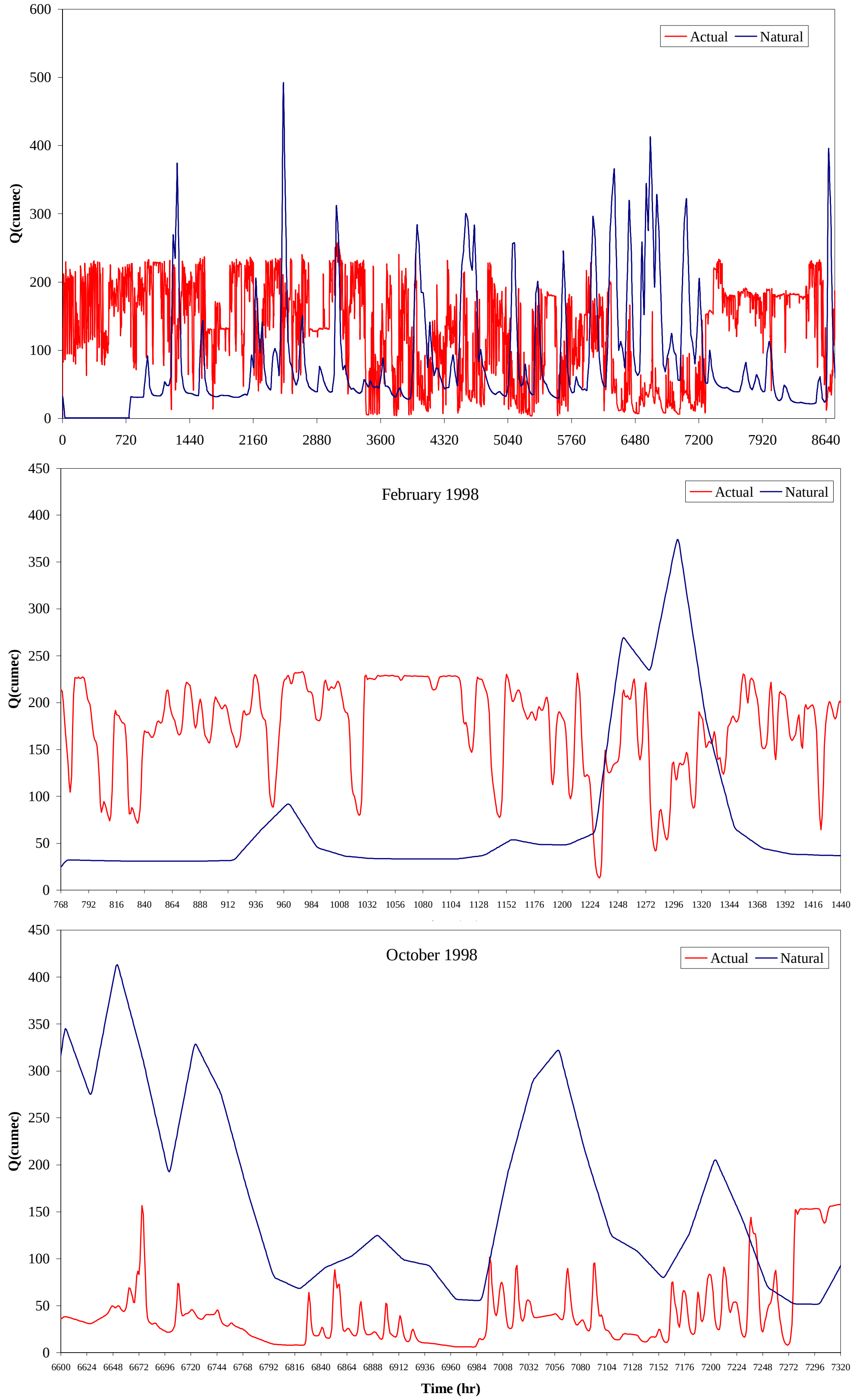


Figure 9. Discharge at site 63 (downstream end of Section 1 of the middle Gordon), for the 1998 year, under simulated natural and actual (current) conditions with details for February and October.

X axes in hourly time scale, with monthly or daily ticks.

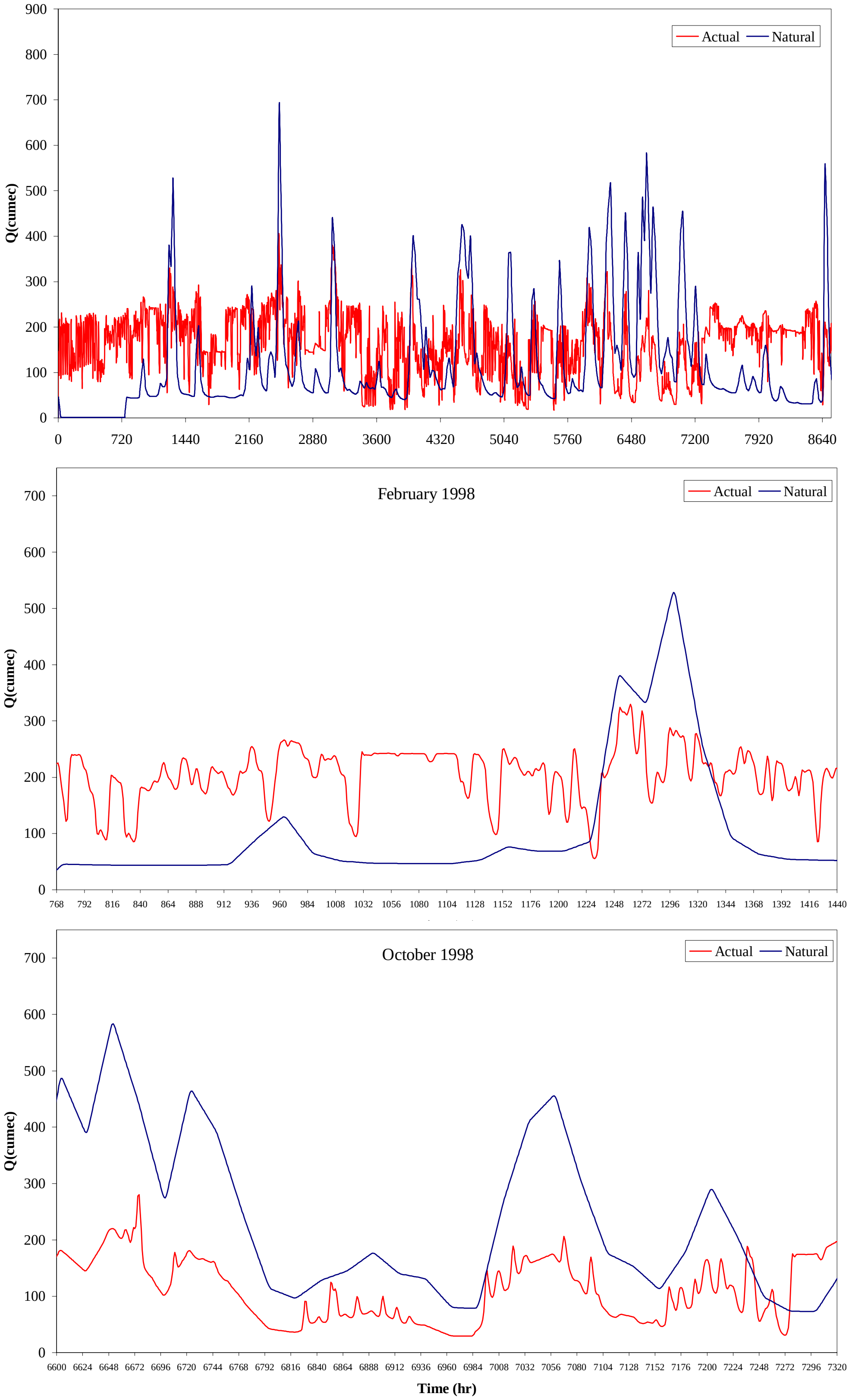


Figure 10. Discharge at site 60 (upstream end of Section 2 of the middle Gordon, downstream of the Denison River), for the 1998 example year, under simulated natural and actual (current) conditions with details for February and October. X axes in hourly time scale, with monthly or daily ticks.

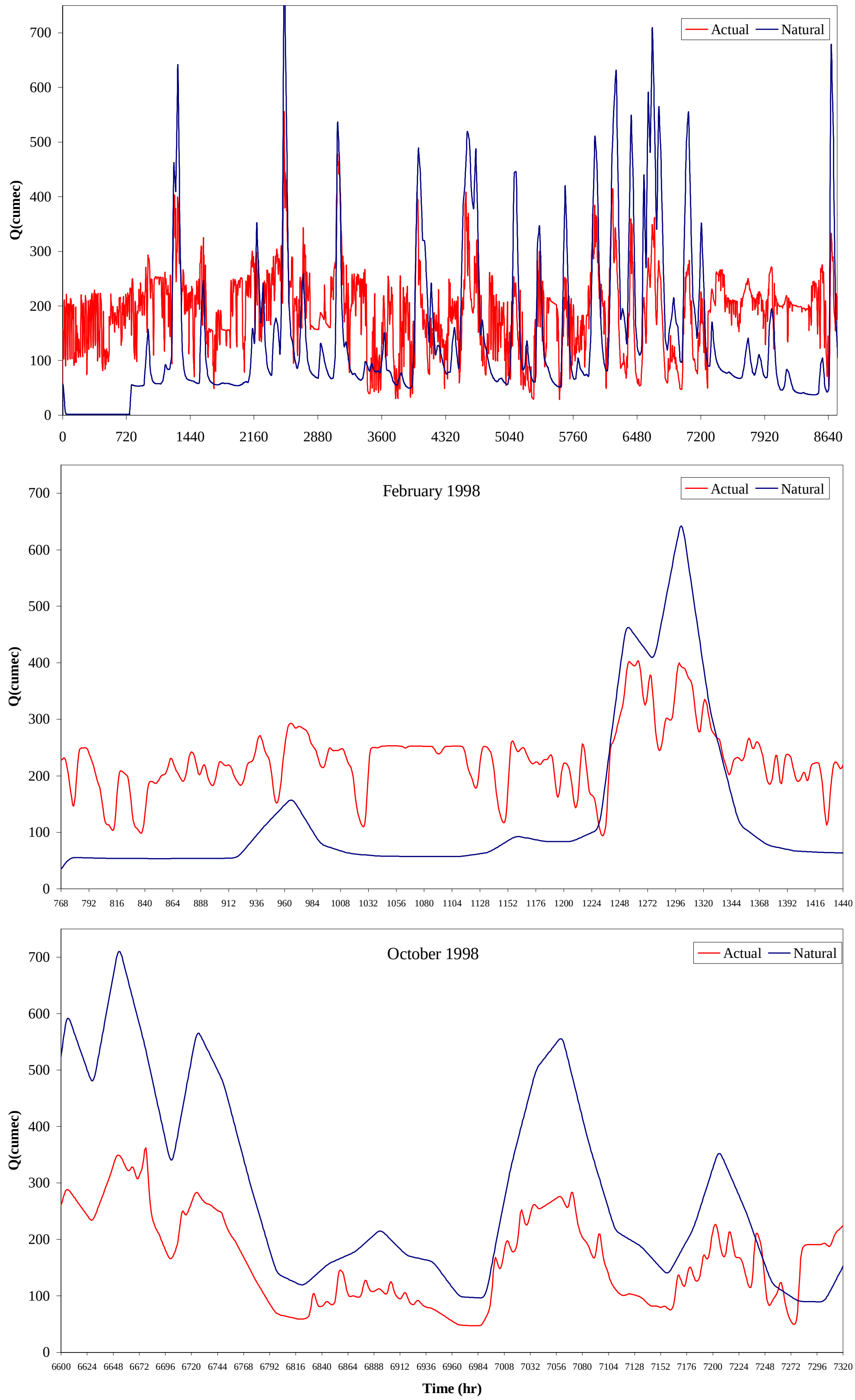


Figure 11. Discharge at site 42 (downstream end of Section 2 of the middle Gordon), for the 1998 example year, under simulated natural and actual (current) conditions with details for February and October.

X axes in hourly time scale, with monthly or daily ticks.

As indicated by Palmer *et al*., (2001), the current flow regime has a strongly reversed seasonal pattern within Section 1 of the middle Gordon, with seasonality being lost in the lower reaches of the river due to the combination of unregulated and regulated flows. This is illustrated for the 1998 example year in Figure 12.

Overall, the current Hydro Tasmania management regime has:

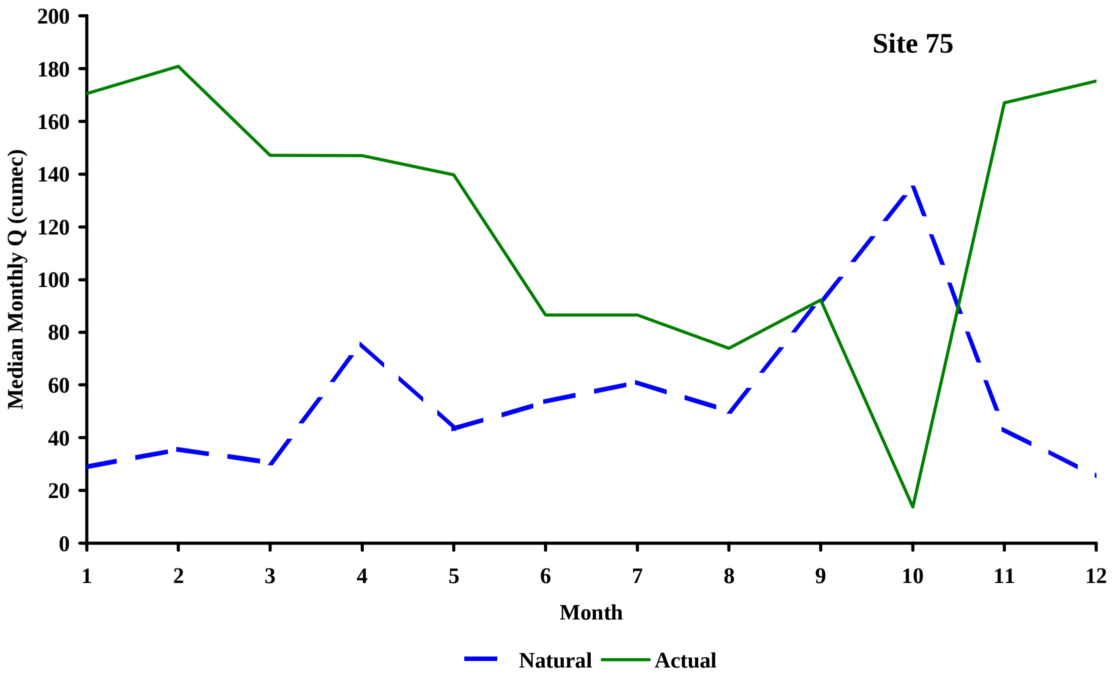
- increased the incidence and duration of high flows of ca 200 cumec (the discharge associated with efficient load operation of three turbines at the Gordon power station);
- created large, short duration changes in discharge, with increases and decreases of the order of 100 - 250 cumec over 1 – 6 hr periods, throughout the river;
- led to the incidence of low to extremely low river flows, of 1 - 6 hr duration during zero power station discharge events, particularly in the section immediately downstream of the power station;
- radically altered the seasonality of flow, illustrated by the pattern of mean monthly flows (Figure 12), with higher summer than winter flows.

Even casual inspection of Figures 8 and 9 reveals a marked increase in the degree and intensity of regulation of flows in Section 1 of the middle Gordon under current conditions. Current hydroelectric operations regulate flows by removing or damping natural responses to rain events, increasing the incidence of flows between 50 and 200 cumec, and inverting seasonal patterns. Thus the upper middle Gordon has become a highly variable flow environment characterised by:

- a complete loss of large natural flood peaks;
- a high incidence of ca 200 cumec discharge from the power station;
- variable flows with rapidly changing river levels between 0 and 225 cumec;
- a frequent occurrence of very low to zero flows as a result of zero power station discharge.

Palmer *et al*., (2001) analysed natural rates of flood rise and recession that occurred in the middle Gordon prior to dam construction. Suitable records exist only for the period 1968 to 1971 at a gauging site above the Olga River junction. They determined that a maximum rate of flood rise of around 22 cumec/hr was found to occur for events that reached between 300 and 400 cumec under natural conditions at that site. Maximum recession rates were estimated as 2 cumec/hr for events below 400 m^3/s and 7 cumec/hr for events between 400 and 600 cumec.

Rates of rise and fall of discharge following commencement and cessation of power station discharge under current operations are much higher. For example at site 75, rates of flow rise recorded in 1998 ranged between 15 and 42 cumec/hr for typical events up to ca 225 cumec. This is up to twice as fast as recorded under natural conditions. At site 75, recession rates following power station shutdowns range between 23 and 48 cumec/hr, 10 to 24 times as fast as natural flow recession rates. Both flow rise and fall rates are therefore greatly enhanced under current conditions, particularly rates of fall.



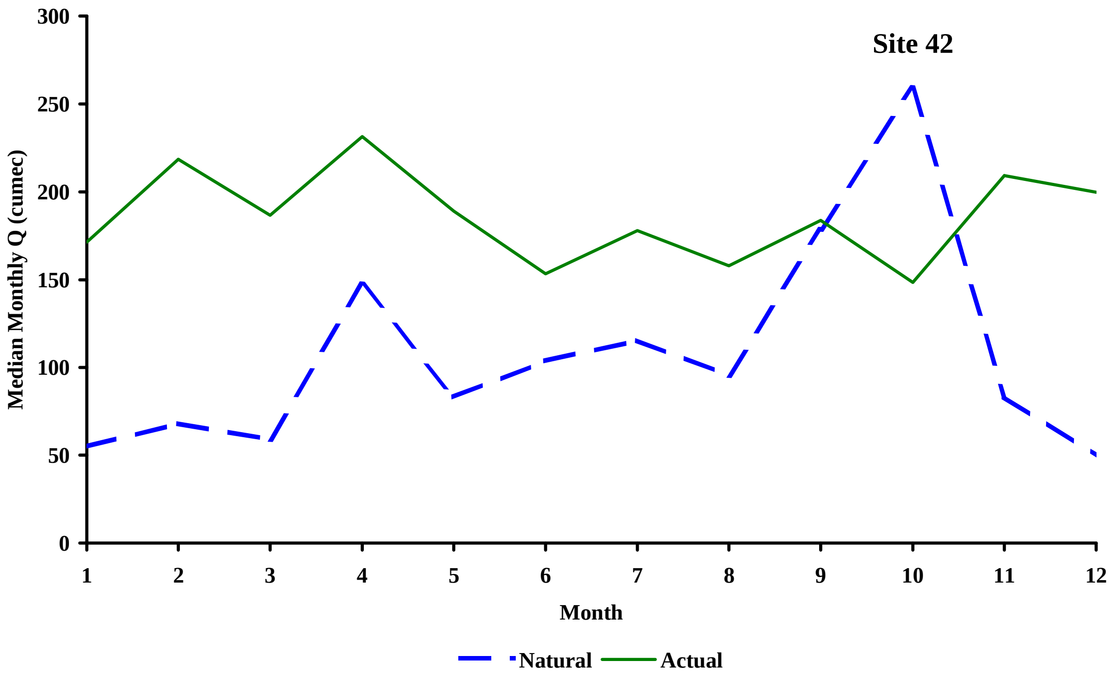


Figure 12. Pattern of monthly median flows at site 75 (2 km downstream of power station), and site 42 (35 km downstream of power station) for current ('actual') and simulated natural conditions for the 1998 example year in the middle Gordon.

Note the major reversal in seasonality at site 75 and the loss of seasonality at site 42 under current conditions.

Section 1 (see Figure 1) therefore has a highly modified flow environment, with few 'natural' characteristics.

Palmer *et al*., (2001) also describe the changes in hydrology due to current hydroelectric operations at various locations downstream from the power station. An example of these changes is shown in Figures 9 to 11 for sites 63, 60 and 42. Again, flows under both natural and current scenarios are shown for 1998. The change in flow regime at site 63 is essentially identical to that shown for site 75, with the exception of minor increases in flows when the power station is off, resulting in minimum flows ranging between 15 and 90 cumec. There is therefore little modification in flow regime between the power station and the Denison River junction. All of Section 1 therefore experiences essentially the same flow regime, which is almost entirely dictated by power station discharges. The inputs from the Albert and Orange Rivers are relatively small, and do not significantly restore natural elements to the hydrology of the middle Gordon.

In Section 2 of the middle Gordon, the flow regimes at site 60, downstream of the Denison River, and site 42, upstream of the Franklin River, are also influenced by inputs from the Denison River and the tributaries. However, it is apparent that Section 2 of the middle Gordon has still experienced a major shift in flow regime (Figures 10 and 11) with a highly variable flow environment characterised by:

- partial to complete loss of large natural flood peaks, with only occasional moderate flood-related peaks, and none > 550 cumec;
- a high incidence of flows in the 200 – ca 270 cumec range, dictated by discharge from the power station;
- periodically highly variable flows with rapidly changing river levels from 15 - 55 to 150 - 250 cumec;
- occurrence of low flows as a result of zero power station discharge, with frequent occurrences of flows in the 20 - 45 cumec range at 60 and 25 - 50 cumec range at 42 (lower than natural base flows);
- significantly lower undisturbed 'base flows' i.e. minimum flows.

An example of the decrease in minimum flows is shown for site 42 during 1998 (Figure 11), in which natural summer baseflows are estimated at between 40 and 60 cumec. Under current conditions, minimum flows are around 30 - 40 cumec.

During wetter periods (e.g. October 1998), when power station discharges decline significantly and/or cease, a pattern of natural flood peaks can be observed at sites 60 and 42 (Figures 10 and 11). These are significantly smaller than would naturally occur however, and are accompanied by very low base- or minimum flows.

Recordings of rates of level rise and fall made in March 2000 at a number of sites downstream of the power station show some attenuation of changes in rates downstream. Both rates of rise and fall associated with power station operations are still much higher than was found for natural flood events however, even as far downstream as the Franklin River junction (Table 5).

Table 5. Maximum rates of river level rise and fall (m/hr) in the middle Gordon recorded in March 2000, compared with maximum rates reported for natural floods at the Gordon above Olga gauging station in 1968-71.

		Maximum rate (m/hr)						
	Site:	**75**	**72**	**69**	**64**	**62**	**u/s Olga R**	**42**
Drawdown (from efficient load)	Current	2.640	1.440	1.280	0.800	0.800		0.400
	Natural						0.013	
Flow rise to efficient load	Current	4.560	5.480	4.240	5.480	3.120		2.880
	Natural						0.150	

Section 2 of the middle Gordon therefore also experiences a highly modified flow regime, with few 'natural' characteristics.

Since the 1970's, the flow regime of the middle Gordon River has been changed markedly compared to natural conditions. The middle Gordon has a highly variable flow regime with tightly constrained high flows interceded by short and deep cycling of river levels, coupled with a loss of large, natural flood peaks. The highly modified flow regime only partially recovers aspects of its former natural hydrology as it approaches the Franklin River.

The biological implications of these changes are discussed in the following section.

3.2 Habitats of the Middle Gordon

3.2.1 Habitat types

Instream habitats of the middle Gordon are dominated by long runs, interspersed with short 'shingle' bars or bedrock rapids. Runs and pools predominate in the lower middle Gordon downstream of the Denison River, particularly downstream of the Olga River junction. These are characterised by long reaches of open water, unbroken even at low flow, with snags (woody material) lining the banks, sand deposits lateral to the channel, and a predominantly fairly uniform cobble-boulder substrate. Shingle bars are generally comprised of extensive beds of cobbles and small boulders overlaying (and in some cases armouring) a mixture of cobbles, gravel and sand. Bands or bars of limestone form a diverse range of short rapids in Section 2 of the middle Gordon and include shelves, slots, multiple weirs and points.

Boulder and slab rapids are frequent upstream of the Denison River, especially in association with the major gorge features such as the Splits and Albert Gorges. These gorges act as controls for hydraulic river levels at high flows. Very high water velocities occur within them during full-gate and efficient-load power station discharges, and they are considered likely to form partial to complete hydraulic barriers to the passage of both fish and platypus under these conditions, and possibly under lower flows as well.

The channel of the middle Gordon also has a number of lateral side channels and pools. However, these only constitute a small proportion of the total riverine habitat.

Overall habitat distributions are shown in Table 6.

3.2.2 General observations

Koehnken *et al*., (2001) describes enhanced bank erosion and treefall in Section 1 of the Gordon River and ascribes these to power station operations. These have undoubtedly led to a decline in edge habitat quality for macroinvertebrates, fish and platypus. The habitat values of increased snag supply from treefall to the channel is offset by the occurrence of rapid drawdowns, making these of only limited value as habitat. Overall there has been a reduction in the quality of snag habitat for biota due to Hydro operations, as well as availability of permanently wetted snag habitat for macroinvertebrates and fish (see report section 3.4.1.3.3).

Field observations confirmed a consistent pattern throughout the middle Gordon in which a distinct 'Plimsoll line' occurs at specific elevations in the river channel. This line is characterised by a sharp lower margin to riparian vegetation coupled with exposure of bank materials. It is more distinct in Section 1 than Section 2, presumably due to the greater constraints on high river levels in Section 1. The bank below this line is frequently actively eroding and, in specific reaches, is characterised by sand/silt materials which move downslope during and following large declines in river level (Koehnken *et al*., 2001).

In addition, there is a distinct 'bathtub ring' consisting of a band of filamentous algae growing on hard surfaces (cobble, bedrock or snags) between the high discharge water level and some 1- 3 m below it. This also occurs in the King River downstream of the John Butters power station, a river section which also experiences highly variable ('hydropeaking') flow regimes. The dominant alga in all of these deposits is the chlorophyte *Mougetia* sp. (Family Zygnemataceae, Order Zygnematales). Such filamentous algal bands have been observed elsewhere downstream of hydropeaking power stations (Benenati *et al.* 1998).

Table 6. Main habitat type as percent of total channel area, by river length for the middle Gordon River.

Section	Reach	Length (km)	% pool-run	% bar	% rapids (bedrock/boulder)
1	Power station - Albert R	5.0	71.5	13.1	15.4
	Albert R - Orange R	7.0	57.7	20.4	21.8
	Orange R - Denison R	6.0	78.9	8.8	12.3
2	Denison R - Olga R	7.1	75.9	7.8	16.3
	Olga R - Sprent R	5.1	86.2	12.1	1.7
	Sprent R - Franklin R	5.5	89.1	8.0	3.0

Examples of channel profiles for runs and pools are shown in Figures 13 and 14 at sites 75, downstream of the power station, and 47, downstream of the Olga River. The central range of natural baseflows are shown, along with the typical range of water levels which occur under current conditions. It can be seen that repeated rise and fall of river levels associated with power station discharge sequences leads to repeated wetting and dewatering of an extensive part of the channel profile. The position of the filamentous algal 'ring' is also shown.

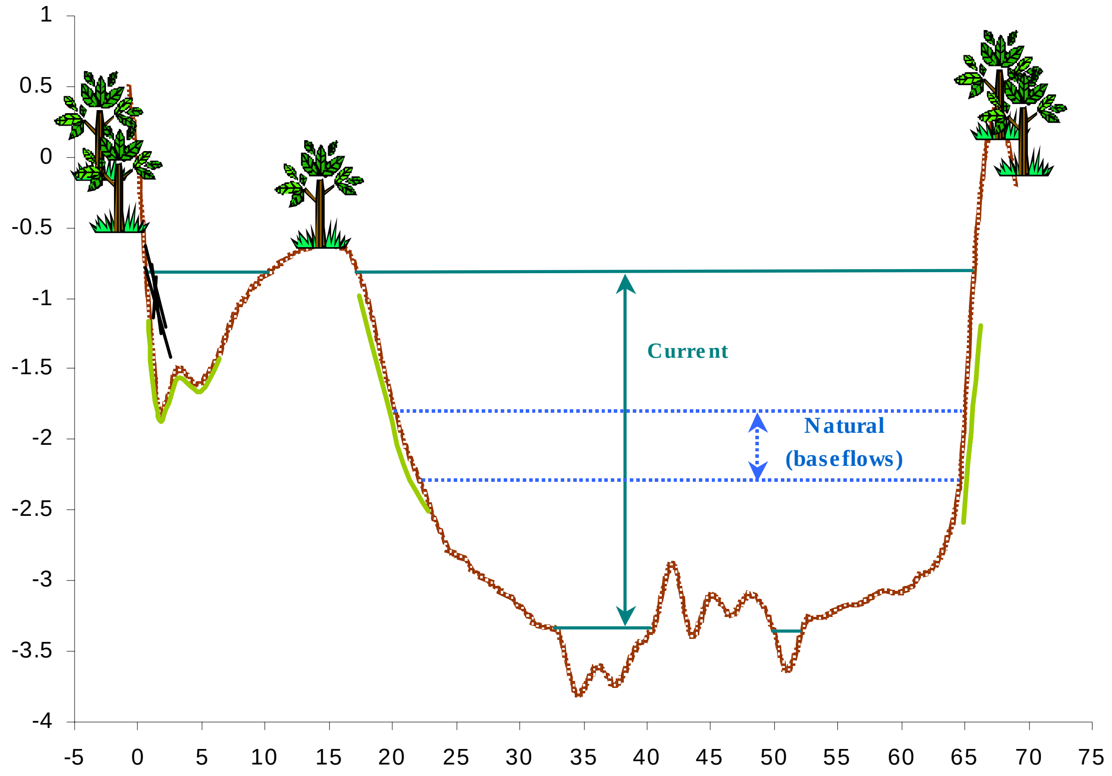


Figure 13. Bar channel profile at site 75 (upstream end of Section 1 of the middle Gordon), showing water levels associated with natural baseflows (dashed blue lines), current power station operations (solid green lines).

Light green lines on the bank indicate the algal 'ring'. Positions of riparian vegetation and snags are also indicated. Scale is in metres relative to a transect datum peg. Note the vertical exaggeration.

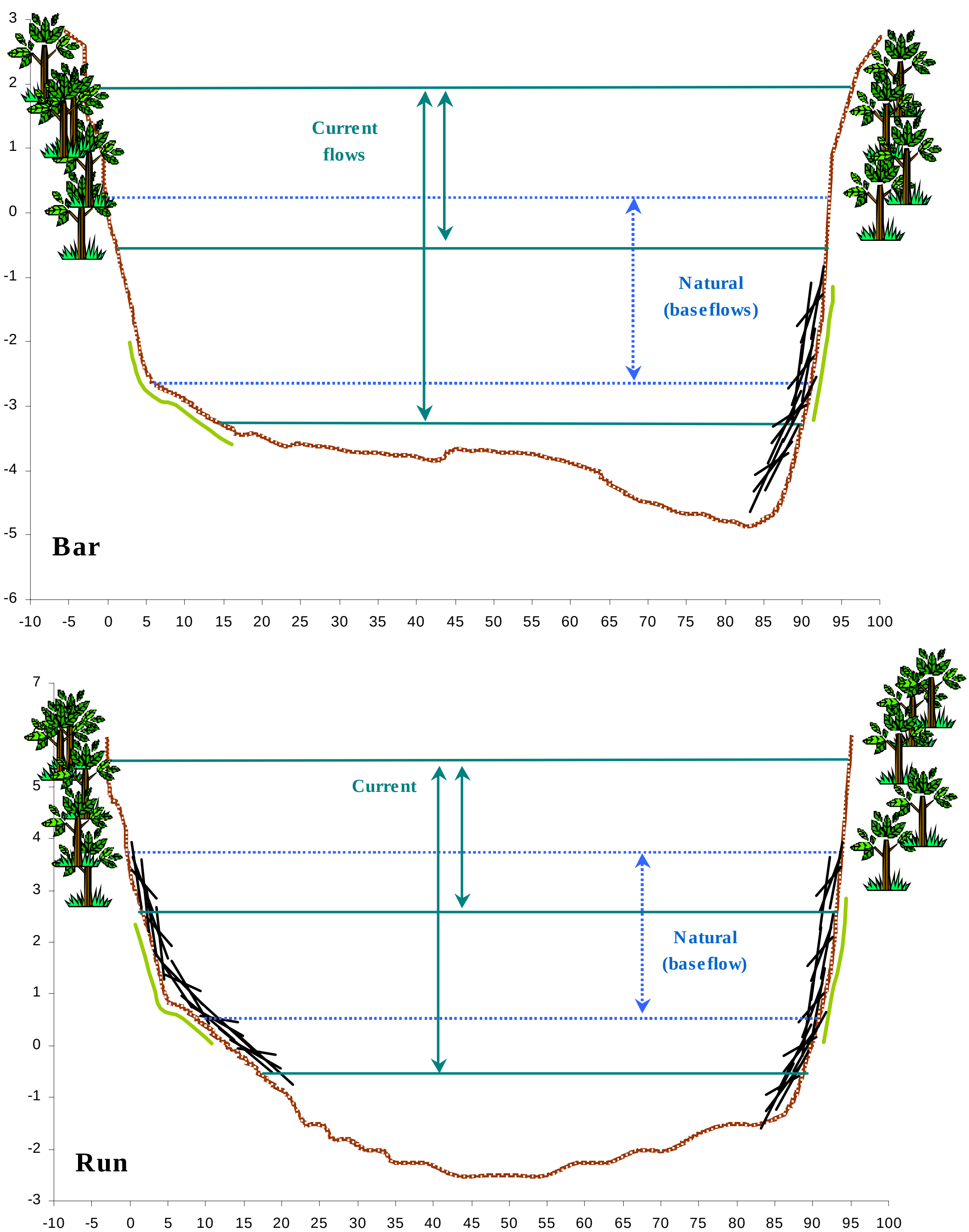


Figure 14. Bar and pool-run channel profiles at site 47 (downstream of Olga River) showing water levels associated with natural baseflows (dashed blue lines), current power station operations (solid green lines, with the upper range in which flows vary most frequently).

Light green lines on the bank indicate the algal 'ring'. Positions of riparian vegetation and snags are also indicated. Scales are in metres relative to a transect datum peg. Note the vertical exaggeration.

3.3 Instream fauna

No faunal sampling or survey work was conducted in the Gordon River prior to the presence of Hydro infrastructure. Sampling of instream aquatic fauna was first conducted by Coleman (1978) in the period following dam closure as part of the HEC Lower Gordon River Scientific Survey. Coleman quantitatively sampled aquatic macroinvertebrates at a range of sites in the Gordon River catchment in 1977 following the construction of the Gordon Dam, and before releases from the power station commenced. He then re-sampled these sites in 1978, three months after the power station commenced discharge with one turbine operating. Thus the survey was of a significantly disturbed middle-lower Gordon (see also Richardson and Swain 1978). In 1995-96, Davies *et al.* (1999) repeated both quantitative and rapid-assessment sampling of macroinvertebrates at Coleman's sites in the Gordon downstream of the power station, and in tributary rivers. Prior to this study, fish sampling had only been conducted in the tidal reaches of the lower Gordon River, both in the main channel (IFS unpublished data) and in small tributary creeks (Davies *et al.* 1996). Details of the fish assessment are provided by Howland *et al.* (2001). No sampling for platypus was conducted during this study.

3.4 Results and Discussion

3.4.1 Macroinvertebrates

3.4.1.1 Overview of Macroinvertebrate Fauna

Coleman (1978) and Davies *et al.* (1999) provide sufficient data to broadly characterise the macroinvertebrate fauna of the Gordon catchment, including the middle Gordon River. It should be noted that the sampling reported by both these authors was conducted along the deepest point of the channel (hereafter the 'thalweg'), due to the presence of low flows during sampling, and only on bar 'riffle' features apparent at low flows. The fauna described by both Coleman and Davies is therefore that residing along the thalweg in bar habitats. No sampling has been conducted of macroinvertebrates in edge or snag habitats in the Gordon, or at positions other than mid-channel. While they are not therefore comprehensive, these data are still able to provide an assessment of the overall condition of the river's macroinvertebrate communities and an evaluation of impacts and downstream trends.

The fauna of the middle Gordon is typified by high abundances of aquatic insects, particularly leptophlebiid mayflies, hydrobiosid caddisflies, and blackfly larvae, as well as of freshwater worms and crustaceans (isopods and amphipods), as shown in Table 7. This faunal community was present during the late 1970's (Coleman 1978), and again in the mid 1990's (Davies *et al.* 1999), and is broadly similar to that observed in other large rivers within the catchment (e.g. the Franklin, Denison, Olga, upper Gordon, Smith, Albert, Maxwell). The general functional aspects of this fauna have not been substantially altered in the lower reaches of Section 2, particularly between the Olga and Franklin River junctions, either following dam construction or as a result of power station operations, although the species composition may well have been altered. The overall community structure, abundance and diversity have been significantly impacted, however, in Section 1 upstream of the Denison River as a result of power station operations, and also appeared to be impacted in Section 2 between the Denison and Sprent Rivers in the 1970's following dam construction.

1977-78

Coleman (1978) observed a marked trend of increasing abundance and diversity from the Gordon Dam downstream. Very low abundances and species richness were observed in the reach between the dam and the Denison River junction (Figure 15) in both 1977 and 1978. This was associated with the impacts of dam construction and a lack of flow during the period immediately before the power station commenced operations (1977 survey), and an absence of significant recovery three months after power station discharges commenced (1978 survey). Coleman attributed these effects to impacts from sedimentation and absence of flow between the dam and the Albert River. Low flows appeared to have stimulated very high abundances of hydrobiid snails in the Gordon both upstream and downstream of the Denison River. These abundances had declined in 1978, which was attributed to removal of dense algal growth by power station discharges.

In both years, total abundance and number of species had returned to levels within the 95% confidence bounds of reference rivers within the catchment (Figure 15). However, taxa indicative of natural flow regimes and good water quality did not recover to reference river abundances until much further downstream in the vicinity of the Sprent River junction, ca 30km downstream of the dam (Figure 15).

1995-2000 – Faunal composition

Davies *et al.* (1999) re-sampled Coleman's sites in 1995-96, eighteen years after the power station commenced operation. Seven 'reference' river sites were sampled in late 1999 in order to characterise the macroinvertebrate fauna from rivers of the unimpacted Gordon catchment i.e. excluding the middle Gordon. These rivers were as follows: the Jane, Maxwell, Denison, Olga, and Albert Rivers (at sites Ja7, Ma7, De7, Ol1 & Ol5, Al0 respectively), the Franklin River at Shingle Island, Blackmans Bend and Flat Island (sites Fr1, Fr11, Fr21), and the upper Gordon River near Gordon bend (site UG10).

Table 7. Summary of macroinvertebrate abundances (n/0.6m^2) from quantitative (WSE) samples from sites in the middle Gordon River and reference river sites in the Gordon catchment in 1995/96. (original sites names from Coleman (1978) and Davies *et al.* 1999 also indicated).

		River :	Middle Gordon				Albert	Smith	Denison	Olga	Franklin	Jane	Maxwell	Serpentine
		Site names (*) :	76,75,73	72,69,63	62,60,58	50,46,44,42	Al0	Sm0	De7	Ol1,5	Fr1,11,21	Ja7	Ma7	Se0
Order	**Class**	**Family**	**G2-4**	**G5-7**	**G8-10**	**G11-15**	**G22**	**G16**	**G21**	**G17,24**	**G18-20**	**J1**	**M1**	**S1**
Platyhelminthes	Turbellaria									0.5				
Nematoda			0.3	1	5	2					0.3	1	2	
Mollusca	Bivalvia	Sphaeriidae				0.2								
	Gastropoda	Hydrobiidae			0.3	1		4		2			25	
Annelida	Oligochaeta		11	87	108	45		10	13	38	170	209	23	10
Arachnida	Hydracarina				0.3	0.4		1		0.5	0.3		1	
Crustacea	Amphipoda	Paramelitidae	3			0.4	1	4					4	2
		Ceinidae	0.3											
		Eusiridae						1		1				
		Corophidae										1		
	Isopoda	Janiridae	3	1	0.3					0.5		1		
	Ostracoda		5											
Insecta	Plecoptera	Eusthenidae			0.3			2		3			3	
		Austroperlidae	0.3	0.3		0.4		3					1	1
		Gripopterygidae	3	10	4	8	2	1	4	12	0.3	3	33	62
		Notonemouridae	2	6	1	5	1	55	1	2	0.3		7	18
	Ephemeroptera	Leptophlebiidae	1	5	11	10	22	23	9	50	15	155	58	11
		Oniscigastridae		2	10	3	12	4	15	9	6	20	8	9
		Baetidae			1	0.4			10			1	5	
		Siphlonuridae			0.3							3		
	Hemiptera	Saldidae							1					
	Mecoptera						1							
Diptera	Chironomidae	Chironomidae	82	20	12	21	33	119	27	20	9	35	18	46
		Simuliidae	2	3	60	64	1		11	10	8	13	6	3
		Tipulidae	1	1	8	8	3	3	4	3	2		2	1
		Athericidae		1	0.3	1				0.5			1	
		Blephariceridae			0.3	0.4				6		1		
		Ceratopogonidae			0.3	0.2				0.5		1		
		Empididae	0.3											
		Tabanidae												
		Unid. pupae	3	0.3	1	0.2		4	3				1	1
	Trichoptera	Calocidae											1	
		Conoesucidae	1	1	0.3	3				6		1	21	
		Ecnomidae	0.3	2	1	2					0.3		8	
		Glossosomatidae											5	
		Helicophidae		1			1	4					1	2
		Helicopsychidae								0.5				
		Hydrobiosidae	2	4	6	1	4	1	1	14	0.3	13	8	7
		Hydropsychidae	3	3	0.3	4	4		3	10	5	1	11	1
		Hydroptilidae								2			2	
		Leptoceridae		0.3	0.3				1	7	0.3	13	11	
		Limnephilidae			0.3	0.2		2						
		Philopotamidae											4	
		Philorheithridae			0.3	0.4		1	1	1			2	
		Plectrotarsidae				0.2				0.5				
		Polycentropodidae						1						
		Unid. pupae	0.3								0.3			
	Coleoptera	Adult Elmidae		0.3	1	2				6	0.7	32	25	
		Adult Heterocidae		1	1	1		1	12	4		9	4	1
		Larval Elmidae		4	7	2	9	2	1	16	2	327	39	6
		Scirtidae		1	1	0.4	1	5	2	4	16	6	4	
		Psephenidae		0.3		0.2		4		2	2		3	1
		Dytiscidae		1				1					1	1
		N Taxa	**20**	**25**	**30**	**31**	**14**	**24**	**18**	**22**	**11**	**21**	**34**	**18**
		Total Abundance	**122**	**155**	**240**	**184**	**95**	**256**	**119**	**225**	**237**	**846**	**348**	**183**

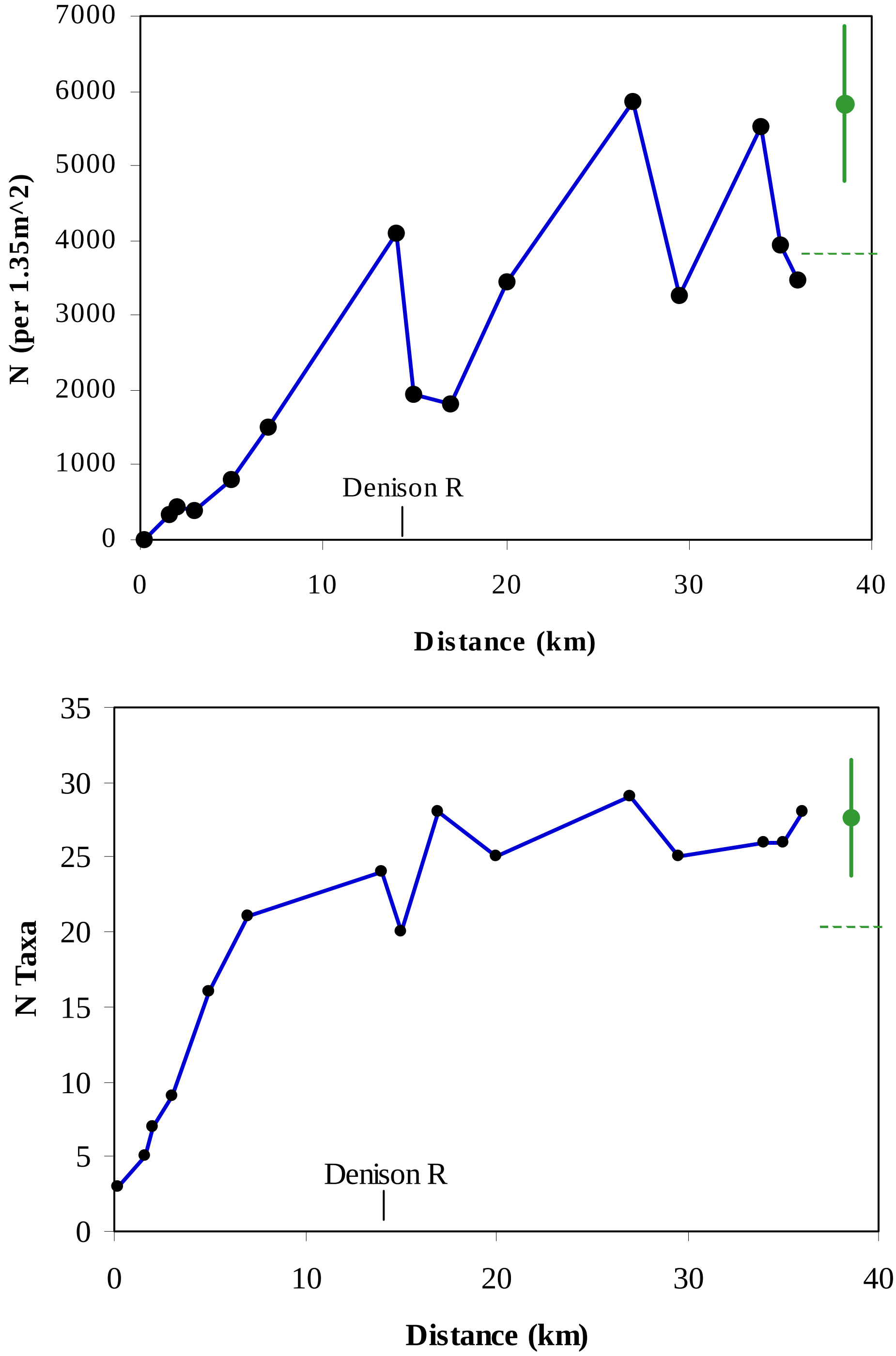


Figure 15. Plots of total macroinvertebrate abundance and diversity (taxon richness) in the middle Gordon against distance downstream of the power station in 1977, as determined from quantitative surber samples.

Green circle, solid and dashed lines indicate mean, standard deviation and 95% confidence limits of variables from reference river sites. Note downstream trends of increasing abundance and diversity. (Raw data from Coleman 1978).

The fauna of these reference river sites (Table 7) was characterised as follows:

- numerical dominance by leptophlebiid mayflies;
- high abundances of blackfly (simuliid) larvae and freshwater worms;
- moderate to low abundances of baetid mayflies, Diptera (true flies) of the families blephariceridae and chironomidae, stoneflies (Plecoptera) of the family gripopterygidae, caddis (Trichoptera) of the family hydrobiosidae and philorheithridae, beetles of the families elmidae, scirtidae, and psephenidae.

Macroinvertebrate sampling conducted across a range of velocities, depths and substrate types at one site in the lower Franklin downstream of Blackmans Bend (to develop habitat preference relationships, report section 2.5.2.6) resulted in a total of 19 mayfly species, indicating high local species diversity.

Davies *et al.* (1999) characterised the reach immediately downstream of the Gordon power station in the middle Gordon as being severely impacted, with loss of 35 to 57% of macroinvertebrate taxa predicted to occur there, and a further 7 – 15% loss of rank abundance categories in the remaining taxa. The macroinvertebrate fauna of the stream bed along the thalweg at bars (‘riffles’ at low flows) in this reach (sites 75 – 76), was characterised by:

- dominance by high abundances of midge larvae (chironomids primarily of the sub-family orthocladiinae);
- high to moderate abundances of hydrobiosid caddis larvae;
- moderate to low abundances of leptophlebiid mayflies, blackflies (simuliidae), stoneflies (Plecoptera) of the families austroperlidae, eusthenidae and gripopterygidae, caddis (Trichoptera) of the family conoesucidae, and freshwater worms (oligochaetae);
- low abundances of janirid isopods (species *Heterias pusilla*).

The middle Gordon between the Albert and Denison River junctions (sites 63 – 72) shows some recovery in biological condition, with an increase in the number of expected macroinvertebrate taxa occurring in bar habitats. It was still, however, classed as significantly impacted by Davies *et al.* (1999). Here, the thalweg bar fauna is characterised by:

- intermittent dominance by leptophlebiid mayflies;
- high abundances of midge (chironomid) larvae, hydrobiosid caddis larvae, stoneflies (Plecoptera) of the family gripopterygidae and freshwater worms;
- moderate to low abundances of blackflies (simuliidae), caddis (Trichoptera) of the family conoesucidae, psephenid beetle larvae.

This fauna is therefore intermediate between that of the severely impacted reach upstream and that of sites in Section 2, downstream of the Denison River.

Sites in Section 2 (sites 42 - 62) between the Denison and the Franklin Rivers were assessed as being equivalent to reference by Davies *et al.* (1999), though he noted that the O/E bioassessment score fell into the lower end of the range anticipated for undisturbed conditions, with losses of 1 – 3 taxa. As noted above, they combined samples from adjacent sites for this reach, which may have increased their O/E values. It should also be noted that this bioassessment is based on semi-quantitative family level data, and that some further degree of impact on community composition in this reach may be detectable at species level. The macroinvertebrate fauna of the stream bed along the thalweg at bars in this reach was typified by:

- intermittent dominance by leptophlebiid mayflies and blackflies (simuliidae);
- high abundances of hydrobiosid caddis and midges (chironomidae);
- moderate to low abundances of baetid mayflies, Diptera (true flies) of the families tipulidae, stoneflies (Plecoptera) of the family gripopterygidae, caddis (Trichoptera) of the family conoesucidae and leptoceridae, beetles of the families elmidae and scirtidae, amphipods (parameletidae) and worms.

1995-2000 – Abundance and diversity

Both total abundance and number of taxa were low at site 76 (Figure 16) immediately downstream of the power station, and there was a trend of increasing total number of taxa and abundance in the first 10 km downstream of the power station in 1995-96. There was no substantial trend or depression in either total abundance or number of taxa of macroinvertebrates downstream of the Denison River junction. The trend in total macroinvertebrate abundance produced using surber-sample derived quantitative data (Figure 16) showed a substantial increase in abundance with distance downstream of the power station. Thus, the abundance of macroinvertebrates is significantly depressed in Section 1 (by 52 – 76% compared with the downstream sites in Section 2), with some minor recovery in a downstream direction. Further recovery in abundance occurs immediately downstream of the Denison River, with an ongoing, increasing trend downstream. Overall, the trend in total macroinvertebrate abundance appears to be almost linear with distance downstream from the Gordon power station.

Trends in combined macroinvertebrate data at least partially mask responses of individual taxa. When the proportions of individual taxa were examined (Figure 17), there was a substantially higher relative abundance of chironomid midge larvae, particularly in the first 5 km downstream of the power station. Simulid (blackfly) relative abundance was significantly depressed between the power station and Denison River junction, then increased in a downstream direction. Leptophlebiid mayflies were absent or very low in abundance in the first 5 - 8 km downstream of the power station, then increased in relative abundance over the first 20km downstream. Their relative abundance was variable between the Smith and Franklin Rivers.

As expected, the patterns in the number of taxa (at ‘family’ level) were broadly similar between the RAP WSE and surber-derived quantitative data sets. However, the much larger benthic area sampled by the RAP approach (3 m^2) reduces the potential for noise due to localised, clumped distributions of particular taxa, which may more greatly influence the community compositional data derived using surbers. 10 pooled surber samples are equivalent to 0.9m^2 in sampled benthic area, as opposed to the 3 m^2 sampled by in RAP kick-sampling. We therefore consider the RAP WSE-derived trends shown in Figure 16 to more accurately portray the true pattern in diversity. The number of taxa reached a plateau of ca 15 – 25 from site 69 downstream (ie from 8km downstream of the power station) for all bar one site. When compared with a mean of 16.2 taxa in reference sites (and standard deviation of 4.2), this suggests that there is no substantial influence on diversity downstream of the Denison River junction (Section 2). There may however be shifts in community composition in this section which can only be detected using multivariate analysis and/or predictive (RIVPACS modelling).

Inspection of an ordination plot of middle Gordon catchment sites (Figure 18) revealed that sites 76, 73, 75, 72 and 69 all fell outside the 95% confidence ellipse for Gordon River catchment reference sites, indicating that macroinvertebrate community composition was significantly different to that at sites at both the downstream middle Gordon sites (which mainly fell within the confidence ellipse) and reference sites.

Thus, macroinvertebrate community composition was significantly different from reference composition for some 8 km downstream of the Gordon power station. Also, the remaining downstream Gordon sites fell to one side or close to the boundary of the confidence ellipse, supporting the contention of an overall shift in composition away from the reference condition (see Figure 20) throughout the middle Gordon.

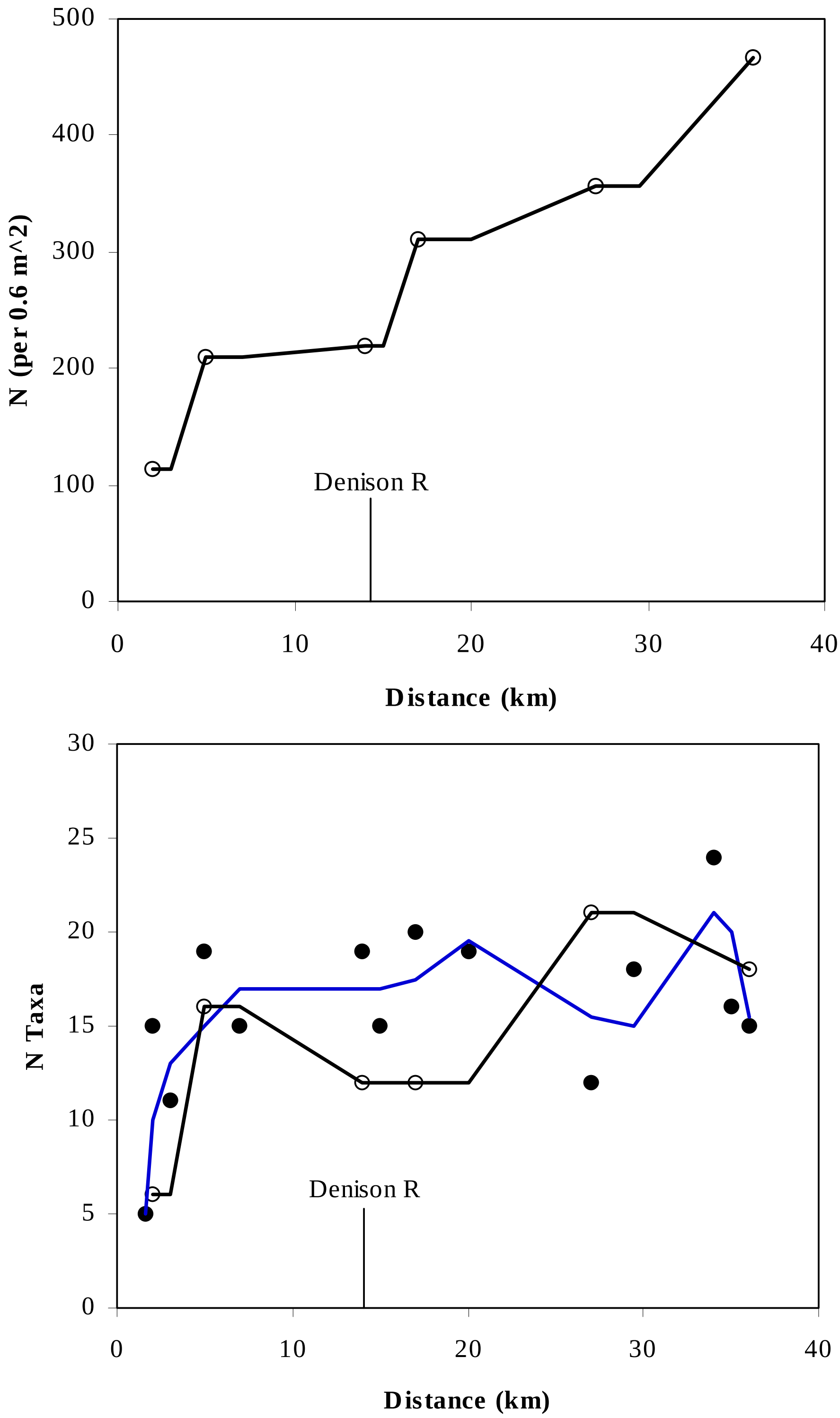


Figure 16. Plots of total macroinvertebrate abundance and diversity (taxon richness) in the middle Gordon against distance downstream of the power station, as determined from quantitative surber samples –(unfilled circles) and kick samples (RAP WSE's – filled circles) collected in spring 1995.

Lines indicate trends (2 point moving averages). Note downstream trend in diversity, and high variability in reference site abundance values.

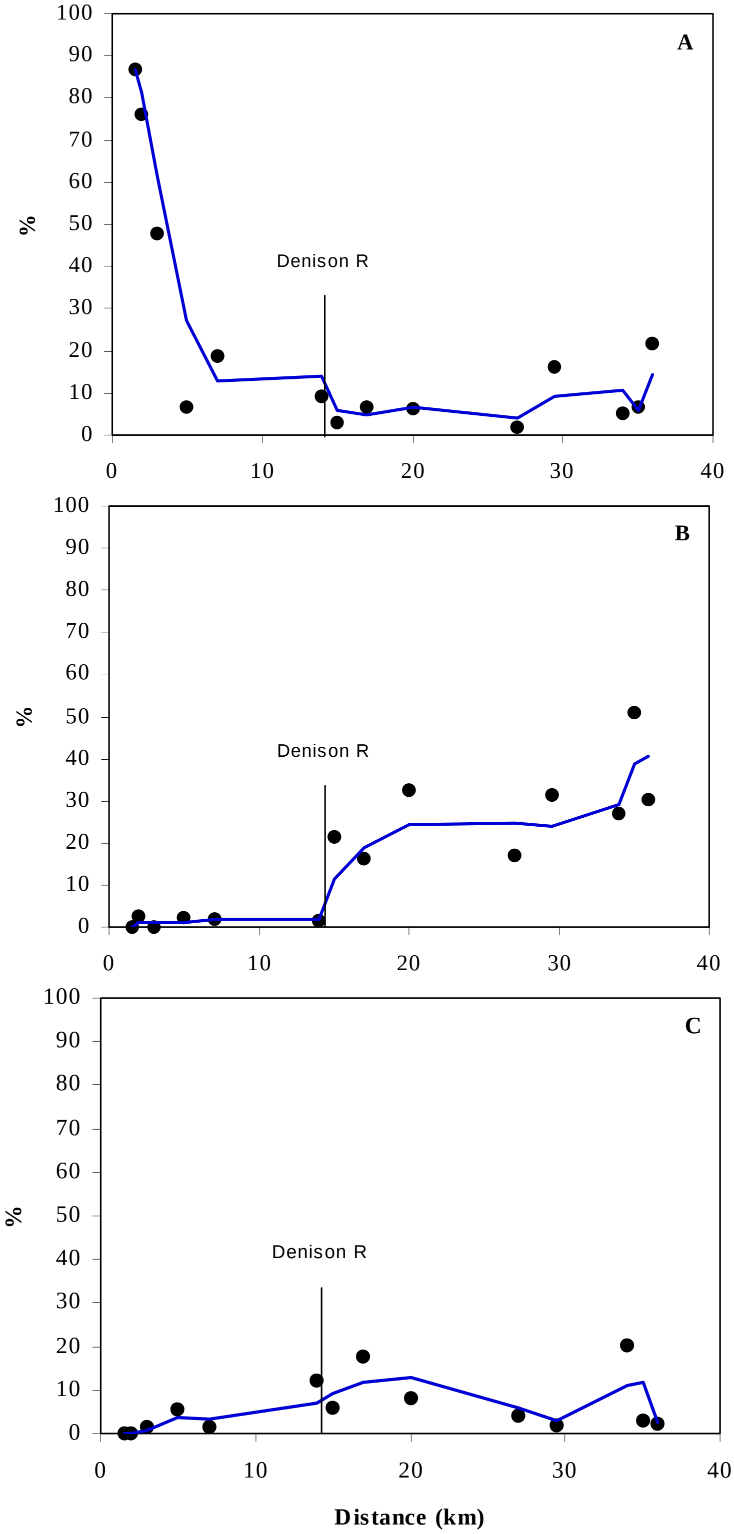
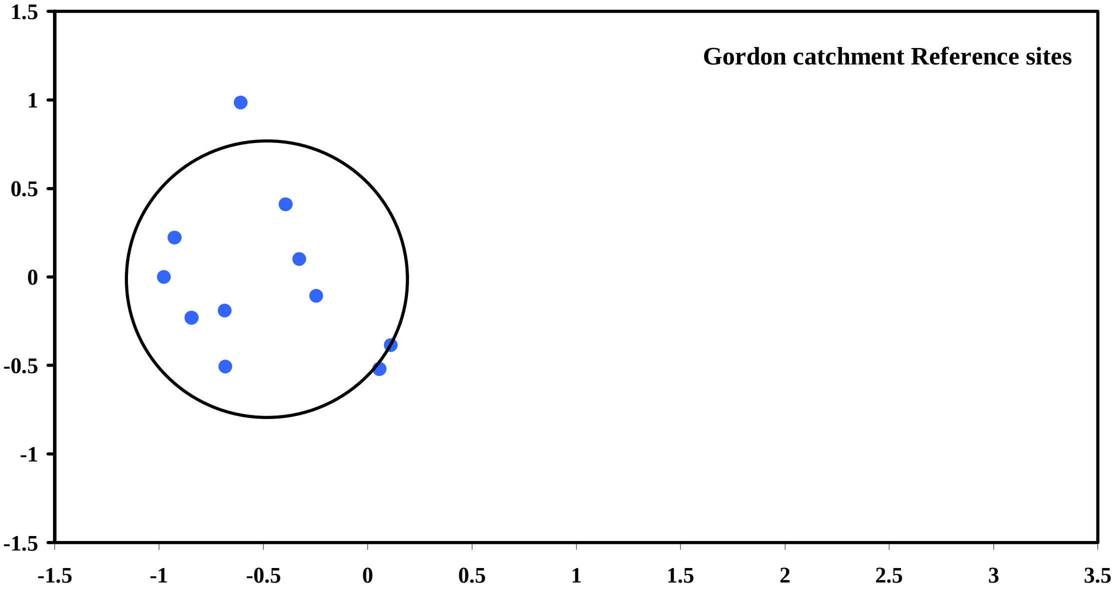


Figure 17. Plots of proportions of chironomidae (A), simuliidae (B) and leptophlebiidae (C) in macroinvertebrate communities of the middle Gordon against distance downstream of the Gordon power station, determined from quantitative RAP (WSE) kick samples collected in spring 1995.

Blue lines indicate trends (2 point moving averages).



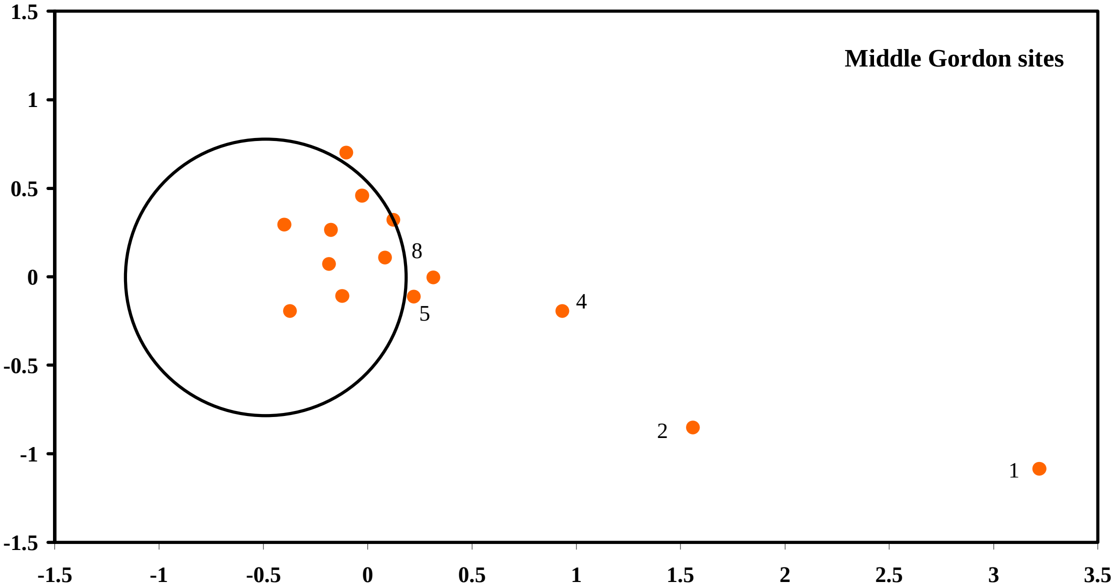


Figure 18. MDS ordination plot of quantitative macroinvertebrate samples from the middle Gordon and Gordon catchment reference sites in spring-summer 1995. Plot has been split into two to highlight middle Gordon site trends.

Numbers indicate distance downstream of power station. Circle is 95% confidence ellipse for reference site ordination scores. Note that Gordon sites 76 (1 km downstream), 75 (2), 73 (4), 72 (5) and 69 (8) all fall outside the ellipse and therefore differ significantly in macroinvertebrate community composition from the majority of the remaining middle Gordon and from reference sites. Note also that approximately 1 in every 20 sites should fall outside the 95% confidence ellipse by chance alone.

1977-78 vs 1995-96

The downstream trend observed by Davies *et al.* (1999) in 1995-96 differed in several key aspects from the trend observed by Coleman (1978). On analysis of Coleman's 1977-78 raw survey data, there is evidence of a strong downstream trend in total abundance, number of taxa and community composition. Total abundance and number of taxa were strongly depressed between sites 78 and 72 in 1977 (Figure 15), with depressions in total abundance at sites 62 and 60. This was accompanied by severe depression or elimination of certain 'clean water' taxa (e.g. leptophlebiid mayflies and simuliid blackfly larvae) at sites 76 - 63, all of which had experienced severe low flows as well as pollution by rock and cement dust, and oil. Site 63 experienced an elevation in abundance which was due to high densities of hydrobiid snails, associated with high benthic algal abundances.

We analysed the two quantitative data sets from 1977-78 and 1995-96 in one MDS ordination, using the WSE data from spring 1995 and Coleman's data from 1977. It is apparent (Figure 19) that community compositional changes at sites in the middle Gordon upstream of the Denison River are quite different between the two surveys i.e. are oriented in two different directions in the ordination. These sites would be expected to fall along the same direction in the ordination if they had similar community compositional differences (and, by inference, similar impacts) to the downstream and reference sites. Community compositional changes at sites 76 - 63 for the 1977-78 survey were consistent with loss of taxa from sediment pollution (e.g. Doeg *et al.* 1987). Changes at the same sites in 1995-96 (arrow B in Figure 19) were significantly different, with loss of flow obligates and facultative taxa at sites 76 to 69, rather than water quality sensitive taxa (see Davies *et al.* 1999).

Davies *et al.* (1999) examined flow and pollution sensitivity indices for the taxa at several sites downstream of Tasmanian power stations, including 76 and 75. They observed that the taxa which were eliminated were predominantly flow 'obligates' rather than sensitive to water quality, and included the families leptophlebiidae, eusthenidae, gripopterygidae, blepheraceridae, conoesucidae, elmidae and simuliidae. They concluded that these changes were common to most sites downstream of power stations which had experienced significant flow regulation, with changes in both seasonality and magnitude and variability of flows at short (daily or hourly) time steps.

There were a number of consistent differences between the 1977-78 and 1995-96 sample sets, which were presumably responsible for the spatial separation of the two sets of survey points in the ordination in Figure 19. Some of these are attributable to differing biases in the sampling methods, due to different mesh sizes and sampling techniques. Hence, although both surveys were conducted with quantitative sampling methods, absolute changes between 1977-78 and 1995-96 cannot at this stage be quantified.

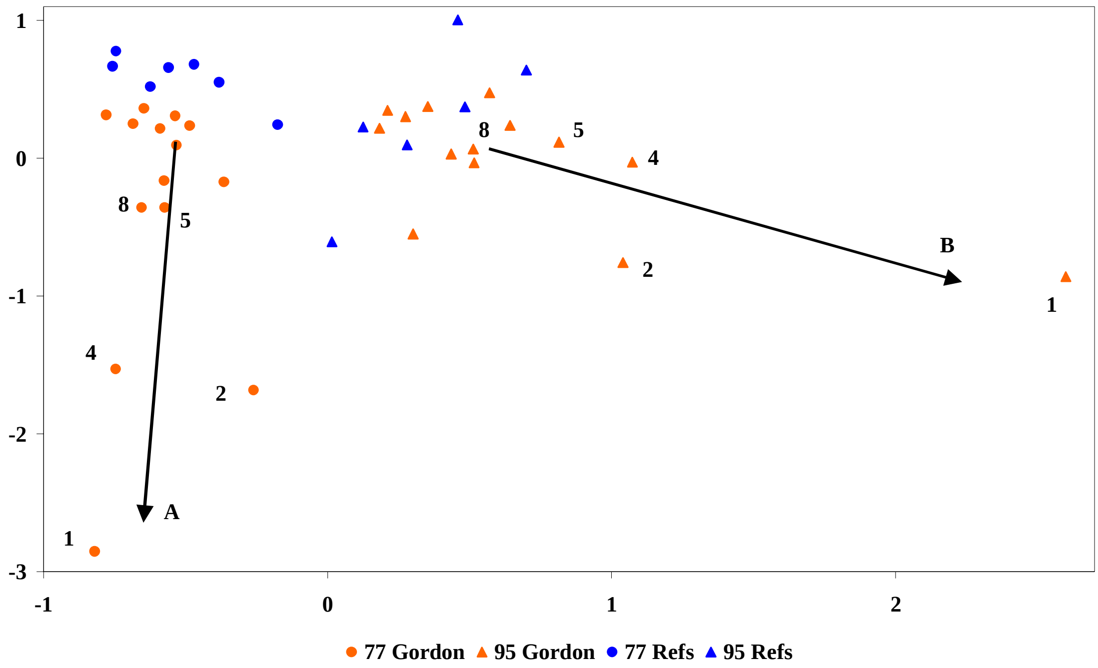


Figure 19. Ordination (MDS) plot of macroinvertebrate samples taken from the middle Gordon River (orange symbols) and reference rivers (blue symbols), in summer 1977 (circles) and spring-summer 1995 (triangles).

Arrows indicate direction of macroinvertebrate community compositional change associated with the impact of dam construction (A) and the existing (‘current’) flow regime (B). Arrows point in direction of trend toward Gordon power station, and numerals indicate distance downstream of power station (km). Samples are quantitative (pooled surbers in 1977, WSE kick samples in 1995).

1995-2000 – RIVPACS bioassessment results

O/E values derived using the 1999/2000 combined-season RAP data, analysed with the RIVPACS bioassessment models developed by Davies *et al.* (1999) are shown in Table 8, along with their respective band assignments.

O/Epa is an index of the extent to which the taxa expected to be at a site are present. For example, an O/Epa of 0.6 indicates that 40% of expected taxa are absent at the site. O/Erk is an index of the extent to which rank abundance categories of macroinvertebrates expected to be at a site are present, and is more sensitive to the impacts of flow disturbance than O/Epa, due to the influence of flow disturbance on both loss of taxa and reduction in abundance of the remaining taxa (Davies *et al.* 1999). The difference between O/Epa and O/Erk is therefore a measure of the reduction in the abundance (measured as number of abundance categories) of the taxa remaining at the site.

One of the limitations of Davies *et al.* (1999)'s assessment of the middle Gordon was their inability to sample sites 62 to 42 in autumn 1996 due to high flows. Thus, data from these sites collected in spring was combined pairwise to produce interim site O/E scores. All sites could be sampled in both seasons in 1999/2000, allowing a more accurate assessment of sites in Section 2. The downstream trends in O/Erk and O/E pa values (O/E values calculated using rank abundance data and presence-absence data, respectively) for the combined spring and autumn season 1999-2000 survey are shown in Table 8, and plotted against distance downstream of the power station in Figure 20.

In 1999/2000, site 76, in the gorge immediately downstream of the tailrace, was severely impacted, and had only 50% of expected taxa (O/Epa, Table 8), and had a further 20% reduction in rank abundance categories of the remaining taxa (O/Erk – 0.41, Table 8). Sites 75 to 69 were all significantly impacted, and had lost between 21 and 50% of their expected taxa, and had experienced a further reduction in rank abundance of the remaining taxa (ie O/E rk was lower than O/E pa). Scores derived for sites 62 to 42 – all sites downstream of the Denison River - were all within the lower section of the reference band, with the single exception of site 46 for which both O/E values were just below the lower bound of band A (Figure 20).

O/Epa values were also generated for the reference sites used to develop the presence-absence RIVPACS models for comparison with middle Gordon values. In 1999/2000, the values of O/Epa were significantly lower for sites in Section 1 than for reference sites ($p = 0.004$, $t = 5.94$, $df = 4$).

Table 8. O/E values for all middle Gordon river sites RAP sampled for macroinvertebrates in 1999/2000.

pa = presence absence data, rk = rank abundance category data. Bands are derived according to Davies *et al.* (1999). Note that a lower O/Erk than O/Epa indicates reduction in rank abundance of remaining taxa.

Site	O/E pa	O/E rk	Band (pa)	Band (rk)
76	0.504	0.407	B	C
75	0.573	0.539	B	B
73	0.787	0.665	B	B
72	0.700	0.600	B	B
69	0.503	0.440	B	C
63	0.799	0.638	A	B
62	0.933	0.954	A	A
60	0.861	0.804	A	A
58	0.777	0.799	B	A
50	0.907	0.949	A	A
48	0.765	0.676	B	B
42	0.955	0.990	A	A

There was a mean of 5.5 fewer taxa in Section 1 than expected under unimpacted (reference) conditions, out of 15 predicted taxa. Thus these data indicate that the residual macroinvertebrate communities along the thalweg of the middle Gordon are significantly to severely impacted between the power station and the Denison River, with substantial loss of biodiversity. Most of the taxa lost from these sites are flow ‘obligates’ or ‘facultatives’ (*sensu* Growns and Davis 1994), and are consistent with the taxa observed by Davies *et al*. (1999) to be eliminated below most Tasmanian hydroelectric power stations.

Sites in Section 2 contain the majority (>75%) of those taxa predicted to occur under unimpacted conditions, but fall within the lower section of the reference, or A band (Figure 20). This implies a loss of between 1 and 3 macroinvertebrate taxa in this section. In 1999/2000, the values of O/Epa were statistically significantly lower for sites in Section 2 than for reference sites ($p = 0.00077$, $t = 3.93$, $df = 6$), despite falling between the A band bounds. There was a mean of 2.4 taxa less in Section 2 than would be expected under unimpacted (reference) conditions. Therefore, sites in Section 2 are also less diverse than would be expected. We propose that this is also due to flow regulation by the power station, as those taxa lost in this Section are generally flow obligates or facultatives, namely larvae of philorheithrid and leptocerid caddisflies, tipulids, and elmid and scirtid beetles.

The pattern of O/E values observed in 1999-2000 was essentially the same as observed in 1995-96, and the conclusions are thus the same. There were only minor differences between the survey results, and O/E values for the same sites and sections were not statistically significantly different (all $p > 0.1$ by t-test).

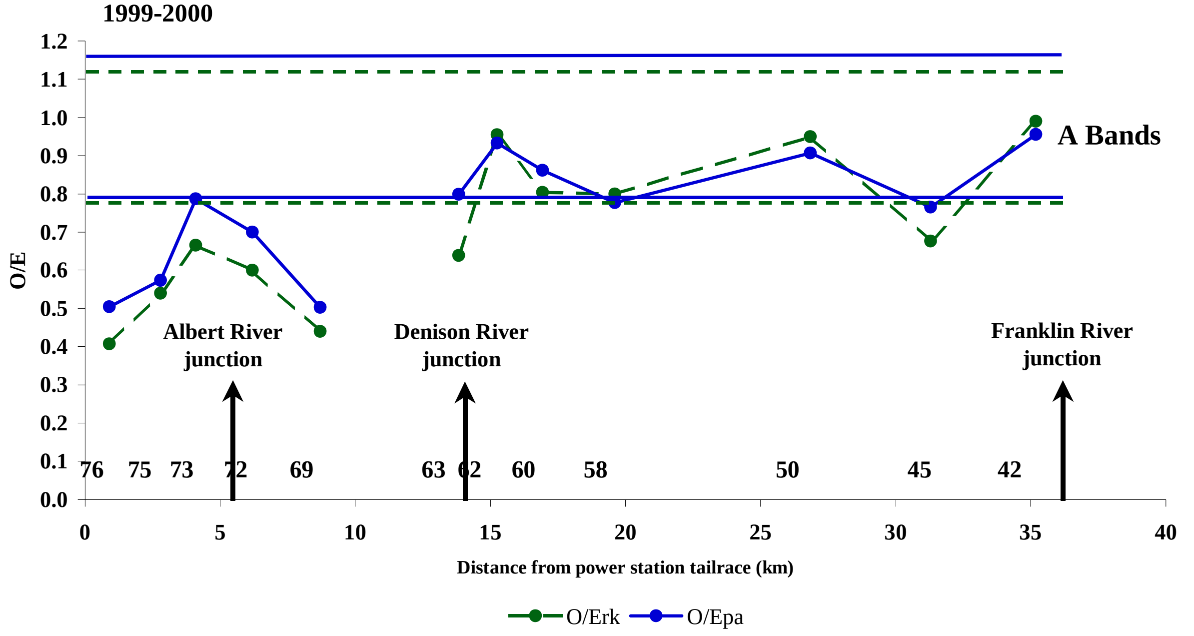


Figure 20. Trends in O/E bioassessment scores in the middle Gordon downstream of the power station tailrace in 1999-2000.

Horizontal lines indicate upper and lower bounds of the A band within which sites are considered to be equivalent to reference (unimpacted) condition. Note where the O/Erk (dashed) line falls below the O/Epa (solid) line, an additional reduction in abundance of expected taxa is occurring. Site numbers are indicated above x-axis.

Crayfish populations

Astacopsis tricornis

The large freshwater crayfish, *Astacopsis tricornis*, occupies riverine habitats in common with fish. It is also likely to be impacted by the same processes as fish and other macroinvertebrate fauna.

Electrofishing is not an effective sampling method for this species. Consequently, standard CPUE determinations cannot be applied with accuracy to this species, and it is not included in the discussions about relative distributions and abundances of fish species (as found in Appendix 8 of this report series – Gordon River Fish Assessment (Howland *et al.* 2001)). Neither was it amenable to capture using standard macroinvertebrate sampling techniques. In this study, *A tricorni*s was captured by a combination of electrofishing, gill netting, bait trapping and visual observation.

A. tricornis was found in all fish sampling areas, both within and outside the Gordon catchment. It was captured in the Davey River catchment, the Henty River and the Birchs Inlet rivers (Sorell and Pocacker), as well as tributaries of the Franklin River. It was also present in both Sections of the Gordon, from the Serpentine River to the Franklin junction, in main channel and tributary stream habitats. It was found in a range of size classes from small juveniles to large adults. Table 9 shows the sites in the Gordon River and tributaries, the Franklin and tributaries and the out-of-catchment rivers in which this species was caught, as well as the numbers captured from each site.

Table 9. Fish sampling sites at which *Astacopsis tricornis* was captured, and the numbers caught at each site.

(See Appendix 8 (Howland *et al.* 2001), Attachment 9.1 for the location of fish sampling sites).

Gordon River Sites	Number captured	**Gordon Tributary Sites**	Number captured	**Franklin River and out-of-catchment Sites**	Number captured
Section 1, Fish Zone 1		*Section 1, Fish Zone 1*		**Franklin River & tribs.**	
G3	1	Serpentine River	1	Wattle Camp Creek	1
Section 1, Fish Zone 2		*Section 1, Fish Zone 2*		Forester Creek	1
G5	2	Mudback Creek	2	Franklin @ Pyramid Island	1
G5a	1	Splits Creek	1	**Birchs Inlet rivers**	
G6	2			Pocacker River	1
Section 2, Fish Zone 3		*Section 2, Fish Zone 3*		Sorell River	1
at Grotto Creek	1	Denison u/s Maxwell River	1	**Davey River catchment**	
G16	1	Smith River	1	Crossing d/s Gorge	1
Section 2, Fish Zone 4		*Section 2, Fish Zone 4*		Hardwood @ Turner Creek	2
at Howards Creek	1	Olga @ Gordon	2	**Henty River**	
at Platypus Creek	1	Platypus Creek	7	Henty u/s Bottle Creek	1
Section 2, Fish Zone 5		Sprent River	1		
G14	1				

Three large adults were found associated with such large, deep pool habitats, one each in zones 1, 2 and 5 (see Howland *et al.* 2001). One was caught in a gill net and the other two were captured after being observed in relatively shallow water on the rocky margins of large pools. A female with attached young was found in zone 1 (the closest to the power station).

Juveniles and sub-adults, were mainly observed in tributary streams (possibly an artefact of inefficient sampling of deep, main-channel pools), were relatively ubiquitous throughout the sampling area, including the tributaries in the upstream zones of the Gordon, indicating successful recruitment in recent years. The ability to move across land possibly aids recruitment and migration from the main channel in this region.

No inference can be drawn on the suitability or otherwise of conditions in the middle Gordon for this species, as there are no data indicating changes in population status associated with Hydro operations.

Burrowing crayfish

Field observations of burrowing crayfish species (*Parastacoides*/*Engaeus* species) were made by in December 1999, and concluded, "… it is clear that (burrowing) crayfish continue to inhabit the cut-off channels, suggesting that the flow regime to date has not seriously affected the channels' quality as crayfish habitat. Provided that the regulated flow regime permits occasional flood events that flush the cut-off channels, it is likely that the crayfish will persist in these habitats" (A. Richardson, pers. comm.).

3.4.1.2 Conservation Status

Six species are listed from the Gordon River catchment under the Threatened Species Protection Act (1995). They are all classified as rare:

- The beddomeid snail *Phrantela richardsoni* (known from a tributary of the Olga River);
- The beddomeid snail *Phrantela umbilicata* (from a creek at Kutikina Cave);
- The stonefly *Neboissoperla sp.* undescribed (from a tributary of Franklin River);
- The calocid caddisfly *Caloca sp.* undescribed. (from the Strathgordon area);
- The hydrobiosid caddisfly *Ethochorema ithyphallicum* (from the Strathgordon area);
- The leptocerid caddisfly *Oecetis umbra* (from the Olga River).

There are no species listed as threatened or endangered within the Gordon catchment, and no species are listed under the Threatened Species Protection Act as occurring in the Gordon River. The torrent midge *Edwardsina tasmaniae* (family Blephariceridae) was described as rare, having been previously found only in the middle Denison River, and was therefore identified as one of a number of key biological values listed during the nomination of the Tasmanian south-west wilderness for World Heritage Area status (Anon 1989). It is not listed however, under the Tasmanian Threatened Species Protection Act. A number of rare or threatened caddisflies (Trichoptera) have recently been described from the Lake Pedder area by Jackson (1999), with these species being uncommon and low in abundance in that area. None of those species have been recorded in the Gordon River area.

A total of 70 taxa were identified from the eight sample sets examined from sites in the middle Gordon (sites 75, 63 and 50) or in ‘reference’ tributary rivers (sites Fr1, Al0, Ma7, Ja7, U58). None of the six taxa listed under the Tasmanian Threatened Species Protection Act were found in these samples. All blephariceridS found in Gordon River catchment samples were *Edwardsina tasmaniae*, which was found at sites in the Olga and Jane Rivers as well as at sites 45 and 58 in Section 2 of the middle Gordon, always at low abundance.

There are eight species of freshwater snail known only from the Gordon catchment additional to the two listed above, occurring in the middle Gordon, Franklin, Denison and Maxwell rivers. They are *Beddomeia franklinensis*, *Beddomeia acheronensis acheronensis*, *Beddomeia acheronensis absona*, *Phrantela bobbrowni*, *Nannocochlea parva* and *Fluvidona sp. 1.714*, *Fluvidona sp.1.717*, *Fluvidona sp. 1.723* (Ponder and Colgan 1992, Ponder *et al.* 1993). These species are not listed under the Threatened Species Protection Act (1995) and appear to be common and widespread in the catchment. *Beddomeia franklinensis* is known from a number of sites in the middle Gordon (Ponder *et al.* 1993), and was also found in this study at site 50, while all three genera were observed in abundance in the Maxwell River (see Table 10 for species data from quantitative kick samples).

Of all the aquatic insects, mayflies (class Ephemeroptera) are known to be highly sensitive to changes in environmental conditions, including water quality and flow regime. Davies *et al.* (1999) found that leptophlebiid mayflies were greatly reduced in abundance downstream of Tasmanian hydroelectric power stations and dams. While the quantitative surber sample data collected in the Franklin River were predominantly used to develop habitat preference curves for habitat modelling, relationships between individual mayfly species abundance and environmental variables were also examined. The numerically dominant mayfly species in the Franklin River surber samples were (in order of descending total abundance) the leptophlebiids *Nousia* sp AV6, *Tilyardophlebia* sp AV2, Genus Z sp AV1, and *Austrophlebioides* spAV10, and the baetids *Centroptilum sp* and Baetid Genus 2 MV sp 3. Analytical results are not reported in detail here but there were four types of habitat preference within this group of species:

Table 10. Macroinvertebrate data from three middle Gordon River and five reference river sites identified to species level for families containing species listed under the Tasmanian Threatened Species Protection Act (1995). Data are from WSE kick-samples collected in spring 1995.

				Middle Gordon			Reference River Sites				
			River:	Gordon	Gordon	Gordon	Gordon	Franklin	Jane	Denison	Maxwell
			Site:	u/s Albert	u/s Denison	d/s Olga	u/s L Gordon	Shingle I.		d/s Maxwell	
Order	**Class**	**Family**	**Species/Genus/Sub-Family**	**G4**	**G7**	**G11**	**G27**	**G18**	**J1**	**D1**	**M1**
Platyhelminthes	Turbellaria				1		1				
Nematoda							5		1		2
Mollusca	Gastropoda	Hydrobiidae	*Beddomeia sp.*			1					5
			Phrantela sp								7
			Fluvidona sp.								13
	Oligochaeta			24	20	64	112	6	203	7	19
Crustacea	Amphipoda	Paramelitidae		10							3
	Isopoda	Phreatoicidae	*Phreatoicoides gracilis*						1		
		Janiridae	*Heterias pusilla*	18							
Insecta	Plecoptera	Eusthenidae	*Eusthenia spectabilis*				1				3
			Eusthenia costalis			1					
		Austroperlidae	*Tasmanoperla thalia*	1							
		Gripopterygidae	*Cardioperla incerta*		1		2			2	6
			Cardioperla media/lobata		5				1		23
			Dinotoperla bassae						1	2	5
			Dinotoperla serricauda							1	
			Trinotoperla zwicki		1				1		4
			Trinotoperla tasmanica							1	
		Notonemouridae	*Austrocercoides sp.*	1		1		1		1	1
	Ephemeroptera	Leptophlebiidae	*Tilyardophlebia sp AV2*	1	2		15	3	1	8	3
			Nousia sp AV6	1	8	4	19	2	165	5	40
			Nousia sp AV7		1	1	2			1	8
			Nousia sp AV8						1	1	20
		Baetidae	*Baetid Genus 2 MV sp 3*			1			2	10	5
	Hemiptera	Saldidae								1	
	Diptera	Chironomidae	Chironominae					1	3	3	
			Orthocladiinae	18	6		5		5	3	13
			Podonominae			3	1	5	26	18	6
		Tanypodinae					3	5	1	3	
		Diamesinae		38							
		Simuliidae			1	23	5	3	13	15	6
		Tipulidae					1			2	1
		Blephericeridae	*Edwardsina tasmaniensis*						1		
		Ceratopogonidae							1		
		Unid. pupae		2						3	1
	Trichoptera	Calocidae	*Tamasia variegata*				9				1
		Conoesucidae	*Conoesucus digitiferus*		1						14
			Conoesucus norelus								1
			Conoesucus nepotulus						1		
			Matasia satana								1
			Costora ramosa								1
			Costora luxata								7
			Hampa patona								1
		Glossosomatidae	*Agapetus sp AV1*								5
		Hydrobiosidae	*Apsilochorema obliquum*						3		1
			Taschorema sp AV4	1	1				11	1	
			Ethochorema nesydrion						1		
			Taschorema asmanum	1					1		
			Taschorema apobamum				1		1		2
			Taschorema sp AV2	2	2						2
			Moruya sp AV2								4
			Taschorema sp AV1								1
			Moruya opora	1							

Table 10 (cont'd).

				Middle Gordon			Reference River Sites				
			River:	Gordon	Gordon	Gordon	Gordon	Franklin	Jane	Denison	Maxwell
			Site:	u/s Albert	u/s Denison	d/s Olga	u/s L Gordon	Shingle I.		d/s Maxwell	
Order	**Class**	**Family**	**Species/Genus/Sub-Family**	**G4**	**G7**	**G11**	**G27**	**G18**	**J1**	**D1**	**M1**
	Trichoptera	Hydropsychidae	*Smicrophylax spAV3*								8
			Asmicridea spAV1								1
		Leptoceridae	*Notalina spAV7*		1		60		13	1	10
			Leptorussa darlingtoni								1
		Philopotamidae	*Hydrobiosella waddama*								4
		Philorheithridae	*Tasmanthrus galbinomaculatus*				3				
			Philorheithrus spAV2								1
	Coleoptera	Elmidae (Adult)			9	2	60		46		40
		Elmidae(Larvae)	*Austrolimnius sp.*		4		94		328	1	31
			Simsonia leai		2				1		10
		Scirtidae							2		2
		Psephenidae	*Sclerocyphon secretus*				2				4
			Ntaxa	**14**	**16**	**11**	**19**	**8**	**28**	**22**	**46**
			Total abundance (n/0.6m^2)	**119**	**65**	**102**	**400**	**26**	**835**	**90**	**347**

- preference for (i.e. higher abundances at) high velocities (> 1.5 m/s) and shallow to moderate (0.5 – 1 m) depths on cobble-boulder substrate, e.g. by *Nousia* sp AV6 and *Austrophlebioides* spAV10;

- preference for low to moderate velocities and deep water (>1.5 m) on sand, gravel or cobble substrate, e.g. by *Tilyardophlebia* sp AV2;

- preference for moderate velocities (0.4 – 1 m/s) and moderate depths (0.5 – 1.0 m) on boulder substrate, e.g. by Baetid Genus 2 MV sp 3;

- preference for moderate to high velocities (0.4 – 1 m/s) and moderate depths (0.5 – 1.0 m) on sand substrate, e.g. by *Centroptilum sp.*

The most abundant mayfly species in thalweg riffle habitat in the middle Gordon and reference sites were *Nousia* sp AV6 and *Tilyardophlebia* sp AV2, with *Nousia* sp AV8 and Baetid Genus 2 MV sp 3 also occurring in reference sites (e.g. see Table 10). All of the mayfly species found in the middle Gordon also occurred in reference river riffle (bar) habitats, as well as in the lower Franklin across a range of habitat conditions.

None of the rare or threatened caddisflies listed under the Threatened Species Protection Act (1995), or by Jackson (1999) were found in the collections of larval material made during our surveys. Attempts to organise light-trap surveys of the middle Gordon were unsuccessful, and we would recommend the conduct of such a survey.

We conclude that there are no significant threatened macroinvertebrate species issues evident in the middle Gordon associated with hydroelectric development that would trigger actions under the Tasmanian Threatened Species Protection Act (1995). The macroinvertebrate fauna of the middle Gordon is broadly similar to that of other rivers in the catchment. It has been significantly modified in the reach upstream of the Denison River by the effects of the Gordon dam and power station over the past 26 years, and the principal threat to the conservation status of the macroinvertebrate fauna has been the modification to the flow regime as a result of current Hydro operations.

3.4.1.3 Impacts of current Hydro operations

Impacts from the altered flow regime under current conditions include:

- periodic dewatering and exposure of river bed on bars and the lower margins of banks resulting in loss of substantial areas of habitat;
- major reductions in quality and/or loss of edge and snag habitats through dewatering and/or bank erosion;
- rapid fluctuations in water velocity and depth.

Bank erosion has lead to ongoing instability and localised movement of sand-silt materials on the lower slopes of river banks in many areas (Koehnken *et al*., 2001) of Section 1. This decline in stability and loss of soft edge habitats is associated with loss of an edge fauna with a species composition distinct from those present on the substrates of the main channel.

Some degree of localised infilling of bed or bar cobble-boulder substrate with sands appears to have occurred as a result of bank erosion, although it is difficult to quantify its extent (Koehnken pers. comm.). Such infilling results in a loss of interstitial habitat which may result in additional reductions in abundance and diversity.

3.4.1.3.1 Habitat-flow relationships

A key aspect of our assessment of risks associated with changes in the flow regime on instream fauna is the relationship between habitat and discharge. We used weighted useable area (WUA), derived from transect-based habitat data, combined with data on habitat preference for the key biological variables to evaluate these relationships. The habitat preference data we used is presented graphically in Attachment 2. The plots of weighted useable area of habitat (WUA) against discharge (Q), derived from the middle Gordon transect and Franklin River habitat preference data, are shown in Figures 21 to 26 for all key macroinvertebrate taxa in bar and pool-run habitats in the three study reaches 03, 1215 and 2940.

For bar habitats, the majority of taxa have peaks in WUA at low to moderate flows – 10-20 cumec in reach 03, 15-40 cumec in reach 1215, and 10-75 cumec in reach 2940. At high flows (100-250 cumec), the majority (7 out of 9) of the key macroinvertebrate variables show a decrease or plateau in WUA values, generally due to the counteracting combination of increasing area of wetted channel and the decreasing suitability of habitat along the thalweg as velocities rise. Orthoclad midges are the only taxon to consistently increase in WUA at high flows across all site bar habitats. Only two other taxa show an increase in WUA at high flows on bars - hydrobiids in reach 03 and chironominae in reach 2940, respectively.

For pool-run habitats, the majority of taxa have peaks in WUA at low to moderate flows (< 75 cumec) in reaches 03 and 1215, and then show a decline or plateau in WUA at flows > 100 cumec. In reach 2940, four taxa peak in WUA at flows < 25 cumec, and the majority increase in WUA to a plateau above ca 100 cumec. Hydrobiosid caddis and leptophlebiid mayflies are the two taxa which show marked declines in WUA as flows increase above ca 75 cumec in pool run habitats.

There are some differences between bar and run habitats in responses of macroinvertebrate habitat availability to changing discharge. For bar habitats, there is a distinct peak in WUA for many macroinvertebrate taxa as upper bar slopes become inundated. For pool-runs, WUA values do not generally decrease at very low flows (< 5 - 10 cumec), as there is still substantial wetted area remaining when discharge approaches zero.

Overall, the taxa showing the most sensitive responses in WUA to changes in flow are hydrobiosid caddis, leptophlebiid mayflies and simuliids (blackflies). WUA values for maximal macroinvertebrate abundance and taxon richness (‘T Abund’ and ‘N Taxa’ in Figures 21 to 26) show the same response in all habitats and sites, with a peak at low to moderate flows, and plateauing at lower levels as flows exceed 100 cumec, with the exception of pool-runs in reach 2940.

The WUA-Q curves derived here indicate a general trend for most of the key macroinvertebrate taxa with :

- declining habitat availability at very low flows (typically less than 10-20 cumec) for most taxa in bar habitats;
- peaks in habitat availability at low to moderate flows in both habitats;
- decreases or plateaux in habitat availability at high flows (typically greater than 100 cumec).

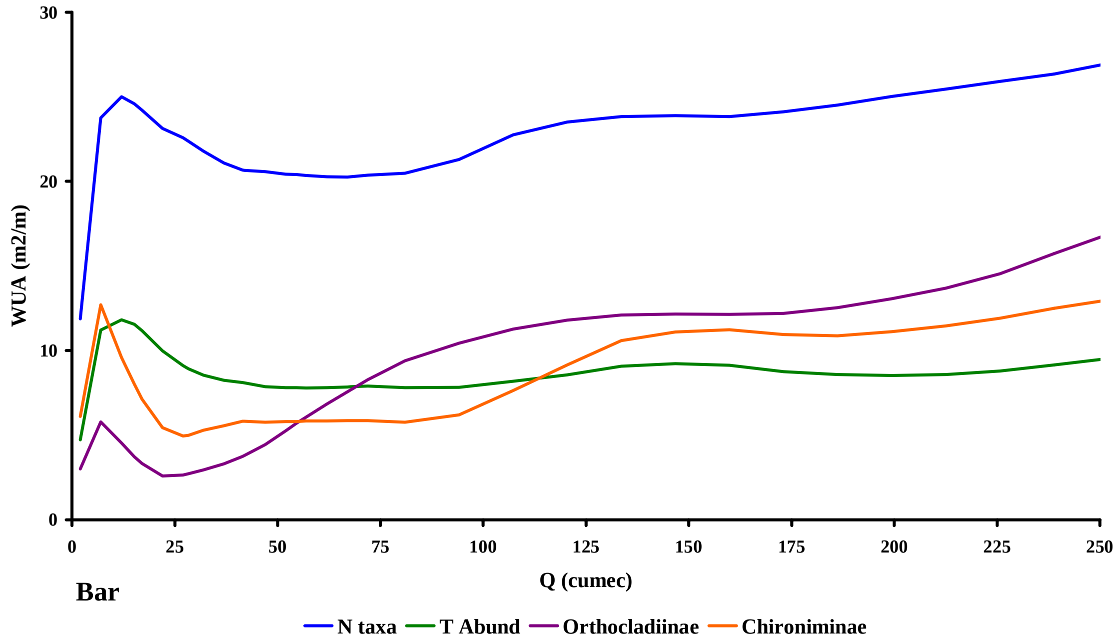
Thus, both sustained discharge of the power station under efficient load or full gate, and pulsing of discharge between very low and high values results in both chronic or acute declines in habitat suitability for much of the biota in all reaches. Again, it should be noted that increases in wetted area of stream bed are not synonymous with increases in habitat availability for aquatic biota, as wetted area rises monotonically with discharge at all sites (Figure 27).

While more frequent, high discharge events (ca 200-250 cumec) result in a greater wetted area of the channel, large declines in power station discharge result in substantial declines in wetted area (Figure 28). When compared with natural baseflows, these dewatering events result in complete loss (through repeated exposure) of the biological value of:

- between 35 and 50% of benthic habitat, accompanied by almost complete loss (90%) of permanently wetted snag habitat, in Section 1; and
- between 10 and 20% of benthic habitat, accompanied by loss of 75% of permanently wetted snag habitat, in Section 2.

Rapid declines in water level can resulting in stranding of macroinvertebrates (see following report section). In addition, exposure, drying and subsequent sloughing of phytobenthic biofilms occurs. Macroinvertebrates may fail to substantially re-colonise re-wetted substrate due to the inability of the biofilm to re-establish between periods of dewatering.

Time scales for macroinvertebrate communities to re-colonise previously dewatered stream beds are substantial. Blinn *et al.* (1995) reported > 85% reduction in macroinvertebrate biomass following one 12 hour exposure due to water level fluctuations downstream of the Glen Canyon Dam. Macroinvertebrate recolonisation was very slow, with abundance < 30% of controls after three months. They also reported reductions in benthic algal biomass on river cobbles to < 50% following only two days exposure. They concluded that two 12 hour periods of bed exposure required at least four months of inundation for full recolonisation to levels equal to permanently submerged benthos. Gersich and Brusven (1981) found that at least 47 days were required to establish control aquatic insect densities on river cobbles that had been exposed downstream of a hydropeaking station.



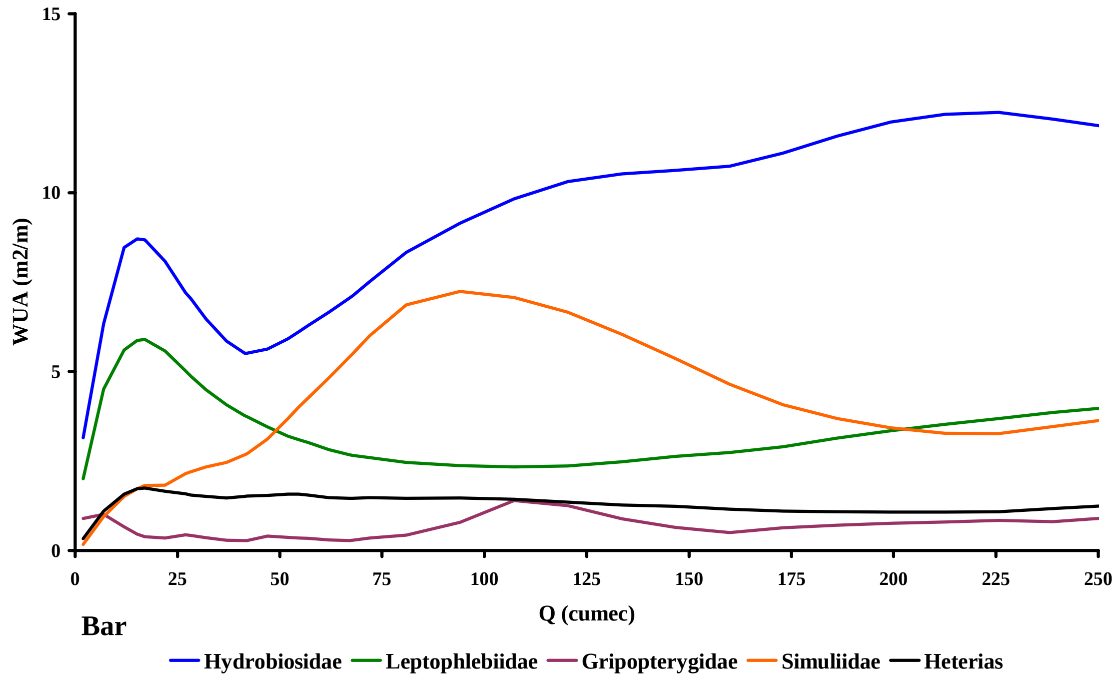
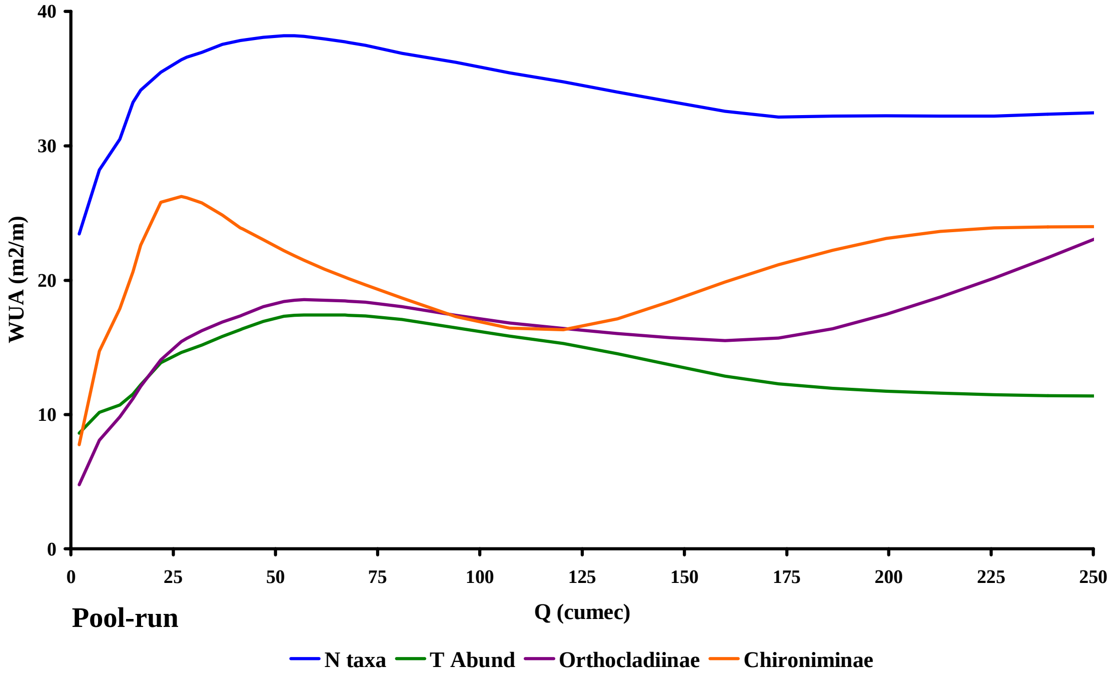


Figure 21. Plot of weighted useable area (WUA) for dominant macroinvertebrate taxa and maximum macroinvertebrate abundance and taxon richness against discharge for *bar* habitat at study reach 03. Note how WUA peaks at low to moderate Q for many taxa.



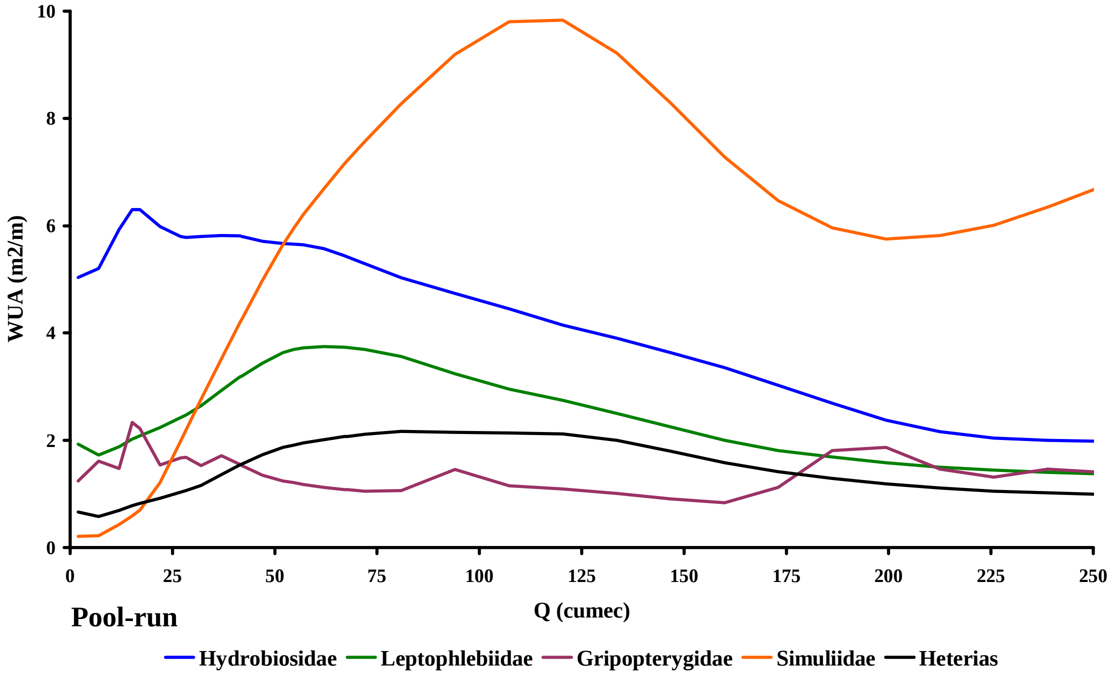
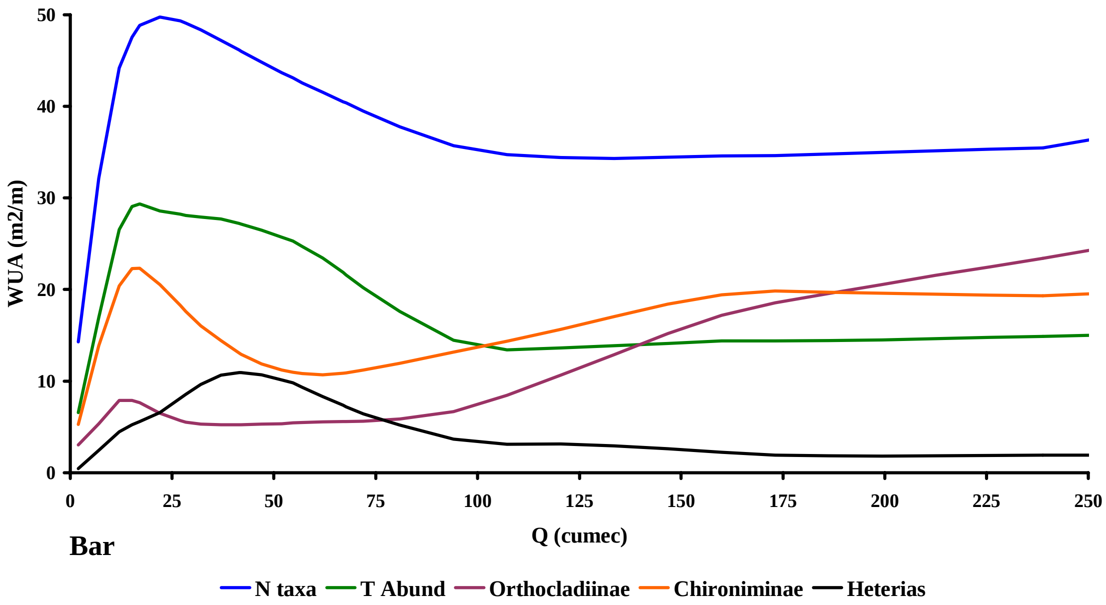


Figure 22. Plot of weighted useable area (WUA) for dominant macroinvertebrate taxa and maximum macroinvertebrate abundance and taxon richness against discharge for *pool-run* habitat at study reach 03. Note how WUA peaks at low to moderate Q for many taxa.



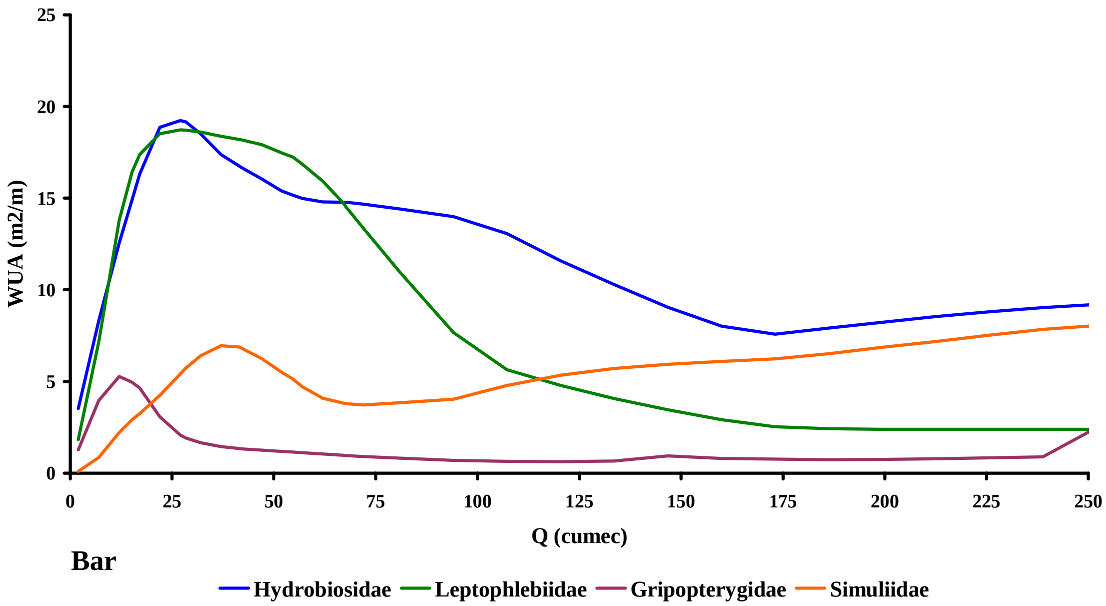


Figure 23. Plot of weighted useable area (WUA) for dominant macroinvertebrate taxa and maximum macroinvertebrate abundance and taxon richness against discharge for *bar* habitat at study reach 1215. Note how WUA peaks at low to moderate Q for many taxa.

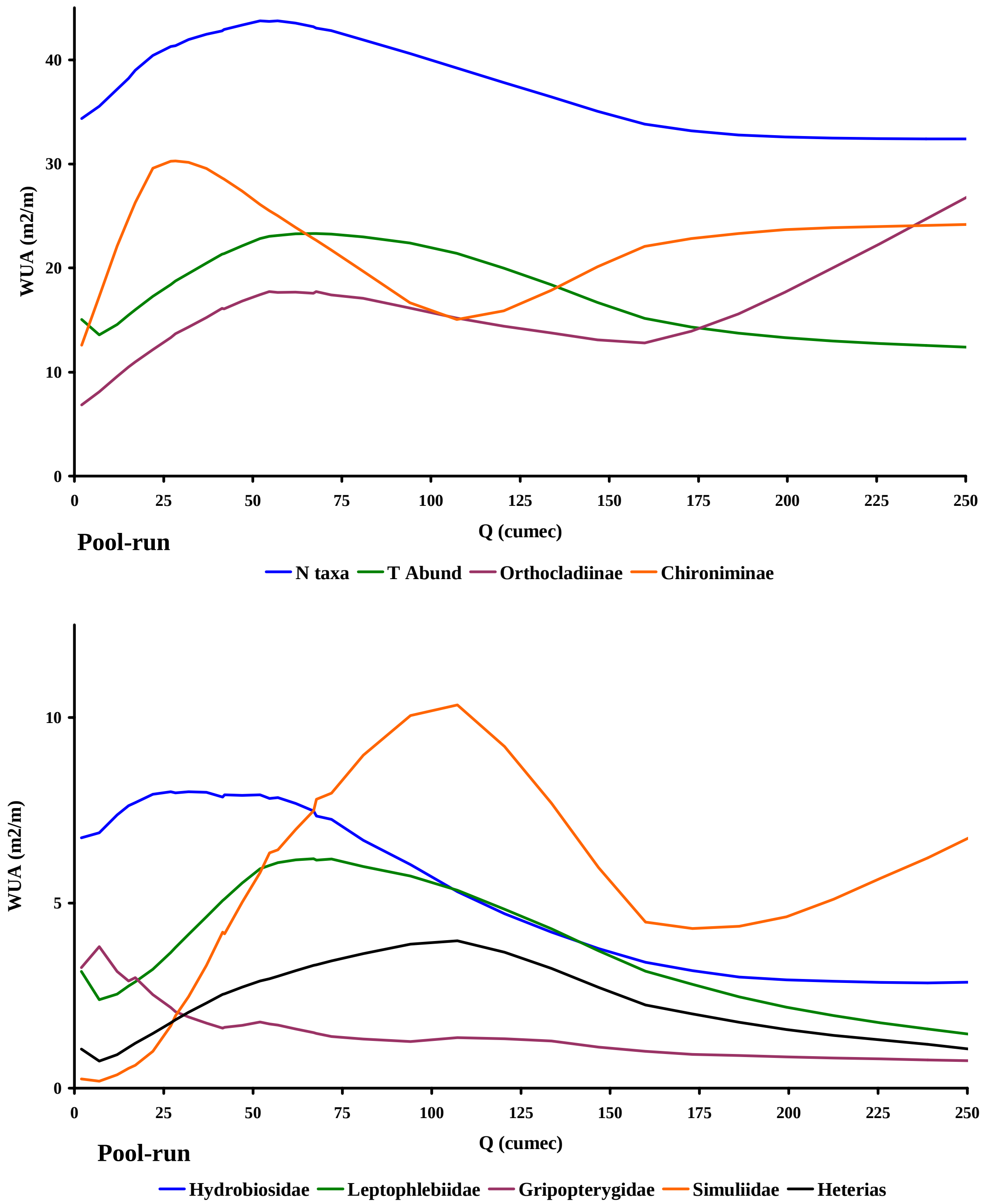
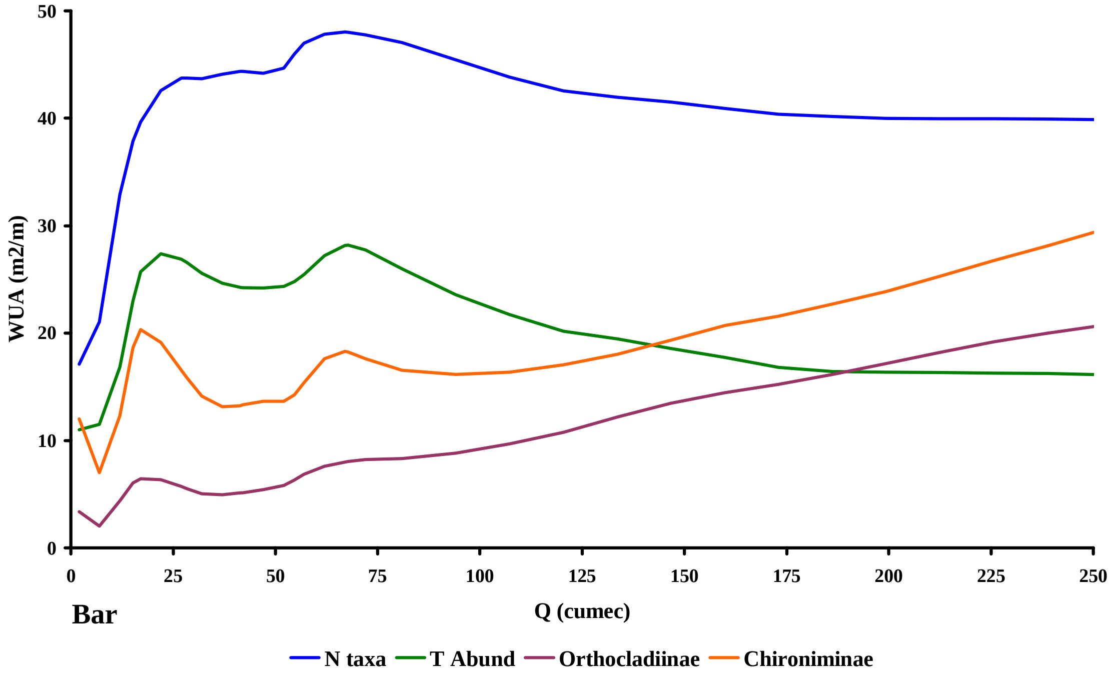


Figure 24. Plot of weighted useable area (WUA) for dominant macroinvertebrate taxa and maximum macroinvertebrate abundance and taxon richness against discharge for *pool-run* habitat at study reach 1215. Note how WUA peaks at low to moderate Q for many taxa.



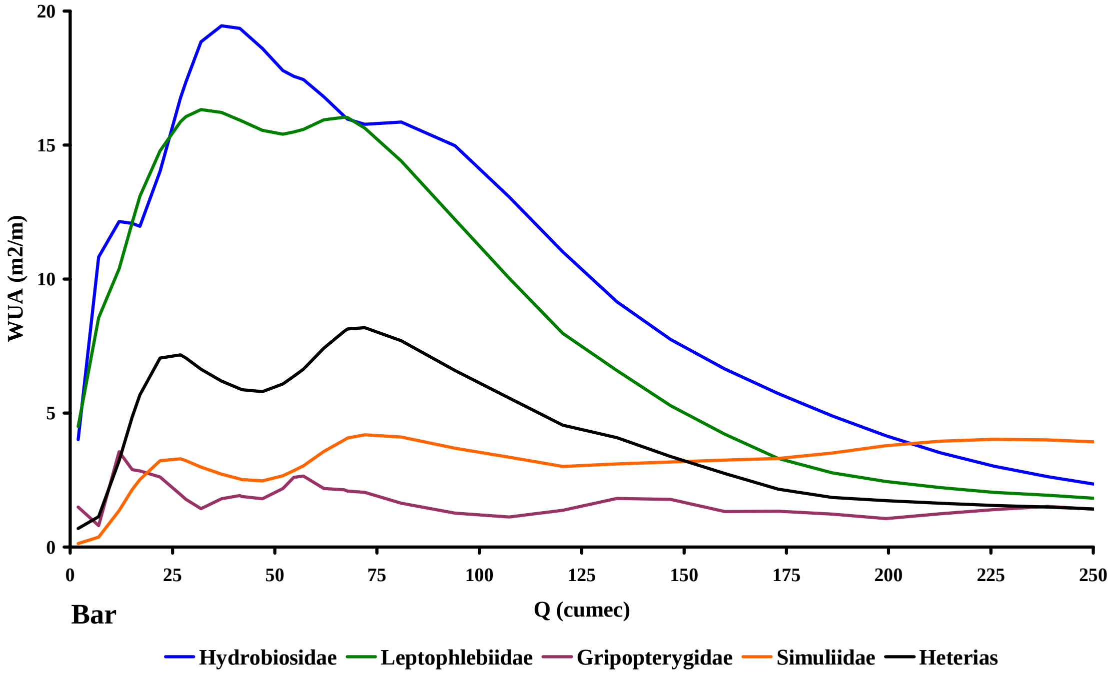
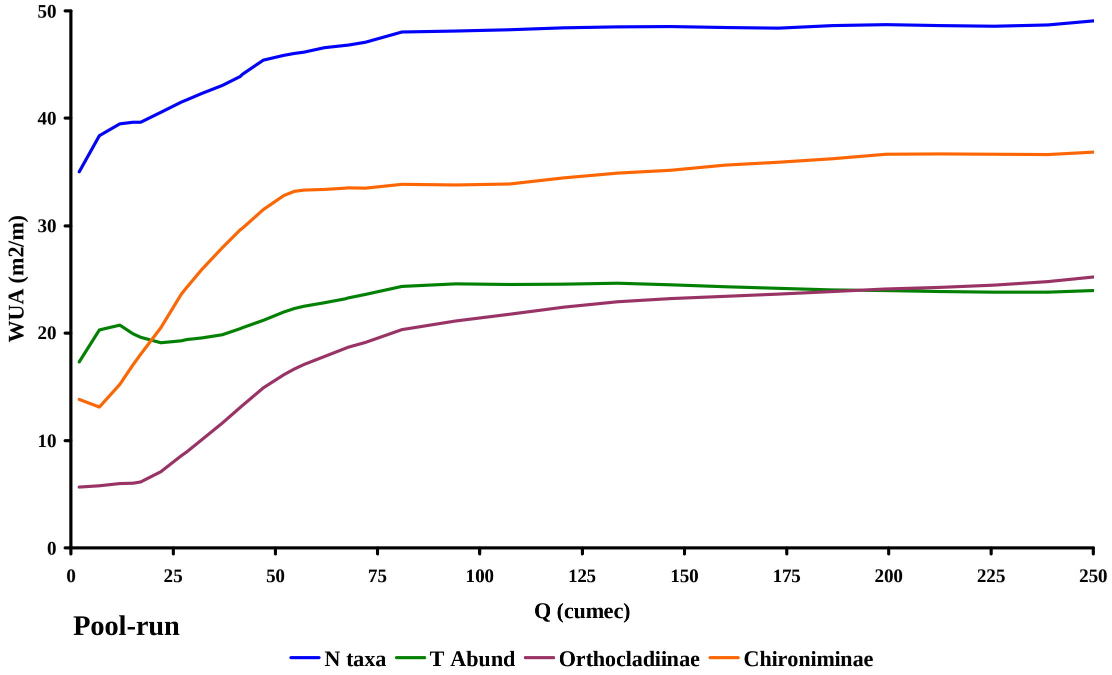


Figure 25. Plot of weighted useable area (WUA) for dominant macroinvertebrate taxa and maximum macroinvertebrate abundance and taxon richness against discharge for *bar* habitat at study reach 2940. Note how WUA peaks at low to moderate Q for many taxa.



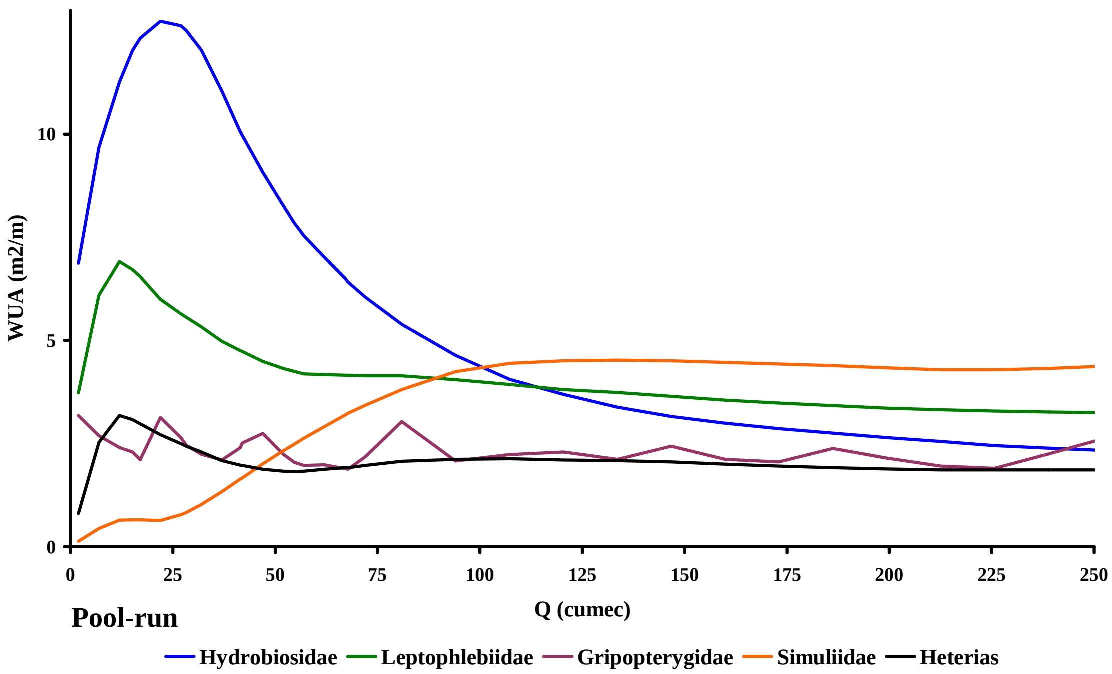


Figure 26. Plot of weighted useable area (WUA) for dominant macroinvertebrate taxa and maximum macroinvertebrate abundance and taxon richness against discharge for *pool-run* habitat at study reach 2940. Note how WUA peaks at low to moderate Q for several taxa.

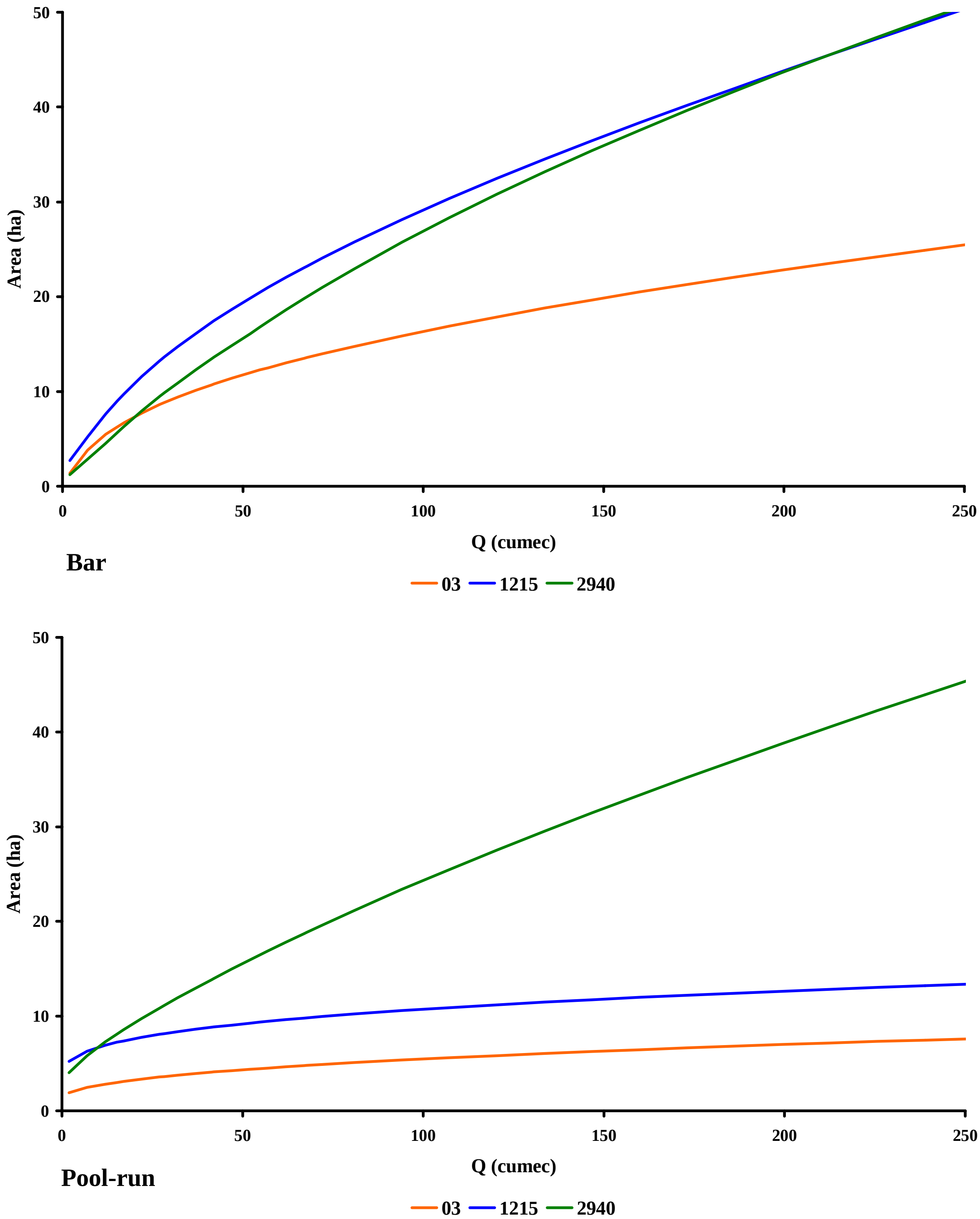


Figure 27. Plot of wetted channel area (in ha/km) against discharge for bar and pool-run habitats in study reaches 03, 1215 and 2940 of the middle Gordon. Note that wetted area increases monotonically with discharge, in contrast to WUA in Figures 21-26.

Benenati *et al.* (1998) observed that colonisation of algal biofilm (phytobenthos) took between 5 and 8 weeks in the Colorado river following a three month period of desiccation on upper bar slopes. They concluded that repeated desiccation of the biofilm (phytobenthos) due to flow fluctuations downstream of a hydroelectric power station had major effects on the Colorado ecosystem.

Davies and Cook (unpub. data) observed a consistent sequence of colonisation on previously exposed cobble substrates in artificial streams supplied with flow and macroinvertebrate colonists from a southern Tasmanian stream. Simuliid larvae commenced colonisation within 1-3 days of flow commencing and reached peak densities between 14 and 21 days later. Significant increases in diversity and total abundance was only observed after ca 30 days. Colonisation with a community similar to that of the source stream was only achieved by 10-12 weeks later.

Overall then, it appears that some macroinvertebrate taxa colonise exposed substrate rapidly, while colonisation with a 'mature' community takes up to 3 months.

In the middle Gordon, Coleman (1978) observed a marked decline in macroinvertebrate abundance and diversity at locations within the channel that had been dewatered for substantial periods prior to power station releases commencing. Thus, at two sites - 63 and 46 - the predominant cobble/boulder habitat had not substantially recovered in either macroinvertebrate abundance or species richness even three months after power station discharges had commenced, having only 20 and 64% respectively of the species and 13 and 21% respectively of total abundance of that found in historically wetted locations at the same sites. Davies and Cook (unpub. data) observed that periods of three to four months were required to develop a macroinvertebrate community that resembled that in source-water streams in experimental channels on previously dry cobble substrate, with early colonisation over the first month only by simuliids.

These studies indicate that colonisation of previously dewatered habitat is a process much slower than durations of reinundation experienced at positions within the middle Gordon channel away from the centre (or thalweg), and is probably mediated by the delay in development of a biofilm on the substrate.

Both increases and plateaux in habitat suitability are indicated at high flows for macroinvertebrates from the WUA analysis above. However, the quality of habitats in the 'intertidal zone' (particularly above the water level at around 50 - 100 cumec) is much lower than along the channel thalweg due to the absence of a permanent biofilm-associated food resource, particularly for grazing macroinvertebrates.

3.4.1.3.2 Macroinvertebrate stranding

Power station shut-down – startup sequences are associated with episodic, rapid variations in water velocity, periods of high shear stress and rapid dewatering on pool-run margins and bars. Field observations in 1999-2000 indicated that these events continue to be associated with stranding of macroinvertebrates, including:

- substantial areas of hydropsychid net 'fields', established after prolonged periods of high discharge, being completely exposed (leading to mortality of the caddis) or stranded in still margins, backwaters or pools (with velocities unsuitable for caddis feeding and/or respiration);

- eusthenid stonefly carcasses or stressed individuals being observed on recently exposed bar and channel margin areas. The high mobility of these individuals also suggests that significant stranding and mortality of other, less mobile species occurs in these areas.

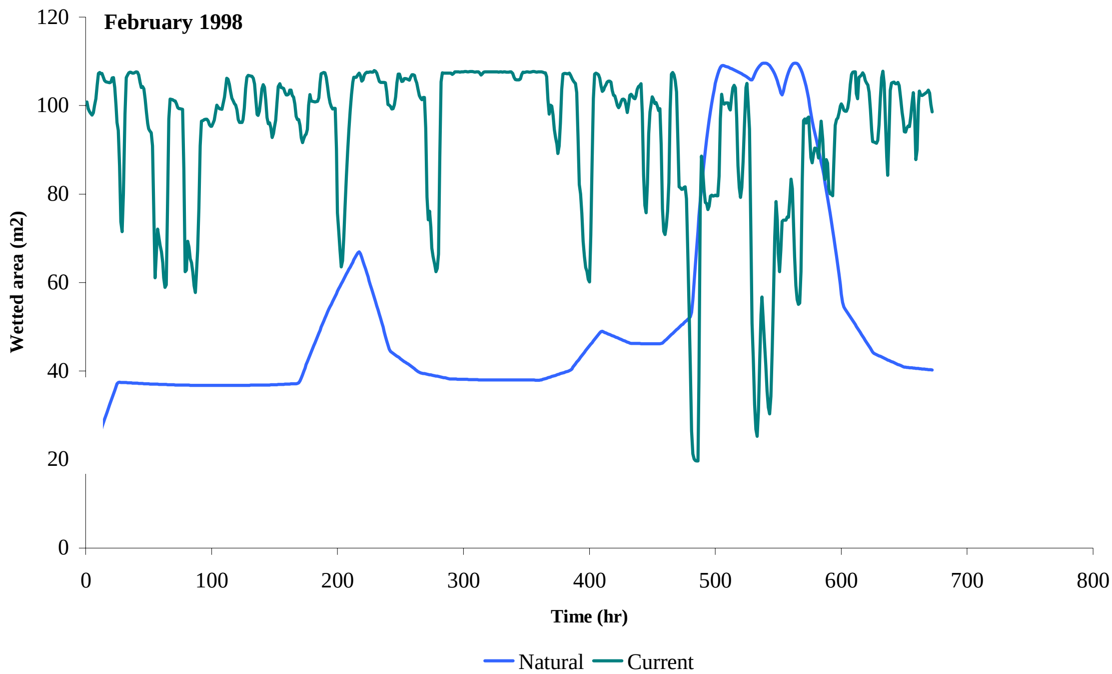


Figure 28. Plot of wetted area of river bed under the current flow regime for February 1998, compared with that which would occur under a natural flow regime for the same period.

Plot is for bar habitat at site 75. Note greater wetted area on average, interspersed by acute drops in wetted area associated with power station shutdowns.

We sampled four bar sites in the middle Gordon in August 2000 to assess if there was any further evidence of significant stranding on exposed channel bed material, and what pattern was evident. Plots of number of taxa and abundance are shown in Figure 29. Macroinvertebrates occurred in dewatered substrate at all sites, but with two distinctive patterns of distribution. Oligochaetes, nematodes and *Heterias pusilla* (a janiirid isopod) all had much higher abundances on dewatered substrate than instream, with a peak between 10 and 25 m from the water's edge. Their abundances are shown in Figure 29, combined for convenience. This pattern suggests that these taxa concentrate in damp substrate away from the main flow, and we suggest that these are 'moist sediment dwellers' which may prefer repeatedly dewatered habitat.

All remaining taxa showed a decline in abundance with distance from the water's edge, though with slightly varying patterns (Figure 29). However, the diversity was relatively high, with a mean of 50% of the number of taxa found instream being found in dewatered substrates throughout the first 30 m from the water's edge. There was also a significant abundance of macroinvertebrates associated with dewatered substrate, with a mean total abundance of non-oligochaete, nematode or isopod taxa equivalent to 32% of that found in the wetted channel. On examination of the relative areas of wetted and dewatered channel observed during surveys of the 15 'IFIM' sites, we estimate that power station shutdowns result in exposure of approximately 50% of gravel-cobble-boulder-bedrock substrate in Section 1, and 16% in Section 2. Using the abundance figure of 32% derived above, power station shut-downs are estimated to result in stranding of some 15% of the total non 'sediment dwelling' macroinvertebrate population in Section 1 and 5% in Section 2.

It appears that stranding of macroinvertebrates as a result of power station shutdowns is not likely to be a substantial issue in Section 2, downstream of the Denison River. However, the significance of the 15% figure for Section 1 is dependent on whether this pattern is repeated with each shut down, and whether the stranded macroinvertebrates die as a result of the stranding.

We repeated the sampling of exposed channel bed at two sites (74 and 72) immediately following commencement of a prolonged power station shutdown in September 2000, and four weeks later, to assess if the pattern of 'stranded' fauna described above was repeated, and if there was a reduction in abundance of 'stranded fauna' over time during a shut-down. Unfortunately, high river levels prevented sampling across the bars, precluding a comparative assessment.

This initial assessment, suggests that there is a repeated stranding of ca 15% of the macroinvertebrate population following power station shutdowns. This represents a significant source of mortality for macroinvertebrates within Section 1 of the middle Gordon, even if only a portion of that stranded population dies following each stranding event.

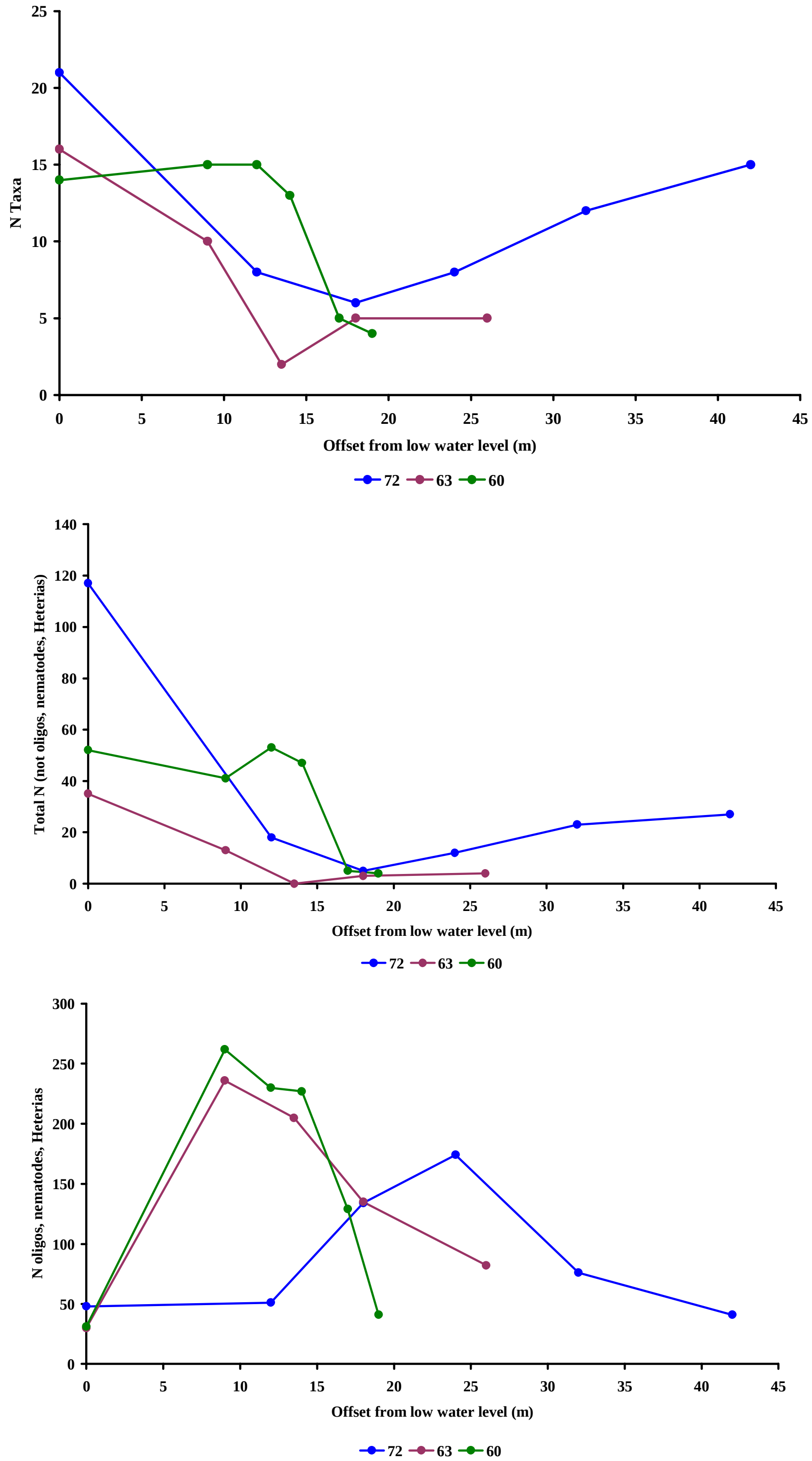


Figure 29. Plots of number of taxa and abundance of macroinvertebrates against distance from low water level at three sites in the middle Gordon following a power station shut down on 19 August 2000. Note that oligochaetes, nematodes and *Heterias* differ significantly in trends from remaining taxa.

3.4.1.3.3 Snag habitat

Most snags in the middle Gordon are marginal to the channel, whether they are associated with natural treefall or hydroelectric-induced erosion (see Koehnken *et al*., 2001), and are therefore highly susceptible to dewatering. Data from the 15 transect sites used for habitat assessment was used to derive estimates of snag area and volume within the river channel, between the power station and the Franklin River junction. Some 7% of channel area overall is occupied by snags, with a little more occurring in Section 1 than Section 2 (Table 11). The percent of that total snag volume which is wetted at low flows, equivalent to summer baseflows observed under current conditions when the power station is off, is very low (9% overall) and is substantially lower in Section 1 than 2. This difference is primarily due to the higher baseflows downstream of the Denison River.

When the snag volumes wetted under current baseflows (Qbc) are compared with those wetted under natural (pre-Hydro) baseflows (Qbn), it is apparent that a substantial reduction in permanently wetted snag habitat has occurred as a result of current hydroelectric operations (Table 11). Only 10% of snags permanently wetted under natural baseflows remain permanently wetted under current conditions in Section 1. This rises to 24% in Section 2.

Snag habitats have a distinctive macroinvertebrate fauna, and are also significant foraging habitats for native fish (Boulton and Brock 1999). We were not able to sample the snag fauna of the Gordon or Franklin River for this project due to access and time constraints. Field observations however, suggested that the abundance of macroinvertebrates on the surface of submerged snags in Section 1 of the Gordon was lower than in the lower Franklin. We believe that the majority of the fauna associated with inundated snags has been lost from the middle Gordon, particularly upstream of the Denison River, due to dewatering. This would be further exacerbated by repeated fluctuations in velocity. This represents a reduction in overall diversity, which was not detected by either Coleman (1978) or Davies *et al.* (1999), due to their focus on main-channel bed habitats. Further sampling should be conducted to confirm this.

Table 11. Percent of total middle Gordon channel area as snags, percent of snag volume wetted at current baseflows (Qbc), and percent of snag volume wetted at natural ('no-Hydro') baseflows (Qbn) which is still wetted at current ('with Hydro) baseflows (Qbc). Means and ranges shown for sections 1 and 2 separately and combined. Data derived from 15 'IFIM' transect sites.

	Mean	Range
Section (sites)	**% channel area covered by snags**	
1 (63 - 75)	7.6	2.6 - 16.1
2 (40 - 63)	6.6	1.6 - 10.9
Both (40-75)	7.3	1.6 - 16.1
	% total snag vol wetted at Qbc	
1 (63 - 75)	7.1	0.0 - 25.0
2 (40 - 63)	12.7	0.0 - 25.0
Both (40-75)	8.8	0.0 - 25.0
	% wetted at Qbn still wetted at Qbc	
1 (63 - 75)	10.4	0.0 - 25.0
2 (40 - 63)	23.8	16.7 - 33.3
Both (40-75)	14.9	0.0 - 33.3

3.4.1.4 Conclusions

In summary, there have been two successive impacts of hydroelectric development in the middle Gordon on the macroinvertebrate fauna. The initial impacts were associated with dam construction and corresponding sedimentation and flow reduction. Currently, there is an ongoing impact on the remaining macroinvertebrate communities lying along the channel thalweg in the middle Gordon due to flow regulation, with:

- depressed abundance and diversity within the first 5 km downstream of the power station;
- significant changes in overall community composition within the first 14 km downstream of the power station (Section 1) with loss of up to eight macroinvertebrate families and reduction in abundance of the remaining taxa; and
- a depression in diversity in Section 2 between the Franklin and Denison River junctions with loss of between 1 and 3 macroinvertebrate families.

The key cause of the impact on the macroinvertebrates remaining along the channel thalweg is variability of flow, characterised by frequent rapid changes in depth and velocity. Figure 30 shows a sequence of mid-water column flow velocities experienced along the deepest point of the channel during February 1998, compared with a simulated sequence under natural flow conditions. Prolonged periods of high velocities at 2 to 3 m/s are interspersed with brief, rapid fluctuations down to 1.5 m/s and occasionally to 0.5 to 1 m/s. This is in contrast to the predominantly lower velocities associated with natural baseflows of ca 1 m/s with occasional excursions to higher velocities during flood events.

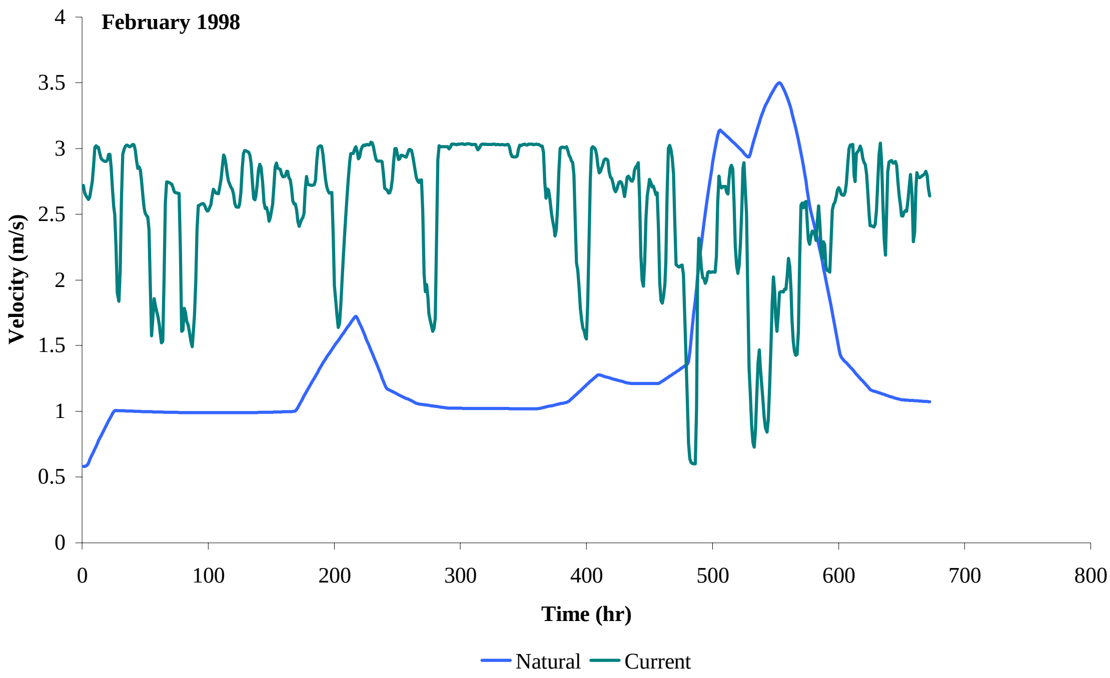


Figure 30. Plot of mid-water column velocity area at the deepest point in the channel under the current flow regime for February 1998, compared with that which would occur under a natural flow regime for the same period.

Plot is for bar habitat at site 75. Note greater wetted area on average, interspersed by acute drops in wetted area associated with power station shutdowns.

There are major impacts on overall macroinvertebrate abundance and diversity for the entire section between the power station and the Denison River junction due to repeated dewatering of channel bottom and bank habitat between periods of power station generation. When compared with natural baseflows, these dewatering events result in complete loss of significant proportions of benthic habitat, accompanied by loss of 75% of wetted snag habitat in Section 2 and 90% in Section 1.

The existing variable flow regime has a number of significant implications for the macroinvertebrate fauna of the middle Gordon River. These can be summarised as follows:

1. loss of habitat and reduction in habitat quality;
2. mortality during stranding events.

A key aspect of the change in flow regime resulting from hydroelectric operations is the period over which areas of stream bed remain inundated without disturbance by dewatering events leading to exposure and drying. Thus a critical variable is the intermittency of disturbance by sudden decreases in water levels.

Natural summer (December to March) baseflows for site 75, 63, 60 and 42 ranged between 20 and 60 cumec (Table 12). Under natural conditions, minimum flows (or baseflows) result in a substantial area of the bed being constantly wetted. For example, results of hydraulic modelling for pool-run and bar habitats at site 75 show that this represents between 19 and 32 % of the stream bed area being constantly wetted in bar reaches and 46 – 51% in pool-runs, with an overall range of 41 to 46% for study reach 03 (between 0.3 and 3 km downstream of the power station).

Table 12. Natural baseflows (cumec) occurring at key sites in the middle Gordon.

Site	Season	Range	Median value
75	summer - autumn	21 – 30	25
	winter - spring	38 – 61	50
63	summer - autumn	22 – 42	28
	winter - spring	30 – 71	55
42	summer - autumn	38 – 60	60
	winter - spring	62 – 141	95

Under current flow conditions, minimum flows have declined significantly, although these have been offset by prolonged periods with higher flows e.g. of 30 – 50 cumec at site 75 (Figure 8). This has resulted in:

- a reduction in the minimum flow and hence the area of wetted stream bed that does not experience a significant dewatering event;
- some areas of the channel being wetted for periods of up to 3 - 7 months of the year, usually during the period December - May, prior to being dewatered for variable periods, typically during June to October.

This pattern has resulted in a permanent macroinvertebrate community positioned along the thalweg (point of deepest water), coupled with areas of bank and bars on which a biofilm and macroinvertebrate community is successfully established for several months of the year. Evidence for the permanent macroinvertebrate community has been presented by Davies *et al.* (1999) and has been reconfirmed in this work. Field observations have also been made of residual biofilms (composite deposits of algae and organic material on cobbles and boulders) and moss beds on bars previously submerged for several weeks/months. These are often accompanied by hydropsychid net 'fields', often of very high density, and comparable with similar fields in wetted sections, as well as macroinvertebrates including eusthenid stoneflies, worms and hydrobiosid caddis larvae.

Under the current flow regime, re-establishment of macroinvertebrate communities on these periodically exposed habitats is presumably dependent on the duration of exposure and the rate of loss and re-establishment of the biofilm and/or mosses. Thus, the channel is divided into three broad 'zones':

- the channel centre or thalweg, with a permanent, though impacted, macroinvertebrate community and biofilm;
- a 'lower intertidal' zone with macroinvertebrates and biofilm with a patchy spatial distribution, colonising over periods of up to 1 – 2 months prior to dewatering;
- an 'upper intertidal' zone, with no macroinvertebrates or substantial biofilm other than some resistant algae.

In addition to losses of habitat through dewatering events, the areas of habitat that remain dewatered at minimum flow experience frequent, short duration fluctuations in both depth and velocity. This results in rapid fluctuations in shear stress at the bed, as shear stress is highly correlated with mean and near-bed water velocities (see report section 3.5). It therefore reduces the quality of habitat for a number of macroinvertebrate taxa which cannot cope with rapid fluctuations in shear stress. Thus, the 'permanent' community residing along the thalweg is reduced in abundance and diversity. The intensity of this is greatest in Section 1 and is significantly reduced further downstream.

3.4.2 Other vertebrates

3.4.2.1 Overview of Fauna

The two dominant terrestrial vertebrates which are partially or completely dependent on instream habitats and food production in rivers of western Tasmania are the platypus (*Ornithorhynchus anatinus*) and the Australian water rat (*Hydromys chrysogaster*). There are no data on the abundance of either species in the Gordon. Both species have been noted in the Gordon and its major tributaries by a range of observers (GT-SPOT records, DPIWE; Connolly and Obendorf 1998). Platypus were occasionally observed in the Gordon during field work in late 1999 and 2000, both immediately upstream and downstream of the Denison River and in the vicinity of the Sprent River junction. They are also frequently observed in the lower, tidal reaches of the Gordon, as well as the lower reaches of the Franklin River.

Benthic macroinvertebrates (aquatic insects and crustaceans) are the major source of food for riverine platypus (Faragher *et al.* 1979), while *Hydromys* has a diet of macroinvertebrates and fish (S. Munks pers. comm.).

Published information is available on diet, habitat use, diving behaviour, energetics and swimming speeds for platypus (e.g. Kruuk 1993, Gust and Handersyde 1995, Fish *et al.* 1997, Serena *et al.* 1998, Ellem *et al.* 1998, Grant and Bishop 1998, Bryant *et al.* 1999, Grant and McDonald 1998) as well as some published and unpublished Tasmanian data on diet, habitat and energetics (Munks *et al.* 1998, Otley *et al.* 2000, Bethge *et al.* submitted), but only limited information on *Hydromys*, on swimming behaviour (Fish and Baudinette 1999).

Both platypus and *Hydromys* use burrows in river banks, sometimes interchangeably, sited with their main entrance at or just above the predominant water level and in consolidated earth bank material and/or associated with vegetation (Serena *et al.* 1998, Bishop and Grant 1998). Otley *et al.* (2000) found that Tasmanian platypus burrows at Lake Lea were sited opportunistically in dense vegetation, log piles and tree roots, generally within 2m of the waters edge in lakes and pools.

Key habitat factors for platypus include overhanging vegetation, the presence of suitable banks, extensive pool and riffle areas for foraging, benthic macroinvertebrate food production and diversity of instream habitats (Bishop and Grant 1998). Grant and Bishop (1998) also considered that greater distances from consolidated banks to the water's edge, and shallower riffle areas, both presented greater risk of predation, particularly by foxes. We do not consider these to be substantial issues for the platypus population of the middle Gordon as predation risk for Tasmanian platypuses is generally considered low (S. Munks pers. comm.), especially along dense rainforest river corridors, despite occasional sightings of predation by large raptors.

3.4.2.2 Conservation Status

Platypus are not listed under the Threatened Species Protection Act (1995), and are widespread and common throughout Tasmania, though considered 'potentially vulnerable' nationally (Kennedy 1992). *Hydromys* is also not listed under the Threatened Species Protection Act and is again widespread and common.

3.4.2.3 Impacts of current Hydro operations

There are no data on the status of populations of platypus or *Hydromys* in the middle Gordon, and hence no data linking conditions under current hydroelectric operations to their status. We propose that impacts from the altered flow regime under current conditions have included:

- *Erosion and instability of soft (sand and peat) banks.* Historical and on-going erosion and withdrawal of soft banks may have impacted on availability of burrow sites, particularly upstream of the Denison River;
- *Loss of overhanging riparian vegetation.* Dense, understorey overhanging vegetation is generally regarded as being a pre-requisite for suitable burrow sites (Ellem *et al.* 1998, S. Munks pers. comm.). It is in the process of being lost on lower slopes of many soft banks in the middle Gordon, with the degree of loss decreasing with distance from the power station (see Appendix 6 of this report series – Gordon River Riparian Vegetation Assessment (Davidson and Gibbons, 2001)).
- *High velocities at full power station discharge.* Simulation and measurement of velocities across the channel at transects on bars and pool-runs (see report section 3.4.1.3.1) indicates that during power station discharge at 'efficient load' or 'full gate' :
  - velocities > 0.75 m/s (up to 3.5 m/s) are sustained across the full width of the channel for the majority of the river upstream of the Denison River, with only channel edges having velocities < 0.5 m/s – this is would significantly reduce foraging habitat, particularly during lactation (November – early February), and is likely to impact on survival of emerging young (S. Munks pers. comm.), and result in reduced condition of all age classes (see Grant and McDonald 1998, Bethge *et al.* submitted);
  - some 10 - 20% of channel width on average has water velocities suitable for platypus, and that the majority of suitable habitat is marginal, with sand-silt substrates which have limited potential for food production.
- *Rapidly fluctuating water levels.* Rapid fluctuations in water level may disrupt access to burrows and may lead to drowning in burrows. Platypus are known to drown as a result of rapid rises in level during large natural floods (Grant 1995, Munks pers. comm.) and this has also been observed on one occasion following power station startup at Poatina power station (J. Connolly, unpub. obs.). Unpredictability of rapid river level rises may lead to downstream displacement of platypus during feeding, and have an impact on the overall energetics of foraging .
- *Reduction in diversity and abundance of benthic macroinvertebrate food.* Reductions in abundance and diversity of macroinvertebrates have been observed by Davies *et al.* (1999), and in this work (see above), implying lower macroinvertebrate standing crop and production, and hence a reduction in available food supply for platypus, by 52 - 76% in Section 1 of the middle Gordon (e.g. see Figure 16).

The degree to which the above effects are manifest in the middle Gordon is unclear, and an assessment of the status of the platypus population, their condition and reproductive status has yet to be conducted. The major impact is likely to be on the foraging success of females with young and on young emerging and/or dispersing from burrow sites. Under current conditions, the middle Gordon platypus population is likely to be resident in tributary streams, with foraging occurring in the main river when flow conditions are favourable (S. Munks pers. comm.).

WUA-Q curves were developed using the habitat preference curves shown in Figure 32 for platypus. WUA-Q curves for the middle (1215) and downstream (2940) study reaches had the same shape for both habitats, with WUA declining in pool-runs as discharge increased, and peaking at moderate discharges in bar habitats (Figure 31). In pool-runs, instream habitat availability was highest at lowest discharges, and declined rapidly as discharge rose, largely due to very large velocities and depths. In bar habitats, habitat availability peaked between 20 and 50 cumec and declined at both lower and higher discharges. This peak was largely due to the availability of suitable habitat as bar slopes became inundated with low to moderate velocity water. WUA plateaus at higher discharges in reach 03 bar habitat due to the presence of cobble-boulder shelves high on the channel margin, providing access to shallow habitat at high flows. There was substantially less habitat available in this reach, however, due to the higher water velocities in this steeper more constrained reach.

We consider the WUA-Q curves from reaches 1215 and 2940 to be more typical of the majority of the middle Gordon. Time-series of WUA for platypus are shown for February 1998 in Figure 33 at study reach 1215 in both bar and pool-run habitats. Overall, it can be seen that habitat availability is significantly and chronically reduced (by ca 50 – 60%) under current flows, in both bar and pool-run habitats.

The major gorges constitute a barrier to the passage of platypus during periods of high discharge, particularly for non-resident individuals dispersing from tributaries. Increased frequency of short low flows may enhance some passage in the gorges of upstream of the Denison River, but this may be offset by their short duration and unpredictability of rapid rise in level as the power station releases re-commence.

3.4.2.4 Conclusions

Overall, we conclude that the current flow regime has resulted in:

- substantial reduction in instream habitat availability for platypus (and probably *Hydromys*) due to sustained high discharges in both Sections 1 and 2;
- reduction in burrow habitat availability through bank erosion and associated localised vegetation loss;
- additional reduction in habitat suitability due to highly varying velocities and flows;
- reduction in benthic macroinvertebrate food production and availability for platypus and *Hydromys* in Section 1 due to repeated dewatering of between 30 and 50% of the river bed.

We conclude that populations of platypus and *Hydromys* are highly likely to have been negatively impacted. *Hydromys* populations are likely to have been affected less than platypus, as they are able to forage for terrestrial prey in the riparian zone. Mortality of dispersing juvenile platypus is likely to have increased in Section 1 due to rapidly fluctuating water levels and high water velocities. Body condition of adults and juveniles, as well as recruitment, are also likely to have been reduced. The status of the platypus and *Hydromys* populations in the middle Gordon requires confirming and monitoring.

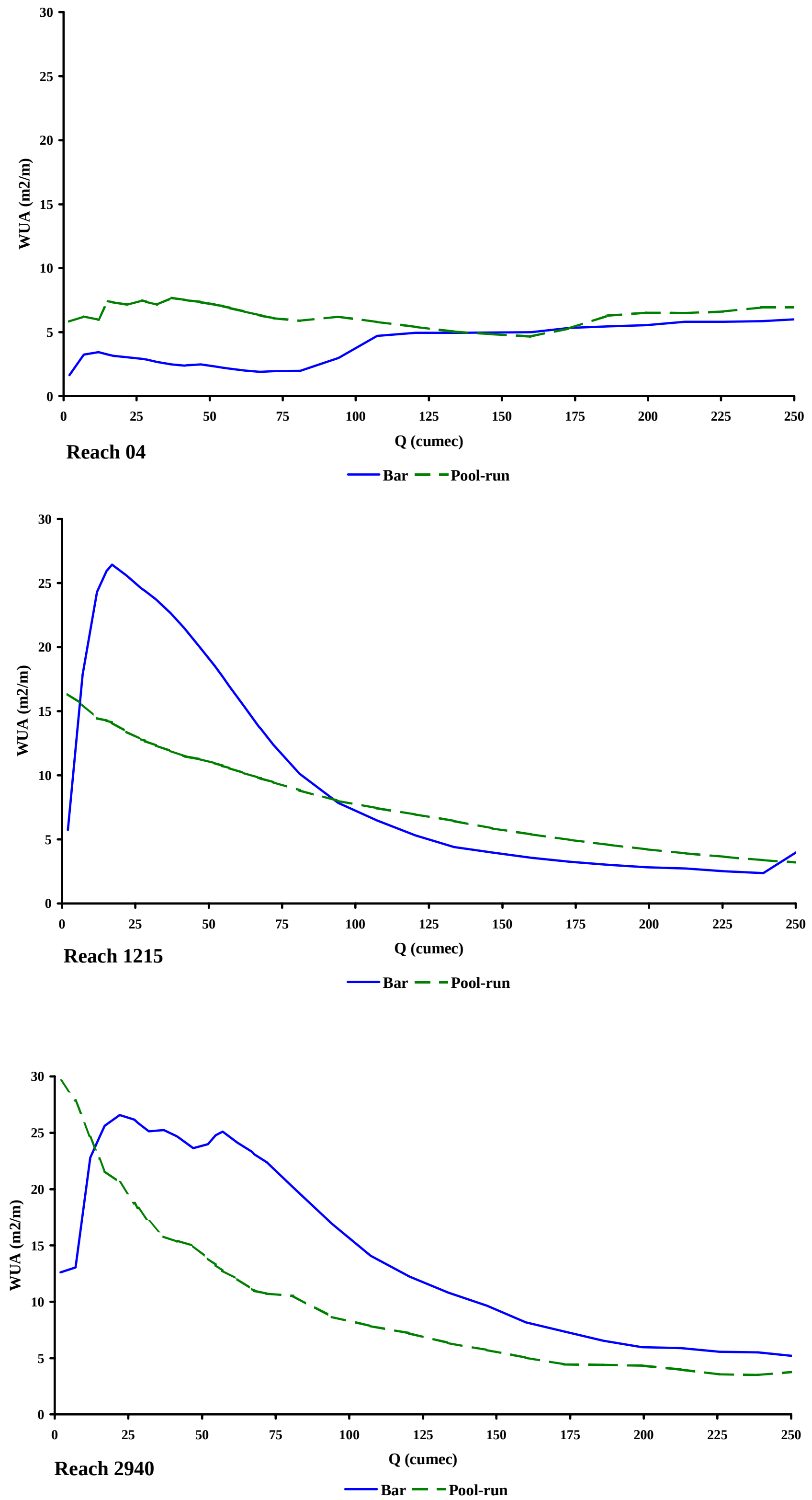


Figure 31. WUA-Q curves for platypus in bar and pool-run habitats for all three study reaches. Note much WUA values in reach 04, and decline in WUA at higher discharges in reaches 1215 and 2940.

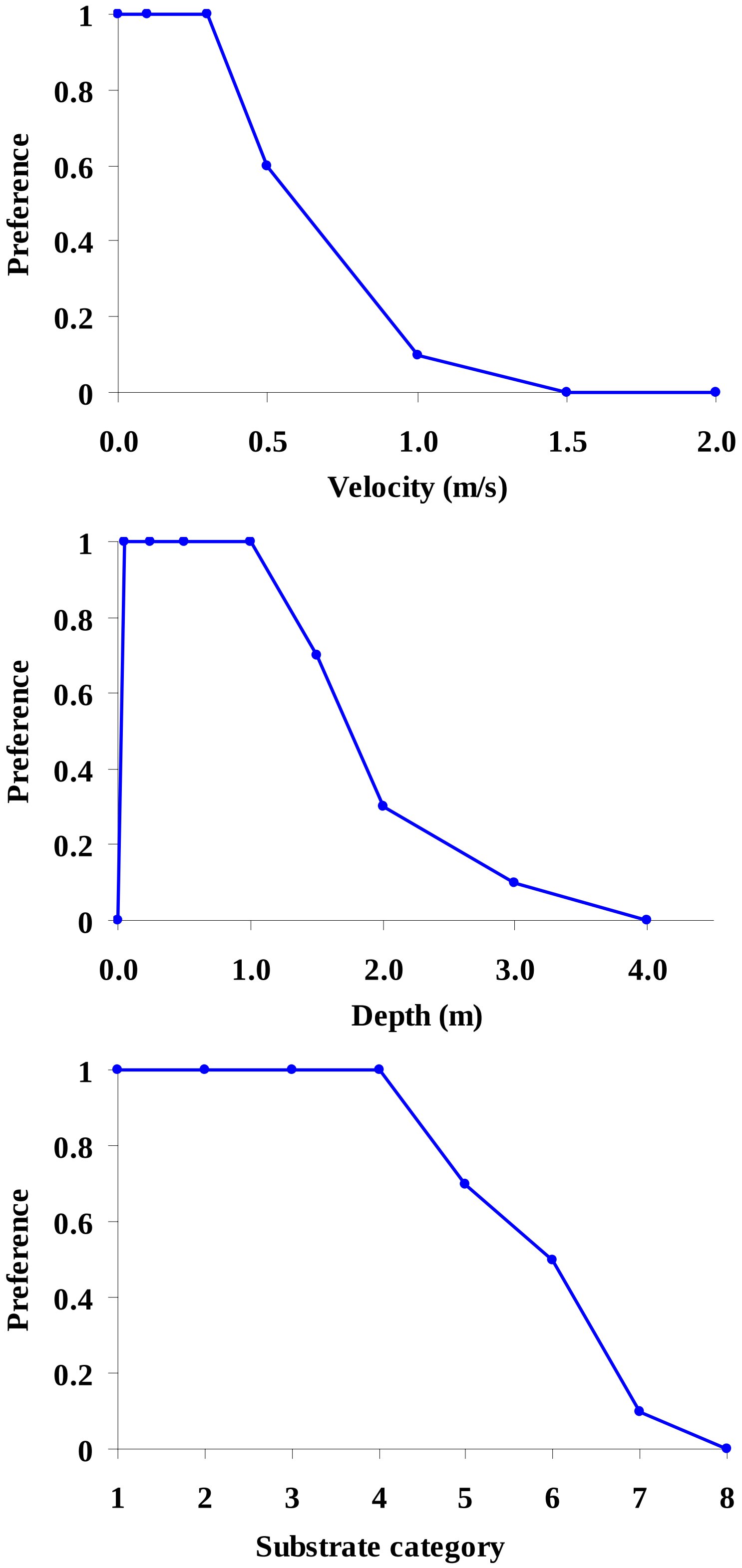


Figure 32. Habitat preference curves derived for platypus in this study for use in analysis of habitat availability.

Substrate categories are: 1 – vegetation, 2 – silt, 3 – sand, 4 – gravel, 5 – small cobble, 6 – large cobble, 7 – boulder , 8 – bedrock.

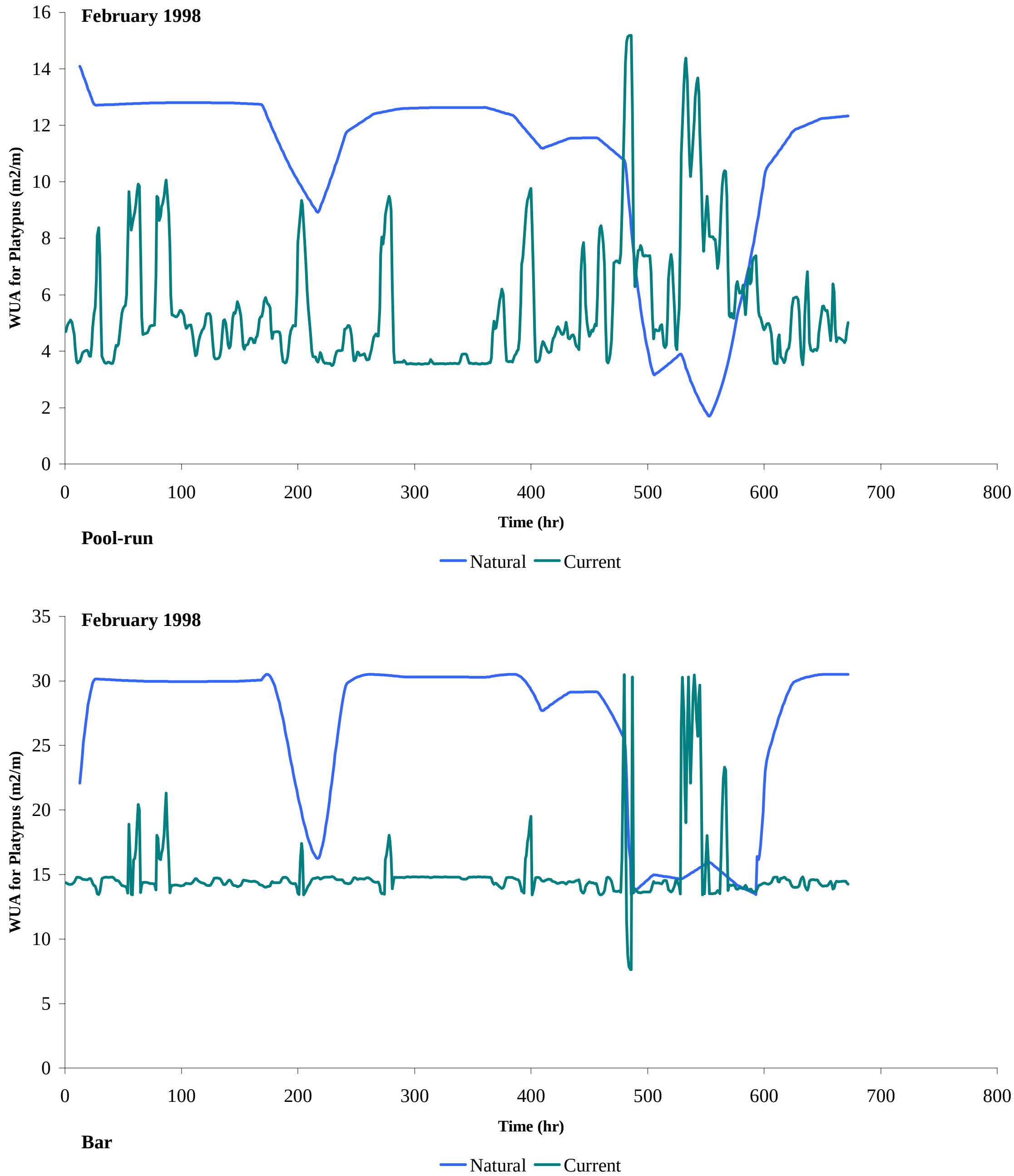


Figure 33. Plots of simulated usable habitat (WUA) for platypus at pool-run and bar habitats for study reach 1215 under natural and current flow regimes during February 1998.

Note the generally lower habitat availability due to high flows under the current flow regime, compared to higher WUA with occasional significant declines during natural floods.

3.5 Shear Stress

Comparative observations of shear stress at the bed were made using FST hemispheres in the Gordon, Franklin and King Rivers. A series of spot observations were made across a range of depth and substrate types in the Gordon and Franklin River at low to moderate flows. Safety and access considerations prevented us making observations of changes in shear stress through a hydropeaking 'wave'. A site on the King River immediately downstream of the John Butters power station was therefore selected to make these observations, since the King River channel was similar in profile and slope characteristics to Section 1 of the middle Gordon.

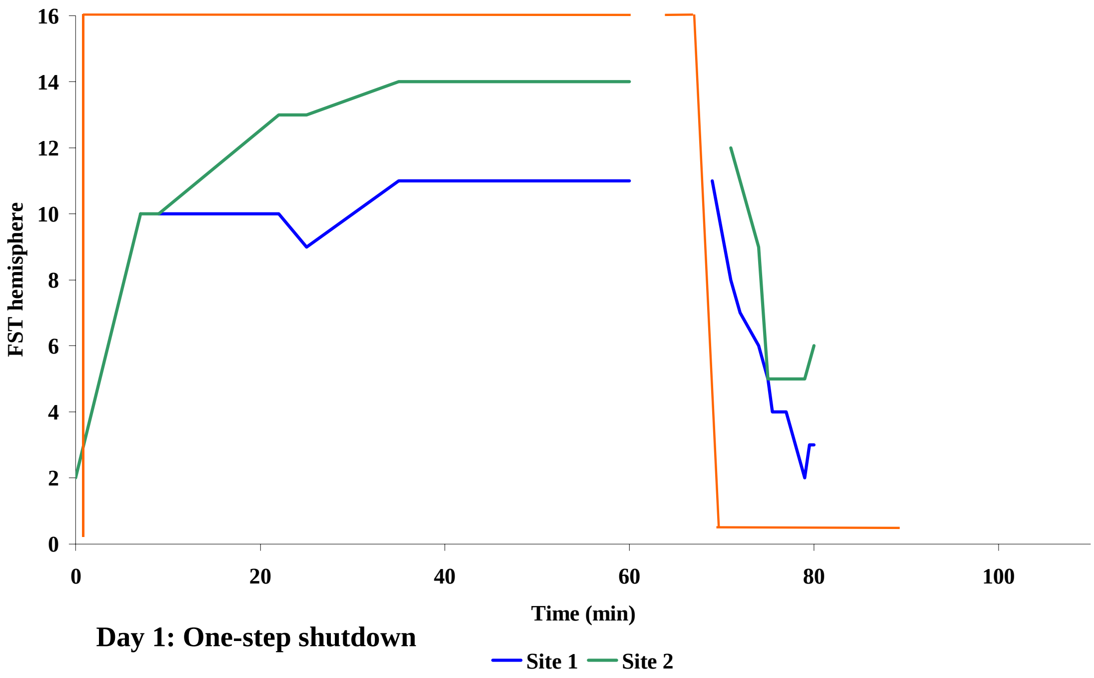
The index of shear stress (the 'FST score' – the number corresponding to the lowest density hemisphere just moved by the current) ranged from 1 up to 14 over all observations. The 'FST score' was most highly correlated with average and near-bed water velocity for both the Franklin and Gordon river data sets. There were no differences between the correlations from the two rivers (by ANCOVA, $p > 0.2$), and all spot survey data was therefore combined. The combined correlations were highly significant between shear stress and both average water-column and near-bed water velocities ($r = 0.79$ and 0.82 respectively, $n = 62$, $p < 0.00000001$). There was no significant correlation between shear stress and depth or hydraulic radius ($p = 0.74$, $n = 99$) in this data set, where depths ranged from 0.1 to 3.8 m. There were also no differences in the correlation with different substrate types (by ANCOVA, $p > 0.4$).

Several series of observations were made in the King River during the rising and falling limb of two separate peaking discharges from the John Butters power station. Plots of change in the FST score are shown in Figure 34 for two step-load sequences at the John Butters power station. These indicated that shear stress rose and fell smoothly with rising and falling velocities. No significant secondary peaks in shear stress were observed that could be associated with different near-bed flow states (e.g. chaotic vs skimming flow *sensu* Davis and Barmuta 1989).

The relationship between near-bed velocity and shear stress determined for the series of observations through the two flow peaks in the King River was not significantly different from that determined from spot observations in the Franklin and Gordon Rivers (by ANCOVA, $p > 0.5$). Log-linear regressions between FST score and mid-column and near-bed water velocities for all data points collected in the Gordon, Franklin and King rivers explained 71 and 74% of the variance in the FST score values, respectively ($n = 160$, 182 respectively, Figure 35).

We conclude therefore that, for depths up to ca 4 m in rivers like the Gordon, shear stress at the bed is largely determined by water velocity and is not significantly controlled by either depth, hydraulic radius or substrate type.

There were no indications of any major shift in shear stress associated with different phases of rising or falling discharge associated with a hydropeaking pulse other than changes associated with water velocity. Thus we regard the relationship between stress forces applied to individual substrate elements in the middle Gordon and discharge to be a simple, monotonic one. There were no indications of any major shift in patterns of rising or falling shear stress associated with rising or falling discharge during hydropeaking flow pulses, other than that associated with changes in water velocity. There are therefore no specific management implications with regard to the impacts of power station discharge events on benthic fauna, such as the need for complex ramping rates or minimum flows (see report section 5.2). This issue was therefore not explored further.



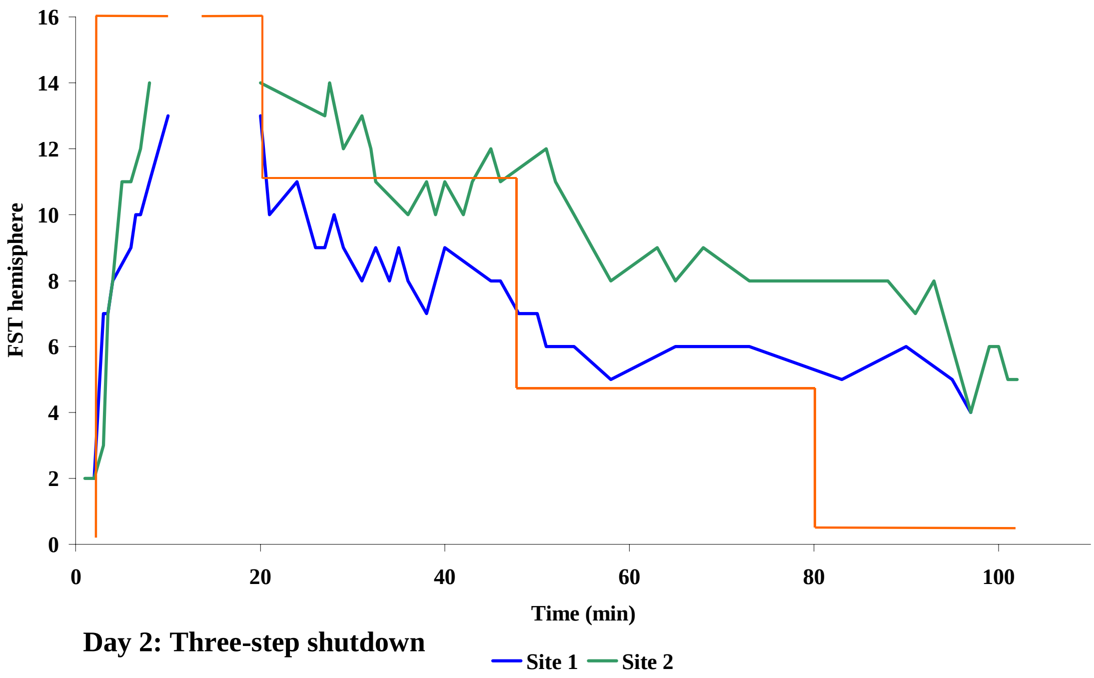


Figure 34. Plots of FST 'score' against time for two sites in the King River downstream of John Butters power station for two peak load sequences – one with a rapid and one with a stepped shutdown.

Power station shutdown sequences are indicated as orange lines. Blue and green lines commence and end when the sites are first inundated and dewatered respectively. Mid-plot break occurs due to high water velocities preventing FST observations being made.

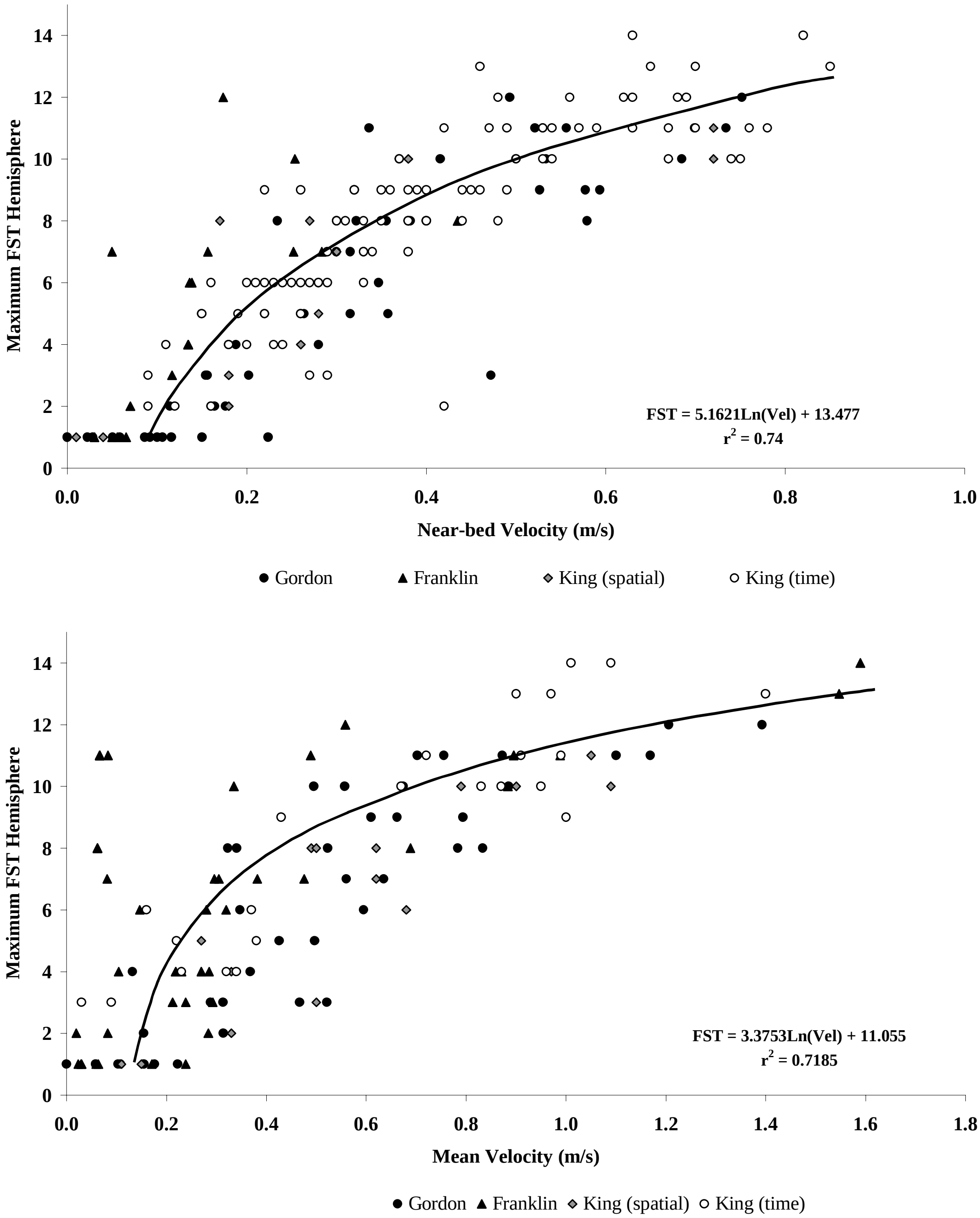


Figure 35. Plots of bed shear stress (measured as maximum FST density moved by the current) against near-bed and mean water-column velocities.

Log-linear regression line indicated. Point ('spatial') data collected in the Gordon, Franklin and King Rivers, differentiated from data collected through peak-load events in the King River ('time'). Note the overall similarity of the relationships, independent of source.

3.6 Current Conditions - General Conclusions

As a result of both historical and current hydroelectric activities, the middle Gordon River has experienced significant biological impacts with:

- decreases in instream macroinvertebrate diversity and abundance;
- shifts in community composition of macroinvertebrates;
- shifts in distribution of macroinvertebrates within the catchment.

We also conclude that populations of platypus and Australian water rat are highly likely to have experienced negative impacts, but have no data to support this other than indices of change in habitat availability and quality.

Most of the impact in the middle Gordon occurs in the reach upstream of the Denison River. However, the data also indicates some reduction in macroinvertebrate diversity and abundance downstream of the Denison River as far downstream as the Franklin River junction.

Overall, the middle Gordon River downstream of the Denison River contains a macroinvertebrate assemblage broadly similar to those in other rivers of the Gordon catchment. There are no current threatened species issues in the middle Gordon (as defined under the Tasmanian Threatened Species Protection Act 1995) for aquatic invertebrates or vertebrates. However, in the section upstream of the Denison River, the middle Gordon is significantly to severely biologically depauperate.

4 POTENTIAL BASSLINK CHANGES AND MANAGEMENT ISSUES

4.1 Flows under current conditions and Basslink

As indicated by Koehnken (2001), no substantial changes in water quality are anticipated under a Basslink scenario. In fact, the expected lower levels in Lake Gordon may reduce the risk of low dissolved oxygen water being released from the power station. The following assessment is therefore focused on risks associated with changes in flow regime under Basslink and how they compare with current conditions.

A comparison between Basslink and current flows can only be made for the 1997 and 1998 years as these are the only years on record with hourly power station discharge data, with only the record for 1998 being complete. Figures 36 to 39 show the same 1998 discharge sequences at site 75 as in Figures 8 to 11 (report section 3.1) under simulated natural and actual conditions. In addition, they show the discharge pattern forecast under Basslink with a 480 MW cable. Overall, the flow regime under Basslink will:

- increase the incidence and duration of constant high flows of 250 cumec (the discharge associated with ‘full-gate’ load operation of three turbines at the Gordon power station);
- greatly increase the incidence of large, short-duration changes in discharge from the power station, of the order of 100 - 250 cumec increases and decreases over 1 – 6 hr;
- increase the incidence of zero power station discharge events, resulting in low to very low river flows, of 1 - 6 hr duration;
- significantly increase the frequency of flow pulses of 16 - 24 hr duration, with a parallel increase in zero flow releases (power station off) of similar durations.

Figures 36 to 39 illustrate a marked increase in the degree and intensity of regulation of flows in the upper section of the middle Gordon under Basslink, even when compared to current operational flows. Under Basslink, Section 1 of the middle Gordon becomes a more variable flow environment characterised by:

- a higher incidence of ca 250 cumec discharge from the power station than at present;
- highly variable flows with rapidly changing river levels between 0 and 250 cumec (more than present);
- a more frequent occurrence of very low to zero flows as a result of zero power station discharge than at present;
- a complete loss of large natural flood peaks (as under present conditions).

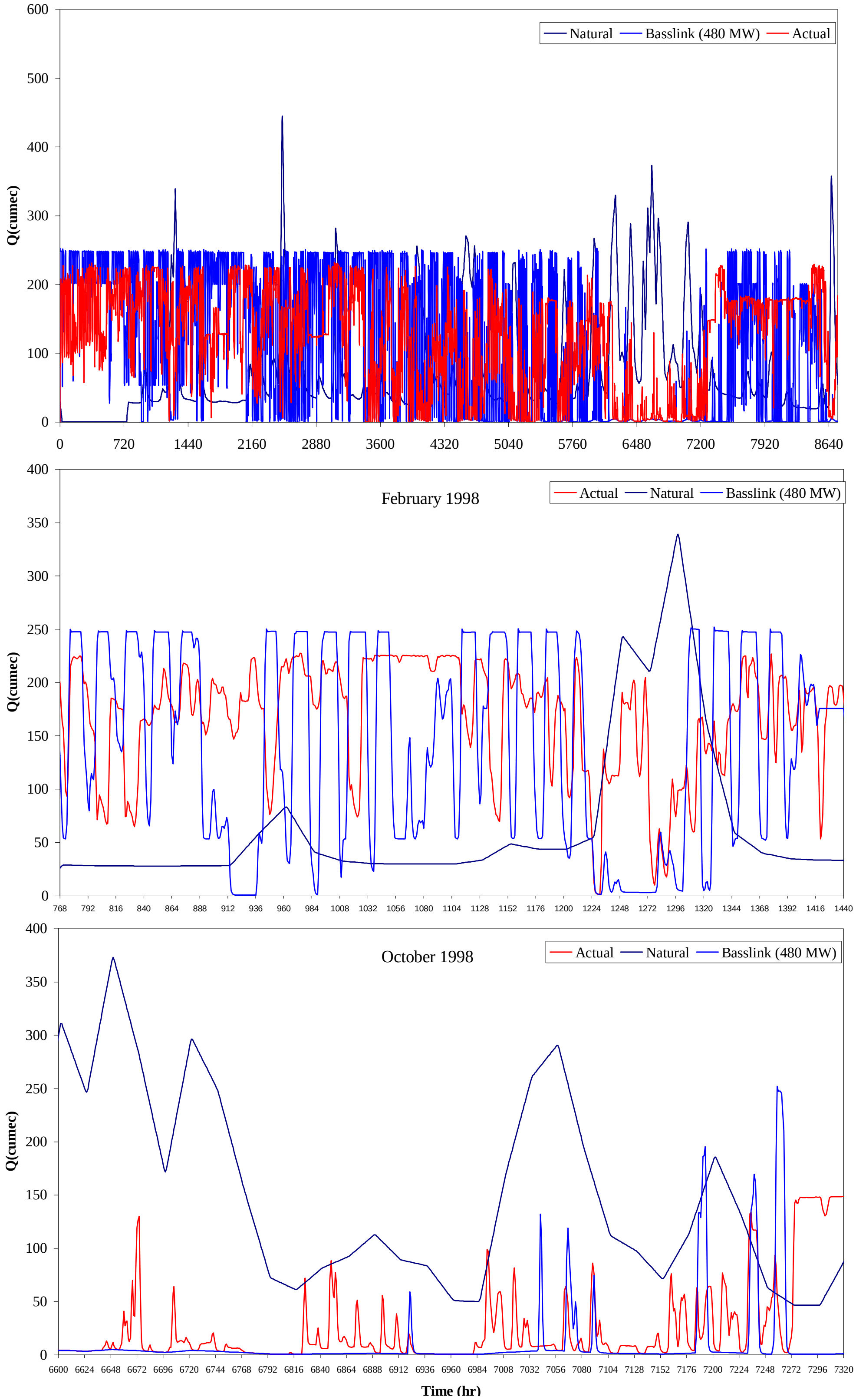


Figure 36. Discharge at site 75 (downstream of the power station), for the 1998 example year, under simulated Basslink scenario, compared with actual (current) and simulated natural conditions, with details for February and October. X axes in hourly time scale, with monthly or daily ticks.

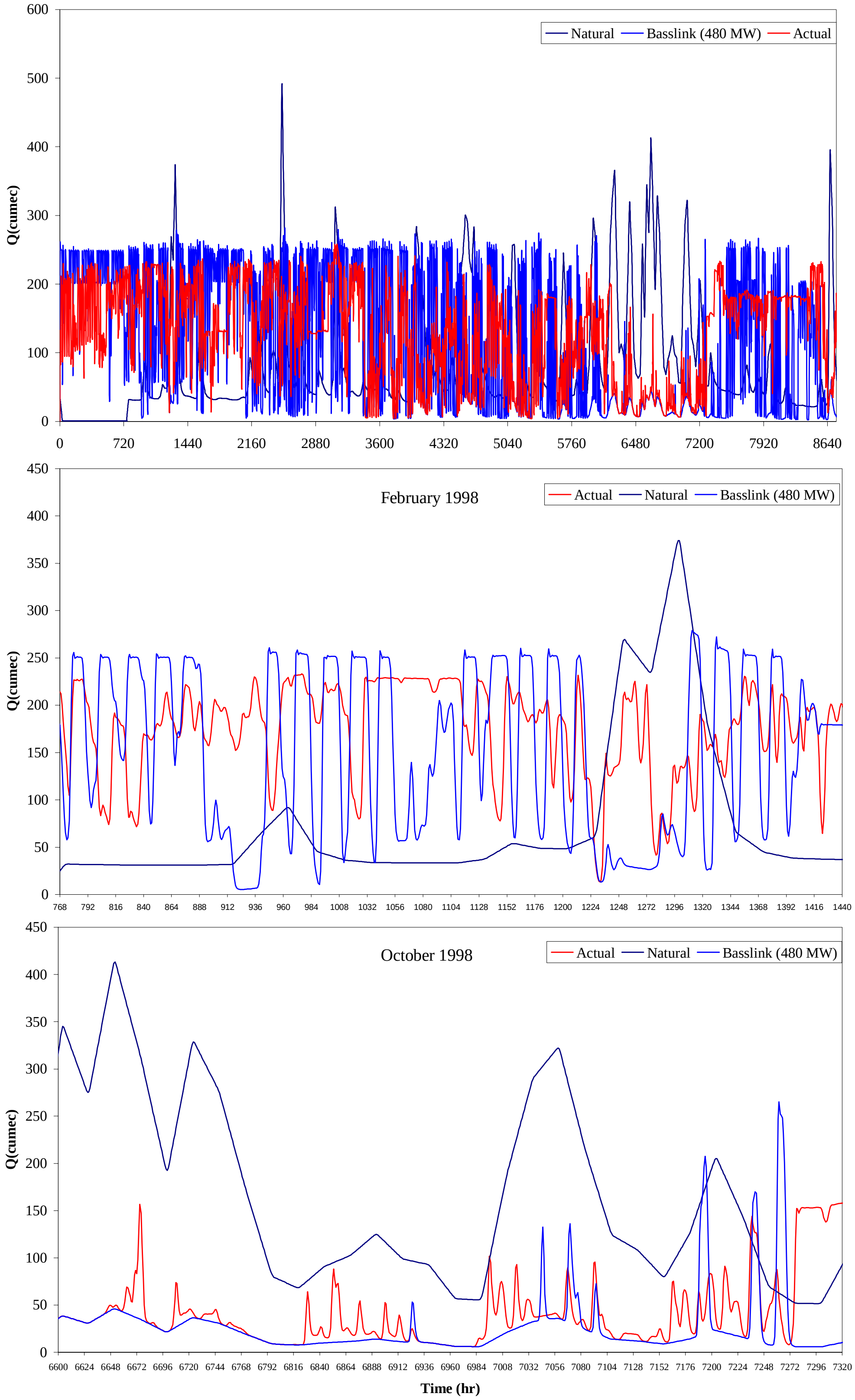


Figure 37. Discharge at site 63 (upstream of the Denison River), for the 1998 example year, under simulated Basslink scenario, compared with actual (current) and simulated natural conditions, with details for February and October. X axes in hourly time scale, with monthly or daily ticks.

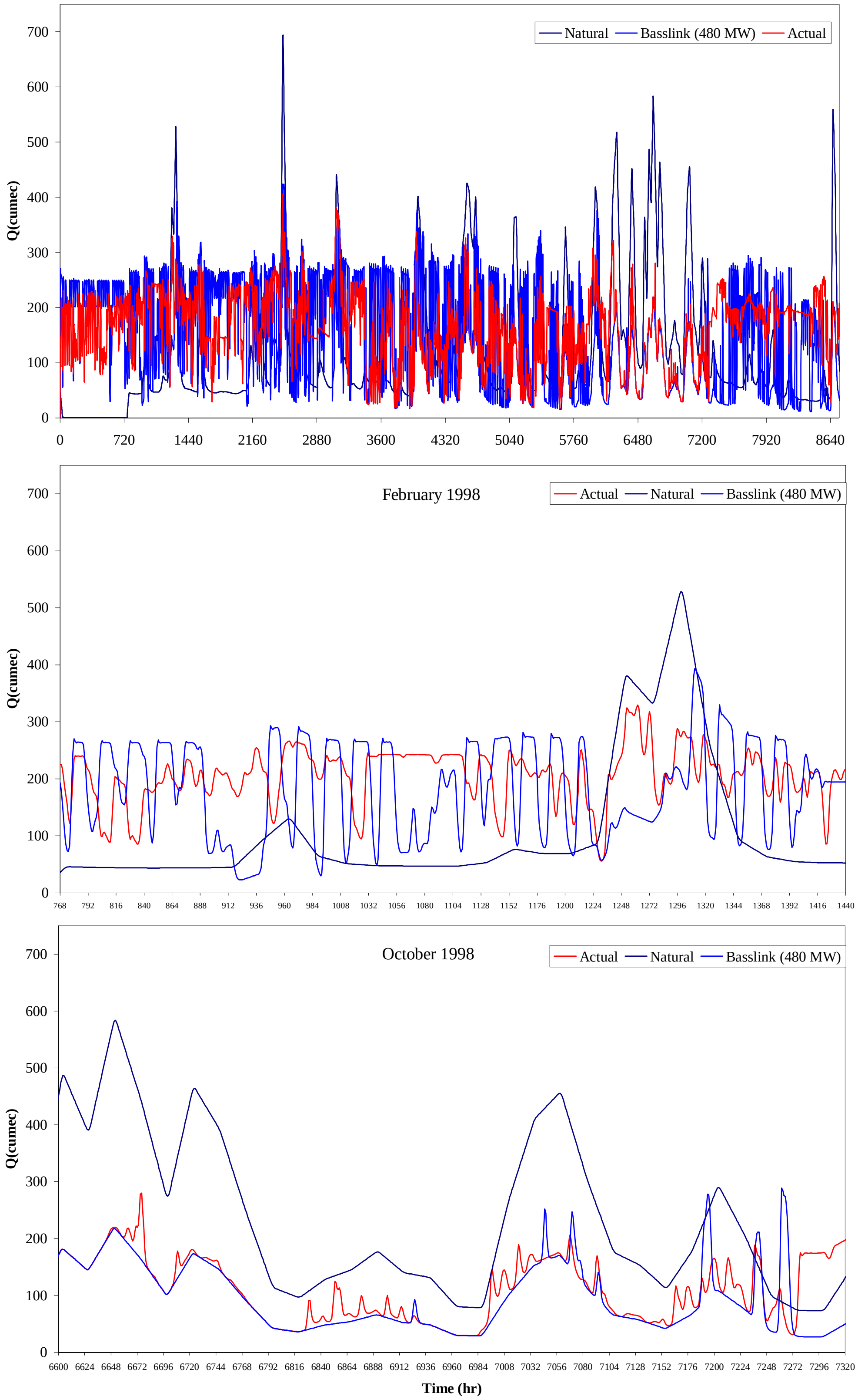


Figure 38. Discharge at site 60 (downstream of the Denison River), for the 1998 example year, under simulated Basslink scenario, compared with actual (current) and simulated natural conditions, with details for February and October. X axes in hourly time scale, with monthly or daily ticks.

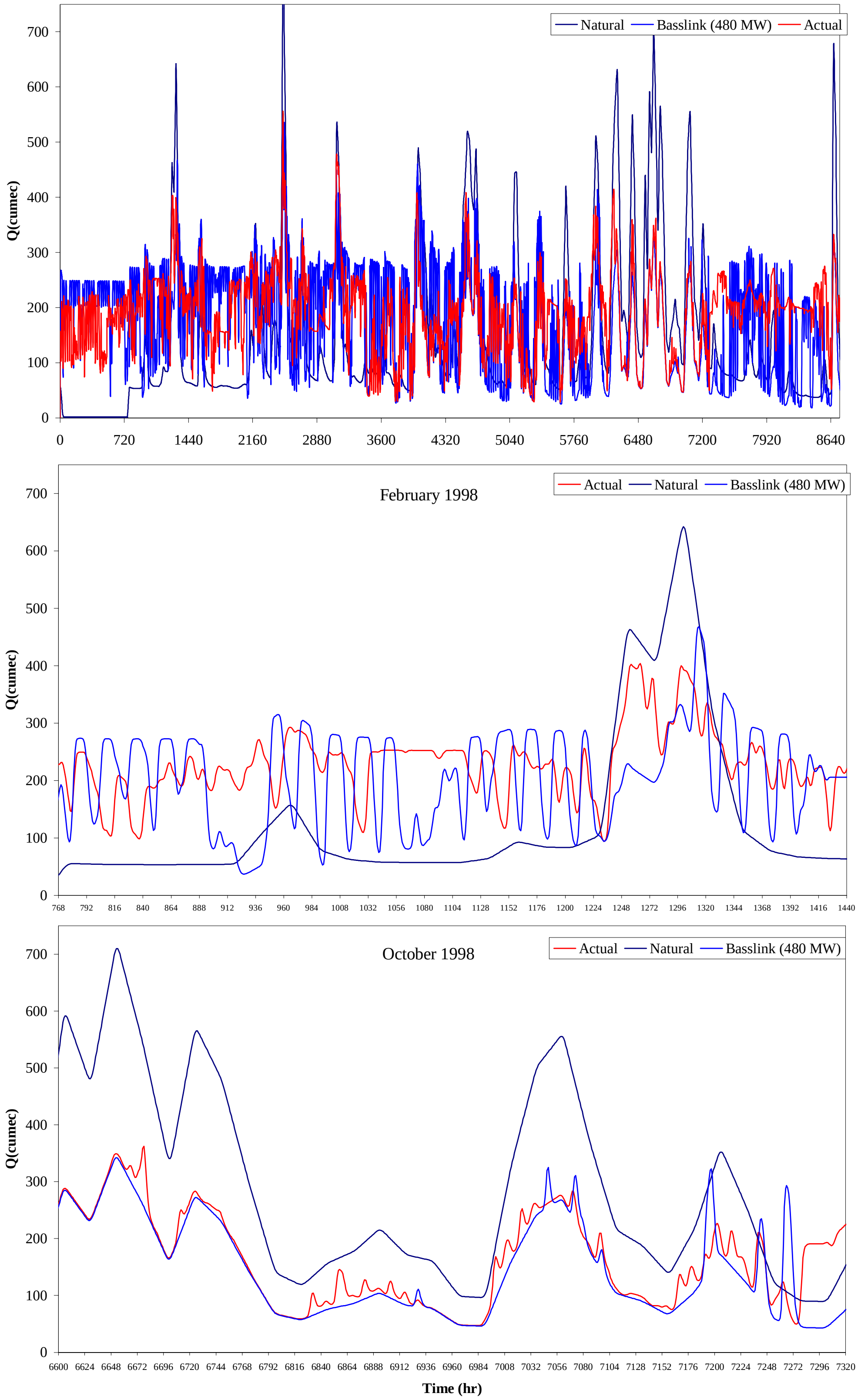


Figure 39. Discharge at site 42 (upstream of the Franklin River), for the 1998 example year, under simulated Basslink scenario, compared with actual (current) and simulated natural conditions, with details for February and October. X axes in hourly time scale, with monthly or daily ticks.

This is therefore an extremely modified flow environment, with few ‘natural’ characteristics.

Examples of changes in hydrology at various locations downstream from the power station are shown in Figures 37 to 39 for sites 63, 60 and 42. Again, flows under a natural, current and Basslink 480 MW scenario are shown for 1998. The change in flow regime at site 63 is essentially identical to that shown for site 75, with the exception of minor increases in flows when the power modification in flow regime between the power station and the Denison River junction.

In Section 2 of the middle Gordon, the flow regimes at sites 60 and 42, upstream of the Franklin River, are also influenced by inputs from the Denison River and the tributaries. However, it is apparent that Section 2 of the middle Gordon still experiences a shift in flow regime under Basslink (Figures 38 and 39) with a highly variable flow environment characterised by:

- a higher incidence of flows in the 250 - 300 cumec range, than at present, dictated by discharge from the power station;
- highly variable flows with rapidly changing river levels between 15 - 30 and 250 cumec (more than at present);
- a more frequent occurrence of low flows as a result of zero power station discharge, than at present, with frequent occurrences of flows in the 15 - 25 cumec range at site 60 and 25 - 50 cumec range at site 42 (all lower than natural base flows);
- partial to complete loss of large natural flood peaks, with only occasional moderate flood-related peaks, and none > 550 cumec (as under current conditions).

During wetter periods (e.g. October 1998), when power station discharges decline significantly and/or cease, a pattern of natural flood peaks can still be observed at sites 60 and 42 (Figures 38 and 39). These are however significantly smaller than would naturally occur, and are again accompanied by very low base- or minimum flows.

Section 2 of the middle Gordon will therefore also experience a more modified flow regime, with few ‘natural’ characteristics.

The flow regime of the middle Gordon under Basslink is changed significantly compared to current and natural conditions, mainly through an increase in the incidence of pulse events (Table 13, also see Palmer *et al*., 2001). Under current conditions, the average number of ‘on-off’ events at the power station was 75 per year in 1997-98. Under Basslink this is projected to increase to 260 ie by 3.5 times. This results in a significantly more variable flow environment for instream biota.

Overseas studies have shown that flow variability at short time steps is the major cause of impact from hydropeaking facilities on instream biota downstream (e.g. Valentin *et al.* 1995, Englund and Malmqvist 1996). Davies *et al.* (1999) found that the variability of flows between days was a key predictor in determining the degree of impact on the macroinvertebrate communities downstream of Tasmanian Hydro power stations. They were not able to conduct their analyses at hourly time steps due to the lack of reliable hourly data.

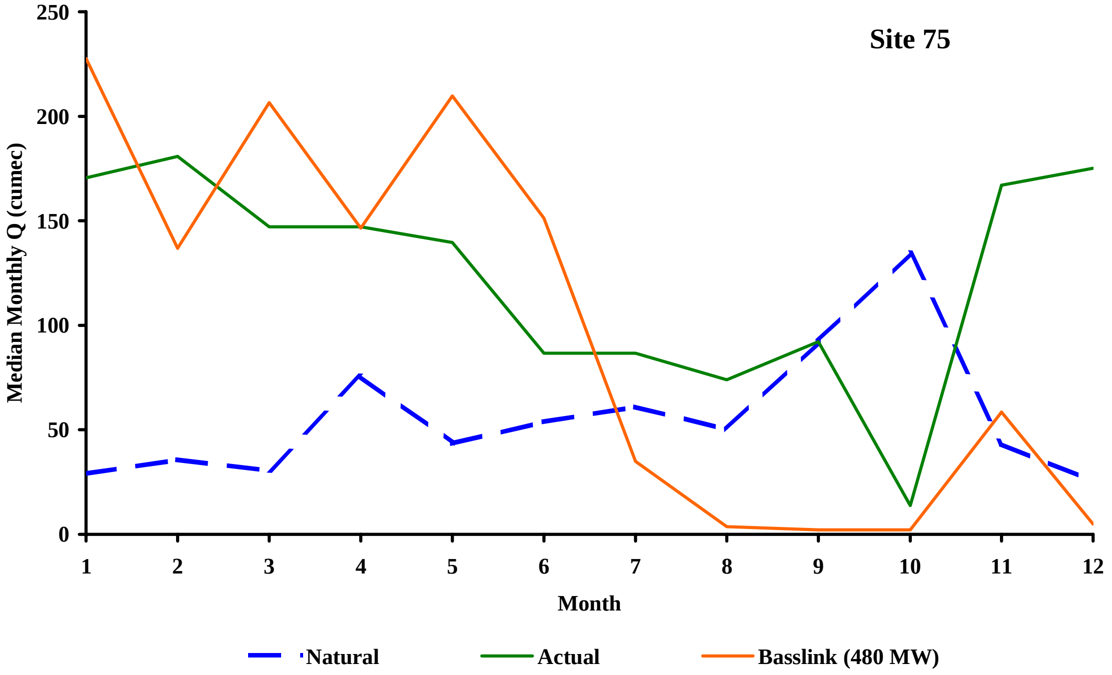
Table 14 illustrates the projected mean and CV of hourly changes in discharge at four sites in the middle Gordon for the 1998 example ‘average’ year. It shows that, despite only slight increases in the size (mean) of hourly time steps under Basslink compared with the current condition, the variability (CV) increase by a factor of 4 at site 75, and remains twice as high for the river downstream, with little attenuation. It should also be noted, however, that the current condition has resulted in hourly changes in discharge that are 20 times more variable than under natural conditions.

Tables 15 and 16 show the number of hourly events in 1998 in which flow decreased or increased by a small amount (<1% ie similar to natural changes), or by a very large amount (> 50% change in discharge in an hour). We selected these event sizes since natural rates of flow change within hourly periods are < 1%, and flow changes of > 50% between 50 and 300 cumec represent very high and biologically significant rates of changes in river height and velocity. These figures are also shown as ratios to natural events of the same magnitude in Tables 15 and 16, and are presented for several sites through the middle Gordon.

There is no significant difference in number of events with a < 1% hourly increase in flow between Basslink and current scenarios. There is only a minor decrease in the number of < 1% decreases in flow under Basslink. By contrast there is a substantial increase in the number of times flows change by > 50% in an hour under Basslink in Section 1 (sites 75 and 63), compared to current operations (Table 15). There is also a substantial increase in the number of hourly flow changes which exceed 50% under Basslink (Table 16), with this increasing in relative importance downstream.

The majority of these large flow change events occur in the range 50 – 200 cumec. This represents a significant increase in the frequency of rapid and large increases in flow, depth and velocity in Section 1, and of rapid, large decreases in these parameters in Section 2.

The seasonal pattern of flows under natural, current and Basslink scenarios is shown in Figure 40. The reversal and loss of seasonality noted under current conditions in the 1998 example year is further exacerbated under Basslink, with a pronounced reverse seasonal pattern throughout the middle Gordon River.



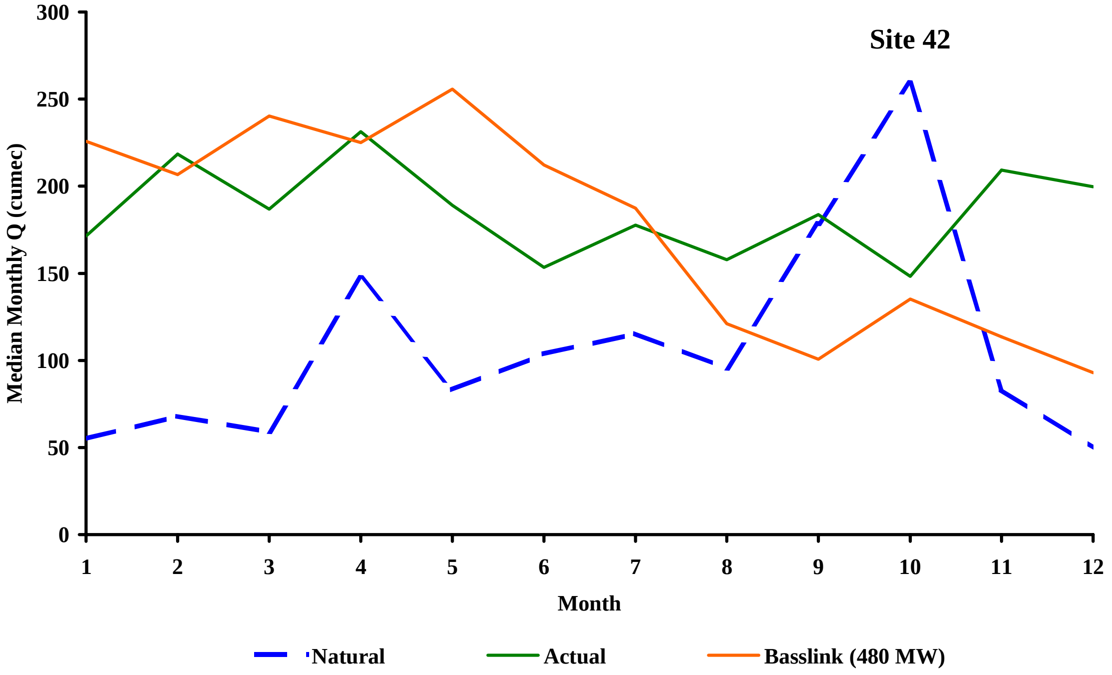


Figure 40. Pattern of monthly median flows at site 75 (2 km downstream of power station), and site 42 (upstream of the Franklin River) for current (‘actual’), simulated natural and simulated Basslink scenarios for the 1998 example year in the middle Gordon.

Note the major reversal in seasonality at site 75 under current conditions, which is further exacerbated under Basslink; and the loss of seasonality at site 42 under current conditions, and partial reversal under Basslink.

Table 13. Mean number of flow ("on/off") events per month, derived from actual (= current) and simulated hourly flow records for 1997-1998, at the Gordon power station.

Month	Natural	PS Actual	Basslink 480MW
January	0	<1	13
February	0	<1	8
March	0	<1	12
April	0	2	24
May	0	5	31
June	0	8	31
July	0	7	43
August	0	19	36
September	0	15	17
October	0	15	14
November	0	<1	17
December	0	3	14
Annual	0	75	260

Table 14. Size (mean) and variability (coefficient of variation) of hourly changes in flow relative to natural flows, under current and Basslink ('cable') scenarios, and their ratio, at four sites in the middle Gordon, for 1998.

Size and Variability Downstream Trend 1998

Hourly flow changes relative to natural flows

		How Big? Mean			*How Variable?* CV		
Site		Current	Basslink	Ratio	Current	Basslink	Ratio
75	d/s power station	1.07	1.63	1.53	22.90	100.25	4.38
63	u/s Denison	1.01	1.06	1.04	6.85	15.86	2.31
60	d/s Denison	1.00	1.02	1.01	4.02	9.26	2.31
42	u/s Franklin	1.00	1.01	1.00	2.74	5.87	2.14

Table 15. Number of hourly flow *decreases* that are < 1% (ie small) or > 50% (very large) relative to natural flows (N), and their ratio(C/Natural), at four sites in the middle Gordon, for 1998.

Flow Decreases
Downstream Trend
1998

Hourly flow changes relative to natural flows

How many?

Site			<1% decrease Current	<1% decrease Basslink	<1% decrease Ratio	>50% decrease Current	>50% decrease Basslink	>50% decrease Ratio
75	**d/s power station**	**C/Natural**	0.45	0.49	1.09	180	669	3.72
		N	1480	1610				
63	**u/s Denison**	**C/Natural**	0.42	0.41	0.97	0	92	na
		N	1366	1327				
60	**d/s Denison**	**C/Natural**	0.48	0.46	0.95	0	0	na
		N	1580	1501				
42	**u/s Franklin**	**C/Natural**	0.53	0.40	0.75	0	0	na
		N	1740	1310				

Table 16. Number of hourly flow *increases* that are < 1% (ie small) or > 50% (very large) relative to natural flows (N), and their ratio (C/Natural), at four sites in the middle Gordon, for 1998.

Flow Increases
Downstream Trend
1998

Hourly flow changes relative to natural flows

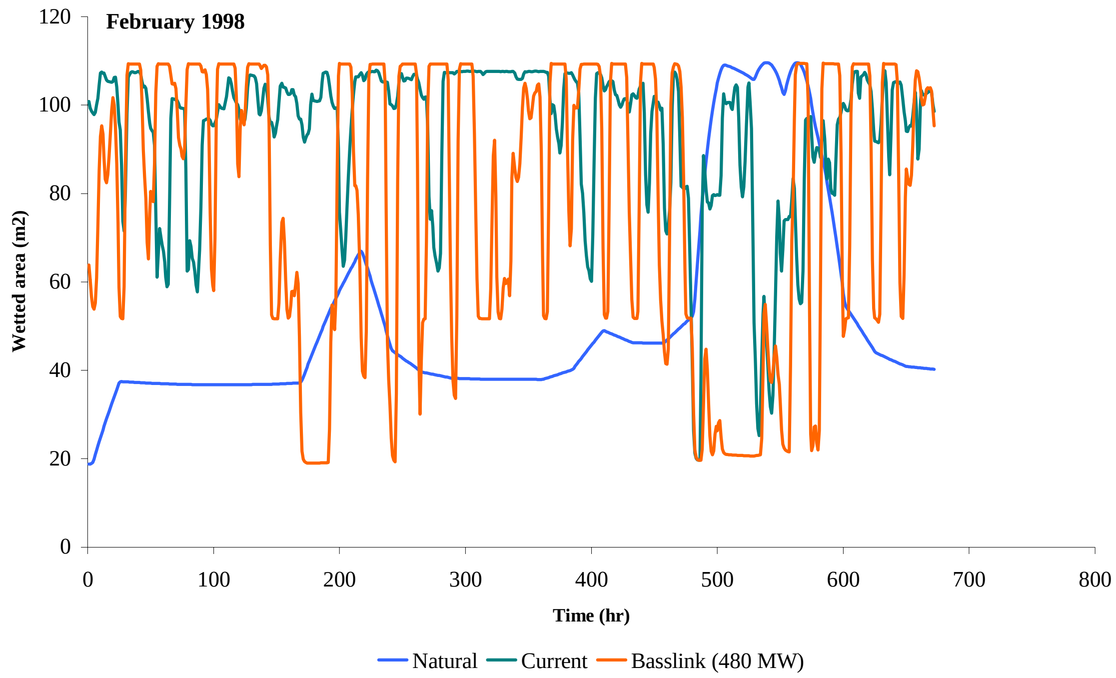
How many?

Site			<1% increase Current	<1% increase Basslink	<1% increase Ratio	>50% increase Current	>50% increase Basslink	>50% increase Ratio
75	**d/s power station**	**C/Natural**	0.86	0.64	0.74	93.0	172.3	1.85
		N	1262	933		372	689	
63	**u/s Denison**	**C/Natural**	0.78	0.70	0.90	42.3	172.3	4.08
		N	1140	1021		169	691	
60	**d/s Denison**	**C/Natural**	0.77	0.66	0.86	na	na	8.90
		N	1126	969		42	374	
42	**u/s Franklin**	**C/Natural**	0.81	0.66	0.82	na	na	30.50
		N	1182	967		4	122	

Velocities and depths will be significantly more variable under a Basslink flow regime, and the area of wetted channel will vary more compared to current conditions. Figure 41 shows a plot of projected mean water column velocities and wetted area of channel for the deepest point of the channel for bar habitat in study reach 03 during February 1998 under current, simulated natural and simulated Basslink flow scenarios. A much greater frequency of large swings in both velocity and wetted area are a feature of flows under Basslink, with wetted area dropping well below that experienced under natural baseflows at the same time of year. Declines of up to 82% in wetted channel area over periods ranging between 5 and 30 hr are experienced several times a month. This pattern persists throughout Section 1.

In Section 2, the intensity of these fluctuations is slightly diminished, but still biologically significant, as shown for bar habitat in study reach 2940 in Figure 32. Velocity fluctuations are frequent but damped compared to study reach 75 (Figure 41). Frequent rapid variations occur between 1 and ca 1.6 m/s, with occasional variation between 0.8 and 1.6 m. While these are large, they do not necessarily indicate a significant ecological impact. The fluctuations in wetted area are severe however, with regular declines of between 50 and 85% in wetted channel area over periods of 10 to 35 hr in duration in direct response to fluctuations in power station discharge. There is therefore little attenuation of the impact of power station operations on cycles of dewatering and inundation of the channel between the upper and lower ends of the middle Gordon.

Basslink therefore represents a further substantial shift in regulation compared with the current condition. The middle Gordon is forecast to develop an even more extremely to highly variable flow regime under Basslink, with short cycling of river levels interspersed with tightly constrained high flows, coupled with a complete loss of natural high flood peaks (as at present). An area of river channel will be repeatedly exposed to much more frequent rapid cycles of wetting and exposure, over and above current conditions. Thus the existing 'intertidal zone', characterised by low biological value (as habitat) and considerable biological risk (due to stranding mortality), will be extended further toward the channel centre. The implications of these changes to the instream fauna are discussed in the following section.



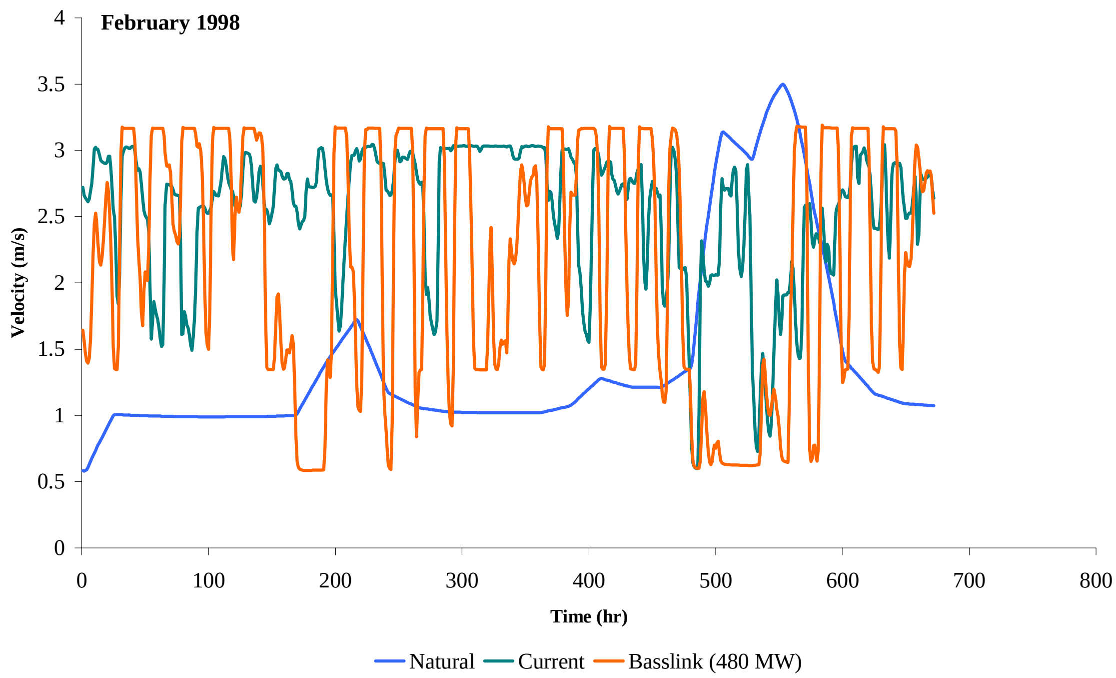
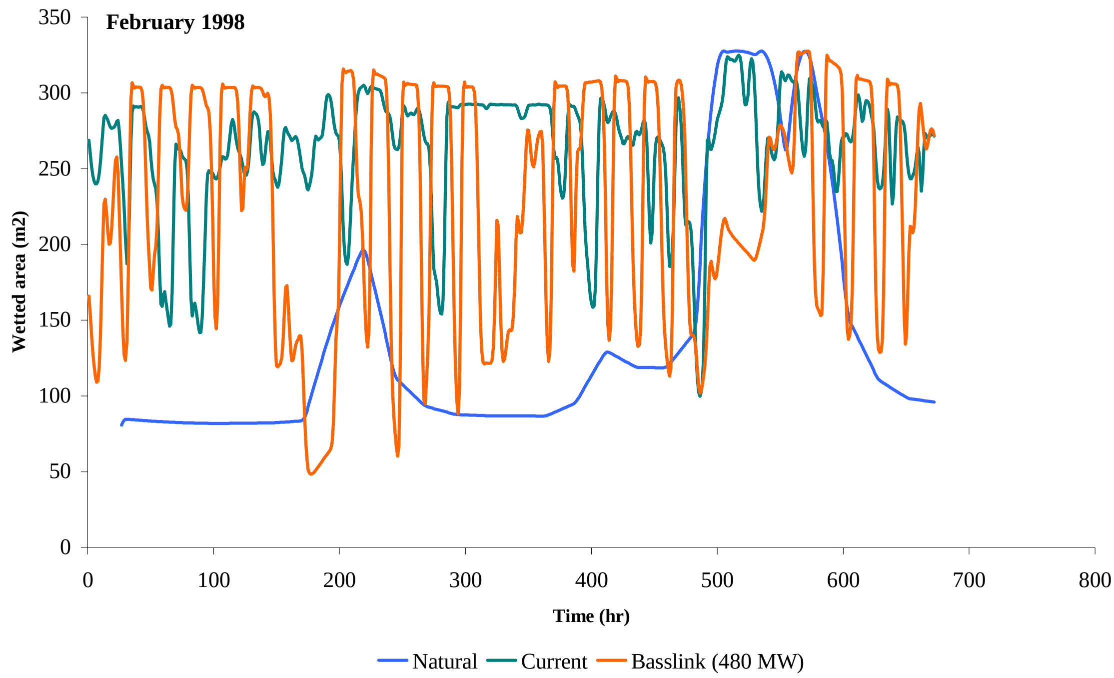


Figure 41. Plot of wetted area of river bed and mean water column velocity under Basslink, current and natural flow regimes for February 1998. Plot is for bar habitat in study reach 03 (downstream of power station).

Note frequent, severe declines in wetted area, with levels dropping below natural baseflow levels, and rapid fluctuations in velocity between 1.5 and 3.2 m/s, and between 0.5 and 3.2 m/s.



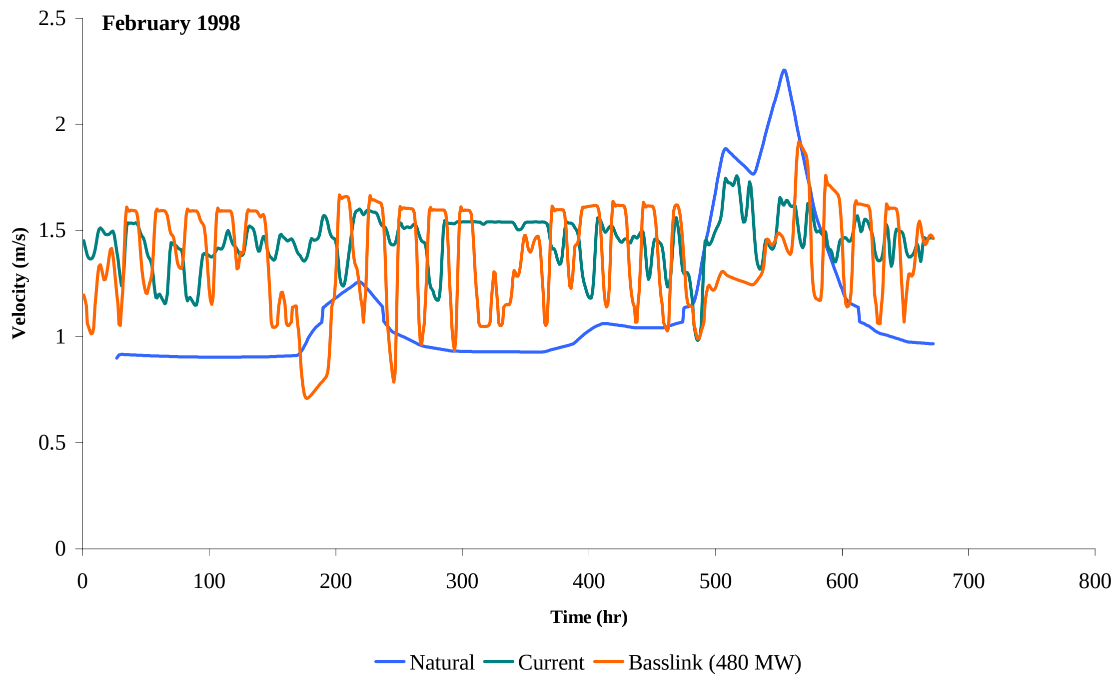


Figure 42. Plot of wetted area of river bed and mean water column velocity under Basslink, current and natural flow regimes for February 1998.

Plot is for bar habitat in study reach 2940 (upstream of the Franklin River in Section 2). Note severe declines in wetted area, and rapid though smaller fluctuations in velocity. Also note partial response to rain event.

4.2 Implications of flow regime changes for instream fauna

4.2.1 Macroinvertebrates

The current flow regime has resulted in a permanent ‘residual’ macroinvertebrate community positioned along the thalweg (point of deepest water), coupled with areas of bank and bars on which a biofilm and macroinvertebrate community is successfully established for up to several months of the year. The existence of the permanent ‘thalweg’ macroinvertebrate community was presented by Davies *et al.* (1999) and has been reconfirmed in this work. Field observations were also made of residual biofilms (composite deposits of algae and organic material on cobbles and boulders) and moss beds on previously submerged bars during the 1995-96 and 1999-2000 surveys. These are often accompanied by hydropsychid net ‘fields’, often of very high density, and comparable with similar fields in wetted sections, as well as macroinvertebrates including eusthenid stoneflies, worms and hydrobiosid caddis larvae found stranded on upper bar slopes during power station shutdowns.

Under the current flow regime, re-establishment of macroinvertebrate communities on these periodically exposed habitats is presumably dependent on the duration of exposure and the rate of loss and re-establishment of the biofilm and/or mosses.

Under natural conditions, minimum flows (or baseflows) resulted in a substantial area of the bed being constantly wetted. For example, natural summer-autumn (December to April) baseflows for study reaches 03 (in Section 1) and 2940 (in Section 2) typically ranged between 25 - 45 and 35 - 60 cumec, respectively in an average year. Winter-spring (May to November) baseflows ranged between 40 - 65 and 60 - 140 cumec respectively. Results of hydraulic modelling show that this represents 26 - 40% and 35 - 58% of the total stream bed area up to the base of the riparian vegetation being constantly wetted in study reach 03 in summer-autumn and winter-spring. The corresponding figures for study reach 2940 are 23 - 40 and 40 - 91% of total stream bed area.

Under current flow conditions, river levels decline occasionally below baseflow levels (Figures 8 and 9, report section 3.1). Under Basslink these low level events are far more frequent (Figures 37 and 38), with minimum flows causing reductions in wetted area to 15 – 20% of total channel area on over 100 occasions per year (based on 1998 hourly flow data). Under current conditions, this occurred for 1205 hours, or 14% of the year in 1998, and there are substantial portions of the year in which the area originally wetted under natural baseflows remained wetted.

Under Basslink, this is projected to increase to 3330 hours, or 38% of the year. In essence this represents a further contraction of wetted channel habitat for biota compared to current conditions, reducing it by around 30 and 50% in summer-autumn and winter-spring respectively. It also represents a further reduction in the quality and availability of snag habitat for macroinvertebrates, due to more frequent dewatering.

In the 1998 illustrative case, site 75 has a natural baseflow of between 25 and 30 cumec (Figure 8, report section 3.1). This flow is equalled or exceeded for several 1 to 2 month periods under current conditions - a period long enough for at least partial biofilm and macroinvertebrate colonisation of stream substrate which is submerged at these flows (see report section 3.4.1.3). Under Basslink, these events last for only several days to a month, and are much less frequent. Thus, the area inundated at this discharge remained submerged for 12, up to 2 and less than 1 month respectively under natural, current and Basslink 480 MW cable scenarios for the 1998 year. When examining the long term daily flow record, it is apparent that this is a common pattern for all years, with Basslink leading to a reduction in the duration of wetting of lower to mid sections of the channel profile to less than a month. As indicated above, these changes correspond to additional losses of habitat suitable for instream biota, as inundation periods are shorter than those for which substantial colonisation is anticipated.

A similar pattern occurs at sites downstream. Even at site 42 (see Figure 11, report section 3.1), there is a significant reduction in the availability of habitat area which is permanently inundated at flows between ca 20 and 45 cumec, with a much higher frequency of these lower discharges than under current conditions. This effectively represents a loss of between 15 and 50% of wetted habitat for instream biota in summer-autumn and winter-spring respectively due to frequent dewatering events.

Thus, under a Basslink flow regime, there will be:

- a further, significant reduction (30 - 50% in Section 1, 15 – 50% in Section 2) in the area of wetted stream bed that does not currently experience a significant dewatering event;
- high to very high frequency of dewatering of these sections of the channel previously seasonally colonised under current flows, effectively removing the biological potential of those areas.

We conclude that, with Basslink, the middle Gordon will shift from a three-zone to a two-zone system with the channel divided into:

- the channel centre or thalweg, with a permanent macroinvertebrate community and biofilm, which is expected to be more degraded under Basslink;
- a broad 'intertidal' zone with no or very few macroinvertebrates and little or no biofilm, other than some resistant filamentous algae, similar to the 'upper tidal' zone observed under current conditions.

In addition to losses of habitat through dewatering events, the areas of habitat that remain dewatered at minimum flow will experience a greater frequency of short-duration fluctuations in both depth and velocity under Basslink. This will result in a greater frequency of rapid fluctuations in shear stress at the bed. As a result, the 'permanent' community residing along the thalweg is likely to be further reduced in abundance and diversity. This may be enhanced by the greater frequency of water depths between 3 and 5 m along the thalweg, depths which may not be suitable for some taxa (e.g. Attachment 2).

Davies *et al.* (1999) described strong correlations between changes in variability of flows at small time steps (days, in their study) and departure of macroinvertebrate community composition from that observed under natural (or 'reference') conditions – as measured by the O/E index. They also observed correlations between measures of change in flow seasonality (shifts in the pattern of mean monthly flows) and O/E. Their observations indicated a marked change in O/E at small changes in daily flow step variability, while O/E changed gradually as the pattern of seasonality changed. This is consistent with a mechanism in which even small rapid, short term changes in flows lead to disruption of macroinvertebrate behaviour and impact significantly on survival, depending where in the channel profile the changes occur. As indicated earlier, the CV of hourly change in flow under the current flow regime is 20 times higher than the variability under a natural flow regime. We suggest that the 2 to 4 fold further increase in variability in rates of flow change projected under Basslink may have a measurable impact on the macroinvertebrate community lying along the thalweg.

Responses to shifts in flow seasonality are likely to be less sensitive, and are probably dependent on the degree to which flow cues for life-history events (e.g. emergence, breeding, metamorphosis etc) are dependent on links with temperature and photoperiod (Cereghino *et al.* 1997, Cereghino and Lavandier 1998). These links are generally broad and weak. Cereghino *et al.* (1997), Cereghino and Lavandier (1998) and Pardo *et al.* (1998) found that changes in abundance, biomass, life history and growth of trichopteran, plecopteran and ephemeropteran species were dictated by rapid fluctuations in river level associated with hydropeaking, rather than by shifts in flow seasonality or temperature regimes. The further shift toward aseasonality forecast under Basslink is unlikely to have any significant implications for macroinvertebrate community, due to the overriding influence of short term flow variability.

The variability of flows is forecast to increase under Basslink, but more importantly the magnitude and variability of rates of change of flows also increases markedly. The CV of change in mean daily discharge (DeldifCV) is doubled under Basslink. Doubling the value of DeldifCV in Davies *et al.*'s

(1999) equation 1 (below) only reduces the O/Erk value by 10%. However, the relationship in that equation was developed using mean daily flow data. It is highly likely that O/E values are more sensitive to hourly-step flow variations. DeldifCV values calculated at hourly time steps indicate a larger (4 fold downstream of the power station) increase in flow variability under Basslink compared to both current and natural flows (Table 14). We propose that O/E values for the 'thalweg' macroinvertebrate community are likely to decrease more than that predicted by equation 1.

Equation 1 (from Davies *et al.* 1999)

$$\mathbf{O/E_{rk} = 0.943 + 0.160*\ln(TIM1+1) - 1.009*\ln(TIM2+1) - 0.077*\ln(DelDifCV+1)}$$

where adjusted $r^2 = 0.89$, and:

TIM1 = *Changed seasonal timing* - SD of ratios for each month of operational to natural mean proportional monthly flow.

TIM2 = *Changed seasonal timing* - SD of differences for each month between operational and natural mean proportional monthly flow.

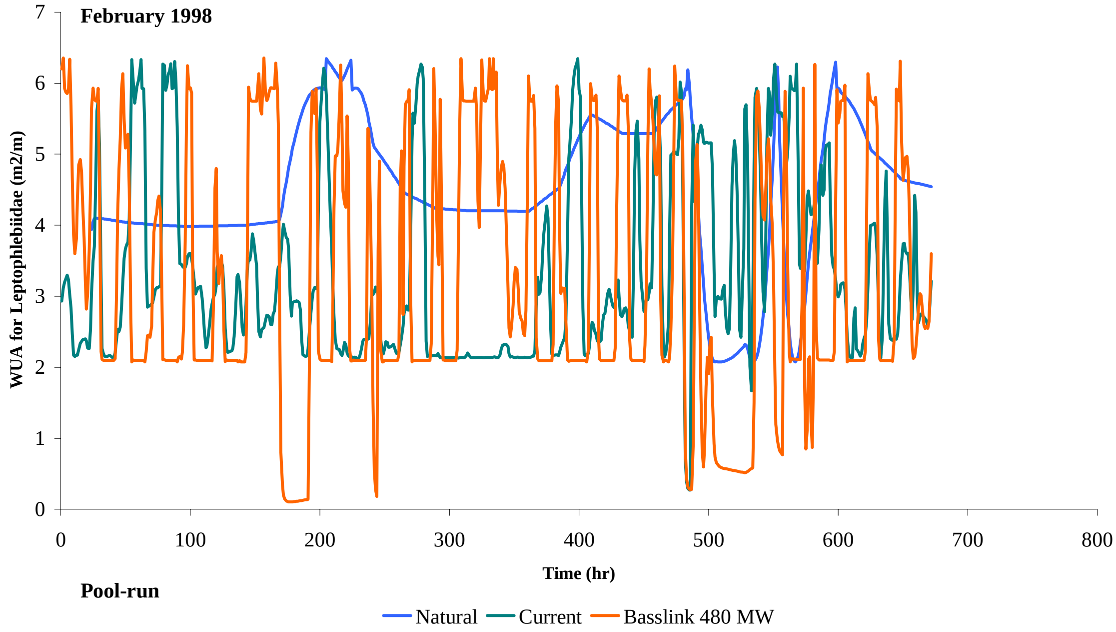
DelDifCV = *Proportional change in CV of daily changes in flow* - Difference between operational and natural flows in CV of daily proportional change in flow.

This may not be substantial, and we would anticipate a reduction of around 0.2 - 0.3 in O/Erk, and 0.1 in O/Epa values for sites in Section 1 under Basslink. This may be sufficient to reduce O/Erk values by one band, with sites in the upper reaches of Section 1 falling in the D or 'extremely impacted' band. We would also anticipate O/E values in Section 2 falling below the A band, with most sites falling into the B or significantly impacted band under Basslink.

Habitat modelling results support the prediction of some impact due to Basslink on macroinvertebrate communities in Section 1 of the middle Gordon. Example habitat (WUA) time-series are shown for natural, current and Basslink scenarios for pool-run and bar habitats for study reach 1215 in Figure 43 for leptophlebiid mayflies. These are broadly representative of most macroinvertebrate taxa. Under Basslink, there is only a slight reduction in habitat availability in bar habitats. However, a substantial increase in the variability of habitat is observed in pool-run habitats, accompanied by occasional severe minima in WUA.

Overall, we conclude that the forecast flow regime under Basslink (with a 480 MW cable), with no provision for minimum flows or other mitigation, will result in:

- for both Sections 1 and 2 - near complete absence of macroinvertebrate fauna in bank and edge habitats, and in upper elevation portions of the bed of the Gordon River due to repeated dewatering, absence of biofilm, and stranding;
- for Section 2 – further reduction in abundance and diversity of macroinvertebrate fauna in areas of river bed that remain wetted during low flows (ie along the 'thalweg') due to frequent, rapid and intense fluctuations in depth, velocity and hence shear stress;
- for Section 2 - further reduction in the quality of channel margins and snags as habitats due to enhanced level fluctuations. These would be exacerbated if erosion and localised sand movement are enhanced under Basslink (see Koehnken *et al*., 2001).



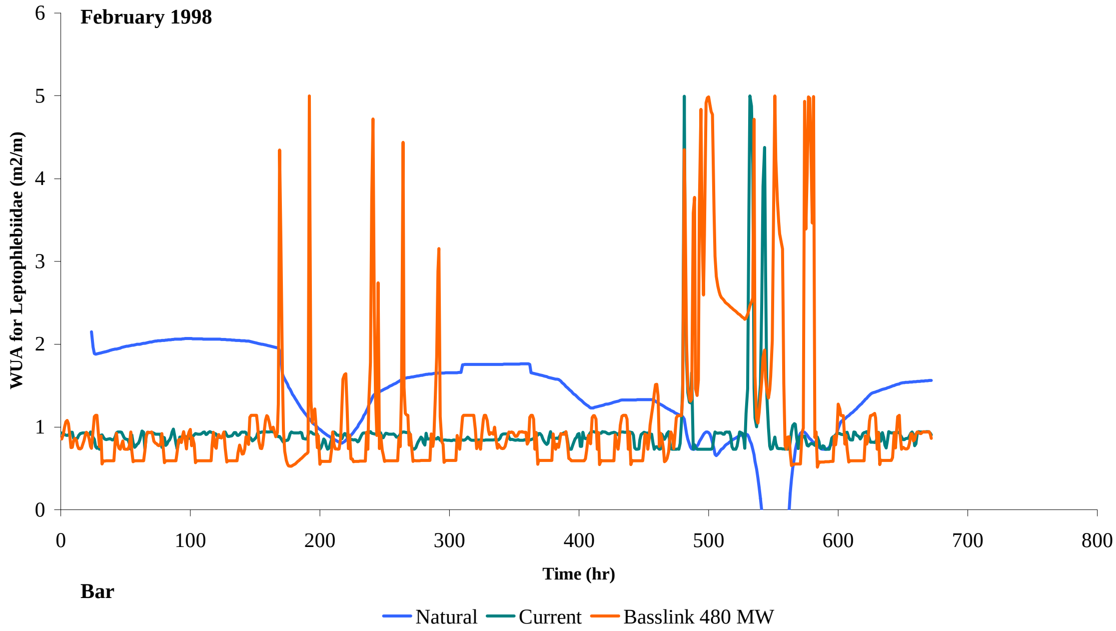


Figure 43. Plots of simulated usable habitat (WUA) for leptophlebiid mayflies at pool-run and bar habitats for study reach 1215 under current, simulated natural and simulated Basslink flow regimes during February 1998.

Note the generally higher variability in habitat availability in the pool-run habitat with occasional severe minima, and slightly lower habitat availability in the bar habitat due to higher peak flows under Basslink compared with the current flow regime.

4.2.2 *Other Vertebrates*

Results for fish are discussed elsewhere (Howland *et al.* 2001). Platypus habitat (WUA) time-series are shown for natural, current and Basslink scenarios for pool-run and bar habitats for study reach 1215 in Figure 44. These plots are typical of all three study reaches and habitat types. Under Basslink, there is no significant reduction in habitat availability, but a substantial increase in the variability of habitat in both pool-run and bar habitats.

These data suggest that Basslink is likely to greatly increase variability in habitat availability, with more frequent peaks in suitable habitat associated with low flows. This does not represent an increase in suitable feeding habitat as most of this will have low to very low macroinvertebrate abundance due to repeated dewatering. Significant areas of instream habitat will remain unsuitable for platypus swimming and foraging due to high velocities when the power station is fully on, as at present.

It is unlikely that mortality due to rapidly rising water levels and high water velocities will substantially increase, as the rates of rise and fall are similar to those occurring under present conditions. However, increased frequency of flow surges may contribute slightly to this under Basslink.

There is unlikely to be any significant change to the passage of platypus under Basslink through the major gorges which constitute a barrier at present. Increased frequency of short-duration low flows may enhance some passage in the gorges of upstream of the Denison River, but this may be offset by their short duration and unpredictability of rapid rise in level as power station commences release again. An increase in the incidence of long shutdowns over weekends, predicted under Basslink, may enhance dispersal opportunities for platypus through gorges and other high flow reaches.

The flow regime forecast under Basslink (with a 480 MW cable), with no provision for minimum flows or other mitigation, will result in reduction in benthic macroinvertebrate food production and availability for platypus and *Hydromys* in Section 1, and potentially in Section 2.

Geomorphological investigations in the middle Gordon indicate (L. Koehnken pers. comm., and Koehnken *et al*., 2001) that under a Basslink (480 MW) scenario:

- initiation and enhancement of bank erosion at sites downstream of Denison River is unlikely; and that
- acceleration of bank erosion upstream of the Denison River may occur but only over very long time scales.

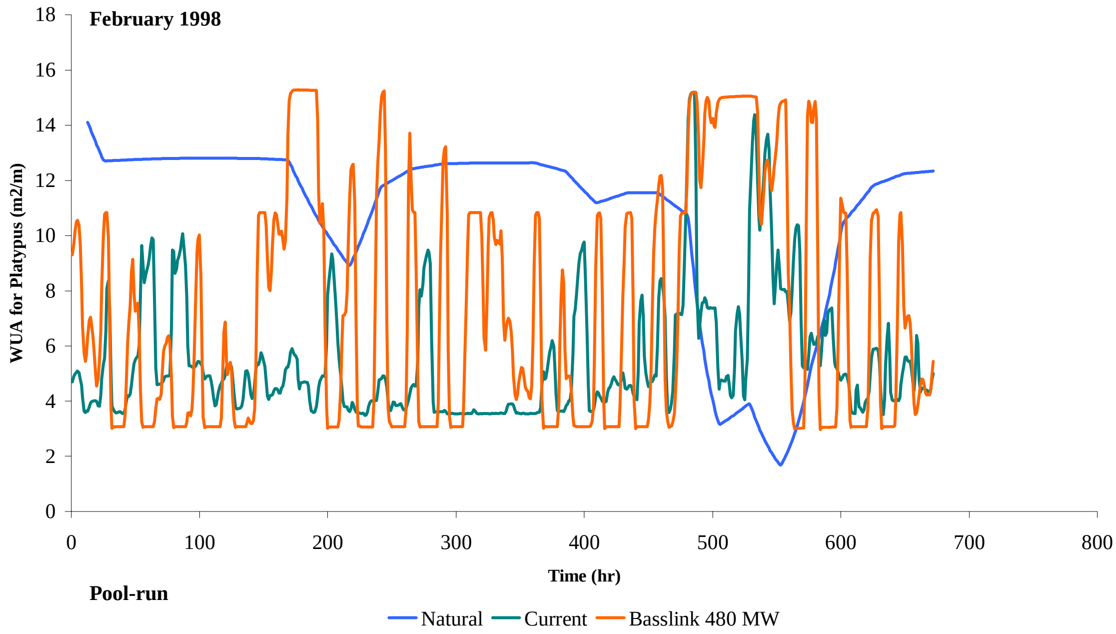
Basslink-induced flow changes are therefore not likely to reduce the availability or stability of platypus burrow sites.

We therefore conclude that Basslink-induced flow changes would only impact further on platypus and *Hydromys* populations by:

- further reduction in food production due to impacts on macroinvertebrate abundance;
- minor potential for increased mortality as a result of increased frequency of rapid level rises, particularly upstream of the Denison River, and particularly for emerging young and dispersing juveniles in autumn-early winter.
- increasing predation risk from raptors and Tasmanian devils on exposed river margins during the lower flow periods predicted under Basslink in late winter-spring.

These impacts are, however, unlikely to be substantial in magnitude.

We therefore believe that there will be no substantial difference in the suitability of conditions for platypus and *Hydromys* in the middle Gordon between Basslink and current operations. Those conditions will continue to remain degraded. Further work is required to establish the status of platypus populations and whether additional measures are required to mitigate any impacts from Hydro generation.



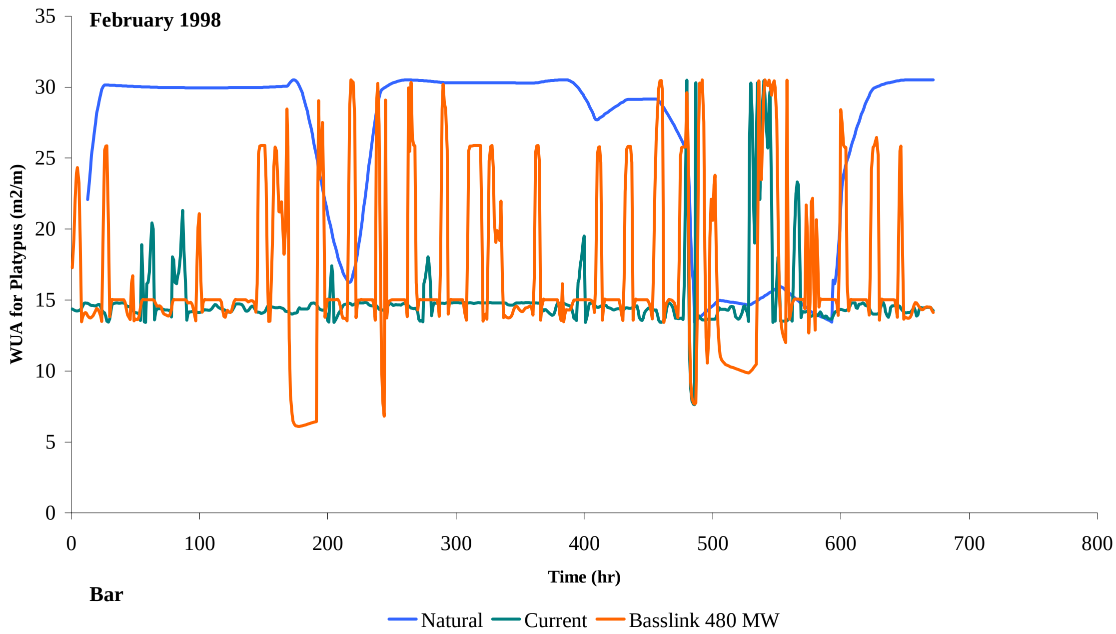


Figure 44. Plots of simulated usable habitat (WUA) for platypus in pool-run and bar habitats for study reach 1215 under current, simulated natural and simulated Basslink flow regimes during February 1998.

Note the higher variability in habitat availability under Basslink compared with the current flow regime.

4.3 Basslink - General Conclusions

Under a 480 MW cable Basslink scenario, the Gordon power station becomes a predominantly hydropeaking power station. The flow regime downstream in the middle Gordon will be dominated by periods of rapidly and widely fluctuating discharge. Compared to current conditions, the frequency of highly fluctuating discharge events would greatly increase. There will be little amelioration of this regime downstream, and rapid fluctuations in depth, velocity, bed shear stress and area of wetted channel would be dominant features of the flow regime as far downstream as the Franklin River junction.

We anticipate that this flow regime would be accompanied by further decreases in diversity and abundance of macroinvertebrates throughout the middle Gordon (as well as fish, see Howland *et al.* 2001). This would be more significant in the section upstream of the Denison River, but would also occur throughout Section 2, downstream of the Denison River.

We also believe that populations of platypus and Australian water rat are likely to experience further negative, though perhaps not substantial, impacts in what is already a degraded environment.

Overall, the middle Gordon River downstream of the Denison River under the proposed Basslink scenario would contain a macroinvertebrate assemblage significantly less diverse and abundant than other, similar rivers of the Gordon catchment and south-western Tasmania.

Key factors unique to Basslink are:

1. the substantial increase in frequency of rapid rates of rise, and particularly, fall in river levels associated with power station discharge pulses;
2. the higher frequency of maximum discharges from the power station during periods of 'full gate' operation.

Key factors which occur under current conditions and are also maintained under Basslink are:

1. the absence of any minimum releases from the power station between peak discharge events;
2. the rapidity of water level changes in response to power station operations.

The following section explores these issues in relation to the potential for mitigation of impacts on the instream fauna of Hydro operations.

5 MITIGATION OPTIONS

5.1 Defining River Management Objectives

There is a pressing need to define specific and detailed objectives for environmental management and mitigation in the Gordon River. While many of these objectives can only be partially quantified, and the flow management rules initially only estimated, we recommend that the principles of adaptive environmental management be used to refine them through feedback between monitoring and management within the socio-economic constraints set for the system.

Instream biological objectives or targets for river management in the middle Gordon can, and should, be stated in numeric terms in order to be of practical use. For macroinvertebrates, this could be in the form of a desired community composition, level of abundance, diversity and or O/E index for various parts of the middle Gordon. For fish, this can include specified catch per unit effort abundance figures for native fish species at specific sites.

Achievement of these targets or objectives can be monitored on an annual or longer timeframe, and values estimated relative to statistically defined bounds. Mitigation options should also be focused on achieving these 'river management objectives' (RMO's).

5.2 Mitigation through flow management

The focus of this discussion on mitigation options is the maintenance of existing biological features of the middle Gordon River, rather than restoration of pre-Hydro conditions. It should be recognised that this is problematic, as there will be ongoing erosional adjustment to the current flow regime in some river sections (Koehnken *et al*., 2001). Current impacts are ongoing and it is unlikely that the river is in a condition of equilibrium with respect to either geomorphological or biological values. Mitigation under any future management scenario, including Basslink, must therefore address both the current and the future incremental impacts resulting from changes to the flow regime.

The only major option available for mitigation of the impacts of Basslink is through appropriate management of flow releases to the river. This could be done through management of the operations and discharge of the Gordon power station, or via releases from the Serpentine or Gordon dam or the provision of a re-regulating structure downstream of the Gordon power station.

We therefore explore the issue of using an environmental flow regime as a tool for environmental management in the middle Gordon River.

Under current conditions the flow regime of the middle Gordon River has very few features that are characteristic of a natural flow regime. The forecast flow regime under Basslink has even less.

In order to maintain the current status of the instream fauna, there is a need to specify an environmental flow *regime* (for a recent Australian example see Gippel and Stewardson 1995). An ideal environmental flow regime should include:

- minimum flows;
- flood sequences with specified magnitudes, return intervals and frequencies for maintenance of channel characteristics and triggering key biological events;
- a seasonal pattern of flows;
- rates of rise and fall of flows which are similar to natural responses to rain events.

The elements which can be incorporated in an environmental flow regime are dependent on the desired target environmental outcome (e.g. RMO). If the goal of management is limited to mitigating any additional impacts which may occur under Basslink, then the target is the current, modified condition. If complete mitigation were being considered, then the entire Hydro generation system should be managed in order to limit additional step events at the Gordon power station under Basslink to a frequency similar to that occurring under current conditions. This is not likely to be a practical proposition, and would also spread the environmental impact across a range of other rivers.

Severe constraints to operations under Basslink limit the extent to which the extremely regulated forecast flow regime can be modified without losing the ability of the Gordon power station to operate as a peakload station. Two key elements are required for some degree of (partial) mitigation of Basslink impacts, which also apply to the current operating conditions – minimum flows and use of flow ramping. Ideally, the environmental flow regime should also include at least one channel forming flood and several minor flood releases at the head of Section 1, as well as a more seasonal pattern than forecast under Basslink, but the options for these are very limited.

The following sections describe the mitigation strategies, and the likely environmental outcomes associated with them.

5.2.1 Minimum Flows

5.2.1.1 Aims

The objective of defining a minimum flow is to ensure that there is a proportion of channel which is protected from dewatering and which maintains a modified but not highly depauperate macroinvertebrate community (as well as habitat for platypus and fish) when the power station is not discharging. Under a Basslink scenario, a minimum flow will:

- eliminate the predicted periods of no or extremely low flows in Section 1, which would otherwise significantly reduce macroinvertebrate populations;
- raise the minimum flows forecast in Section 2 so that they more closely approximate baseflows experienced under natural conditions; and
- result in the maintenance of a permanent, though modified (less abundant and diverse than natural), macroinvertebrate community throughout the middle Gordon.

The results of IFIM habitat-flow modelling were used in a risk analysis, in order to determine the magnitude of a minimum flow. A risk-assessment approach similar to that described by Davies and Humphries (1995) was used for defining minimum flows in the South Esk, Meander and Macquarie Rivers (Tasmania). The approach is described in report section 2.5.2.8, and uses habitat availability (quantified as WUA) as a measure of biological suitability under varying flows by comparison with values under a reference flow. Due to the high variability of flows under current conditions, natural baseflows were used as reference flows, in part because they represent the only flow conditions in which instream habitat along the thalweg was known to be in partial equilibrium. All aquatic biota were included in this analysis ie fish, macroinvertebrates and platypus.

5.2.1.2 Results

Hydraulic modelling indicates that wetted area of stream bed, as well as habitat area for most taxa, had a curvilinear relationship with discharge for all study reaches. Most gain in wetted area and habitat area occurs between 0 and ca 50 cumec (e.g. see Figures 23 - 29). Thus, a minimum environmental flow is likely to fall within this flow range.

The outputs of the risk assessment for all biological variables (including fish, see Howland *et al.* 2001) and study reaches are too large to be shown here (see Attachment 3). An example of %ΔHA values are shown for study reach 03 in Table 17, along with the overall minimum value derived from all variables. These are then shown as risk classes in Table 18.

Table 17. Example of final %ΔHA values for several biota/variables for study reach 03 in winter--spring, for discharges from 2 to 108 cumec, along with the overall minimum values at each discharge.

Bold numerals indicate the values at the reference discharge. See Attachment 3 for all values by habitat and study reach.

	Macroinvertebrates								Overall
Q	*Heterias*	Leptophlebiidae	Orthocladiinae	Simulidae	N Taxa	Tot. Abund.	Platypus	Lamprey juv.	Minimum
2	33.9	54.1	27.1	3.8	61.1	50.4	81.1	27.0	3.8
7	34.9	57.1	46.2	5.6	76.7	63.5	89.4	50.2	5.6
12	43.1	64.6	54.4	10.3	82.6	66.9	86.4	43.9	10.3
15	48.4	68.9	61.1	13.3	89.2	71.1	105.7	82.1	13.3
17	50.5	70.5	65.6	15.3	91.3	74.6	104.0	86.4	15.3
22	54.7	73.3	75.3	23.7	94.2	82.7	101.1	103.7	23.7
25	59.6	76.0	82.5	36.9	96.3	86.3	105.8	112.5	36.9
28	60.8	76.8	83.9	40.5	96.7	86.9	104.3	110.8	40.5
32	65.4	79.7	87.1	50.1	97.4	88.9	100.5	108.4	50.1
37	74.8	85.5	90.5	62.7	98.6	92.1	107.5	103.1	62.7
42	84.7	91.1	93.8	75.4	99.2	95.2	105.1	99.6	75.4
47	93.1	96.1	97.4	88.0	99.8	98.1	103.0	98.8	88.0
50	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
55	101.9	101.1	100.8	105.7	100.0	100.4	98.4	98.8	97.5
57	103.7	101.6	101.2	110.5	99.9	100.6	96.4	96.0	95.0
62	106.2	101.7	101.6	119.6	99.4	100.6	92.2	89.5	89.5
67	108.9	101.0	101.9	128.3	98.8	100.5	88.4	84.1	84.1
68	108.9	100.7	101.8	129.7	98.7	100.5	87.9	83.4	83.4
72	111.0	99.5	101.8	136.5	98.2	100.2	85.1	80.7	80.7
81	113.8	95.9	100.8	149.9	96.8	98.8	82.5	74.6	50.0
94	112.9	87.7	98.1	165.6	95.4	95.3	88.5	94.4	78.9
108	112.1	80.4	95.6	175.2	94.0	92.2	86.2	111.4	76.0

Table 18. Example of risk categories derived from the %ΔHA values shown in Table 17 (using the method described in report section 2.5.2.8), along with the overall risk at discharges from 2 to 108 cumec.

The values at the reference discharge are shown in bold.

	Macroinvertebrates								Overall
Q	*Heterias*	Leptophlebiidae	Orthocladiinae	Simulidae	N Taxa	Tot. Abund.	Platypus	Lamprey juv.	Risk
2	III	III	IV	IV	II	III	II	IV	IV
7	III	III	III	IV	II	II	I	III	IV
12	III	II	III	IV	II	II	I	III	IV
15	III	II	II	IV	I	II	I	II	IV
17	III	II	II	IV	I	II	I	I	IV
22	III	II	II	IV	I	II	I	I	IV
25	III	II	II	III	I	I	I	I	III
28	II	II	II	III	I	I	I	I	III
32	II	II	I	III	I	I	I	I	III
37	II	I	I	II	I	I	I	I	II
42	II	I	I	II	I	I	I	I	II
47	I	I	I	I	I	I	I	I	I
50	**I**	**I**	**I**	**I**	**I**	**I**	**I**	**I**	**I**
55	I	I	I	I	I	I	I	I	I
57	I	I	I	I	I	I	I	I	I
62	I	I	I	I	I	I	I	I	I
67	I	I	I	I	I	I	I	II	II
68	I	I	I	I	I	I	I	II	II
72	I	I	I	I	I	I	I	II	II
81	I	I	I	I	I	I	II	II	III
94	I	I	I	I	I	I	I	I	II
108	I	II	I	I	I	I	I	I	II

Figure 45 shows a plot of the overall minimum %ΔHA value at each study reach, plotted against discharge for the two seasonal periods. The slope of the limbs is steep around the reference discharge, showing that the range of flows for which there are no risks (ie within the 'I' category) is small.

The degree of environmental risk associated with several minimum discharge ranges in shown in Table 19. Those taxa which experience significant habitat loss at each flow range relative to the reference flow are also shown in Table 19. Flows falling within the ranges shown for the II band lead to some habitat loss for a number of taxa, most notably Simuliids, Orthoclads and *Heterias pusilla*.

The sensitivity of minimum flows to the %ΔHA values of individual biota can be explored by examining the tables in Attachment 3. However, a simpler method is to plot the %ΔHA values for the biota with the lowest values at each discharge, against discharge. These plots are shown for reach 03 in Figure 46. They show that a number of taxa have %ΔHA values falling below the minimum risk I threshold close to the reference discharge, and that the method of selecting the minimum %ΔHA value is therefore not overly conservative.

Based on these risk categories, we make the following specific recommendations for minimum discharge into study reach 03 of the middle Gordon River, immediately downstream of the power station:

- a minimum discharge of between 19 and 26 cumec should be maintained at all times in the months of December to May; and
- a minimum discharge of between 36 and 66 cumec should be maintained in the months June to November.

If discharges fall below these levels significant risks to the integrity of the biota will occur due to habitat loss (see Table 19).

This recommendation is based on the desire to minimise impact on aquatic biota by providing the minimum flows to maintain risks within categories I and II.

While it is desirable to maintain minimum flows within the optimum range described for band I, examination of the risk curves reveals that if flows fall within the upper part of the range for band II:

- only three taxa show a habitat response relative to the reference baseflow discharge condition; and that
- these taxa potentially experience only small losses in habitat relative to the reference discharge.

Flows falling within the ranges shown for risk band III lead to substantial habitat loss (ca 70%) for up to five macroinvertebrate taxa (Simuliidae, Orthocladiinae, *Heterias pusilla*, Leptophlebiidae and Chironominae). It is likely therefore that an effective minimum environmental flow would still be provided if discharges fell within the ranges for both bands I and II, though preferably in the middle to upper end of those ranges.

In order to assess this we examined the implications of habitat loss in the minimum flow risk bands I to III for macroinvertebrate community composition. All of the taxa affected by some degree of habitat loss in flow risk bands I to III, with the exception of *H. pusilla*, are included in the list of taxa predicted for sites in the Gordon by the Hydro RIVPACS model developed by Davies *et al.* (1999). Using the list of pseudo-taxa (taxa and rank abundances) predicted for these sites by the rank abundance model, a conservative estimate can be made for changes in O/Erk at differing minimum flows. The term conservative is used here because any estimate based purely on habitat losses at low flows has to also take into account the issue of additional stresses from increased flow and depth variability resulting from Basslink operations. Thus, any changes in O/Erk under Basslink will be largely a result of changes in hydraulic variability during power station operation (see section 4.2.1). They are also influenced, however, by changes in habitat availability/suitability under low flows (ie when the power station is not operating).

Estimates of O/Erk for differing minimum flow mitigation options were requested by Hydro. The values shown in Table 20 are ‘best guess’ estimates only and not formal predictions of O/Erk values. It should be noted here that changes in O/Erk are a product of loss of taxa (families) as well as reductions in relative abundance resulting in reductions in relative abundance the latter represented by loss of rank abundance categories (or ‘pseudotaxa’ in the model).

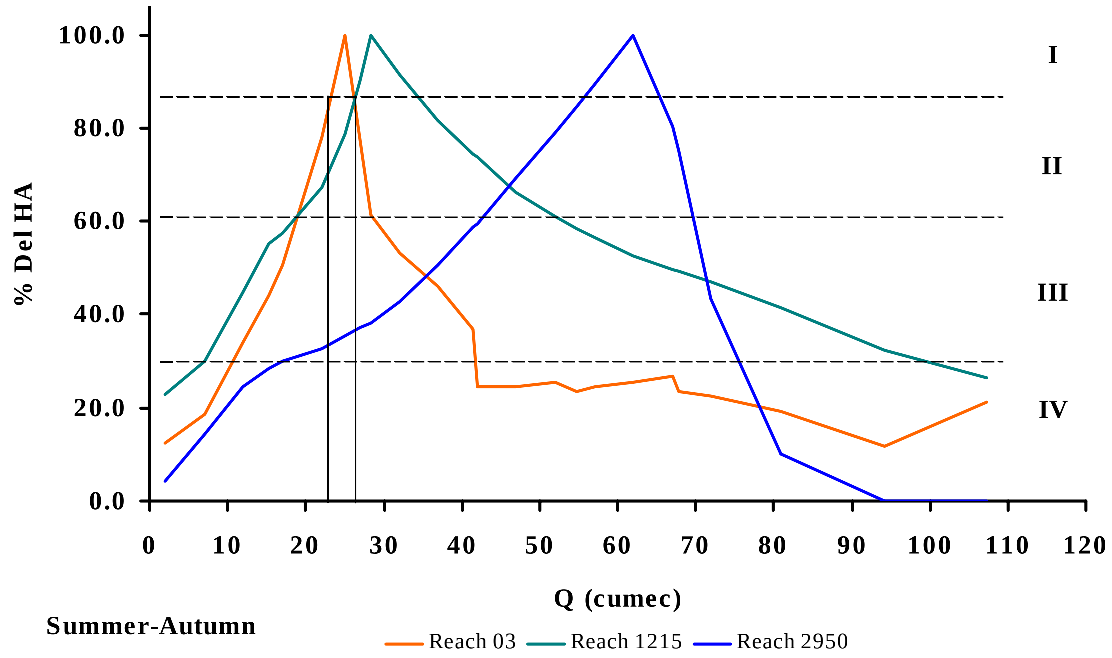
On examination of these values, it is apparent that there is little difference in O/Erk between risk levels I and II. Risk level II results in a decline in habitat availability for simuliids from ranging from 20-40% in both summer-autumn and winter-spring (see Figure 46), but no significant decline in habitat availability for any other taxon. Thus O/Erk values are not significantly different between risk levels I and II under the forecast Basslink flow regime, even when assuming loss of habitat is linearly correlated to reduction in abundance.

Therefore, we recommend that minimum mitigation flows under Basslink should fall in the range 19-26 cumec in summer-autumn (December to May) and 36-66 cumec in winter-spring (June to November).

Table 19. Risks to instream fauna associated with the adoption of minimum environmental flows of different magnitudes (Q, in m^3/s) for the three study reaches in the middle Gordon. Note that values for reach 03 represent flows at the head of Section 1.

		I No risk or beneficial	II Moderate risk	III High risk	IV Very high risk
Summer-autumn					
Reach 03	**Q**	**23 - 26**	**19 - 23**	**11 - 19**	**< 11**
	Taxa with significant habitat loss		**Simuliidae, Ammocoetes**	**TA, Simuliidae, *Heterias*, Orthoc.**	**TA, Simuliidae, *Heterias*, Chiron., Orthoc., platypus, Shortfin eel, Ammocoetes, *Salmo trutta* adult (WA)**
Reach 1215	**Q**	**26 - 35**	**19 - 26**	**7 - 19**	**< 7**
	Taxa with significant habitat loss		**Simuliidae, *Heterias*, Leptophlebiidae**	**TA, Simuliidae, *Heterias*, Leptophlebiidae, Chiron., Orthoc., *S. trutta* spawning. (WA)**	**TA, NT, Simuliidae, *Heterias*, Leptophlebiidae, Chiron., Orthoc., Hydrobiosidae, *S. trutta* spawning & adults (WA)**
Reach 2940	**Q**	**55 - 66**	**42 - 55**	**17 - 42**	**< 17**
	Taxa with significant habitat loss		**Simuliidae, Orthoc. (WA)**	**Simuliidae, Orthoc., Chiron. (WA)**	**TA, Simuliidae, *Heterias*, Orthoc., Chiron., *S. trutta* adults (WA)**
Winter-spring					
Reach 03	**Q**	**46 - 66**	**36 - 46**	**24 - 36**	**< 24**
	Taxa with significant habitat loss		**Simuliidae, *Heterias***	**TA, Simuliidae, *Heterias*, Leptophlebiidae, Orthocladiinae**	**TA, NT, Simuliidae, Leptophlebiidae, *Heterias*, Chiron., Hydrobiosidae, Orthoc., Shortfin eel, Ammocoetes, *S. trutta* adults & spawning. (WA)**
Reach 1215	**Q**	**49 - 63**	**38 - 49**	**25 - 38**	**< 25**
	Taxa with significant habitat loss		**Simuliidae, *Heterias*, Leptophlebiidae**	**TA, NT, Simuliidae, *Heterias*, Leptophlebiidae, Chiron., Orthoc., Hydrobiosidae, *S. trutta* spawning. (WA)**	**TA, NT, Simuliidae, *Heterias*, Leptophlebiidae, Chiron., Orthoc., Hydrobiosidae, *S. trutta* spawning & adults, ammocoetes. (WA)**
Reach 2940	**Q**	**73 - 96**	**54 - 73**	**31 - 54**	**< 31**
	Taxa with significant habitat loss		**Simuliidae, Orthoc. (WA)**	**TA, Simuliidae, Orthoc., Chiron. (WA)**	**TA, NT, Simuliidae, *Heterias*, Orthoc., Chiron., *S. trutta* adults (WA)**

WA = wetted area, NT = number of macroinvertebrate taxa, TA = total macroinvertebrate abundance, Orthoc. = Orthocladiinae, Chiron. = Chironominae, Ammocoetes = early life stage of the lamprey Geotria australis.



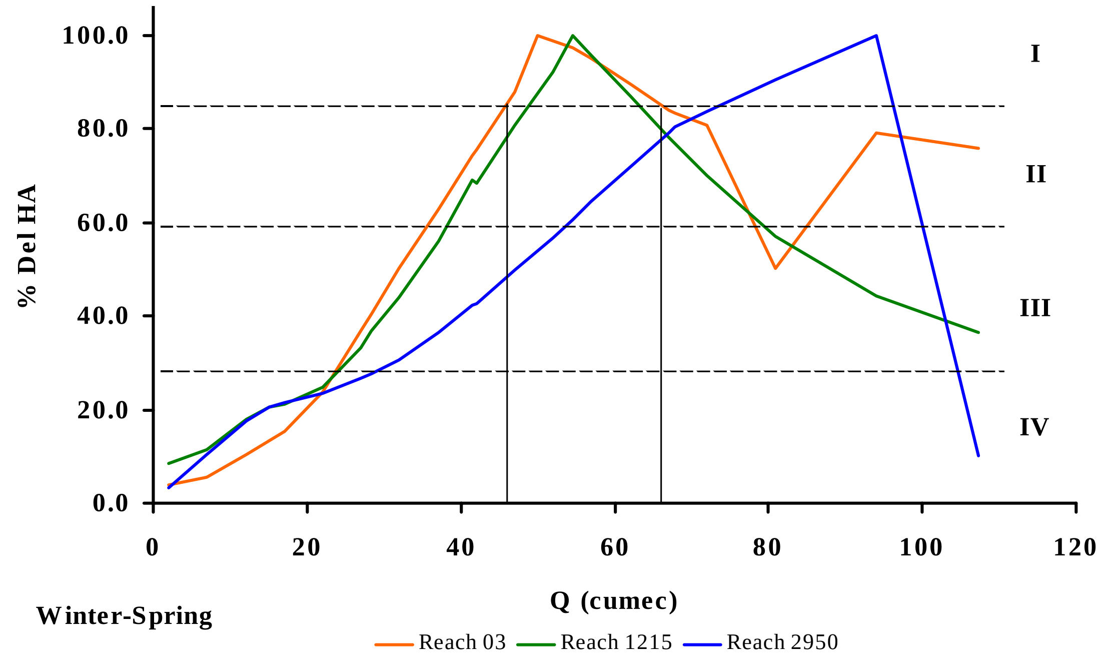
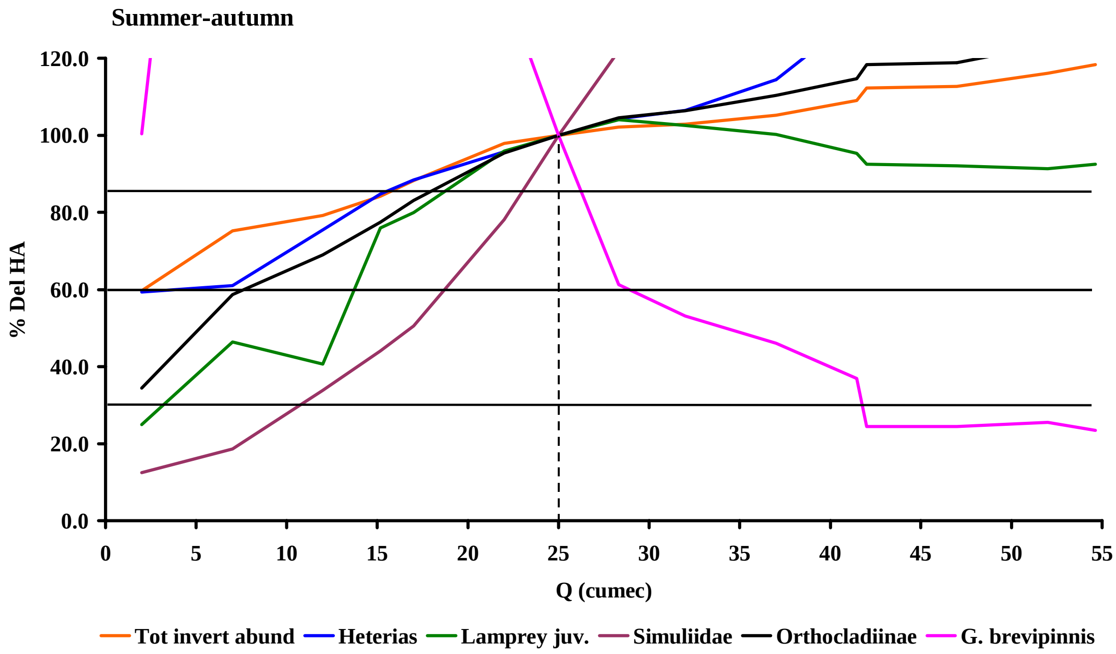


Figure 45. Plots of minimum %ΔHA values against discharge for the three middle Gordon River study reaches.

Separate plots are shown for the two seasonal periods. Horizontal dashed lines show bounds for risk categories I – IV, see Table 4. Vertical solid lines show range of minimum flows within which all risk categories are I for reach 03.



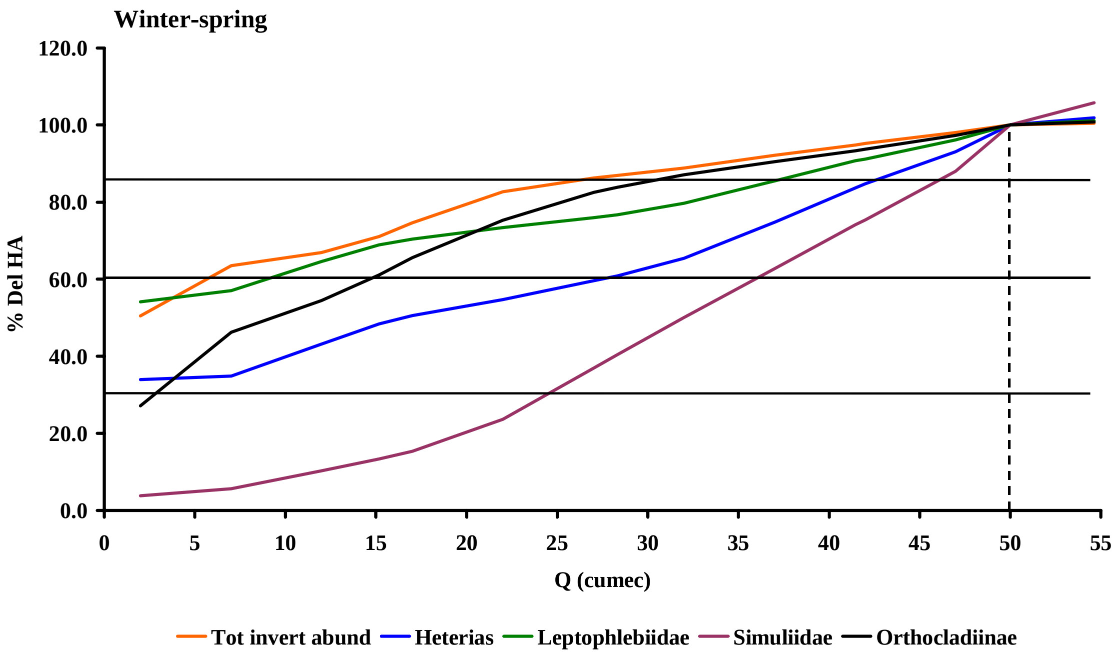


Figure 46. Plot of %ΔHA values in study reach 03 against discharge for those taxa with the lowest values close to the reference discharge (indicated by the vertical dashed line). Horizontal lines indicate risk category bounds.

Table 20. O/Erk values measured in study reach 03 and estimated for different levels of minimum flow mitigation under Basslink.

O/Erk values were requested by Hydro for differing summer and winter minimum flow releases. These are shown along with the associated levels of risk (roman numerals) derived from the habitat-based risk analysis.

				O/E rk
Current	ESAA Study (1998)			0.36
	Basslink Investigations (2000)			0.41
Basslink		**Minimum flows**		
	Mitigation level (as risk)	**Summer**	**Winter**	
	Summer = II, Winter = II	20	40	0.35
	Summer = II, Winter = III	20	30	0.3
	Summer = II, Winter = IV	20	0-20	0.25
	Summer = IV, Winter = II	10	40	0.25
	Summer = IV, Winter = III	10	30	0.25
	Summer = IV, Winter = IV	10	0-20	0.2
	No mitigation	0	0	0.2

5.2.1.3 Recommendation and Conclusions

We recommend adoption of a continuous minimum discharge from the Gordon power station (or other infrastructure in the vicinity of the Gordon power station) of:

- 19 - 26 cumec between December and May;
- 36 - 66 cumec for the months June to November.

We do not recommend any variation in these discharges between years or between months, as the provision of stable minimum habitat conditions for biota under an otherwise extremely variable flow regime should be seen as a priority.

We believe that these discharges will provide for a minimum habitat area for most of the instream biota in the middle Gordon sufficient to maintain a modified faunal community in periods between peak power station discharges. Provision of these discharges at the head of Section 1, combined with additional natural downstream catchment inputs, should lead to provision of sufficient minimum habitat at the downstream reaches to maintain modified macroinvertebrate and fish communities, and should provide a measurable and substantial degree of mitigation of impacts from Basslink operations on these communities.

Provision of flows lower than those recommended above will provide habitat for some taxa, but with potentially increased risks resulting from habitat loss (see Table 19).

Provision of a minimum environmental flow alone will not fully mitigate impacts on the instream biota under the forecast Basslink flow regime. The highly variable nature of the flow regime will continue to be the primary driver of impact on the instream fauna.

5.2.2 Flow Ramping

There is a limited international literature on the relationship between riverine faunal behaviour, survival and community/colonisation responses to varying rates of river level rise and fall. The impacts of hydropeaking on instream fauna have been documented elsewhere (see report section 1), but research into the mechanisms of these impacts and the potential for mitigation is only beginning (e.g. Bradford 1997). Increased rates of flow rise and fall are generally associated with increased mortality, loss of taxa and decreases in abundance of macroinvertebrate and fish. Drift rates of macroinvertebrates increase both acutely and chronically in response to surges and declines in velocity and depth downstream of hydropeaking power stations (Perry and Perry 1986, Layzer *et al.* 1989, Lauters *et al.* 1996), and the phenomenon is well known in response to natural flood events (e.g. Anderson and Lehmkuhl 1968). The intensity of drift can be reduced by reducing rise and fall rates of flow pulses. The exact relationship between drift rates and rates of colonisation and change sin benthic abundance are, however, complex, and drift sampling was not attempted in this study.

Stranding of fish and macroinvertebrates on ‘intertidal’ zones in rivers downstream of hydroelectric power stations can also be reduced by slowing the rate of river level decline (Bradford 1997). Management of rates of discharge rise or fall is conducted by ‘ramping’ the increases or decreases in turbine generation and hence discharge over a managed period. For example, Olson and Metzgar (1987) proposed ramping rates to minimise juvenile salmonid fish stranding downstream of power stations, in the range 0-15 cm of water level change/hr.

5.2.2.1 Assessment of ramping rates

Examination of flow rise and fall during discharge peaks associated with power station operations indicates that rates of rise are either comparable to or slightly faster than natural flood peak rise rates. By contrast, natural flood recession rates are 10 to 24 times slower than recession rates observed under current or Basslink scenarios in the middle Gordon (see report section 3.1).

In the absence of data on rates of flow recession which are compatible with maintaining instream diversity, a general approach is to quantify the rates at which levels respond to natural rain events and to attempt to mimic them. Inspection of flow recession rates under natural flows in the middle Gordon within the range 20 to 300 cumec reveals that they are 10 to 24 times slower than those forecast under Basslink scenario (report section 3.1.1). Any attempt to mimic those rates will essentially eliminate the use of the Gordon power station for hydropeaking. For example, Figure 47 shows typical power station induced flow peaks during February 1998, with discharge ranging between 200-250 and 10-70 cumec for sites 75 and 42. Superimposition of natural flood recession rates on the forecast Basslink flow regime results in very limited potential for fluctuation in power station discharge between demand peaks.

In these circumstances, the slowest ramping rate that can be achieved under Basslink is desirable. The slowest recession ramping rates possible under full hydropeaking operations are those which progress linearly from the peak shoulder to the commencement of discharge for the ensuing peak ie with three turbines progressively shut down over ca 6 – 8 hr. This option is also shown in Figure 47. These rates result in declines of between 25 – 35 cumec/hr at both sites.

5.2.2.2 Recommendations and Conclusions

Flow recession rates should be minimised in order to ensure movement of mobile fauna is away from areas to be dewatered between discharge peaks, but also designed to minimise any periods of shear stress associated with specific hydraulic conditions. Examination of shear stress under stepload discharge pulses in the King River suggests that there are no secondary peaks in shear stress as flows rise or decline (see report section 3.5). Thus shear stress appears to be maximised at peak discharge, rather than during flow rise or fall. We believe this to also be applicable to the middle Gordon.

Therefore, the only consideration in recommending a power station ramping rate for management of instream fauna is the relationship between flow decline and the risk of stranding of mobile instream taxa.

If full hydropeaking is to be maintained at the Gordon power station (ie with the projected range in power station discharge), then we recommend that the slowest possible ramping rates be used during power station shutdown between peaks, so that turbine shutdowns are complete just as load demand increases for the next peak. Monk (1989), Olson and Metzgar (1987) and Bradford *et al.* (1995) all observed reduced rates of juvenile salmonid stranding when water level declines were less than ca 10-15 cm/hr. Bradford (1997) observed greater stranding rates for juvenile fish which responded to declining flows by seeking shelter within the substrate rather than moving laterally across it. Thus, individual species and life stage behaviour influences the degree of stranding and hence the relative success of ramping flows. There are no comparable data for macroinvertebrates or platypus.

From examination of simulated and current discharge data for the Gordon power station, the slowest rates possible under full hydropeaking are of the order of 25 – 35 cumec/hr on average, with three turbines progressively shutting down over ca 6 – 8 hr. At discharges between 50 and 200 cumec this is equivalent to recession rates as low as 25 cm/hr, but still well above the range recommended for reducing stranding risk for highly mobile salmonid fish (Olson and Metzgar 1987). These rates are 2 to 4 times slower than without ramping, but we do not believe they are slow enough to achieve reduction in risk for native fish or macroinvertebrates in the Gordon River.

Ramping rates in which power station outages are spread over a few hours (e.g. 1 turbine shut down per 1-2 hours) will serve only to assist the most highly mobile species (e.g. adult brown trout) to move into deeper water and away from potentially dewatered habitat. Other mobile macroinvertebrates such as amphipods, eusthenid and gripopterygid stoneflies, and some mayfly species, may also respond by actively entering the drift and moving downstream into permanently inundated habitat. However the majority of macroinvertebrates present on substrates vulnerable to dewatering in the ‘intertidal zone’ are likely to be trapped on exposed substrate or in backwaters and side pools. Much of the middle Gordon fauna is sessile or slow moving and would require much slower declines in discharge to reduce stranding risks.

We therefore conclude that, if full hydropeaking is to be maintained at the Gordon power station, ramping rates will not be an effective powerful mitigation tool for protection of instream aquatic ecological values. They may serve to marginally reduce the incidence of stranding mortality for some species (mainly large trout), but will not affect the impact of loss of habitat availability and quality due to large swings in discharge. Only limitations to the ‘depth’ of hydropeaking, through the use of natural flood recession rates would achieve significant environmental outcomes.

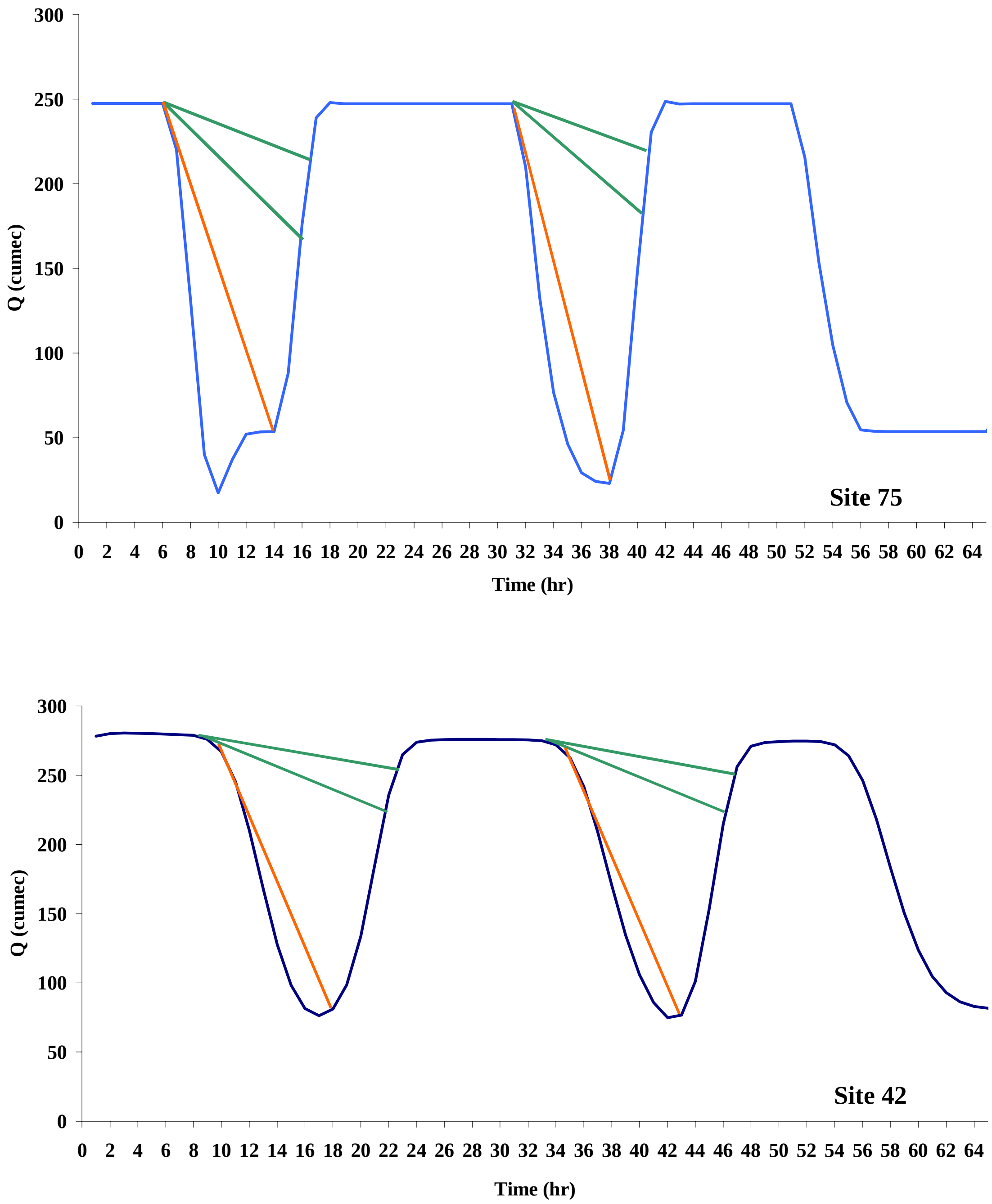


Figure 47. Plots of discharge peaks associated with power station peakload generation under Basslink at sites 75 (downstream of power station) and 42 (upstream of Franklin River, 35 km downstream of power station) in the middle Gordon over 64 hr (for February 1998).

Green lines indicate maximum and minimum natural recession rates for floods of ca 300 cumec in size, shown to illustrate the elimination of hydropeaking if these ramping rates were imposed. Orange lines indicate slowest possible ramping rates which still allow full hydropeaking.

5.3 Discussion – Mitigation and Environmental Management

Cushman (1985) listed three major options for managing environmental impacts of hydropeaking on the receiving riverine ecosystem:

1. *Operational changes* – changes to power station operating rules and hence discharge patterns;
2. *Structural changes* – construction of re-regulating structures;
3. *Habitat modification* – physical engineering of the river channel.

Only the first is being considered in detail in this report, as the latter is implausible, and the re-regulation option is not being considered at present by Hydro management. However, mitigation options using flow management under Basslink are few and likely to be limited in their effectiveness for maintaining the current aquatic biological values. The current and forecast flow regimes have so few natural characteristics that any significant attempt to maintain existing instream faunal communities through modifying the flow regime will severely impact on the utility of the Gordon power station as a hydropeaking station.

Basslink will add a measurable degree of environmental impact to a system already experiencing significant physical and biological impacts from Hydro operations. Substantial environmental mitigation/recovery from the impacts of either the current or Basslink modes of hydro generation in the middle Gordon will only be achieved by radically changing the flow regime back to a more natural one. This cannot be done by changing minor aspects of the flow pattern under peak power production, and would require re-regulation of flows. However, construction of a re-regulation dam would lead to a suite of other environmental impacts.

We feel however that appropriate minimum flows will substantially mitigate the additional impacts posed by Basslink on the current situation, and will largely maintain the current state of the biota in the middle Gordon. The benefits of these management strategies should, however, be monitored in relation to numerically defined and quantifiable river management objectives.

Another management approach is to ‘spread the environmental load’ by constraining operations at the Gordon power station in order to provide a valid or partially valid environmental flow regime in the middle Gordon River, and to operate the Tasmanian hydroelectric system in an integrated manner to provide Basslink power requirements. This approach is included by Moog (1993) in a comprehensive list of alternative management and operational strategies for environmental mitigation downstream of hydropeaking power stations. However, it may result in causing hydropeaking related environmental impacts on other rivers within the Hydro system.

The forecast Basslink scenario (without mitigation) will result in a further reduction in the overall diversity and abundance of instream biota throughout the middle Gordon River with:

- a substantial reduction in permanent aquatic flora and fauna in all ‘intertidal’ channel margin zones and on all bars and rapids, other than a filamentous algal layer, upstream of the Denison River junction;
- a reduction in the abundance of aquatic flora and fauna in all ‘intertidal’ channel margin zones and on all bars and rapids (other than a filamentous algal layer), downstream of the Denison River junction;
- a macroinvertebrate community living along the ‘centre-line’ (thalweg) of the channel with substantially reduced diversity and abundance compared with that under current conditions;
- possible further reduction in platypus and *Hydromys* abundance from the middle Gordon upstream of the Denison River junction, dependent on use of tributary stream habitat;
- possible further reduction in the population size of platypus in the middle Gordon River downstream of the Denison River junction;
- reduction in the abundance and diversity of native fish populations in the lower middle Gordon (see Howland *et al.* 2001);

However, given a minimum environmental flow of 19 to 26 cumec, and 36 to 66 cumec released into Section 1 in summer-autumn and winter-spring, respectively, these impacts will be reduced such that:

- the macroinvertebrate community living along the 'centre-line' or thalweg of the channel will receive substantially more protection from dewatering than currently occurs under current (no-Basslink) conditions, and will experience only a minor reduction in diversity and abundance related to increased flow fluctuations. O/E ratios are expected to remain close to current values;
- any potential reductions in fish and platypus (and possibly *Hydromys*) from the middle Gordon upstream of the Denison River junction will be reduced due to the stability of low flows and degree of maintenance of aquatic macroinvertebrate food production.
- the condition of the currently depauperate aquatic flora and fauna in all 'intertidal' channel margins and on all bars and rapids will remain poor.

We therefore make specific recommendations with regard to minimum flows to be discharged from the Gordon power station. Provision of a minimum discharge from the power station is, in our view, an essential requirement of environmental management of the middle Gordon with or without Basslink, but will significantly aid mitigation of Basslink impacts.

The range of anticipated possible biological outcomes resulting from several flow mitigation scenarios under Basslink are shown in Tables 20 and 21.

Truly substantial improvement in the state of the instream biota, through mitigation of the consequences of the peaking flow regime under both Basslink and current Hydro operational conditions, will only occur if:

- the Gordon power station is no longer used for peak power production; or
- discharges from the power station are re-regulated using a second regulatory structure.

These conclusions have been reached elsewhere for rivers downstream of hydropeaking stations. For example, recommendations for mitigation of impacts on biological values in the Flathead River, Montana USA include elimination of peaking downstream through the use of a re-regulating structure, or major changes in power station operations (Stanford and Hauer 1992). Significant, though partial, recovery from downstream impacts of hydropeaking have been reported for the Bregenzerach River in Austria following construction and operation of a re-regulating dam which smoothed much of the short and long term peaking in downstream flows (Parasiewicz *et al.* 1998). This is a significant finding, with recovery of 60% of benthic biomass downstream of the new reregulating dam. Parasiewicz *et al.* (1998) also found no increase in fish biomass despite improved minimum flows, but predicted that fish biomass would improve significantly with further adjustment to operation of the re-regulated discharges. That study demonstrates that remediation of natural rates of variability in the flow regime downstream of a hydropeaking station can result in significant biological recovery.

6 MONITORING CONSIDERATIONS

Any further monitoring of Gordon River macroinvertebrates and aquatic mammals should consider the following:

6.1 Biological Monitoring

Biological monitoring in the middle Gordon River should have three primary objectives:

- documenting biological changes resulting from changes to flow management;
- assessing compliance with biological management targets or objectives (RMO's); and
- along with other environmental data (e.g. on bank erosion), providing core data for adaptive environmental management.

All three objectives can be satisfied by the same monitoring program. A biological monitoring program should contain the following:

6.1.1 Macroinvertebrate monitoring

Samples should be taken twice a year (in spring and autumn) from sites 75, 72, 69, 63, in Section 1 and sites 60, 58, 46 and 42 in Section 2 in the middle Gordon. In addition 6 reference sites should be sampled – Ja7 (Jane River), Fr11 (Franklin R downstream of Blackman's bend), Fr21 (Franklin R at Flat Island), De7 (Denison downstream of Maxwell R), De35 (Denison R upstream of the Truchanas Reserve) and UG10 (upper Gordon R downstream of Gordon Bend).

At each site, a standard rapid assessment kick sample is to be taken from bar riffle habitat. These samples are to be live-picked using the original 30 minute live-pick AUSRIVAS protocol. The required environmental variables should also be recorded at each site on each visit. The resulting environmental and biological data are to be analysed using both the presence-absence and rank abundance RIVPACS models developed by Davies *et al.* (1999). This will provide O/Epa and O/Erk outputs and associated bands, which are to be compared with previous years' data.

Quantitative surber samples should also be taken from bar riffle habitat at each site on each occasion. Ten surber samples (mesh size 500 micron) should be collected, pooled and processed to family level (with subsampling). These data should be analysed to assess changes in time cf control sites by conducting an ANOVA with time (year) and location (Gordon section vs reference rivers) as factors, and abundance of each species and overall diversity as test statistics. The time*location interaction term (at an alpha of 0.05) should be used to assess the significance of any changes. These analyses should be conducted separately by section within the middle Gordon.

They should also be compared (by paired t-test) with previous years' data to assess temporal changes within the middle Gordon.

6.1.2 Platypus monitoring

Monitoring of platypus population responses to Basslink (and in response to Hydro management changes in the middle Gordon) should be conducted to:

- establish the presence of resident individuals (from repeated captures at a site);
- identify and assess status of burrow sites of resident individuals;
- assess changes in the condition of adults and juveniles, in the and reproductive status of breeding (lactating) females;
- assess changes in habitat 'quality' for platypus.

Platypus presence, condition and reproductive status should be monitored in the middle Gordon once every 3 – 4 years, at two sites in each of Section 1 and in Section 2, and at two Gordon catchment sites – one each in the lower Franklin, and the Denison downstream of the Maxwell River. Due to the large ranges of platypus (particularly males), these latter sites may well be affected by impacts within the middle Gordon. Thus, in order to assess whether changes within the Gordon catchment are related to changes in power station operations, reference (‘control’) sites must be surveyed which are outside the middle Gordon catchment. One external reference site should be monitored in each of the Huon, Picton and Weld Rivers.

The population surveys should be conducted in autumn (Feb - March) to be outside the breeding season and winter periods (when catch rates are low), and to allow capture of juveniles. Direct observations of platypus should be conducted over a standard observation period, and key environmental variables measured. A minimum of five nights days fyke-net and/or gill net trapping should be conducted for each site (between 1500 and 0300), with all animals trapped and observed recorded, and where handled they should be sexed, measured (bill and total body length), weighed and have their condition assessed (tail fat index). Reproductive status should be assessed (lactating/non-lactating) should be determined (using the oxytocin induction method).

These data should be analysed to assess changes through time cf control sites by conducting an ANOVA with time (year) and location (Gordon vs Gordon catchment vs external reference rivers) as factors, and abundance of each species and overall diversity as test statistics. The time*location interaction term (at an alpha of 0.05) should be used to assess the significant of any changes. Test statistics should include catch per unit effort and condition.

The survey should also follow the methods of Grant and McDonald (1998), and should include an assessment of impacts on and status of resting and natal burrow sites.

We also recommend a student project be conducted in parallel in order to assess behavioural responses of individuals to flow events using radio-tracking. This should also include identification of selected burrow sites for assessment.

6.1.3 Algal monitoring

Seven sites should be monitored for algae and moss cover on riverine substrate - 75, 72, 69, 63, 60, 58 and 42, at the same time as macroinvertebrate sampling. Observations of the extent and % cover of filamentous algae, moss and characeous algae should be made across the relevant IFIM transect. Distance from the peg and % cover should be recorded at 0.5 m intervals across the relevant sections of each transect, where algae and moss occur. Five scrapes of filamentous algae should be take from the upper surface of boulder/cobbles in the centre of the algal ‘band’ at each site, and suitably preserved prior to determining the dominant algal species in the samples. In addition, the locations on the transect where terrestrial vegetation occurs should be noted, again as offsets from the datum peg.

These data should be compared with previous data by conducting paired t-tests (paired by transect) of overall mean algal cover in order to assess significant of any changes. The locations of peak algal abundance and of upper and lower margins should also be compared between years to assess shifts in algal distribution within the channel. These analyses are to be conducted separately for filamentous algae, moss and characeous algae.

6.2 Flow ‘compliance’ monitoring

If minimum flows become an integral part of operating rules at the Gordon power station, then compliance with these requirements should be monitored, with standardised reporting of hourly power station outputs on a quarterly and annual basis. These reports should include analysis of flow records from sites within both Sections 1 and 2, to assess the affect of the power station on flows downstream, and hence their efficacy at providing required minimum flows and flow recession rates in both Sections of the middle Gordon.

7 REFERENCES

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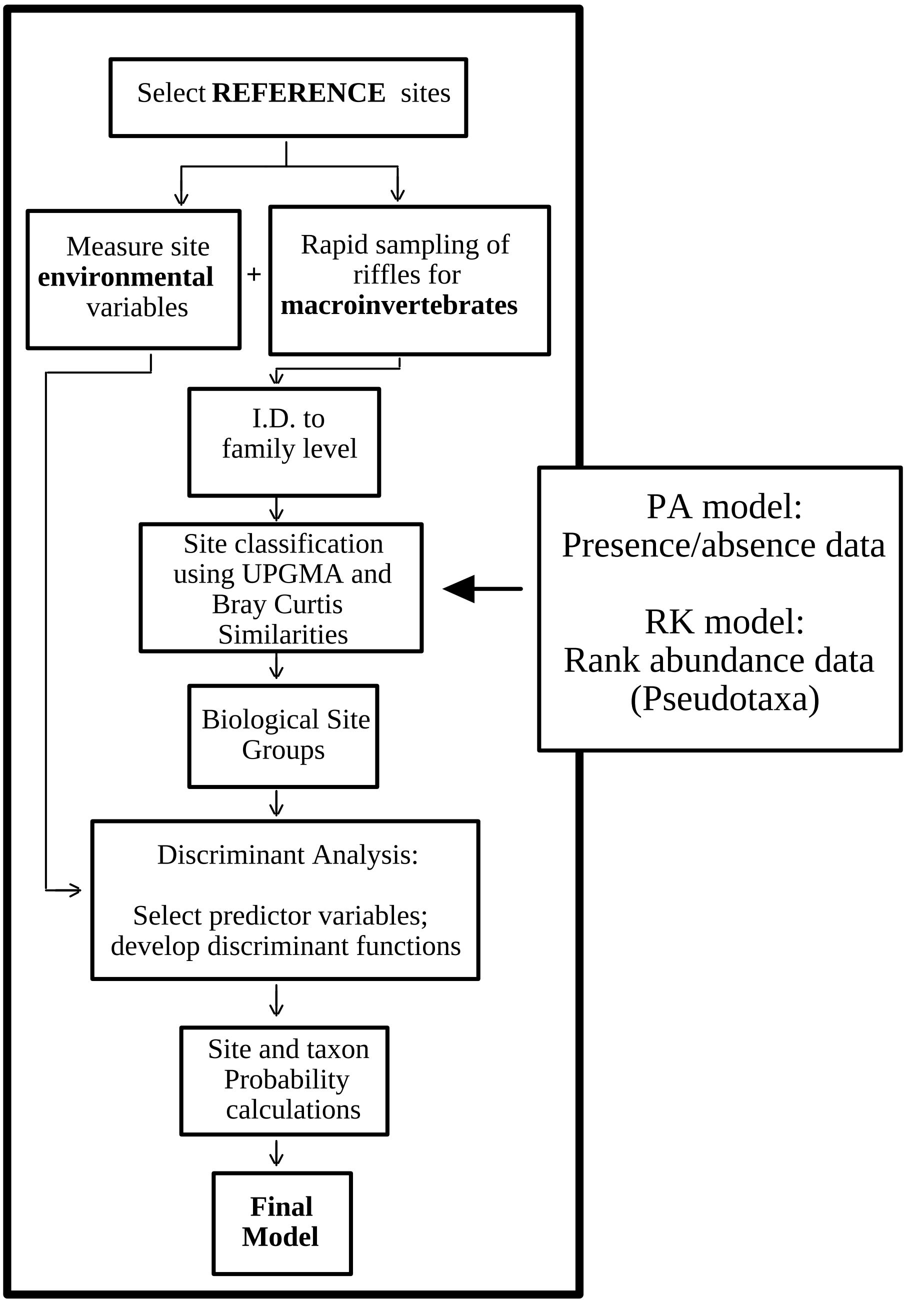
ATTACHMENT 1.

RIVPACS MODEL DEVELOPMENT AND USE.

RIVPACS river bioassessment.

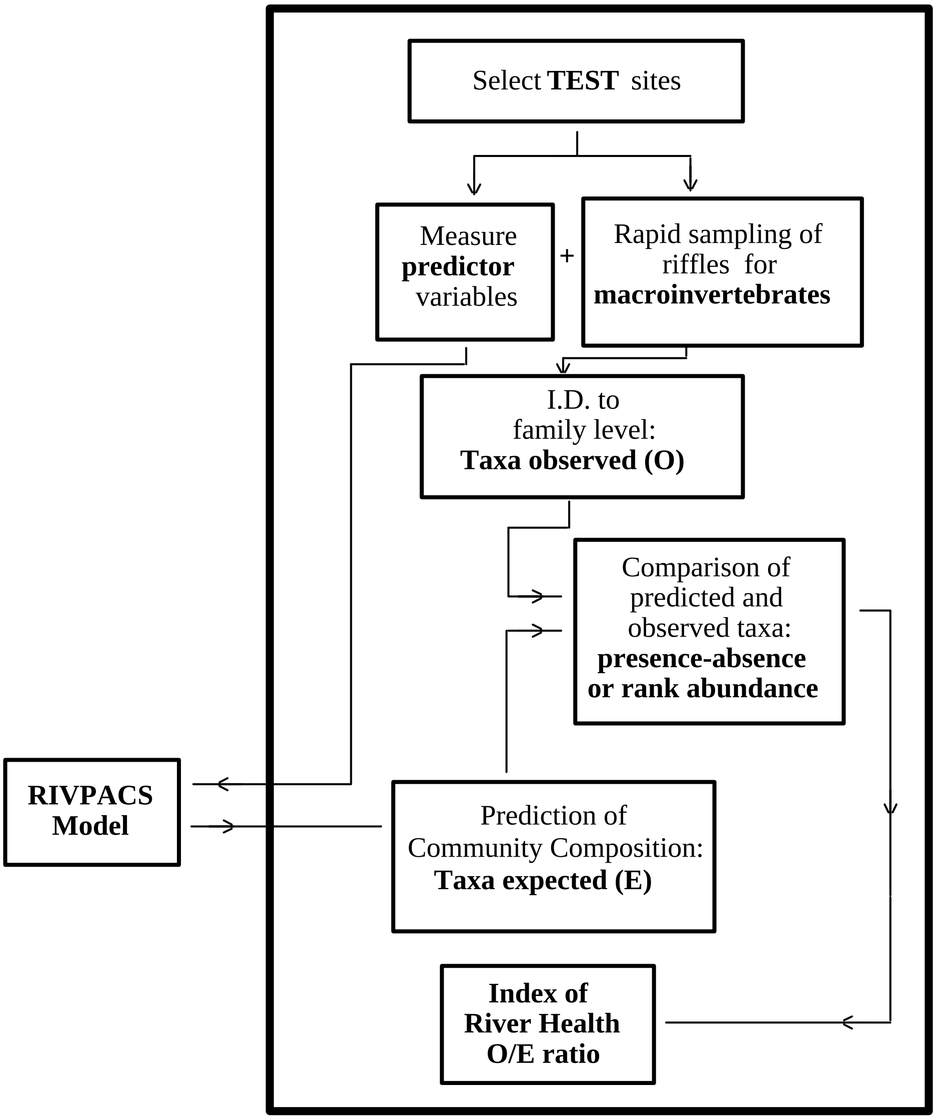
I. Developing RIVPACS



Process of RIVPACS model development. Refer to report section 2.5.1 and Davies *et al.* (1999) for details.

RIVPACS river bioassessment.

II. Using RIVPACS

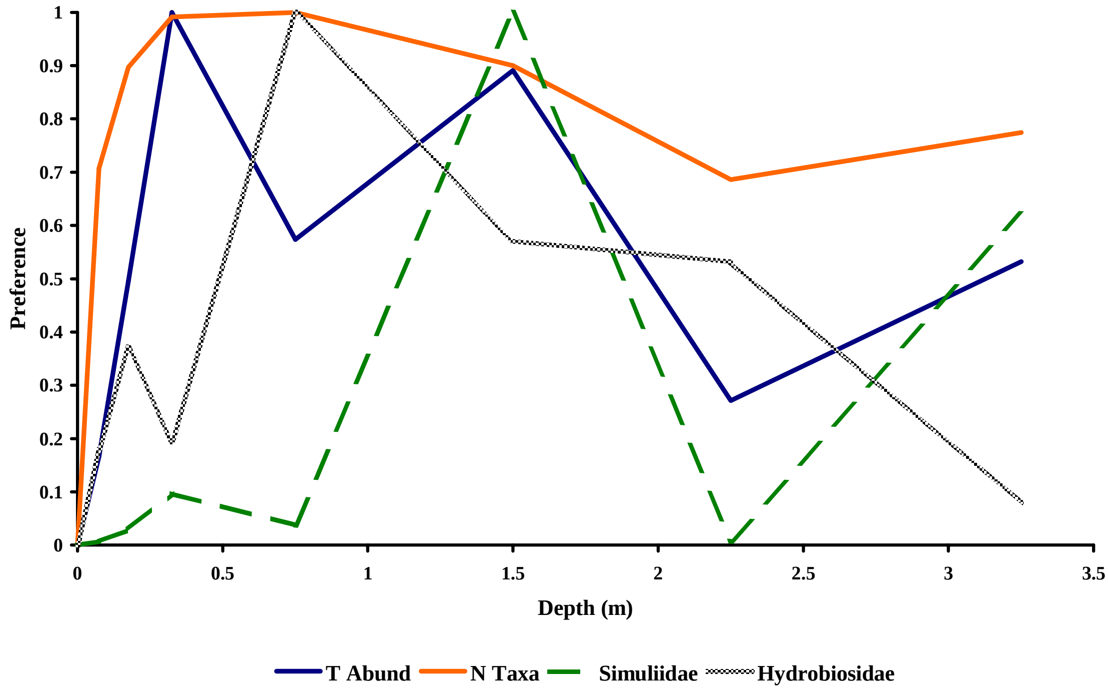


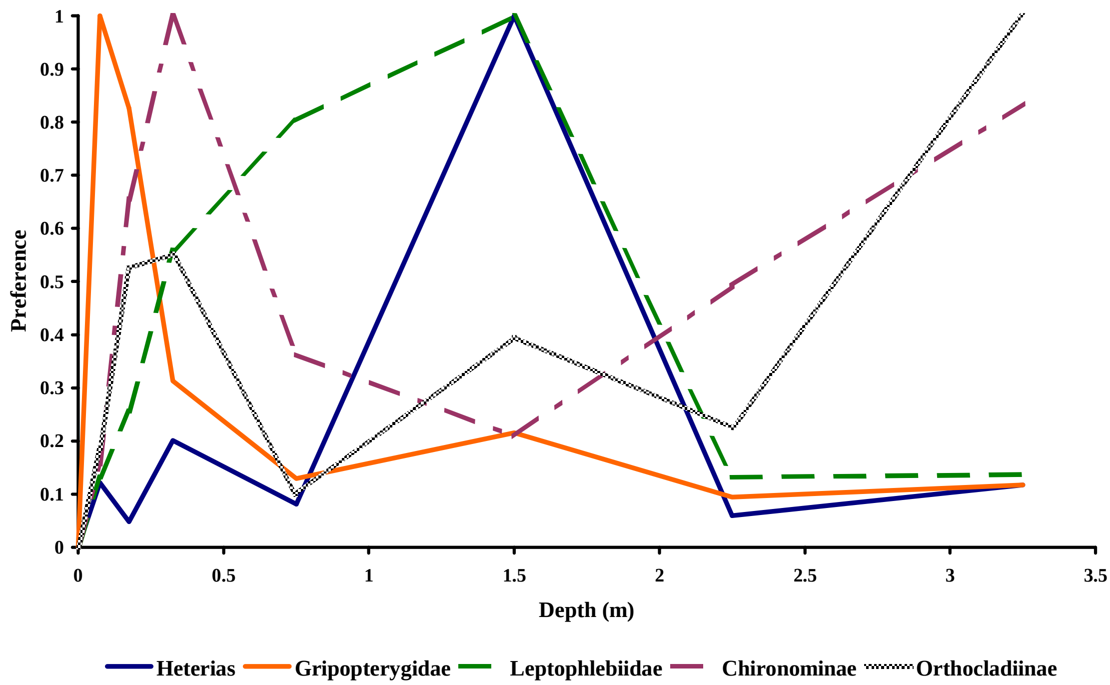
Process of using the RIVPACS model for site assessment. Refer to report section 2.5.1 and Davies *et al.* (1999) for details.

ATTACHMENT 2.

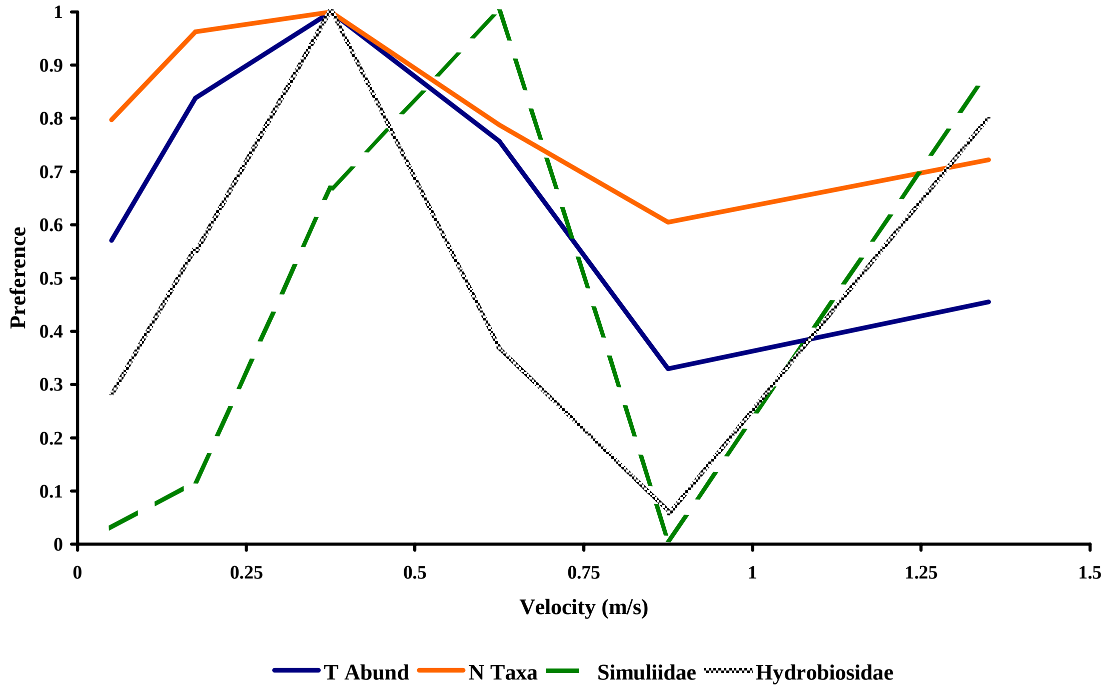
HABITAT PREFERENCE CURVES FOR MACROINVERTEBRATES AND PLATYPUS, USED IN HABITAT MODELLING.

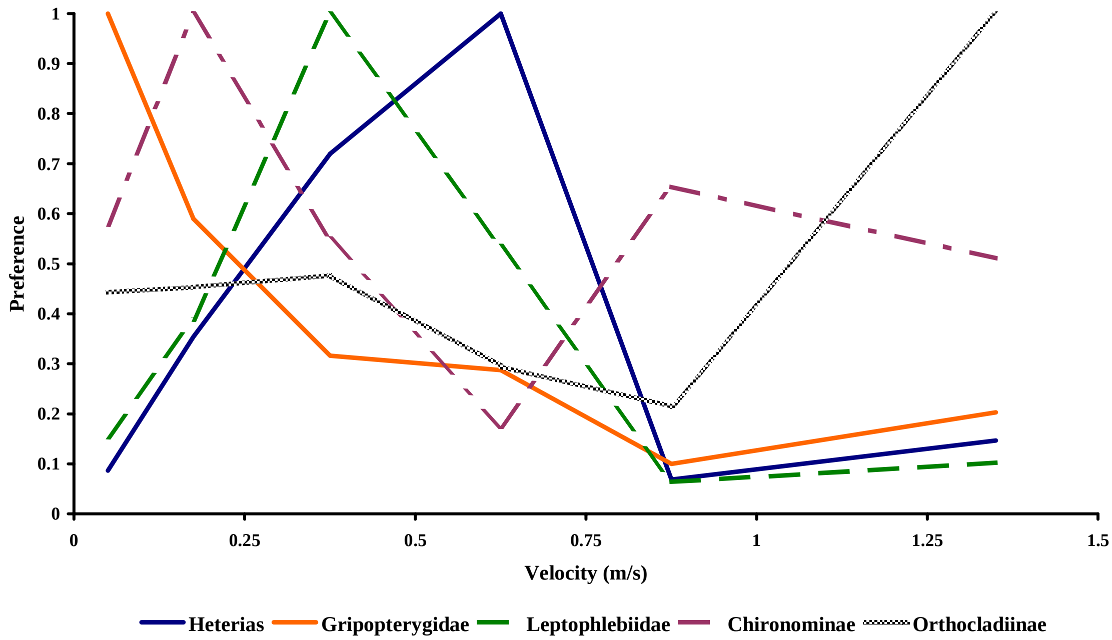
Depth preferences, macroinvertebrates





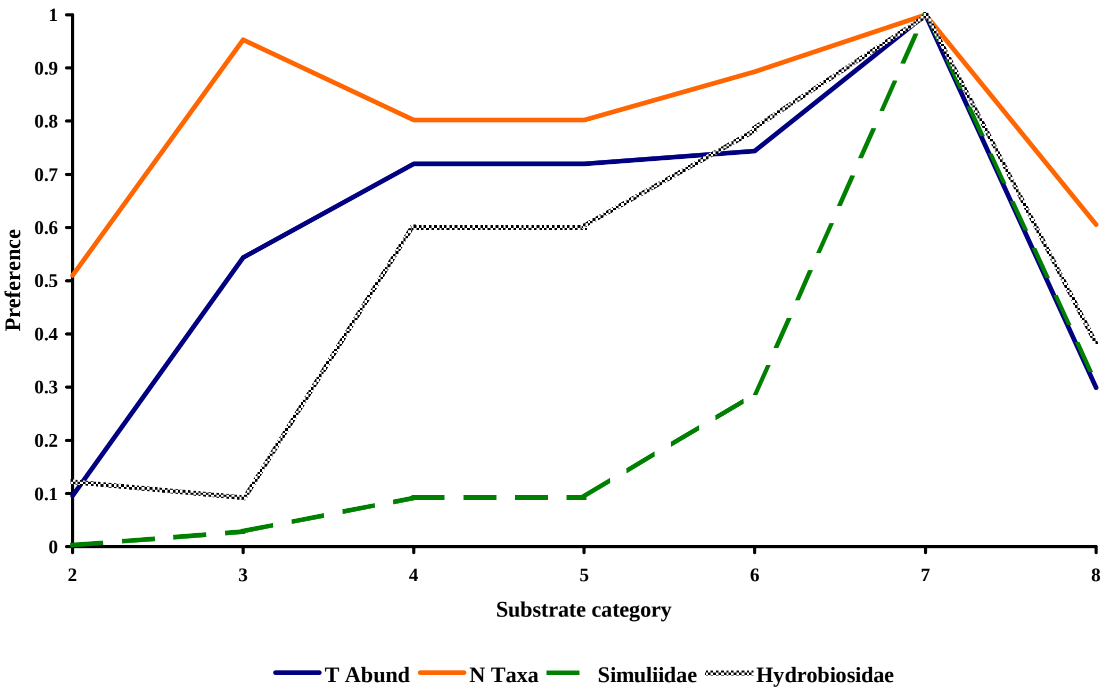
Velocity preferences, macroinvertebrates

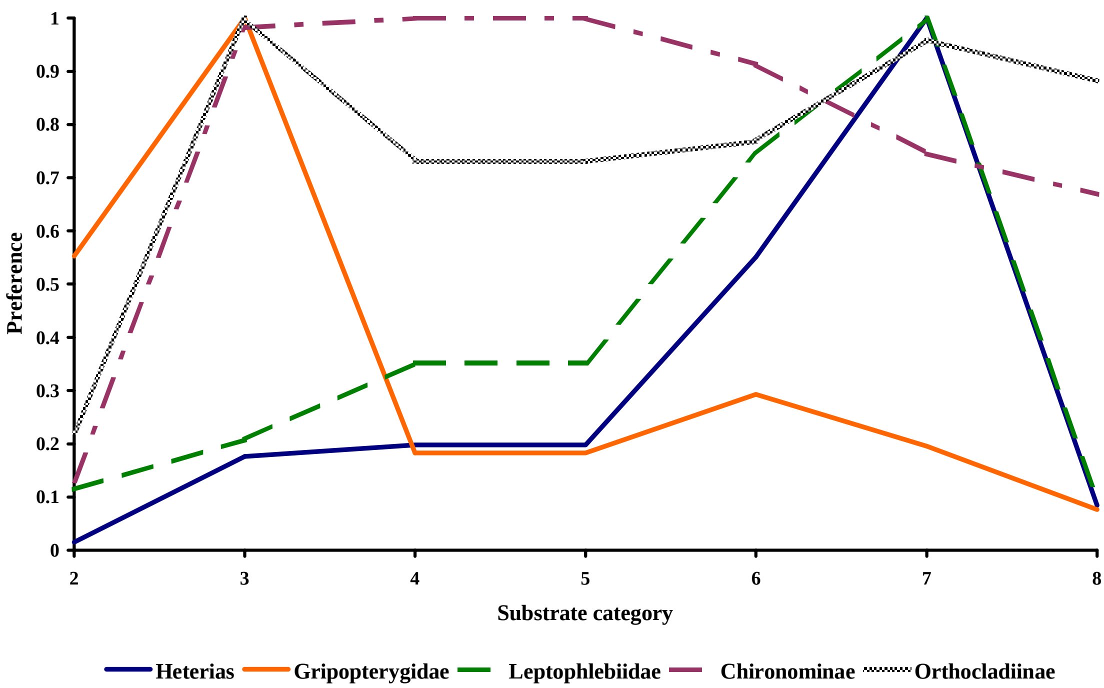




Substrate preferences, macroinvertebrates.

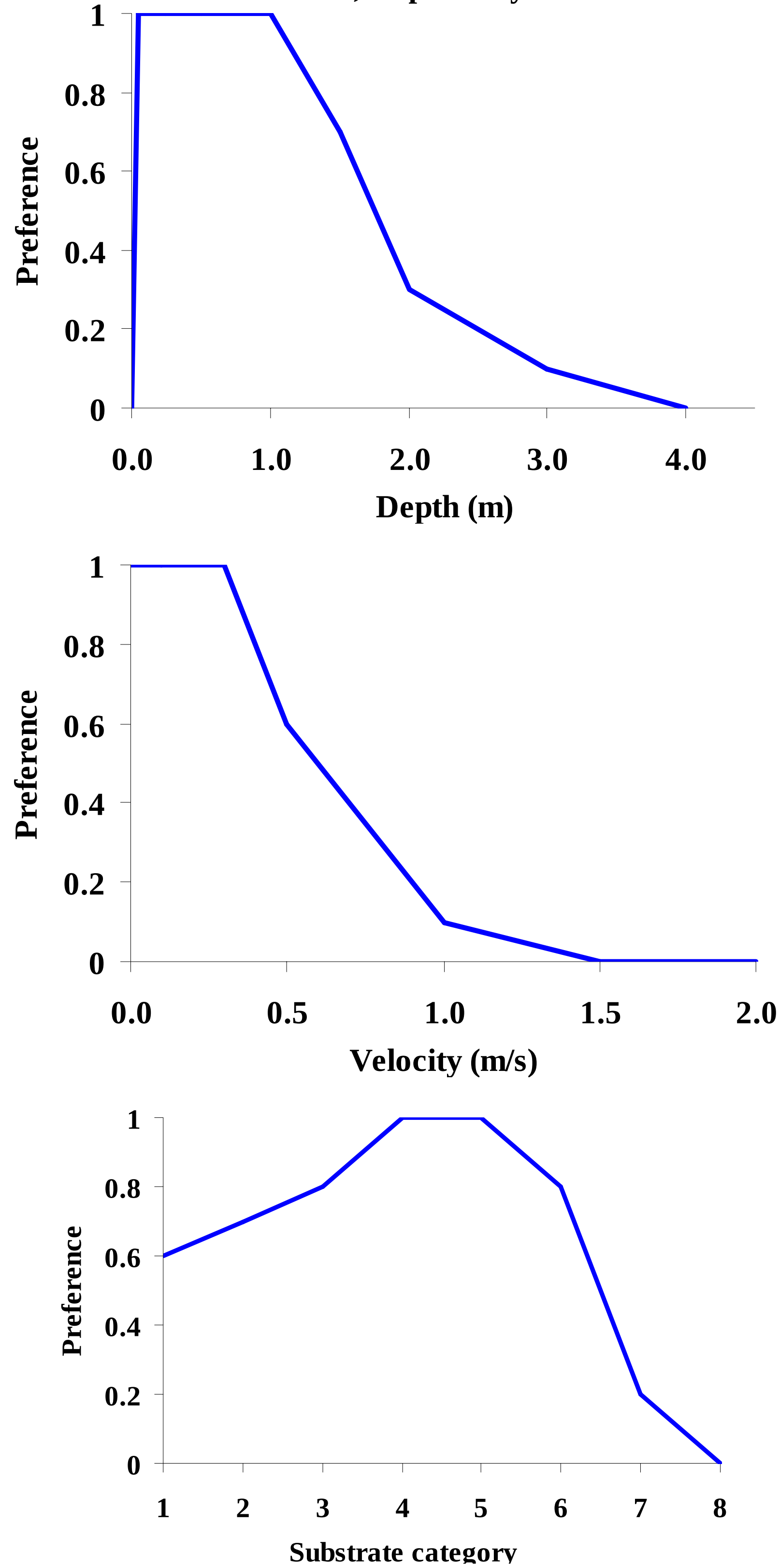
Numbers 2 - 8 = silt, sand, gravel, pebble, cobble, boulder, bedrock, respectively.





Depth, velocity and substrate preferences for platypus.

Substrate numbers 1 - 8 = aquatic vegetation, silt, sand, gravel, pebble, cobble, boulder, bedrock, respectively.



ATTACHMENT 3.

RISK ANALYSIS TABLES FOR THE THREE STUDY REACHES.

G4 RISK SUMMER-AUTUMN

Summer-autumn' : Dec- May. Ref flow= 25 cumec.

Flow (m3/s) Q	Wetted area Area	WUA/m (m) Janiirid	WUA/m (m) Gripop	WUA/m (m) Leptop	WUA/m (m) Chironominae	WUA/m (m) Orthocladiinae	WUA/m (m) Simulidae	WUA/m (m) Hydrobiosidae	WUA/m (m) N Taxa	WUA/m (m) T Abund	WUA/m (m) Platypus	WUA/m (m) G. brevipinnis	WUA/m (m) A. australis	WUA/m (m) Lamprey juv	WUA/m (m) G. maculatus	WUA/m (m) G. truttaceus	WUA/m (m) S. trutta fry	WUA/m (m) S. trutta juv	WUA/m (m) S. trutta ad	WUA/m (m) S. trutta spawn	WUA/m (m) S. trutta ad Ral
2	66.68	0.59	1.14	1.84	7.18	4.35	0.20	4.58	21.00	7.77	5.07	0.10	0.35	0.57	3.76	3.43	1.75	3.19	14.26	0.00	38.39
7	87.48	0.61	1.46	1.94	13.76	7.42	0.29	5.07	26.32	9.78	5.59	0.32	0.57	1.06	4.41	4.06	4.02	4.82	16.16	0.01	44.28
12	100.67	0.75	1.31	2.20	16.08	8.74	0.53	5.91	28.36	10.31	5.40	0.17	0.50	0.93	4.34	4.02	3.86	4.92	17.50	0.01	46.92
15.16	107.65	0.84	2.01	2.34	18.21	9.80	0.69	6.25	30.62	10.95	6.61	0.24	0.94	1.73	5.27	4.78	4.35	6.04	18.09	0.01	48.89
17	111.39	0.88	1.91	2.40	19.78	10.52	0.79	6.25	31.34	11.49	6.50	0.25	0.99	1.82	5.16	4.67	4.58	6.68	18.39	0.01	49.26
22	120.49	0.95	1.33	2.49	22.28	12.09	1.22	5.92	32.34	12.73	6.32	0.14	0.86	2.19	4.91	4.41	4.43	5.88	20.48	0.01	51.60
25	124.48	1.00	1.39	2.54	22.42	12.66	1.56	5.79	32.71	13.01	6.47	0.10	0.84	2.28	5.01	4.49	4.31	5.37	20.66	0.01	51.87
27	128.48	1.04	1.45	2.59	22.56	13.24	1.90	5.67	33.08	13.28	6.61	0.06	0.83	2.37	5.12	4.57	4.20	4.86	20.84	0.01	52.15
28.32	130.43	1.06	1.46	2.61	22.50	13.47	2.08	5.63	33.21	13.38	6.52	0.05	0.83	2.33	5.06	4.51	4.15	4.73	20.87	0.01	52.25
32	135.63	1.14	1.32	2.71	22.21	13.98	2.58	5.58	33.44	13.68	6.28	0.05	0.81	2.28	4.90	4.37	3.93	4.77	20.99	0.01	52.38
37	142.14	1.30	1.47	2.91	21.48	14.52	3.23	5.53	33.86	14.19	6.72	0.04	0.77	2.17	5.19	4.66	3.11	4.62	21.71	0.02	52.02
41.47	147.54	1.46	1.33	3.09	20.71	14.99	3.81	5.49	34.06	14.60	6.59	0.03	0.75	2.11	5.05	4.53	2.43	4.49	21.84	0.03	50.80
42	148.15	1.48	1.32	3.10	20.63	15.05	3.88	5.48	34.07	14.66	6.57	0.03	0.75	2.10	5.03	4.52	2.36	4.47	21.82	0.02	50.59
47	153.74	1.62	1.18	3.27	19.95	15.63	4.53	5.42	34.26	15.10	6.44	0.03	0.71	2.08	4.87	4.38	1.83	3.88	21.43	0.02	48.14
52	158.98	1.74	1.08	3.40	19.28	16.05	5.14	5.41	34.34	15.40	6.25	0.02	0.68	2.11	4.71	4.24	1.52	2.88	21.02	0.01	46.10
54.63	161.63	1.78	1.05	3.44	18.96	16.18	5.44	5.43	34.32	15.47	6.15	0.03	0.68	2.08	4.62	4.16	1.42	2.29	20.83	0.01	45.24
57	163.94	1.81	1.03	3.46	18.69	16.25	5.69	5.43	34.28	15.49	6.02	0.03	0.68	2.02	4.55	4.09	1.34	2.09	20.66	0.01	44.54
62	168.64	1.85	0.97	3.46	18.13	16.30	6.15	5.41	34.12	15.49	5.77	0.03	0.68	1.89	4.39	3.96	1.13	1.91	20.31	0.01	43.27
67	173.12	1.90	0.94	3.44	17.64	16.35	6.60	5.35	33.93	15.48	5.53	0.02	0.69	1.77	4.24	3.82	0.92	1.73	19.91	0.02	42.12
67.79	173.81	1.90	0.94	3.42	17.56	16.34	6.67	5.34	33.89	15.47	5.49	0.02	0.69	1.76	4.22	3.81	0.89	1.70	19.84	0.02	41.94
72	177.40	1.94	0.92	3.38	17.17	16.33	7.02	5.27	33.71	15.43	5.32	0.02	0.70	1.70	4.11	3.71	0.73	1.57	19.47	0.02	40.95
80.95	184.66	1.98	0.94	3.26	16.32	16.18	7.71	5.14	33.24	15.21	5.16	0.01	0.76	1.57	3.95	3.57	0.50	1.03	18.63	0.01	38.93
94.11	194.55	1.97	1.30	2.98	15.21	15.75	8.52	4.99	32.76	14.68	5.54	0.02	0.98	1.99	4.19	3.84	0.37	0.87	17.44	0.01	36.09
107.26	203.70	1.95	1.12	2.74	14.64	15.34	9.01	4.82	32.27	14.20	5.39	0.05	0.99	2.35	4.22	3.86	0.46	0.83	16.36	0.01	33.34

% change in WUA relative to reference flow

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	53.6	59.3	82.0	72.5	32.0	34.4	12.5	79.1	64.2	59.7	78.4	100.4	41.3	24.9	75.0	76.4	40.5	59.4	69.0	0.0	74.0	12.5
7	70.3	61.0	105.2	76.4	61.4	58.6	18.6	87.4	80.5	75.2	86.5	307.7	67.6	46.4	87.9	90.5	93.2	89.8	78.2	83.3	85.4	18.6
12	80.9	75.5	93.9	86.5	71.7	69.0	33.8	102.1	86.7	79.2	83.5	160.6	59.4	40.6	86.5	89.5	89.4	91.6	84.7	108.3	90.4	33.8
15.16	86.5	84.7	144.3	92.2	81.2	77.4	44.0	107.9	93.6	84.2	102.1	232.2	111.1	75.9	105.1	106.4	100.8	112.6	87.6	100.0	94.3	44.0
17	89.5	88.4	137.1	94.4	88.2	83.1	50.6	107.8	95.8	88.3	100.5	243.9	116.6	79.9	102.9	104.0	106.1	124.4	89.0	108.3	95.0	50.6
22	96.8	95.8	95.7	98.2	99.4	95.5	78.2	102.2	98.9	97.9	97.8	138.7	102.1	96.0	97.9	98.3	102.7	109.5	99.1	108.3	99.5	78.2
25	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
28.32	103.2	104.2	104.3	101.8	100.6	104.5	121.8	97.8	101.1	102.1	102.2	61.3	97.9	104.0	102.1	101.7	97.3	90.5	100.9	91.7	100.5	61.3
32	104.8	106.4	104.7	102.8	100.4	106.4	133.6	97.2	101.5	102.9	100.8	53.1	98.1	102.5	101.0	100.4	96.1	88.1	101.0	83.3	100.7	53.1
37	109.0	114.4	95.2	106.8	99.1	110.4	165.3	96.4	102.2	105.2	97.2	46.1	96.2	100.2	97.8	97.2	91.0	88.8	101.6	108.3	101.0	46.1
41.47	114.2	130.8	105.5	114.5	95.8	114.7	207.1	95.5	103.5	109.1	103.9	36.9	90.9	95.4	103.5	103.8	72.0	86.0	105.1	166.7	100.3	36.9
42	118.5	146.5	95.7	121.5	92.4	118.4	244.7	94.7	104.1	112.3	101.8	24.5	88.3	92.5	100.6	100.9	56.3	83.6	105.7	191.7	97.9	24.5
47	119.0	148.3	94.6	122.0	92.0	118.9	248.8	94.6	104.2	112.7	101.6	24.5	89.3	92.1	100.3	100.6	54.7	83.2	105.6	183.3	97.5	24.5
52	123.5	162.8	84.6	128.7	89.0	123.4	290.4	93.5	104.7	116.1	99.5	25.6	84.6	91.4	97.1	97.5	42.3	72.2	103.7	133.3	92.8	25.6
54.63	127.7	174.9	77.8	133.9	86.0	126.8	330.1	93.4	105.0	118.4	96.7	23.4	80.7	92.5	94.0	94.4	35.2	53.6	101.7	108.3	88.9	23.4
57	129.8	178.3	75.8	135.4	84.6	127.8	349.1	93.7	104.9	118.9	95.1	24.5	80.8	91.3	92.2	92.8	33.0	42.6	100.8	100.0	87.2	24.5
62	131.7	181.5	73.9	136.1	83.3	128.3	364.9	93.7	104.8	119.1	93.1	25.6	80.8	88.8	90.7	91.1	31.0	39.0	100.0	100.0	85.9	25.6
67	135.5	185.7	70.0	136.2	80.9	128.7	394.7	93.4	104.3	119.1	89.1	26.6	80.8	82.8	87.6	88.2	26.1	35.5	98.3	100.0	83.4	26.6
67.79	139.1	190.6	67.4	135.3	78.7	129.1	423.6	92.3	103.7	119.0	85.5	23.4	81.6	77.8	84.6	85.2	21.4	32.2	96.4	125.0	81.2	23.4
72	139.6	190.6	67.5	134.8	78.3	129.1	428.0	92.1	103.6	119.0	85.0	22.4	81.6	77.2	84.1	84.8	20.7	31.7	96.0	133.3	80.8	22.4
80.95	142.5	194.2	66.1	133.3	76.6	129.0	450.5	91.0	103.0	118.6	82.3	19.2	83.0	74.7	81.9	82.6	17.0	29.2	94.2	133.3	79.0	19.2
94.11	148.3	199.0	67.4	128.4	72.8	127.8	494.8	88.8	101.6	117.0	79.7	11.7	90.3	69.0	78.7	79.5	11.5	19.2	90.2	100.0	75.0	11.7
107.26	156.3	197.4	93.8	117.4	67.9	124.4	546.5	86.1	100.2	112.9	85.6	21.3	116.6	87.3	83.6	85.5	8.6	16.2	84.4	75.0	69.6	21.3

Risk categories

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	III	III	II	II	III	III	IV	II	II	III	II	I	III	IV	II	II	III	III	II	IV	II	IV
7	II	II	I	II	II	III	IV	I	II	II	I	I	II	III	I	I	I	I	II	II	I	IV
12	II	II	I	I	II	II	III	I	I	II	II	I	III	III	I	I	I	I	II	I	I	III
15.16	I	II	I	I	II	II	III	I	I	II	I	I	I	II	I	I	I	I	I	I	I	III
17	I	I	I	I	I	II	III	I	I	I	I	I	I	II	I	I	I	I	I	I	I	III
22	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
25	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
28.32	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	II
32	I	I	I	I	I	I	I	I	I	I	I	III	I	I	I	I	I	I	I	II	I	III
37	I	I	I	I	I	I	I	I	I	I	I	III	I	I	I	I	I	I	I	I	I	III
41.47	I	I	I	I	I	I	I	I	I	I	I	III	I	I	I	I	II	I	I	I	I	III
42	I	I	I	I	I	I	I	I	I	I	I	IV	I	I	I	I	III	II	I	I	I	IV
47	I	I	I	I	I	I	I	I	I	I	I	IV	I	I	I	I	III	II	I	I	I	IV
52	I	I	II	I	I	I	I	I	I	I	I	IV	II	I	I	I	III	II	I	I	I	IV
54.63	I	I	II	I	I	I	I	I	I	I	I	IV	II	I	I	I	III	III	I	I	I	IV
57	I	I	II	I	II	I	I	I	I	I	I	IV	II	I	I	I	III	III	I	I	I	IV
62	I	I	II	I	II	I	I	I	I	I	I	IV	II	I	I	I	III	III	I	I	I	IV
67	I	I	II	I	II	I	I	I	I	I	I	IV	II	II	I	I	IV	III	I	I	II	IV
67.79	I	I	II	I	II	I	I	I	I	I	I	IV	II	II	II	I	IV	III	I	I	II	IV
72	I	I	II	I	II	I	I	I	I	I	II	IV	II	II	II	II	IV	III	I	I	II	IV
80.95	I	I	II	I	II	I	I	I	I	I	II	IV	II	II	II	II	IV	IV	I	I	II	IV
94.11	I	I	II	I	II	I	I	I	I	I	II	IV	I	II	II	II	IV	IV	I	I	II	IV
107.26	I	I	I	I	II	I	I	I	I	I	I	IV	I	I	II	I	IV	IV	II	II	II	IV

G4 RISK WINTER-SPRING

Winter-spring' : June - October Ref flow = 50 cumec.

Flow (m3/s) Q	Wetted area Area	WUA/m (m) Janiirid	WUA/m (m) Gripop	WUA/m (m) Leptop	WUA/m (m) Chironominae	WUA/m (m) Orthocladiinae	WUA/m (m) Simulidae	WUA/m (m) Hydrobiosidae	WUA/m (m) N Taxa	WUA/m (m) T Abund	WUA/m (m) Platypus	WUA/m (m) G. brevipinnis	WUA/m (m) A. australis	WUA/m (m) Lamprey juv	WUA/m (m) G. maculatus	WUA/m (m) G. truttaceus	WUA/m (m) S. trutta fry	WUA/m (m) S. trutta juv	WUA/m (m) S. trutta ad	WUA/m (m) S. trutta spawn	WUA/m (m) S. trutta ad Ral
2	66.68	0.59	1.14	1.84	7.18	4.35	0.20	4.58	21.00	7.77	5.07	0.10	0.35	0.57	3.76	3.43	1.75	3.19	14.26	0.00	38.39
7	87.48	0.61	1.46	1.94	13.76	7.42	0.29	5.07	26.32	9.78	5.59	0.32	0.57	1.06	4.41	4.06	4.02	4.82	16.16	0.01	44.28
12	100.67	0.75	1.31	2.20	16.08	8.74	0.53	5.91	28.36	10.31	5.40	0.17	0.50	0.93	4.34	4.02	3.86	4.92	17.50	0.01	46.92
15.16	107.65	0.84	2.01	2.34	18.21	9.80	0.69	6.25	30.62	10.95	6.61	0.24	0.94	1.73	5.27	4.78	4.35	6.04	18.09	0.01	48.89
17	111.39	0.88	1.91	2.40	19.78	10.52	0.79	6.25	31.34	11.49	6.50	0.25	0.99	1.82	5.16	4.67	4.58	6.68	18.39	0.01	49.26
22	120.49	0.95	1.33	2.49	22.28	12.09	1.22	5.92	32.34	12.73	6.32	0.14	0.86	2.19	4.91	4.41	4.43	5.88	20.48	0.01	51.60
27	128.48	1.04	1.45	2.59	22.56	13.24	1.90	5.67	33.08	13.28	6.61	0.06	0.83	2.37	5.12	4.57	4.20	4.86	20.84	0.01	52.15
28.32	130.43	1.06	1.46	2.61	22.50	13.47	2.08	5.63	33.21	13.38	6.52	0.05	0.83	2.33	5.06	4.51	4.15	4.73	20.87	0.01	52.25
32	135.63	1.14	1.32	2.71	22.21	13.98	2.58	5.58	33.44	13.68	6.28	0.05	0.81	2.28	4.90	4.37	3.93	4.77	20.99	0.01	52.38
37	142.14	1.30	1.47	2.91	21.48	14.52	3.23	5.53	33.86	14.19	6.72	0.04	0.77	2.17	5.19	4.66	3.11	4.62	21.71	0.02	52.02
41.47	147.54	1.46	1.33	3.09	20.71	14.99	3.81	5.49	34.06	14.60	6.59	0.03	0.75	2.11	5.05	4.53	2.43	4.49	21.84	0.03	50.80
42	148.15	1.48	1.32	3.10	20.63	15.05	3.88	5.48	34.07	14.66	6.57	0.03	0.75	2.10	5.03	4.52	2.36	4.47	21.82	0.02	50.59
47	153.74	1.62	1.18	3.27	19.95	15.63	4.53	5.42	34.26	15.10	6.44	0.03	0.71	2.08	4.87	4.38	1.83	3.88	21.43	0.02	48.14
52	158.98	1.74	1.08	3.40	19.28	16.05	5.14	5.41	34.34	15.40	6.25	0.02	0.68	2.11	4.71	4.24	1.52	2.88	21.02	0.01	46.10
54.63	161.63	1.78	1.05	3.44	18.96	16.18	5.44	5.43	34.32	15.47	6.15	0.03	0.68	2.08	4.62	4.16	1.42	2.29	20.83	0.01	45.24
57	163.94	1.81	1.03	3.46	18.69	16.25	5.69	5.43	34.28	15.49	6.02	0.03	0.68	2.02	4.55	4.09	1.34	2.09	20.66	0.01	44.54
62	168.64	1.85	0.97	3.46	18.13	16.30	6.15	5.41	34.12	15.49	5.77	0.03	0.68	1.89	4.39	3.96	1.13	1.91	20.31	0.01	43.27
67	173.12	1.90	0.94	3.44	17.64	16.35	6.60	5.35	33.93	15.48	5.53	0.02	0.69	1.77	4.24	3.82	0.92	1.73	19.91	0.02	42.12
67.79	173.81	1.90	0.94	3.42	17.56	16.34	6.67	5.34	33.89	15.47	5.49	0.02	0.69	1.76	4.22	3.81	0.89	1.70	19.84	0.02	41.94
72	177.40	1.94	0.92	3.38	17.17	16.33	7.02	5.27	33.71	15.43	5.32	0.02	0.70	1.70	4.11	3.71	0.73	1.57	19.47	0.02	40.95
80.95	184.66	1.98	0.94	3.26	16.32	16.18	7.71	5.14	33.24	15.21	5.16	0.01	0.76	1.57	3.95	3.57	0.50	1.03	18.63	0.01	38.93
94.11	194.55	1.97	1.30	2.98	15.21	15.75	8.52	4.99	32.76	14.68	5.54	0.02	0.98	1.99	4.19	3.84	0.37	0.87	17.44	0.01	36.09
107.26	203.70	1.95	1.12	2.74	14.64	15.34	9.01	4.82	32.27	14.20	5.39	0.05	0.99	2.35	4.22	3.86	0.46	0.83	16.36	0.01	33.34

% change in WUA relative to reference flow

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	41.9	33.9	105.4	54.1	37.3	27.1	3.8	84.6	61.1	50.4	81.1	428.5	51.3	27.0	79.8	81.0	115.1	110.8	67.8	0.0	83.3	3.8
7	55.0	34.9	135.2	57.1	71.4	46.2	5.6	93.6	76.7	63.5	89.4	1313.6	83.8	50.2	93.5	95.9	264.7	167.4	76.9	76.9	96.0	5.6
12	63.3	43.1	120.8	64.6	83.4	54.4	10.3	109.2	82.6	66.9	86.4	685.5	73.6	43.9	92.1	94.8	253.9	170.7	83.2	100.0	101.8	10.3
15.16	67.7	48.4	185.5	68.9	94.5	61.1	13.3	115.5	89.2	71.1	105.7	991.3	137.7	82.1	111.8	112.7	286.2	210.0	86.1	92.3	106.1	13.3
17	70.1	50.5	176.3	70.5	102.6	65.6	15.3	115.4	91.3	74.6	104.0	1040.9	144.6	86.4	109.5	110.1	301.4	232.0	87.5	100.0	106.9	15.3
22	75.8	54.7	123.1	73.3	115.6	75.3	23.7	109.4	94.2	82.7	101.1	592.1	126.5	103.7	104.1	104.1	291.6	204.1	97.4	100.0	111.9	23.7
27	80.8	59.6	134.1	76.0	117.0	82.5	36.9	104.7	96.3	86.3	105.8	261.6	121.4	112.5	108.7	107.7	276.4	168.7	99.1	84.6	113.1	36.9
28.32	82.0	60.8	134.7	76.8	116.7	83.9	40.5	104.0	96.7	86.9	104.3	226.9	121.6	110.8	107.4	106.3	273.0	164.2	99.3	76.9	113.3	40.5
32	85.3	65.4	122.4	79.7	115.2	87.1	50.1	103.2	97.4	88.9	100.5	196.7	119.3	108.4	104.0	103.0	258.5	165.5	99.8	100.0	113.6	50.1
37	89.4	74.8	135.7	85.5	111.5	90.5	62.7	102.2	98.6	92.1	107.5	157.4	112.7	103.1	110.1	110.0	204.5	160.4	103.3	153.8	112.8	62.7
41.47	92.8	83.7	123.0	90.7	107.4	93.4	74.1	101.4	99.2	94.8	105.4	104.5	109.5	100.0	107.1	106.9	159.8	155.8	103.9	176.9	110.2	74.1
42	93.2	84.7	121.6	91.1	107.0	93.8	75.4	101.2	99.2	95.2	105.1	104.5	110.8	99.6	106.7	106.5	155.3	155.1	103.8	169.2	109.7	75.4
47	96.7	93.1	108.8	96.1	103.5	97.4	88.0	100.1	99.8	98.1	103.0	109.1	104.9	98.8	103.3	103.3	120.2	134.6	101.9	123.1	104.4	88.0
50	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
54.63	101.7	101.9	97.5	101.1	98.4	100.8	105.7	100.3	100.0	100.4	98.4	104.5	100.2	98.8	98.1	98.3	93.7	79.5	99.1	92.3	98.1	97.5
57	103.1	103.7	95.0	101.6	96.9	101.2	110.5	100.3	99.9	100.6	96.4	109.1	100.2	96.0	96.5	96.5	87.9	72.8	98.3	92.3	96.6	95.0
62	106.1	106.2	90.0	101.7	94.1	101.6	119.6	100.0	99.4	100.6	92.2	113.6	100.2	89.5	93.2	93.5	74.2	66.3	96.6	92.3	93.9	89.5
67	108.9	108.9	86.7	101.0	91.5	101.9	128.3	98.8	98.8	100.5	88.4	100.0	101.2	84.1	90.0	90.3	60.7	60.0	94.7	115.4	91.4	84.1
67.79	109.3	108.9	86.8	100.7	91.1	101.8	129.7	98.6	98.7	100.5	87.9	95.5	101.2	83.4	89.4	89.9	58.9	59.0	94.4	123.1	91.0	83.4
72	111.6	111.0	85.1	99.5	89.1	101.8	136.5	97.4	98.2	100.2	85.1	81.8	103.0	80.7	87.2	87.5	48.4	54.4	92.6	123.1	88.8	80.7
80.95	116.2	113.8	86.6	95.9	84.6	100.8	149.9	95.0	96.8	98.8	82.5	50.0	112.0	74.6	83.7	84.2	32.6	35.8	88.6	92.3	84.4	50.0
94.11	122.4	112.9	120.6	87.7	78.9	98.1	165.6	92.2	95.4	95.3	88.5	90.9	144.5	94.4	88.9	90.6	24.3	30.1	83.0	69.2	78.3	78.9
107.26	128.1	112.1	103.5	80.4	76.0	95.6	175.2	89.0	94.0	92.2	86.2	186.4	145.8	111.4	89.5	91.0	30.1	28.7	77.8	100.0	72.3	76.0

Risk categories

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	III	III	I	III	III	IV	IV	II	II	III	II	I	III	IV	II	II	I	I	II	IV	II	IV
7	III	III	I	III	II	III	IV	I	II	II	I	I	II	III	I	I	I	I	II	II	I	IV
12	II	III	I	II	II	III	IV	I	II	II	I	I	II	III	I	I	I	I	II	I	I	IV
15.16	II	III	I	II	I	II	IV	I	I	II	I	I	I	II	I	I	I	I	I	I	I	IV
17	II	III	I	II	I	II	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
22	II	III	I	II	I	II	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
25	II	III	I	II	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	II	I	III
28.32	II	II	I	II	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	II	I	III
32	I	II	I	II	I	I	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
37	I	II	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
41.47	I	II	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
42	I	II	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
47	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
50	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
54.63	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I
57	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I
62	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	II	I	I	I	I
67	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	II	III	I	I	I	II
67.79	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	III	III	I	I	I	II
72	I	I	I	I	I	I	I	I	I	I	I	II	I	II	I	I	III	III	I	I	I	II
80.95	I	I	I	I	II	I	I	I	I	I	II	III	I	II	II	II	III	III	I	I	II	III
94.11	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV	III	II	II	II	II
107.26	I	I	I	II	II	I	I	I	I	I	I	I	I	I	I	I	III	IV	II	I	II	II

G6a7 RISK SUMMER-AUTUMN

Summer-autumn' : Dec- May. Ref flow= 25 cumec.

Flow (m3/s) Q	Wetted area Area	WUA/m (m) Janiirid	WUA/m (m) Gripop	WUA/m (m) Leptop	WUA/m (m) Chironominae	WUA/m (m) Orthocladiinae	WUA/m (m) Simulidae	WUA/m (m) Hydrobiosidae	WUA/m (m) N Taxa	WUA/m (m) T Abund	WUA/m (m) Platypus	WUA/m (m) G. brevipinnis	WUA/m (m) A. australis	WUA/m (m) Lamprey juv	WUA/m (m) G. maculatus	WUA/m (m) G. truttaceus	WUA/m (m) S. trutta fry	WUA/m (m) S. trutta juv	WUA/m (m) S. trutta ad	WUA/m (m) S. trutta spawn	WUA/m (m) S. trutta ad Ral
2	89.30	1.15	2.97	2.96	11.50	6.69	0.53	6.09	31.27	14.97	15.37	0.78	2.01	2.75	11.35	9.80	6.04	9.13	40.94	0.77	43.27
7	108.59	1.36	3.68	2.55	16.26	8.70	0.71	6.29	32.82	15.44	15.66	1.90	2.72	4.50	12.76	11.02	7.41	9.84	44.50	1.03	46.23
12	120.09	2.01	3.28	2.81	21.25	10.65	1.11	6.86	34.71	17.55	15.65	2.47	2.10	4.94	12.88	11.19	6.78	9.30	47.54	1.65	47.63
15.16	125.83	2.51	3.12	2.98	23.93	11.66	1.28	7.15	35.89	18.68	15.75	2.62	1.82	4.83	12.98	11.32	6.14	8.89	48.01	2.32	47.81
17	128.81	2.79	3.25	3.05	25.38	12.11	1.32	7.25	36.73	19.29	15.63	2.66	1.67	4.61	12.95	11.30	5.79	8.75	48.26	2.41	47.90
22	135.97	3.53	2.93	3.20	28.48	12.99	1.55	7.56	38.26	20.52	14.92	2.56	1.42	4.05	12.37	10.79	4.69	7.94	48.84	2.68	48.29
25	139.04	3.91	2.85	3.35	28.80	13.40	1.82	7.65	38.66	21.01	14.64	2.51	1.37	3.78	12.07	10.53	4.20	7.60	49.02	2.80	48.42
27	142.11	4.29	2.78	3.50	29.12	13.80	2.08	7.74	39.07	21.50	14.36	2.46	1.32	3.51	11.78	10.27	3.72	7.25	49.21	2.91	48.56
28.32	143.60	4.50	2.71	3.61	29.12	14.08	2.31	7.75	39.13	21.79	14.22	2.44	1.30	3.40	11.62	10.13	3.50	7.10	49.28	2.95	48.61
32	147.54	5.05	2.69	3.90	29.00	14.51	2.75	7.84	39.60	22.38	13.88	2.37	1.24	3.10	11.18	9.74	2.95	6.68	49.25	3.00	48.70
37	152.44	5.77	2.65	4.31	28.44	15.17	3.50	7.88	39.97	23.13	13.47	2.26	1.21	2.78	10.62	9.26	2.34	5.79	48.26	2.97	48.20
41.47	156.46	6.42	2.55	4.69	27.62	15.83	4.31	7.76	40.18	23.80	13.09	2.15	1.21	2.53	10.17	8.87	1.95	4.81	46.81	2.93	46.60
42	156.91	6.50	2.57	4.73	27.51	15.77	4.28	7.81	40.30	23.84	13.05	2.14	1.22	2.50	10.13	8.82	1.91	4.73	46.68	2.92	46.22
47	161.06	7.16	2.59	5.11	26.44	16.32	5.05	7.74	40.62	24.42	12.78	2.00	1.25	2.25	9.80	8.55	1.57	4.04	45.25	2.86	43.02
52	164.92	7.80	2.62	5.45	25.24	16.80	5.77	7.68	40.91	24.90	12.43	1.85	1.28	2.07	9.47	8.28	1.35	3.36	43.74	2.79	40.52
54.63	166.86	8.13	2.55	5.52	24.68	17.07	6.26	7.54	40.83	25.05	12.20	1.77	1.30	1.98	9.28	8.11	1.24	2.98	42.94	2.74	39.48
57	168.55	8.42	2.46	5.58	24.19	16.98	6.33	7.53	40.86	25.07	11.98	1.70	1.32	1.92	9.10	7.96	1.16	2.72	42.19	2.70	38.62
62	171.98	9.05	2.27	5.65	23.12	17.00	6.84	7.32	40.66	25.11	11.50	1.54	1.35	1.78	8.75	7.65	1.00	2.30	40.55	2.61	37.03
67	175.24	9.68	2.08	5.67	22.02	16.91	7.30	7.11	40.35	25.03	11.01	1.38	1.38	1.68	8.39	7.34	0.85	1.99	38.99	2.52	35.47
67.79	175.73	9.78	2.05	5.63	21.85	17.05	7.57	6.98	40.22	25.02	10.93	1.36	1.38	1.67	8.33	7.29	0.83	1.96	38.75	2.50	35.22
72	178.34	10.30	1.90	5.65	20.89	16.77	7.73	6.90	39.99	24.88	10.53	1.24	1.39	1.60	8.04	7.05	0.72	1.76	37.42	2.43	33.89
80.95	183.55	11.36	1.72	5.46	18.82	16.58	8.67	6.41	39.17	24.47	9.71	1.01	1.45	1.47	7.44	6.52	0.54	1.46	34.40	2.28	30.98
94.11	190.60	12.91	1.50	5.22	15.77	15.86	9.71	5.83	37.94	23.73	8.65	0.78	1.53	1.30	6.68	5.88	0.33	1.11	30.14	2.06	27.31
107.26	197.03	14.31	1.54	4.87	14.11	15.10	10.15	5.25	36.60	22.74	8.04	0.65	1.58	1.16	6.13	5.42	0.18	0.83	26.95	1.87	24.00

% change in WUA relative to reference flow

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	62.2	25.7	109.6	82.0	39.5	47.5	22.8	78.7	79.9	68.7	108.1	32.0	155.1	81.1	97.7	96.8	172.7	128.6	83.1	26.1	89.0	22.8
7	75.6	30.2	135.9	70.5	55.8	61.8	30.6	81.2	83.9	70.9	110.2	78.0	209.9	132.4	109.8	108.8	211.9	138.6	90.3	34.9	95.1	30.2
12	83.6	44.7	121.1	77.9	73.0	75.7	48.3	88.5	88.7	80.6	110.1	101.6	161.5	145.6	110.8	110.5	193.9	131.1	96.5	56.2	98.0	44.7
15.16	87.6	55.7	115.3	82.4	82.2	82.8	55.3	92.3	91.7	85.7	110.8	107.6	140.6	142.2	111.7	111.7	175.8	125.2	97.4	78.8	98.3	55.3
17	89.7	62.0	119.8	84.3	87.2	86.0	57.3	93.7	93.9	88.5	109.9	109.2	129.1	135.9	111.4	111.6	165.7	123.2	97.9	82.0	98.5	57.3
22	94.7	78.5	108.0	88.5	97.8	92.3	67.2	97.6	97.8	94.2	104.9	105.3	109.7	119.3	106.4	106.5	134.1	111.9	99.1	91.1	99.3	67.2
25	96.8	87.0	105.2	92.7	98.9	95.1	78.7	98.8	98.8	96.4	103.0	103.1	105.7	111.4	103.9	104.0	120.3	107.0	99.5	94.9	99.6	78.7
27	99.0	95.5	102.4	96.9	100.0	98.0	90.2	99.9	99.8	98.7	101.0	100.9	101.8	103.5	101.4	101.4	106.5	102.1	99.8	98.7	99.9	90.2
28.32	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
32	102.7	112.2	99.3	107.9	99.6	103.1	119.3	101.2	101.2	102.7	97.6	97.4	95.2	91.4	96.3	96.2	84.3	94.1	99.9	101.7	100.2	91.4
37	106.2	128.3	97.7	119.3	97.7	107.7	151.9	101.7	102.1	106.1	94.7	92.9	93.0	81.7	91.4	91.4	66.9	81.6	97.9	100.7	99.1	81.7
41.47	109.0	142.9	94.1	129.8	94.8	112.5	187.0	100.2	102.7	109.3	92.1	88.4	93.4	74.5	87.5	87.5	55.9	67.7	95.0	99.4	95.9	74.5
42	109.3	144.4	94.8	131.0	94.5	112.0	185.4	100.8	103.0	109.4	91.8	87.8	94.0	73.7	87.2	87.1	54.7	66.7	94.7	99.3	95.1	73.7
47	112.2	159.2	95.5	141.5	90.8	115.9	218.8	99.9	103.8	112.1	89.9	81.9	96.1	66.4	84.3	84.4	45.0	56.9	91.8	97.2	88.5	66.4
52	114.8	173.5	96.8	150.7	86.7	119.3	250.3	99.1	104.5	114.3	87.4	76.0	98.5	60.9	81.5	81.8	38.5	47.3	88.8	94.6	83.3	60.9
54.63	116.2	180.7	94.0	152.9	84.8	121.2	271.3	97.4	104.3	115.0	85.8	72.7	100.4	58.4	79.9	80.1	35.6	41.9	87.1	93.0	81.2	58.4
57	117.4	187.2	90.8	154.6	83.1	120.6	274.6	97.2	104.4	115.1	84.2	69.6	101.7	56.5	78.3	78.6	33.2	38.2	85.6	91.6	79.4	56.5
62	119.8	201.3	83.9	156.4	79.4	120.7	296.4	94.5	103.9	115.2	80.8	63.1	104.3	52.5	75.3	75.6	28.5	32.3	82.3	88.5	76.2	52.5
67	122.0	215.2	76.9	156.9	75.6	120.1	316.5	91.9	103.1	114.9	77.4	56.8	106.3	49.5	72.2	72.5	24.2	28.1	79.1	85.4	73.0	49.5
67.79	122.4	217.4	75.6	155.9	75.0	121.1	328.2	90.2	102.8	114.8	76.9	55.8	106.3	49.2	71.7	72.0	23.7	27.5	78.6	85.0	72.5	49.2
72	124.2	229.0	70.2	156.5	71.7	119.1	335.0	89.0	102.2	114.2	74.0	50.9	106.9	47.0	69.2	69.6	20.7	24.8	75.9	82.5	69.7	47.0
80.95	127.8	252.7	63.3	151.2	64.6	117.7	375.9	82.7	100.1	112.3	68.3	41.5	111.7	43.4	64.0	64.4	15.5	20.6	69.8	77.2	63.7	41.5
94.11	132.7	287.1	55.2	144.4	54.1	112.7	421.1	75.3	97.0	108.9	60.8	32.2	118.0	38.2	57.5	58.1	9.5	15.6	61.1	69.9	56.2	32.2
107.26	137.2	318.2	56.9	134.8	48.4	107.2	440.2	67.7	93.5	104.4	56.5	26.5	122.1	34.3	52.7	53.5	5.2	11.7	54.7	63.4	49.4	26.5

Risk categories

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	II	IV	I	II	III	III	IV	II	II	II	I	III	I	II	I	I	I	I	II	IV	I	IV
7	II	III	I	II	III	II	III	II	II	II	I	II	I	I	I	I	I	I	I	III	I	III
12	II	III	I	II	II	II	III	I	I	II	I	I	I	I	I	I	I	I	I	III	I	III
15.16	I	III	I	II	II	II	III	I	I	I	I	I	I	I	I	I	I	I	I	II	I	III
17	I	II	I	II	I	I	III	I	I	I	I	I	I	I	I	I	I	I	I	II	I	III
22	I	II	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
25	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
28.32	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
32	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I	I
37	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	II	II	I	I	I	II
41.47	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	III	II	I	I	I	II
42	I	I	I	I	I	I	I	I	I	I	I	I	I	II	I	I	III	II	I	I	I	II
47	I	I	I	I	I	I	I	I	I	I	I	II	I	II	II	II	III	III	I	I	I	II
52	I	I	I	I	I	I	I	I	I	I	I	II	I	II	II	II	III	III	I	I	II	II
54.63	I	I	I	I	II	I	I	I	I	I	I	II	I	III	II	II	III	III	I	I	II	III
57	I	I	I	I	II	I	I	I	I	I	II	II	I	III	II	II	III	III	I	I	II	III
62	I	I	II	I	II	I	I	I	I	I	II	II	I	III	II	II	IV	III	II	I	II	III
67	I	I	II	I	II	I	I	I	I	I	II	III	I	III	II	II	IV	IV	II	I	II	III
67.79	I	I	II	I	II	I	I	I	I	I	II	III	I	III	II	II	IV	IV	II	II	II	III
72	I	I	II	I	II	I	I	I	I	I	II	III	I	III	II	II	IV	IV	II	II	II	III
80.95	I	I	II	I	II	I	I	II	I	I	II	III	I	III	II	II	IV	IV	II	II	II	III
94.11	I	I	III	I	III	I	I	II	I	I	II	III	I	III	III	III	IV	IV	II	II	III	III
107.26	I	I	III	I	III	I	I	II	I	I	III	IV	I	III	III	III	IV	IV	III	II	III	IV

G6a7 RISK WINTER-SPRING

Winter-spring' : June - October Ref flow = 50 cumec.

Flow (m3/s) Q	Wetted area Area	WUA/m (m) Janiirid	WUA/m (m) Gripop	WUA/m (m) Leptop	WUA/m (m) Chironominae	WUA/m (m) Orthocladiinae	WUA/m (m) Simulidae	WUA/m (m) Hydrobiosidae	WUA/m (m) N Taxa	WUA/m (m) T Abund	WUA/m (m) Platypus	WUA/m (m) G. brevipinnis	WUA/m (m) A. australis	WUA/m (m) Lamprey juv	WUA/m (m) G. maculatus	WUA/m (m) G. truttaceus	WUA/m (m) S. trutta fry	WUA/m (m) S. trutta juv	WUA/m (m) S. trutta ad	WUA/m (m) S. trutta spawn	WUA/m (m) S. trutta ad Ral
2	89.30	1.15	2.97	2.96	11.50	6.69	0.53	6.09	31.27	14.97	15.37	0.78	2.01	2.75	11.35	9.80	6.04	9.13	40.94	0.77	43.27
7	108.59	1.36	3.68	2.55	16.26	8.70	0.71	6.29	32.82	15.44	15.66	1.90	2.72	4.50	12.76	11.02	7.41	9.84	44.50	1.03	46.23
12	120.09	2.01	3.28	2.81	21.25	10.65	1.11	6.86	34.71	17.55	15.65	2.47	2.10	4.94	12.88	11.19	6.78	9.30	47.54	1.65	47.63
15.16	125.83	2.51	3.12	2.98	23.93	11.66	1.28	7.15	35.89	18.68	15.75	2.62	1.82	4.83	12.98	11.32	6.14	8.89	48.01	2.32	47.81
17	128.81	2.79	3.25	3.05	25.38	12.11	1.32	7.25	36.73	19.29	15.63	2.66	1.67	4.61	12.95	11.30	5.79	8.75	48.26	2.41	47.90
22	135.97	3.53	2.93	3.20	28.48	12.99	1.55	7.56	38.26	20.52	14.92	2.56	1.42	4.05	12.37	10.79	4.69	7.94	48.84	2.68	48.29
27	142.11	4.29	2.78	3.50	29.12	13.80	2.08	7.74	39.07	21.50	14.36	2.46	1.32	3.51	11.78	10.27	3.72	7.25	49.21	2.91	48.56
28.32	143.60	4.50	2.71	3.61	29.12	14.08	2.31	7.75	39.13	21.79	14.22	2.44	1.30	3.40	11.62	10.13	3.50	7.10	49.28	2.95	48.61
32	147.54	5.05	2.69	3.90	29.00	14.51	2.75	7.84	39.60	22.38	13.88	2.37	1.24	3.10	11.18	9.74	2.95	6.68	49.25	3.00	48.70
37	152.44	5.77	2.65	4.31	28.44	15.17	3.50	7.88	39.97	23.13	13.47	2.26	1.21	2.78	10.62	9.26	2.34	5.79	48.26	2.97	48.20
41.47	156.46	6.42	2.55	4.69	27.62	15.83	4.31	7.76	40.18	23.80	13.09	2.15	1.21	2.53	10.17	8.87	1.95	4.81	46.81	2.93	46.60
42	156.91	6.50	2.57	4.73	27.51	15.77	4.28	7.81	40.30	23.84	13.05	2.14	1.22	2.50	10.13	8.82	1.91	4.73	46.68	2.92	46.22
47	161.06	7.16	2.59	5.11	26.44	16.32	5.05	7.74	40.62	24.42	12.78	2.00	1.25	2.25	9.80	8.55	1.57	4.04	45.25	2.86	43.02
52	164.92	7.80	2.62	5.45	25.24	16.80	5.77	7.68	40.91	24.90	12.43	1.85	1.28	2.07	9.47	8.28	1.35	3.36	43.74	2.79	40.52
54.63	166.86	8.13	2.55	5.52	24.68	17.07	6.26	7.54	40.83	25.05	12.20	1.77	1.30	1.98	9.28	8.11	1.24	2.98	42.94	2.74	39.48
57	168.55	8.42	2.46	5.58	24.19	16.98	6.33	7.53	40.86	25.07	11.98	1.70	1.32	1.92	9.10	7.96	1.16	2.72	42.19	2.70	38.62
62	171.98	9.05	2.27	5.65	23.12	17.00	6.84	7.32	40.66	25.11	11.50	1.54	1.35	1.78	8.75	7.65	1.00	2.30	40.55	2.61	37.03
67	175.24	9.68	2.08	5.67	22.02	16.91	7.30	7.11	40.35	25.03	11.01	1.38	1.38	1.68	8.39	7.34	0.85	1.99	38.99	2.52	35.47
67.79	175.73	9.78	2.05	5.63	21.85	17.05	7.57	6.98	40.22	25.02	10.93	1.36	1.38	1.67	8.33	7.29	0.83	1.96	38.75	2.50	35.22
72	178.34	10.30	1.90	5.65	20.89	16.77	7.73	6.90	39.99	24.88	10.53	1.24	1.39	1.60	8.04	7.05	0.72	1.76	37.42	2.43	33.89
80.95	183.55	11.36	1.72	5.46	18.82	16.58	8.67	6.41	39.17	24.47	9.71	1.01	1.45	1.47	7.44	6.52	0.54	1.46	34.40	2.28	30.98
94.11	190.60	12.91	1.50	5.22	15.77	15.86	9.71	5.83	37.94	23.73	8.65	0.78	1.53	1.30	6.68	5.88	0.33	1.11	30.14	2.06	27.31
107.26	197.03	14.31	1.54	4.87	14.11	15.10	10.15	5.25	36.60	22.74	8.04	0.65	1.58	1.16	6.13	5.42	0.18	0.83	26.95	1.87	24.00

% change in WUA relative to reference flow

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	53.5	14.2	116.6	53.6	46.6	39.2	8.4	80.8	76.6	59.8	126.0	44.0	154.5	138.8	122.3	120.8	485.7	306.6	95.3	28.0	109.6	8.4
7	65.1	16.7	144.6	46.1	65.9	51.0	11.3	83.3	80.4	61.6	128.4	107.3	209.1	226.7	137.4	135.9	595.7	330.5	103.7	37.6	117.1	11.3
12	72.0	24.7	128.9	50.9	86.1	62.4	17.8	90.9	85.0	70.1	128.3	139.7	160.9	249.3	138.7	138.0	545.2	312.5	110.7	60.4	120.6	17.8
15.16	75.4	30.8	122.7	53.9	96.9	68.3	20.4	94.8	87.9	74.6	129.1	147.9	140.0	243.4	139.8	139.5	494.2	298.6	111.8	84.8	121.1	20.4
17	77.2	34.3	127.4	55.2	102.8	70.9	21.1	96.2	90.0	77.0	128.2	150.3	128.6	232.7	139.4	139.3	465.8	293.9	112.4	88.1	121.3	21.1
22	81.5	43.5	114.9	57.9	115.4	76.1	24.8	100.3	93.7	81.9	122.3	144.8	109.3	204.2	133.2	133.0	377.0	266.8	113.8	98.0	122.3	24.8
27	85.2	52.8	109.0	63.4	118.0	80.8	33.2	102.6	95.7	85.9	117.7	138.8	101.4	177.2	126.9	126.6	299.5	243.4	114.6	106.1	123.0	33.2
28.32	86.1	55.3	106.4	65.4	118.0	82.5	36.9	102.7	95.8	87.0	116.6	137.5	99.6	171.2	125.2	124.8	281.2	238.5	114.8	107.5	123.1	36.9
32	88.4	62.1	105.6	70.6	117.5	85.0	44.0	104.0	97.0	89.3	113.8	134.0	94.9	156.5	120.5	120.1	237.2	224.4	114.7	109.4	123.4	44.0
37	91.4	71.0	104.0	78.1	115.2	88.9	56.0	104.4	97.9	92.3	110.5	127.8	92.6	139.9	114.4	114.1	188.1	194.6	112.4	108.3	122.1	56.0
41.47	93.8	79.0	100.2	84.9	111.9	92.8	68.9	102.9	98.4	95.0	107.3	121.6	93.0	127.6	109.6	109.3	157.1	161.4	109.0	106.9	118.0	68.9
42	94.0	79.9	100.8	85.7	111.5	92.4	68.3	103.6	98.7	95.2	107.0	120.7	93.6	126.2	109.1	108.8	153.8	159.0	108.7	106.8	117.1	68.3
47	96.5	88.1	101.6	92.5	107.1	95.6	80.6	102.6	99.5	97.5	104.8	112.7	95.8	113.6	105.5	105.4	126.5	135.7	105.4	104.5	109.0	80.6
52	98.8	96.0	103.0	98.6	102.2	98.4	92.2	101.8	100.2	99.4	101.9	104.6	98.1	104.2	102.0	102.1	108.2	112.7	101.9	101.7	102.6	92.2
54.63	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
57	101.0	103.6	96.6	101.1	98.0	99.5	101.2	99.8	100.1	100.1	98.2	95.7	101.3	96.7	98.1	98.2	93.3	91.2	98.3	98.5	97.8	95.7
62	103.1	111.4	89.2	102.3	93.7	99.6	109.2	97.1	99.6	100.2	94.3	86.8	103.9	90.0	94.3	94.3	80.1	77.1	94.4	95.1	93.8	86.8
67	105.0	119.1	81.8	102.6	89.2	99.0	116.6	94.3	98.8	99.9	90.2	78.1	105.9	84.7	90.4	90.5	68.1	67.0	90.8	91.9	89.8	78.1
67.79	105.3	120.3	80.5	102.0	88.5	99.9	121.0	92.6	98.5	99.9	89.7	76.8	105.9	84.2	89.7	89.9	66.5	65.7	90.3	91.4	89.2	76.8
72	106.9	126.7	74.7	102.3	84.6	98.3	123.5	91.4	97.9	99.3	86.3	70.0	106.5	80.4	86.6	86.8	58.1	59.2	87.2	88.7	85.9	70.0
80.95	110.0	139.8	67.3	98.9	76.2	97.1	138.5	84.9	95.9	97.7	79.6	57.1	111.3	74.3	80.1	80.4	43.7	49.2	80.1	83.1	78.5	57.1
94.11	114.2	158.9	58.8	94.4	63.9	92.9	155.2	77.3	92.9	94.7	70.9	44.3	117.5	65.4	72.0	72.5	26.8	37.2	70.2	75.2	69.2	44.3
107.26	118.1	176.1	60.6	88.1	57.2	88.4	162.3	69.6	89.6	90.8	65.9	36.5	121.7	58.7	66.0	66.8	14.5	27.9	62.8	68.2	60.8	36.5

Risk categories

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	III	IV	I	III	III	III	IV	II	II	III	I	III	I	I	I	I	I	I	I	IV	I	IV
7	II	IV	I	III	II	III	IV	II	II	II	I	I	I	I	I	I	I	I	I	III	I	IV
12	II	IV	I	III	I	II	IV	I	I	II	I	I	I	I	I	I	I	I	I	II	I	IV
15.16	II	III	I	III	I	II	IV	I	I	II	I	I	I	I	I	I	I	I	I	II	I	IV
17	II	III	I	III	I	II	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
22	II	III	I	III	I	II	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
25	I	III	I	II	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
28.32	I	III	I	II	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
32	I	II	I	II	I	I	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
37	I	II	I	II	I	I	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
41.47	I	II	I	II	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
42	I	II	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
47	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
52	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
54.63	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
57	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
62	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II	II	I	I	I	I
67	I	I	II	I	I	I	I	I	I	I	I	II	I	II	I	I	II	II	I	I	I	II
67.79	I	I	II	I	I	I	I	I	I	I	I	II	I	II	I	I	II	II	I	I	I	II
72	I	I	II	I	II	I	I	I	I	I	I	II	I	II	I	I	III	III	I	I	I	II
80.95	I	I	II	I	II	I	I	II	I	I	II	III	I	II	II	II	III	III	II	II	II	III
94.11	I	I	III	I	II	I	I	II	I	I	II	III	I	II	II	II	IV	III	II	II	II	III
107.26	I	I	II	I	III	I	I	II	I	I	II	III	I	III	II	II	IV	IV	II	II	II	III

G11b15 RISK SUMMER-AUTUMN

Summer-autumn' : Dec- May. Ref flow= 25 cumec.

Flow	Wetted	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m	WUA/m
(m3/s)	area	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)	(m)
Q	**Area**	**Janiirid**	**Gripop**	**Leptop**	**Chironominae**	**Orthocladiinae**	**Simulidae**	**Hydrobiosidae**	**N Taxa**	**T Abund**	**Platypus**	**G. brevipinnis**	**A. australis**	**Lamprey juv**	**G.maculatus**	**G. truttaceus**	**S. trutta fry**	**S. trutta juv**	**S. trutta ad**	**S. trutta spawn**	**S. trutta ad Ral**
2	40.88	0.78	2.90	3.76	13.31	5.27	0.13	6.36	31.99	16.14	26.82	0.69	2.67	7.00	22.33	18.31	22.55	28.98	39.74	0.33	35.80
7	60.16	2.30	2.39	6.29	12.05	5.21	0.42	9.64	35.36	18.75	25.39	0.17	1.94	4.58	23.72	19.37	14.02	22.83	46.70	0.24	41.51
12	75.62	3.12	2.51	7.22	14.54	5.67	0.72	11.15	37.82	19.82	23.92	0.48	2.29	3.94	23.44	19.14	10.17	15.87	49.70	0.27	43.85
15.16	84.60	3.25	2.32	7.29	16.92	5.90	0.83	11.80	38.62	19.94	22.52	0.52	2.36	3.48	22.53	18.40	9.49	13.82	51.47	0.52	45.14
17	89.61	3.27	2.16	7.27	17.99	6.06	0.88	12.03	38.84	20.02	21.70	0.46	2.27	3.30	21.81	17.84	8.83	12.87	52.84	0.57	46.41
22	102.60	3.22	3.00	7.01	19.92	6.85	0.95	12.64	40.02	19.80	20.97	0.26	2.42	3.30	20.74	17.11	7.63	10.74	53.81	0.41	46.97
27	114.91	3.06	2.50	6.86	22.25	8.03	1.09	12.92	40.97	19.87	19.34	0.20	2.37	3.47	18.89	15.65	7.10	9.59	55.03	0.35	46.77
28.32	118.05	2.99	2.32	6.81	22.68	8.34	1.12	12.89	41.14	19.96	18.94	0.19	2.29	3.50	18.40	15.27	6.80	9.38	55.69	0.33	47.11
32	126.68	2.81	2.09	6.65	23.88	9.23	1.26	12.68	41.66	19.97	17.82	0.14	2.23	3.52	16.98	14.13	6.22	9.05	56.39	0.27	47.31
37	138.05	2.58	2.02	6.34	25.45	10.53	1.48	11.91	42.33	20.09	16.69	0.14	2.27	3.33	15.46	12.95	5.74	8.14	56.74	0.14	47.30
41.47	147.96	2.45	2.29	6.11	26.88	11.80	1.72	11.08	43.10	20.51	16.26	0.13	2.34	3.14	14.59	12.33	5.44	7.31	57.34	0.12	47.67
42	149.11	2.44	2.38	6.09	27.03	11.95	1.75	10.98	43.26	20.57	16.29	0.14	2.36	3.15	14.56	12.32	5.38	7.29	57.40	0.13	47.69
47	159.96	2.34	2.56	5.84	28.54	13.38	2.03	10.14	44.37	21.16	15.80	0.16	2.53	3.21	13.75	11.67	5.48	7.28	57.38	0.12	47.43
52	170.55	2.35	2.19	5.68	29.66	14.49	2.32	9.34	44.81	21.83	14.89	0.13	2.57	3.30	12.80	10.89	5.22	7.17	57.70	0.08	47.32
54.63	176.05	2.38	2.08	5.63	30.08	15.00	2.48	8.96	45.13	22.17	14.51	0.13	2.54	3.33	12.46	10.59	5.01	6.64	58.21	0.06	47.65
57	180.94	2.42	2.02	5.59	30.32	15.41	2.63	8.68	45.35	22.43	14.11	0.13	2.51	3.19	12.14	10.33	4.86	6.55	58.21	0.05	47.58
62	191.08	2.55	1.97	5.62	30.66	16.15	2.94	8.15	45.81	22.93	13.35	0.12	2.54	2.87	11.55	9.82	4.42	6.07	58.11	0.11	47.08
67	201.02	2.68	1.88	5.62	30.86	16.82	3.23	7.62	46.02	23.39	12.48	0.10	2.54	2.70	10.83	9.22	3.98	5.93	57.99	0.16	46.65
67.79	202.5661	2.6902	1.8599	5.6199	30.873	16.9245	3.2818	7.5246	46.0383	23.4566	12.336	0.0912	2.5381	2.6891	10.6993	9.1058	3.9113	5.7089	57.9454	0.1638	46.5633
72	210.7556	2.7392	2.1182	5.5509	30.7617	17.3376	3.4589	7.1926	46.2281	23.676	12.0299	0.0528	2.5408	2.671	10.3561	8.869	3.4195	4.9161	57.9686	0.1469	46.2953
80.95	227.7366	2.7605	2.7874	5.391	30.9325	18.3536	3.7715	6.6433	46.942	24.0736	11.5713	0.0124	2.6307	2.8766	9.7681	8.5023	2.4759	3.8531	56.9932	0.1092	45.233
94.11	251.7442	2.6587	1.9331	5.0311	30.8249	19.1228	4.0837	5.8901	46.8301	23.9826	9.5606	0	2.4255	2.7684	8.0848	7.1153	1.2079	2.4031	56.5162	0.0312	43.691
107.26	274.8071	2.5333	2.0411	4.6457	30.9359	19.7583	4.218	5.1488	46.713	23.6571	8.5029	0	2.5059	2.3179	6.9131	6.187	0.577	0.9548	55.4802	0	42.103

2) as % diff from ref flow

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	21.4	30.5	146.7	66.8	43.4	32.7	4.3	78.0	69.8	70.4	200.8	565.4	105.2	243.6	193.3	186.6	510.5	477.7	68.4	313.6	76.0	4.3
7	31.5	90.0	121.0	111.9	39.3	32.2	14.3	118.2	77.2	81.8	190.2	143.0	76.5	159.4	205.3	197.3	317.5	376.4	80.4	225.9	88.2	14.3
12	39.6	122.2	127.1	128.6	47.4	35.1	24.5	136.8	82.6	86.4	179.1	391.5	90.1	137.2	202.9	195.0	230.3	261.7	85.5	255.6	93.1	24.5
15.16	44.3	127.2	117.5	129.7	55.2	36.6	28.3	144.7	84.3	87.0	168.7	428.3	92.8	121.3	195.1	187.4	214.9	227.8	88.6	492.6	95.9	28.3
17	46.9	128.1	109.4	129.4	58.7	37.6	30.0	147.6	84.8	87.3	162.5	374.4	89.4	114.8	188.8	181.7	200.0	212.2	90.9	538.3	98.6	30.0
22	53.7	126.1	151.9	124.9	65.0	42.5	32.5	155.1	87.4	86.3	157.0	216.8	95.3	114.7	179.5	174.3	172.8	177.2	92.6	387.7	99.8	32.5
27	60.1	119.7	126.5	122.1	72.6	49.7	37.1	158.5	89.4	86.7	144.8	165.5	93.6	120.7	163.5	159.5	160.7	158.1	94.7	329.6	99.3	37.1
28.32	61.8	117.1	117.6	121.3	74.0	51.6	38.3	158.1	89.8	87.0	141.8	154.8	90.2	121.7	159.3	155.5	154.0	154.6	95.8	311.1	100.1	38.3
32	66.3	110.0	105.8	118.4	77.9	57.2	42.8	155.6	90.9	87.1	133.4	115.8	87.8	122.4	147.0	144.0	140.8	149.2	97.0	253.1	100.5	42.8
37	72.2	101.1	102.2	112.9	83.0	65.2	50.5	146.1	92.4	87.6	125.0	112.1	89.6	115.8	133.8	131.9	130.0	134.2	97.7	130.9	100.5	50.5
41.47	77.4	95.9	115.9	108.8	87.7	73.1	58.7	135.9	94.1	89.4	121.8	108.3	92.4	109.2	126.3	125.6	123.1	120.5	98.7	118.5	101.2	58.7
42	78.0	95.4	120.5	108.4	88.1	74.0	59.5	134.7	94.4	89.7	122.0	115.3	93.1	109.5	126.0	125.5	121.7	120.2	98.8	122.2	101.3	59.5
47	83.7	91.8	129.8	103.9	93.1	82.9	69.1	124.4	96.9	92.3	118.3	133.0	99.6	111.6	119.1	118.9	124.1	120.0	98.7	113.6	100.7	69.1
52	89.3	91.8	110.8	101.0	96.7	89.7	78.9	114.6	97.8	95.2	111.5	108.3	101.2	115.0	110.8	110.9	118.2	118.2	99.3	72.8	100.5	78.9
54.63	92.1	93.0	105.3	100.1	98.1	92.9	84.4	109.9	98.5	96.7	108.7	106.6	100.1	115.9	107.8	107.9	113.4	109.4	100.2	56.8	101.2	84.4
57	94.7	94.6	102.2	99.4	98.9	95.4	89.6	106.4	99.0	97.8	105.7	107.6	98.8	111.2	105.1	105.2	110.0	107.9	100.2	51.9	101.1	89.6
62	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67	105.2	104.9	95.4	100.1	100.7	104.2	110.1	93.5	100.4	102.0	93.5	80.3	100.0	94.1	93.7	93.9	90.2	97.8	99.8	149.4	99.1	80.3
67.79	106.0	105.3	94.2	100.0	100.7	104.8	111.8	92.3	100.5	102.3	92.4	74.9	100.0	93.6	92.6	92.8	88.6	94.1	99.7	155.6	98.9	74.9
72	110.3	107.2	107.3	98.8	100.3	107.4	117.8	88.2	100.9	103.2	90.1	43.4	100.1	92.9	89.6	90.3	77.4	81.1	99.8	139.5	98.3	43.4
80.95	119.2	108.1	141.1	96.0	100.9	113.7	128.4	81.5	102.5	105.0	86.7	10.2	103.7	100.1	84.6	86.6	56.1	63.5	98.1	103.7	96.1	10.2
94.11	131.7	104.1	97.9	89.6	100.5	118.4	139.1	72.3	102.2	104.6	71.6	0.0	95.6	96.3	70.0	72.5	27.3	39.6	97.3	29.6	92.8	0.0
107.26	143.8	99.2	103.4	82.7	100.9	122.4	143.7	63.2	102.0	103.2	63.7	0.0	98.7	80.7	59.8	63.0	13.1	15.7	95.5	0.0	89.4	0.0

3) as risk category (see Davies and Humphries 1996)

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	IV	III	I	II	III	III	IV	II	II	II	I	I	I	I	I	I	I	I	II	I	II	IV
7	III	I	I	I	III	III	IV	I	II	II	I	I	II	I	I	I	I	I	II	I	I	IV
12	III	I	I	I	III	III	IV	I	II	I	I	I	I	I	I	I	I	I	I	I	I	IV
15.16	III	I	I	I	III	III	IV	I	II	I	I	I	I	I	I	I	I	I	I	I	I	IV
17	III	I	I	I	III	III	IV	I	II	I	I	I	I	I	I	I	I	I	I	I	I	IV
22	III	I	I	I	II	III	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
25	II	I	I	I	II	III	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
28.32	II	I	I	I	II	III	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
32	II	I	I	I	II	III	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
37	II	I	I	I	II	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
41.47	II	I	I	I	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
42	II	I	I	I	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
47	II	I	I	I	I	II	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
52	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	II	I	II
54.63	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	III	I	II
57	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III	I	I
62	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
67	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	II
67.79	I	I	I	I	I	I	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	II
72	I	I	I	I	I	I	I	I	I	I	I	III	I	I	I	I	II	II	I	I	I	III
80.95	I	I	I	I	I	I	I	II	I	I	I	IV	I	I	II	I	III	II	I	I	I	IV
94.11	I	I	I	I	I	I	I	II	I	I	II	IV	I	I	II	II	IV	III	I	IV	I	IV
107.26	I	I	I	II	I	I	I	II	I	I	II	IV	I	II	III	II	IV	IV	I	IV	I	IV

G11b15 RISK WINTER-SPRING

Winter-spring' : June - October Ref flow = 50 cumec.

1) Sum (bar and riff in propn)

Flow (m3/s) Q	Wetted area Area	WUA/m (m) Janiirid	WUA/m (m) Gripop	WUA/m (m) Leptop	WUA/m (m) Chironominae	WUA/m (m) Orthocladiinae	WUA/m (m) Simulidae	WUA/m (m) Hydrobiosidae	WUA/m (m) N Taxa	WUA/m (m) T Abund	WUA/m (m) Platypus	WUA/m (m) G. brevipinnis	WUA/m (m) A. australis	WUA/m (m) Lamprey juv	WUA/m (m) G.maculatus	WUA/m (m) G. truttaceus	WUA/m (m) S. trutta fry	WUA/m (m) S. trutta juv	WUA/m (m) S. trutta ad	WUA/m (m) S. trutta spawn	WUA/m (m) S. trutta ad Ral
2	40.88	0.78	2.90	3.76	13.31	5.27	0.13	6.36	31.99	16.14	26.82	0.69	2.67	7.00	22.33	18.31	22.55	28.98	39.74	0.33	35.80
7	60.16	2.30	2.39	6.29	12.05	5.21	0.42	9.64	35.36	18.75	25.39	0.17	1.94	4.58	23.72	19.37	14.02	22.83	46.70	0.24	41.51
12	75.62	3.12	2.51	7.22	14.54	5.67	0.72	11.15	37.82	19.82	23.92	0.48	2.29	3.94	23.44	19.14	10.17	15.87	49.70	0.27	43.85
15.16	84.60	3.25	2.32	7.29	16.92	5.90	0.83	11.80	38.62	19.94	22.52	0.52	2.36	3.48	22.53	18.40	9.49	13.82	51.47	0.52	45.14
17	89.61	3.27	2.16	7.27	17.99	6.06	0.88	12.03	38.84	20.02	21.70	0.46	2.27	3.30	21.81	17.84	8.83	12.87	52.84	0.57	46.41
22	102.60	3.22	3.00	7.01	19.92	6.85	0.95	12.64	40.02	19.80	20.97	0.26	2.42	3.30	20.74	17.11	7.63	10.74	53.81	0.41	46.97
27	114.91	3.06	2.50	6.86	22.25	8.03	1.09	12.92	40.97	19.87	19.34	0.20	2.37	3.47	18.89	15.65	7.10	9.59	55.03	0.35	46.77
28.32	118.05	2.99	2.32	6.81	22.68	8.34	1.12	12.89	41.14	19.96	18.94	0.19	2.29	3.50	18.40	15.27	6.80	9.38	55.69	0.33	47.11
32	126.68	2.81	2.09	6.65	23.88	9.23	1.26	12.68	41.66	19.97	17.82	0.14	2.23	3.52	16.98	14.13	6.22	9.05	56.39	0.27	47.31
37	138.05	2.58	2.02	6.34	25.45	10.53	1.48	11.91	42.33	20.09	16.69	0.14	2.27	3.33	15.46	12.95	5.74	8.14	56.74	0.14	47.30
41.47	147.96	2.45	2.29	6.11	26.88	11.80	1.72	11.08	43.10	20.51	16.26	0.13	2.34	3.14	14.59	12.33	5.44	7.31	57.34	0.12	47.67
42	149.11	2.44	2.38	6.09	27.03	11.95	1.75	10.98	43.26	20.57	16.29	0.14	2.36	3.15	14.56	12.32	5.38	7.29	57.40	0.13	47.69
47	159.96	2.34	2.56	5.84	28.54	13.38	2.03	10.14	44.37	21.16	15.80	0.16	2.53	3.21	13.75	11.67	5.48	7.28	57.38	0.12	47.43
52	170.55	2.35	2.19	5.68	29.66	14.49	2.32	9.34	44.81	21.83	14.89	0.13	2.57	3.30	12.80	10.89	5.22	7.17	57.70	0.08	47.32
54.63	176.05	2.38	2.08	5.63	30.08	15.00	2.48	8.96	45.13	22.17	14.51	0.13	2.54	3.33	12.46	10.59	5.01	6.64	58.21	0.06	47.65
57	180.94	2.42	2.02	5.59	30.32	15.41	2.63	8.68	45.35	22.43	14.11	0.13	2.51	3.19	12.14	10.33	4.86	6.55	58.21	0.05	47.58
62	191.08	2.55	1.97	5.62	30.66	16.15	2.94	8.15	45.81	22.93	13.35	0.12	2.54	2.87	11.55	9.82	4.42	6.07	58.11	0.11	47.08
67	201.02	2.68	1.88	5.62	30.86	16.82	3.23	7.62	46.02	23.39	12.48	0.10	2.54	2.70	10.83	9.22	3.98	5.93	57.99	0.16	46.65
67.79	202.5661	2.6902	1.8599	5.6199	30.873	16.9245	3.2818	7.5246	46.0383	23.4566	12.336	0.0912	2.5381	2.6891	10.6993	9.1058	3.9113	5.7089	57.9454	0.1638	46.5633
72	210.7556	2.7392	2.1182	5.5509	30.7617	17.3376	3.4589	7.1926	46.2281	23.676	12.0299	0.0528	2.5408	2.671	10.3561	8.869	3.4195	4.9161	57.9686	0.1469	46.2953
80.95	227.7366	2.7605	2.7874	5.391	30.9325	18.3536	3.7715	6.6433	46.942	24.0736	11.5713	0.0124	2.6307	2.8766	9.7681	8.5023	2.4759	3.8531	56.9932	0.1092	45.233
94.11	251.7442	2.6587	1.9331	5.0311	30.8249	19.1228	4.0837	5.8901	46.8301	23.9826	9.5606	0.001	2.4255	2.7684	8.0848	7.1153	1.2079	2.4031	56.5162	0.0312	43.691
107.26	274.8071	2.5333	2.0411	4.6457	30.9359	19.7583	4.218	5.1488	46.713	23.6571	8.5029	0.0001	2.5059	2.3179	6.9131	6.187	0.577	0.9548	55.4802	0.001	42.103

2) as % diff from ref flow

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	16.2	29.3	149.8	74.6	43.2	27.6	3.1	108.0	68.3	67.3	280.5	68810.0	110.1	252.9	276.2	257.4	1866.6	1205.7	70.3	1058.3	81.9	3.1
7	23.9	86.5	123.7	125.0	39.1	27.2	10.3	163.6	75.5	78.2	265.6	17400.0	80.0	165.4	293.4	272.2	1160.8	950.0	82.6	762.5	95.0	10.3
12	30.0	117.4	129.8	143.6	47.2	29.7	17.7	189.3	80.8	82.6	250.2	47640.0	94.2	142.4	290.0	269.0	842.2	660.5	87.9	862.5	100.4	17.7
15.16	33.6	122.2	120.1	144.8	54.9	30.9	20.3	200.3	82.5	83.2	235.6	52120.0	97.1	125.9	278.7	258.5	785.8	575.0	91.1	1662.5	103.3	20.3
17	35.6	123.0	111.8	144.5	58.3	31.7	21.6	204.2	82.9	83.5	227.0	45560.0	93.5	119.2	269.7	250.7	731.3	535.7	93.5	1816.7	106.2	21.6
22	40.8	121.1	155.2	139.4	64.6	35.8	23.4	214.7	85.5	82.6	219.3	26380.0	99.7	119.1	256.5	240.5	632.0	447.1	95.2	1308.3	107.5	23.4
27	45.6	115.0	129.3	136.3	72.2	42.0	26.7	219.3	87.5	82.9	202.3	20140.0	97.9	125.3	233.6	220.0	587.5	399.1	97.4	1112.5	107.1	26.7
28.32	46.9	112.5	120.1	135.4	73.6	43.6	27.5	218.8	87.9	83.2	198.1	18840.0	94.4	126.4	227.5	214.5	563.0	390.3	98.5	1050.0	107.8	27.5
32	50.3	105.6	108.1	132.2	77.5	48.3	30.7	215.4	89.0	83.3	186.4	14090.0	91.9	127.1	210.0	198.6	514.8	376.7	99.8	854.2	108.3	30.7
37	54.8	97.1	104.4	126.0	82.6	55.1	36.3	202.2	90.4	83.8	174.6	13640.0	93.7	120.2	191.3	181.9	475.2	338.8	100.4	441.7	108.3	36.3
41.47	58.8	92.2	118.4	121.4	87.2	61.7	42.2	188.0	92.0	85.5	170.1	13180.0	96.7	113.4	180.4	173.3	450.0	304.1	101.5	400.0	109.1	42.2
42	59.2	91.7	123.1	121.0	87.7	62.5	42.8	186.5	92.4	85.8	170.3	14030.0	97.4	113.7	180.0	173.2	445.1	303.3	101.6	412.5	109.1	42.8
47	63.5	88.1	132.7	116.0	92.6	70.0	49.7	172.1	94.7	88.3	165.2	16190.0	104.2	115.9	170.1	164.0	453.7	302.9	101.5	383.3	108.6	49.7
52	67.7	88.2	113.2	112.8	96.2	75.8	56.8	158.6	95.7	91.0	155.7	13180.0	105.9	119.4	158.4	153.0	432.3	298.2	102.1	245.8	108.3	56.8
54.63	69.9	89.3	107.6	111.8	97.6	78.4	60.7	152.0	96.4	92.5	151.8	12970.0	104.7	120.3	154.1	148.9	414.8	276.2	103.0	191.7	109.1	60.7
57	71.9	90.9	104.4	111.0	98.4	80.6	64.4	147.3	96.8	93.5	147.6	13090.0	103.4	115.4	150.2	145.1	402.3	272.4	103.0	175.0	108.9	64.4
62	75.9	96.1	102.2	111.7	99.5	84.4	71.9	138.4	97.8	95.6	139.7	12170.0	104.6	103.8	142.9	138.0	365.6	252.4	102.8	337.5	107.8	71.9
67	79.9	100.7	97.4	111.7	100.1	88.0	79.1	129.4	98.3	97.5	130.5	9770.0	104.6	97.7	133.9	129.5	329.6	246.7	102.6	504.2	106.8	79.1
67.79	80.5	101.2	96.2	111.7	100.2	88.5	80.4	127.7	98.3	97.8	129.0	9120.0	104.6	97.1	132.3	128.0	323.8	237.6	102.5	525.0	106.6	80.4
72	83.7	103.0	109.6	110.3	99.8	90.7	84.7	122.1	98.7	98.7	125.8	5280.0	104.8	96.5	128.1	124.6	283.1	204.6	102.6	470.8	106.0	83.7
80.95	90.5	103.8	144.2	107.2	100.3	96.0	92.4	112.8	100.2	100.4	121.0	1240.0	108.5	103.9	120.8	119.5	205.0	160.3	100.8	350.0	103.5	90.5
94.11	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
107.26	109.2	95.3	105.6	92.3	100.4	103.3	103.3	87.4	99.7	98.6	88.9	10.0	103.3	83.7	85.5	87.0	47.8	39.7	98.2	3.2	96.4	10.0

3) as risk category (see Davies and Humphries 1996)

Q	Area	Janiirid	Gripop	Leptop	Chironominae	Orthocladiinae	Simulidae	Hydrobiosidae	N Taxa	T Abund	Platypus	G. brevipinnis	A. australis	Lamprey juv	G. maculatus	G. truttaceus	S. trutta fry	S. trutta juv	S. trutta ad	S. trutta spawn	S. trutta ad Ral	Min
2	IV	IV	I	II	III	IV	IV	I	II	II	I	I	I	I	I	I	I	I	II	I	II	IV
7	IV	I	I	I	III	IV	IV	I	II	II	I	I	II	I	I	I	I	I	II	I	I	IV
12	III	I	I	I	III	IV	IV	I	II	II	I	I	I	I	I	I	I	I	I	I	I	IV
15.16	III	I	I	I	III	III	IV	I	II	II	I	I	I	I	I	I	I	I	I	I	I	IV
17	III	I	I	I	III	III	IV	I	II	II	I	I	I	I	I	I	I	I	I	I	I	IV
22	III	I	I	I	II	III	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
25	III	I	I	I	II	III	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
28.32	III	I	I	I	II	III	IV	I	I	II	I	I	I	I	I	I	I	I	I	I	I	IV
32	III	I	I	I	II	III	III	I	I	II	I	I	I	I	I	I	I	I	I	I	I	III
37	III	I	I	I	II	III	III	I	I	II	I	I	I	I	I	I	I	I	I	I	I	III
41.47	III	I	I	I	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
42	III	I	I	I	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
47	II	I	I	I	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
52	II	I	I	I	I	II	III	I	I	I	I	I	I	I	I	I	I	I	I	I	I	III
54.63	II	I	I	I	I	II	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
57	II	I	I	I	I	II	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
62	II	I	I	I	I	II	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
67	II	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
67.79	II	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
72	II	I	I	I	I	I	II	I	I	I	I	I	I	I	I	I	I	I	I	I	I	II
80.95	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
94.11	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
107.26	I	I	I	I	I	I	I	I	I	I	I	IV	I	II	I	I	III	III	I	IV	I	IV