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Basslink Baseline Report

Information from all consolidated data collected by the Gordon River Basslink Monitoring Program 2001-05

Volume 2: Appendices

Prepared by

Hydro Tasmania

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Introduction

Information for all consolidated data collected by Gordon River Basslink Monitoring Program 2001-05 is presented in the following sections as appendices.

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A1 Gordon River Basslink Monitoring Program

The following appendix is extracted from the Special Licence held by Hydro Tasmania under the *Water Management Act* 1999. Note that the present BMP may differ in some minor details, due to the changes implemented since 2001.

'3.0 Gordon Basslink Monitoring Program

The Gordon River Basslink Monitoring Program comprises:

A monitoring regime prior to the Basslink Commencement Date which aims to extend the understanding gained during the 1999-2000 investigative years on the present condition, trends, and spatial and temporal variability of potentially Basslink-affected aspects of the Middle Gordon River ecosystem; and

A monitoring regime for six years following the Basslink Commencement Date aimed at determining the effects of Basslink operations and to assess the effectiveness of the Mitigation Measures.

The aim of the Gordon River Basslink Monitoring Program is to obtain long-term datasets for potentially Basslink-affected aspects of the Middle Gordon River ecosystem, which will then allow refinement of theories and more precise quantification of spatial and temporal variability, processes and rates.

It is acknowledged and agreed that minor modifications may be made to this monitoring program from time to time (by agreement between the Licensee and the Minister) without the need to formally amend this Agreement, provided such modifications do not significantly interfere with the statistical power of individual elements of the monitoring program.

The results of monitoring and analysis required to be undertaken pursuant to this monitoring program must be presented in the relevant Gordon River Basslink Annual Report.

In the final Gordon River Basslink Monitoring Annual Report prior to the conclusion of the Gordon River Basslink Monitoring Program, Hydro Tasmania must undertake a review to determine what, if any, continued monitoring of Basslink changes should be undertaken in the Gordon River.

3.1 Logistical Considerations

Access continues to present significant challenges in this Tasmanian Wilderness World Heritage Area. On-site monitoring activities require helicopter support, due to the density of the terrestrial vegetation and the absence of access infrastructure, and power station shutdowns. Power station shut-downs are needed because the only viable landing sites are on cobble bars in the river bed which are only exposed when there is little or no discharge from the power station. They are also required because most of the biotic monitoring activities require measurements or sampling to take place within the river channel, which would not be possible under conditions of power station discharge.

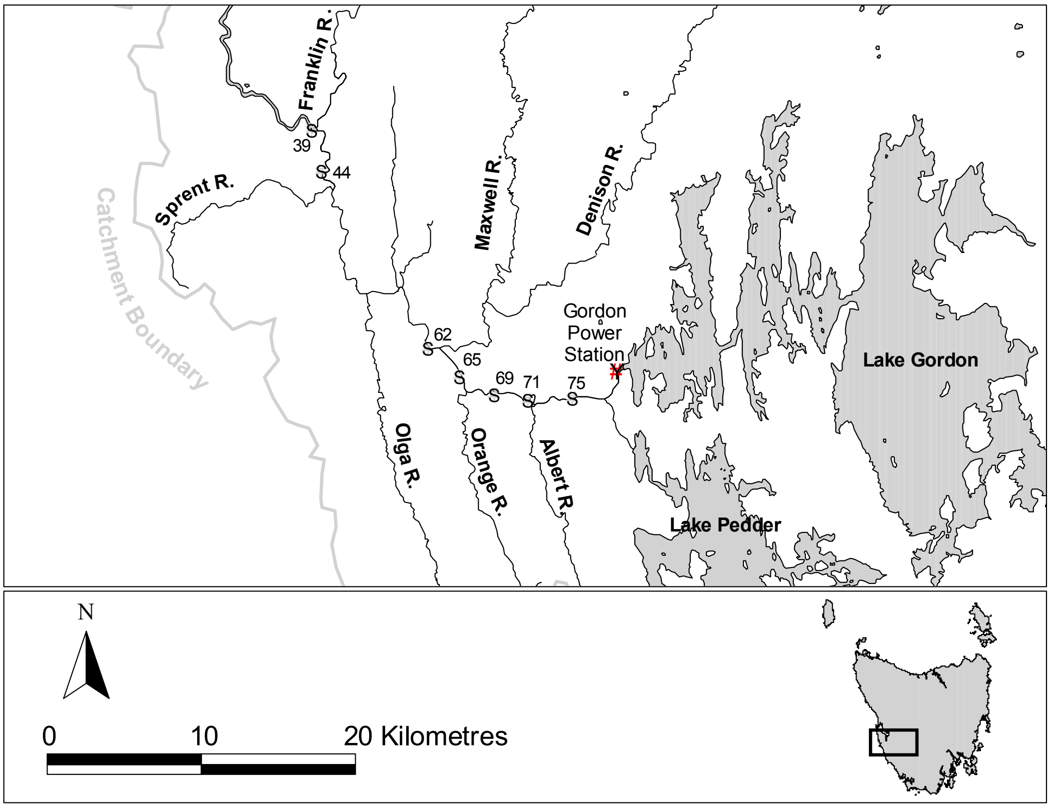
The Gordon River Basslink Monitoring Program has a schedule of four visits per year, each involving two consecutive days of power station shutdown. These would be most likely to occur on weekends when hydro generation requirements from the power station are lowest. For these eight days of the year, the proposed minimum environmental flow would not be able to be delivered, in order to facilitate helicopter landings on the riverbed. If access is impossible on the planned shutdown weekends, the 'outage' for the Gordon Power Station will be postponed to a subsequent weekend. Co-ordination with station maintenance requirements is an essential requirement of the monitoring program.

3.2 Hydrology

3.2.1 Site locations

The environmental flow compliance monitoring site shown on Map 1.1 (site 65 - coordinates at or about 405700E 5267950N) must be installed prior to the Basslink Commencement Date and maintained for the duration of the monitoring program.

The other 6 gauging stations shown on Map 1.1 must be maintained for the duration of this monitoring program, or until such time as the parties agree that one or more of the sites is no longer required.



Map 1.1. Location of the water level recorders required in the middle Gordon River

3.2.2 Field Methods

Each site must record the water levels at intervals no greater than 60 minutes.

3.2.2.1 Telemetered sites

The following compliance monitoring sites must be telemetered prior to the Basslink Commencement Date:-

Gordon River above its confluence with the Denison River (site 65). (This site will be used to monitor compliance with the minimum environmental flow requirements in this Agreement.)

Gordon Powerstation discharge. (This site will be used to monitor compliance with the ramping rate requirements.)

3.2.2.2 Non-telemetered sites

Each site must be regularly visited by Licensee personnel who must download data.

3.2.3 Reporting

Hourly Time Series Data from the telemetered hydrological monitoring sites at Gordon River above its confluence with the Denison River (site 65), the Gordon River below Huntley Rivulet and the Gordon Powerstation discharge must be provided to the Minister on a monthly basis. All raw hydrological data collected by the Licensee must be included in the Annual Report provided by the Licensee to the Minister under this agreement.

The raw data is Confidential Information under this Agreement. The Gordon River Basslink Monitoring Annual Reports must, however, present the hydrological data in a consolidated format, similar to that used in the IIAS (ie. flow duration curves, event analysis and monthly median flows).

3.3 Water Quality

3.3.1 Site Locations

In Lake Gordon, surface water samples and depth profiles must be taken from the power station intake, and at Calder and Boyes Basins.

In Lake Pedder, water samples and depth profiles must be taken at Groombridge Point. Water samples must also be taken from surface waters at Hermit Basin and Edgar Bay.

Water temperature measurements must be taken at Gordon River 1.5 km below the tailrace (site 75) and 0.5 km downstream of the confluence of the Gordon and Denison River (site 62) daily.

3.3.1.1 Field Methods

Water samples and depth profiles in Lakes Gordon and Pedder must be taken quarterly.

Water Samples

Water samples for nutrient analysis must be taken from the surface waters at each site. For each water sample, the following parameters must be measured by laboratory analysis:

- total phosphorus and Dissolved Reactive Phosphorus (DRP);
- nitrite, nitrate, TKN, ammonia;
- chlorophyll-*a*;
- metals (Fe, Mn, Zn, Cd, Cu, AL, Co, Cr, Ni and Pb);
- sulphate;
- alkalinity; and
- dissolved organic carbon.

Depth Profiles

Depth profiles of basic physico-chemical parameters (water temperature, dissolved oxygen, conductivity, pH, and turbidity) must be taken at approximately 2 m intervals at each of the nominated depth profile sites in Lakes Gordon and Pedder.

3.3.1.2 Analysis and Reporting

Water quality data must be transferred to the TimeStudio database. Water quality data must be analysed for trends and seasonal behaviour.

Temperature data from the tailrace, and sites 75 and 62 must be analysed to investigate the temperature effects of releases from Gordon Dam and the ameliorative effects of tributary streams. Dissolved oxygen data from the tailrace monitoring site must be analysed to indicate the incidence of both low and supersaturated dissolved oxygen conditions.

The results of the above analyses must be presented in the Gordon River Basslink Monitoring Annual Report.

3.3.2 Gas supersaturation

An assessment of the occurrence of gas supersaturation in reaches downstream from the power station must be undertaken once prior to the Basslink Commencement Date and again within the first two years following the Basslink Commencement Date, to determine whether the incidence, duration or persistence of gas supersaturation has increased.

3.3.2.1 Field Methods

Additional monitoring of total gas pressure in the middle Gordon River during high flow must be carried out to ascertain whether elevated total gas pressures accompany elevated dissolved oxygen concentrations.

Field sampling must occur when operating conditions are producing high oxygen saturation levels at the tailrace. A series of gas saturation readings must be taken from the tailrace downstream as far as supersaturated conditions are evident. Initially, the readings should be taken at about 2 km intervals, which may be reduced to increase resolution of points where saturation conditions change.

3.3.2.2 Analysis and Reporting

An initial evaluation of dissolved oxygen levels and their causal factors was carried out in August 2001. The recommendations from this initial evaluation will be used to guide the field sampling program, in terms of the necessary operating conditions required and any other relevant factors.

A second field sampling program will be run following the implementation of Basslink. This will replicate the first and will be used to indicate whether the incidence, magnitude or extent of gas supersaturation has increased under the changed operating conditions.

The results of the above studies and any recommendations must be included in the relevant Gordon River Basslink Monitoring Annual Report.

3.4 Fluvial Geomorphology

The assessment of fluvial geomorphology issues must include aerial photography and on-site field surveys.

3.4.1 Aerial Photography

3.4.1.1 Field Methods

An aerial photography survey covering the Middle Gordon River, including the lower Albert River and the mouths of other tributaries, was carried out in December 1999. A survey of the study area must be repeated under similar river conditions (low natural flows and minimum environmental flows) in the year prior to the Basslink Commencement Date and in the sixth year following the Basslink Commencement Date.

Aerial photos of the study area must be obtained at a scale of approximately 1:5000 and compared with previous aerial photos from the study region using a stereo-plotter.

3.4.1.2 Analysis and Reporting

A set of detailed maps for the study area and a comparison of the outputs from previous studies (showing the extent of changes to the river banks over the intervening period) must be produced. The results of the comparative analysis must include a measure of channel widening or narrowing and the number of tree falls noted since the last aerial photo comparison. These analyses must be included in the relevant Gordon River Basslink Monitoring Annual Report.

3.4.2 Measurement of erosion pins and scour chains, photo monitoring and peizometer

Site Locations

As of April 2002, the sites listed in Tables 1 –5 will be monitored by the Licensee:

Table 1. Geomorphic monitoring sites in zone 1.

Site	Easting	Northing	Site description
1A	55413100	5266600	LB, behind cobble island, a number of pins going along bank, under overhanging branches. Colluvium
1B	55411990	5266375	LB ~30 m downslope cobble bar, little back-eddy area downstream of rock bar. Alluvium over bedrock.
1C	55411575	5266600	LB, alluvium over cobbles, adjacent to bar, ti-tree, flat with low slope. Across from 25m long bedrock outcrop on RB.
1D	55411425	5266750	RB outside bend, ~ 50 m downstream bedrock outcrop. Very gnarly looking bank, mixed small cobbles and alluvium, cavities with heavy organic drapes.
1E	55411010	5266200	LB just upstream Abel Gorge, 5 pins in a profile up slope in alluvium, all 0.75m pins.
1F	55410950	5266300	RB just upstream Abel Gorge.

Table 2. Geomorphic monitoring sites in zone 2.

Site	Easting	Northing	Site description
2A	55410250	5266375	LB adjacent to most upstream cobble bar in this zone. 7 pins perpendicular to flow, going upslope, on crest, and over back of slope in backwater channel “Ben”. Scour chain located 320 mm d/stream of 2A/2.
2B	55410320	5266400	RB opposite site 2A and slightly upstream. Dolomite with sediment flows and lost of broken rock.
2C	55410257	52666800	RB, site previously referred to as Geo2A site 1.
2D	55410180	5266725	LB inside bend, site previously referred to as Geo2A site 2.
2E	55410130	5266875	RB, site previously referred to as Geo2A site 3. Long term peizometer site.
2F	55409950	5266275	LB cobbles, vertical cliff, ~20 m downstream of the end of the G5 cobble bar.
2G	55409800	5266350	RB u/s cobble bar G5a, spew where we trialed angel wings.
2H	55409490	5266600	LB ~ 200m d/s Cold Comfort Camp, medium slope, ti-tree on u/s side, mature trees on d/s side where there are spews, 2 rows of pins going up bank profile, rows ~ 2m apart.
2I	55409125	5266755	LB, low slope, ti-tree, two 0.75m pins.
2J	55408010	5266775	2nd cobble bar u/s Splits, LB, opposite river level recorder, previously called “Geo 2B site 2(u/s)”. 3 pipe meters.
2K	55407950	5266825	2nd cobble bar u/s Splits, LB, opposite river level recorder, previously called “Geo 2B site 2”. 1 star picket, 1 scour chain, 3 erosion pins from old site, 2 new pins put in cavities. Scour chain located 200mm upslope of 2K/4.
2L	55408000	5266900	RB, d/s gauge recorder, previously called “Geo 2B site 1”, 1 star picket, 1 scour chain, 2 erosion pins from old site, augmented with a new pin in a cavity at top of bank.

Table 3. Geomorphic monitoring sites in zone 3.

Site	Easting	Northing	Site description
3A	55405701	5267977	LB, 1st cobble bar d/s Snake Rapids (d/s river level recorder in Snake Rapids), on sand bar, previously called “Geo 3 site 2”.
3B	5405683	5268020	LB, 1st cobble bar d/s Snake Rapids (d/s river level recorder in Snake Rapids), approximately 30 m d/s of site 3B, previously called “Geo 3 site 1”. Note that this is a site of major deformities, with collapsing root mats, and several of the old pins at this site were lost. Scour chain located about 10” upslope of 3B/1, ~½m downslope of tunnel.
3C	55405564	5268243	RB, medium alluvial slope, ti-tree. 4 pins in a profile, plus a 3m pin in cavity at top of bank.
3D	55405529	5268235	LB just opposite site 3C, alluvium, cobbles at depth and back.
3Ea	55405447	5268498	RB, large quartzite beach 1/2 way between snake rapids and Denison confluence, upstream side of quartzite beach, 5 pins set in V-formation.
3Eb	55405439	5268530	RB, large quartzite beach 1/2 way between snake rapids and Denison confluence, immediately downstream of site 3Ea on same beach, 5 pins set in a profile.
3F	55404435	5269638	RB, ~100m upstream of the Gordon and Denison confluence, 1/2 way between island and confluence, cavity upslope under huon, lots of ti-tree and boulders.
3G	55404407	5269616	LB just opposite site 3F. Long low slope, bare, cavity at back. Scour chain located ~1m upstream of 3G/4.

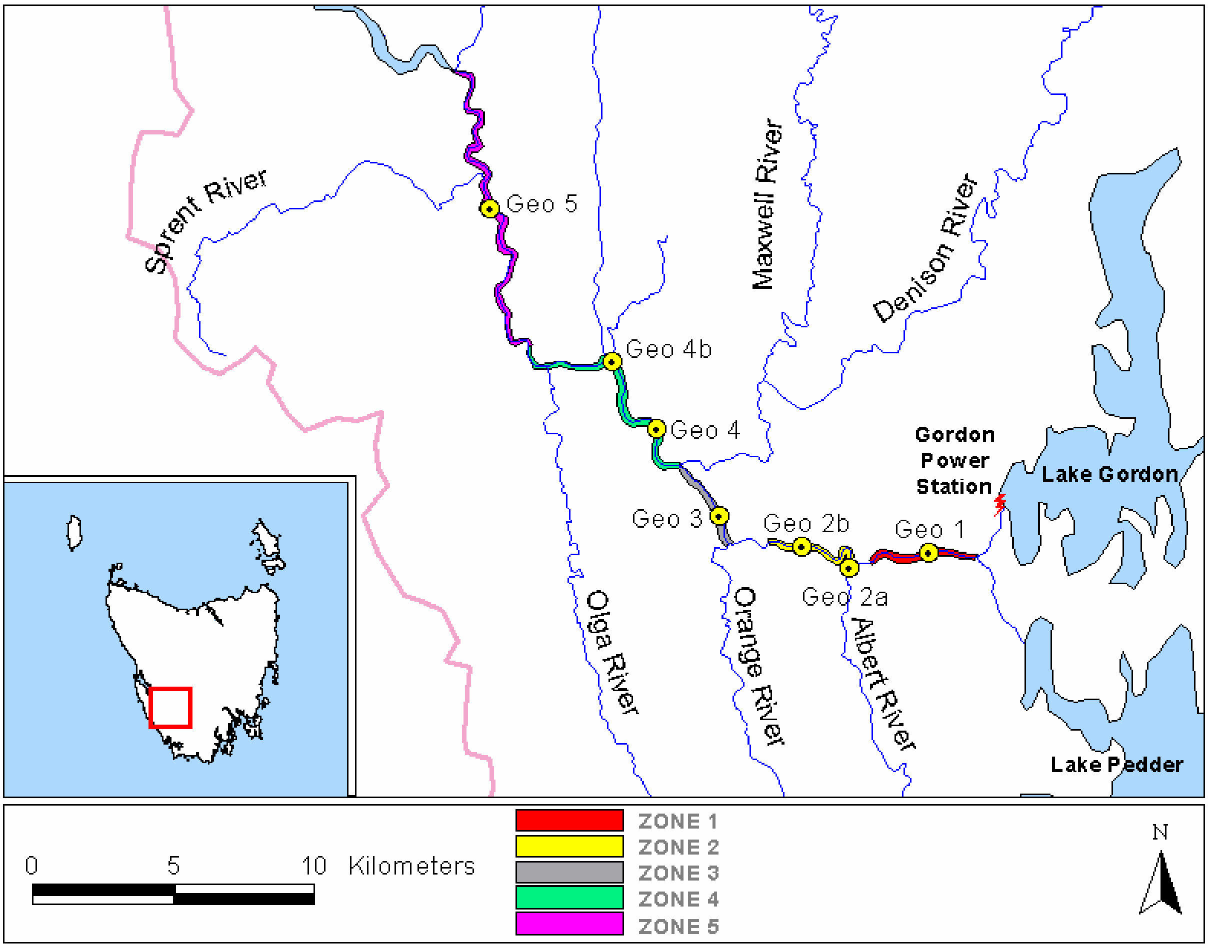
Table 4. Geomorphic monitoring sites in zone 4.

Site	Easting	Northing	Site description
4A	55403559	5269849	LB just after the dinosaur spines, three 0.75m pins up bank profile, alluvial deposit. Scour chain located ~1m upstream of 4A/2.
4B	55403576	5269893	RB just opposite site 4A.
4C	55403572	5270464	RB, vertical cobble banks, two 0.5m pins.
4D	55403587	5270761	LB, old pipemeter site, ~100m d/s of end of cobble bar, medium alluvial slope with ti-tree. Scour chain located ~40 cm downslope of 4D/3.
4E	55403276	5271280	LB across from Kayak Kavern, steep alluvial bank, lots of ti-tree, below wedge-tailed eagle nest. ~800 mm d/stream of 4E/3
4F	55402391	5271452	RB, old existing Geo4 erosion pin site, upstream of first small island above confluence of Smith and Harrison creeks with Gordon River (entrance Ewarts Gorge). Existing site comprised 2 erosion pins and a scour chain at upstream end of site; three new erosion pins were later installed at d/s end of site.
4Ga	55402092	5273110	~500m u/s Sunshine Gorge, last set of alluvial banks on each side of river, upstream of two profiles, four 0.75m pins, slope structure = toe, remnant root mat, grasses.
4Gb	55402092	5273110	~500m u/s Sunshine Gorge, last set of alluvial banks on each side of river, downstream of two profiles, five 0.75m pins.
4H	55401913	5273635	RB, last alluvial bank u/s Ewarts Gorge, d/s end, profile of five pins, interesting veg monitoring point.

Table 5. Geomorphic monitoring sites in zone 5.

Site	Easting	Northing	Site description
5A	55398252	5274804	RB, medium slope alluvium, end of long straight, lots of treefall.
5B	55398247	5275051	LB, alluvial medium slope.
5C	55397984	5275747	RB, inside bend, alluvial, short water level range.
5D	55398014	5277758	RB, short steep alluvial bank, straight reach.
5E	55397973	5277788	LB, straight reach, alluvium covered with some grass.
5F	55398155	5278405	LB, straight reach, alluvium covered with some grass.
5G	55397444	5278981	Existing zone 5 erosion pin site referred to as “Geo 5”, approximately 1 km u/s of Sprent River, behind cobble bar at d/s end, erosion pins near huon pine, five erosion pins, 1 scour chain, 1 star picket.
5H	55397660	5279162	RB, outside bend, alluvium, steep long slope.
5I	55396904	5280974	LB, outside bend, alluvium, medium slope. Scour chain located just behind a log, 5.4m upstream of 5I/3, and 4m upstream and slightly upslope of 5I/4.
5J	55397221	5281758	RB, downstream end of inside bend and start of outside bend, medium alluvial slope. All pins and scour chain driven down to bedrock. Scour chain located ~1m downslope of 5J/3.
5K	55397334	5281773	RB downstream of 5J, upstream side of outside bend, short steep alluvial bank with lots of small-medium LWD.

The specific geomorphological monitoring sites identified above may be varied by the Licensee, based on consideration of representability and practicability. However, it is acknowledged and agreed that a minimum number of 40 geomorphological sites are required to be monitored by the Licensee under this Agreement, and that, subject to logistical practicalities, they must be in representative geomorphological zones and in representative bank types.



Map 1.2. Location of the geomorphology sampling zones in the middle Gordon River.

3.4.2.2 Field Methods

Field surveys at a minimum of 40 sites must be carried out twice per year (October and March-April) every year. Monitoring at a minimum will involve the measurement of erosion pins, and downloading of peizometer data. Selected sites identified by the Licensee will have measurement of scour chains. The selected banks and cobble bars identified by the Licensee will be photographed as a basis for comparison with previous photographs.

3.4.2.3 Analysis and Reporting

Data gathered from erosion pin, peizometer and scour chain measurements must be collated and compared with previous data to determine the rates of erosion or deposition on the banks over time. The outputs of the data comparisons should be supported by photographs as appropriate. The outputs of the analysis must be included in the relevant Gordon River Basslink Monitoring Annual Report.

3.5 Karst geomorphology

3.5.1 Monitoring Strategy

Monitoring of sediment movement in Bill Neilson Cave and Kayak Kavern, both pre- and post-Basslink, will further the understanding of the sediment transfer processes occurring in the caves, and how this may relate to sediment flux in the Gordon River. Eight erosion pins have been installed in Bill Neilson Cave and four in Kayak Kavern.

Monitoring of the dolines close to the riverbank in the Gordon-Albert karst area is being undertaken. Following a survey of this area one doline, with associated passageways has been found and both erosion pins and other monitoring equipment have been installed. This site will be monitored at the same frequency as the other karst sites. Monitoring will comprise inserting a number of erosion pins into the sides of doline features close to the river bank to see whether, over time, there was any movement in the sediments.

3.5.2 Field Methods

The erosion pins in the Gordon-Albert karst area, Bill Neilson Cave and Kayak Kavern must be measured each year during each fluvial geomorphology monitoring visit (October and March-April). A visual inspection of the dry parts of Bill Neilson Cave must also be carried out, to indicate if unusually high water levels have occurred.

3.5.3 Analysis and Reporting

Data gathered from erosion pin measurements must be collated and compared to previous data to examine any changes to the banks over time. The outputs of the analysis must be included in the relevant Gordon River Basslink Monitoring Annual Report.

3.6 Riparian Vegetation

3.6.1 Monitoring Strategy

Monitoring of the riparian vegetation will provide a greater understanding of the processes of change within the river systems. Each year data will be collected to allow both spatial and temporal comparisons. Baseline data collected within the Gordon River will enable detection of changes occurring within the river system both pre and post Basslink. Variations between the Gordon River and the Denison and Franklin Rivers will allow spatial comparisons between affected and reference rivers.

3.6.2 Field Methods

Representative sites will be selected within all three rivers and permanent transects established. Along the Gordon River, sites in four zones, equivalent to geomorphology sampling zones 2-5 (map 2) will be monitored. Reference monitoring sites along the Denison and Franklin Rivers will be directly comparable to those within the Gordon. Comparable reaches will be determined using data on river flow rates, from which mean annual duration of inundation could be calculated, in association with existing knowledge of the plant species and communities.

Within these reaches on the Gordon River, and along the Denison and Franklin Rivers, sites will be further stratified according to habitat type, being either highly illuminated cobble and sand banks common in the river channel or shaded steep river bank. Further stratification within these sites will be determined by the period of inundation and substrate type which corresponds with operation of 1,2 or 3 turbines. These zones will include:

- immediately above the Plimsoll line (eg. at 3 m);
- immediately below the Plimsoll line (eg. at 2 m); and
- immediately above low water mark (eg. at 0.7m) respectively.

Monitoring within these sites will include assessment of species cover and diversity and habitat variables including, but not limited to, substrate, slope and aspect. A balanced replicated monitoring design will allow meaningful statistical analyses to be undertaken on these data.

Sections of the river bank or islands prone to the highest levels of disturbance are those most likely to provide information about processes of recruitment or species loss. Such areas may be considered as those “at the cusp” of significant change and therefore allow detection of subtle changes before detection at other sites.

These studies will allow the detection of changes and construction of models describing the processes by which change occurs in the riparian vegetation.

The use of permanent plots must allow assessment of exactly the same area of vegetation and identification of subtle changes in cover contributed by each species, species diversity, structure and recruitment.

The above monitoring will be carried out annually in autumn. Recruitment monitoring, at the same sites and aimed at quantifying recruitment (which may not be evident in the autumn sampling), will additionally be carried out in summer (December).

3.6.3 Analysis and Reporting

Vascular plant species cover and diversity must be assessed and described for each quadrat in all rivers and a range of habitat variables scored (as described by Davidson and Gibbons 2001). Community structure must be scored using cover estimates of vegetation guilds. Recruitment must be scored as number of individuals.

An independent assessment must be made of habitat disturbance, seedling recruitment and loss of keystone species. The outputs of the analysis must be included in the relevant Gordon River Basslink Monitoring Annual Report.

3.7 Macroinvertebrate monitoring

3.7.1 Field Methods

Samples must be taken during October and March-April each year from sites 75, 72, 69, 63, 60, 58, 48 and 42 in the middle Gordon River. In addition, the following six reference sites must 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
- Ma7 (Maxwell River).

The locations of these sites are shown in Map 1.3.

The specific monitoring sites identified above may be varied by the Licensee, based on consideration of representability and practicability. However, it is acknowledged and agreed that a minimum number of 7 'test' sites and 6 'reference' sites are required to be monitored by the Licensee under this Agreement, and that, subject to logistical practicalities, they must be in representative of the biological zones corresponding to the sites above.

At each site, a standard rapid assessment kick sample must be taken from bar-riffle habitat. Quantitative (surber) sampling of macroinvertebrates consisting of 10 pooled surber samples collected from the thalweg and (when environmental flows are in place) the lateral sections of the channel, again twice a year.

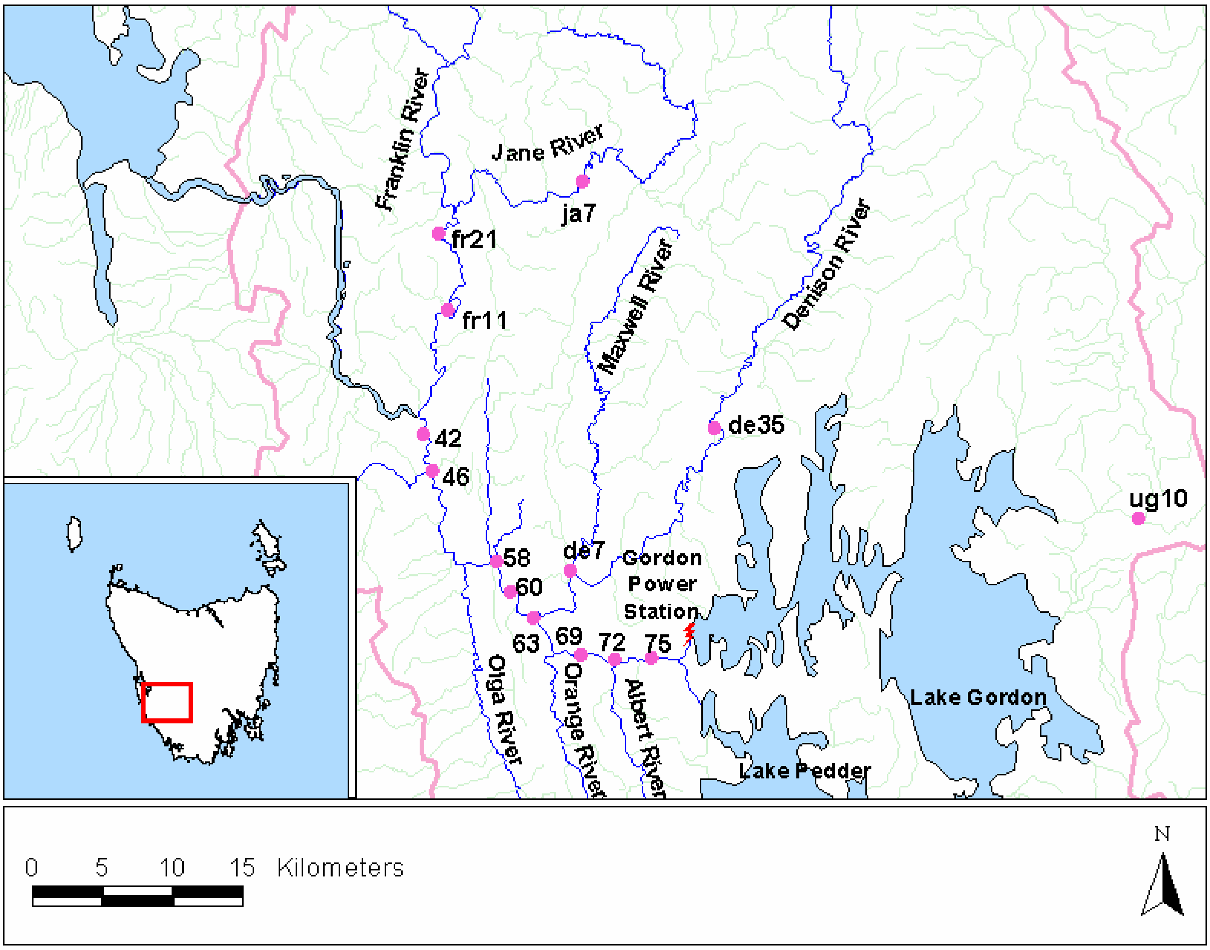
3.7.2 Data Analysis

The resulting environmental and biological data from the rapid assessment must be analysed using the presence-absence and rank abundance RIVPACS models. This will provide O/Epa and O/Erk outputs and associated bands, which must compared with previous years' data.

The data from the quantitative surber samples must be analysed to assess changes in time in relation to reference 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) will be used to assess the significance of any changes. These analyses must be conducted separately by section within the middle Gordon. Data must also be compared (by paired t-test) with previous years' data to assess temporal changes within the middle Gordon.

The outputs of the analysis must be included in the relevant Gordon River Basslink Monitoring Annual Report.



Map 1.3. Location of macroinvertebrate and algal sampling sites in the middle Gordon River, and associated reference sites.

3.8 Algae

3.8.1 Field Methods

Each year, seven sites (sites 75, 72, 69, 63, 60, 58 and 42) must be monitored for algae and moss cover on riverine substrate, concurrent with the macroinvertebrate sampling. Observations of the extent and percent cover of filamentous algae, moss and characeous algae must be made across the relevant IFIM transect. Distance from the peg and percent cover must be recorded at 2.5 m intervals across the channel, independent of zones, but with the extent of substrate zones still being recorded.

The specific monitoring sites identified above may be varied by the Licensee, based on consideration of representability and practicability. However, it is acknowledged and agreed that a minimum number of 6 Gordon River sites are required to be monitored by the Licensee under this Agreement, and that, subject to logistical practicalities, they must be in representative of the biological zones corresponding to the sites above.

Five scrapes of filamentous algae must be taken 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 must be noted, again as offsets from the datum peg.

3.8.2 Data Analysis and Reporting

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

The outputs of the analysis must be included in the relevant Gordon River Basslink Monitoring Annual Report.

3.9 Fish

3.9.1 Monitoring Strategy

Sampling under the fish monitoring program must be undertaken twice per year (December and March-April) each year. The fish monitoring program has been designed to:

Quantify pre- and post-Basslink variability in fish populations and allow statistical comparison between these times and appropriate reference sites (ie. a Before-After-Control-Impact design)

Assess changes in the longitudinal community structure of the Gordon River with the aim of identifying any changes in the zone of influence

Assess potential changes in catch per unit effort (CPUE) that may be related to habitat availability or other hydrological parameters.

Determine changes to the fish populations of affected tributaries and, in particular, whether recruitment success for juvenile galaxiids is improved under Basslink

3.9.2 Site Locations

Sampling must be undertaken at fifteen sites (three in each of the five fish zones) in the main channel of the middle Gordon River, sixteen sites on tributary streams and eleven sites on reference streams. The sampling sites are listed in Table 1 and Table 2 and their locations are shown in Map 1.4.

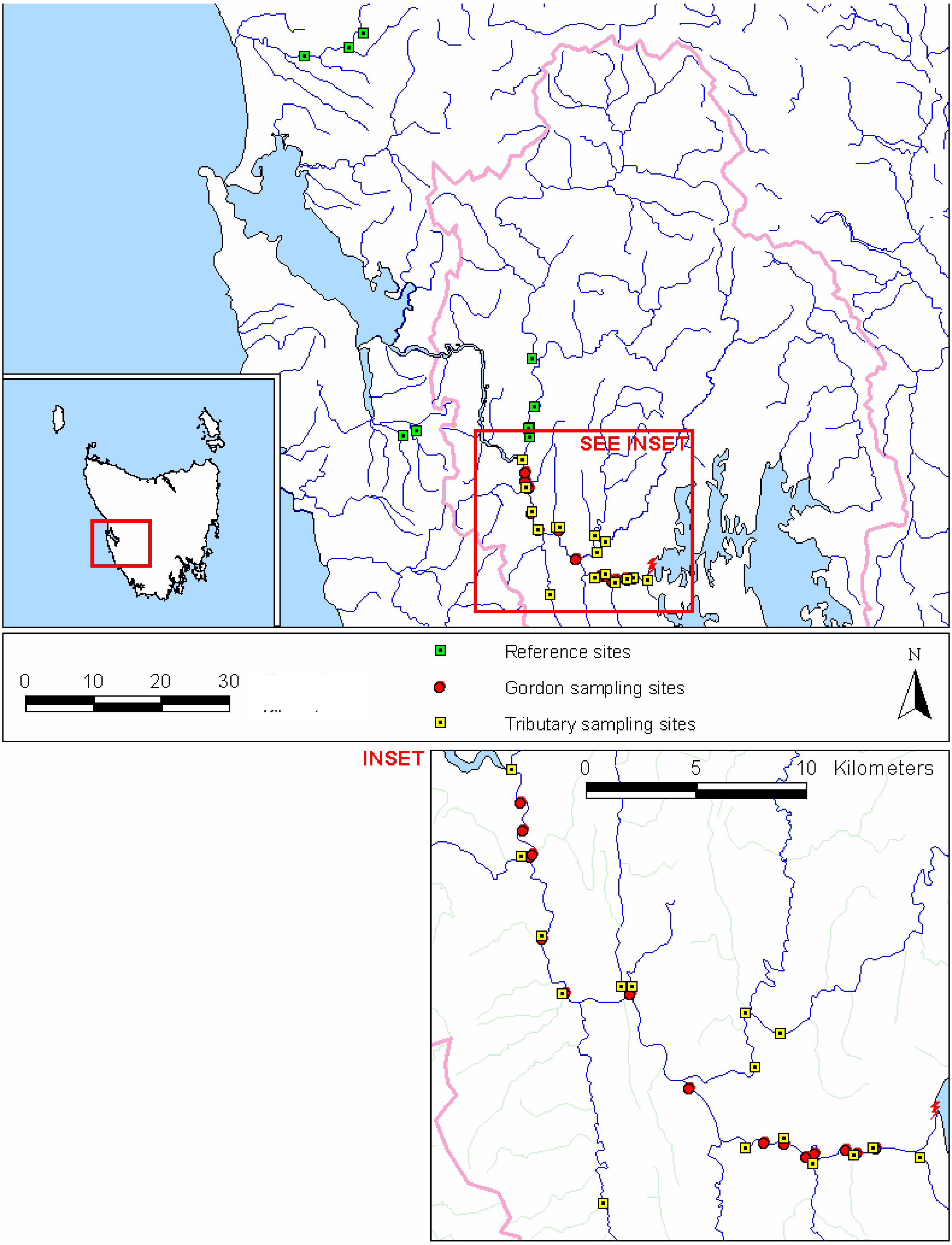
Table 1. Gordon catchment sites to be sampled by the fish monitoring program.

Zone	River Sites	Tributary Sites
1	75, 74, 73	Serpentine River, Indigo Creek, Piguenit Rivulet (1 site each)
2	72, 71, 69	Albert River, Splits Creek, Mudback Creek (1 site each)
3	68, 63, 57	Smith River (1 site), Harrison Creek (1 site) and Denison River (3 sites - u/s Gorge, @ Maxwell, u/s Maxwell)
4	54, 51, 46	Howards Creek, Olga River, Platypus Creek, Sprent River (1 site each)
5	45, 44, 42	Franklin @ Pyramid Island

Table 2. Reference sites to be sampled by the fish monitoring program.

Catchment	River sites	Tributary sites
Franklin	Franklin d/s Big Fall, Franklin u/s Big Fall, Franklin @ Canoe Bar	Forester Creek, Ari Creek, Wattle Camp Creek
Birchs Inlet	Sorell River	Pocacker River
Henty	Henty u/s Bottle Creek, Henty @ Yolande River, Henty @ Sisters	None recommended

The specific monitoring sites identified above may be varied by the Licensee, based on consideration of representability and practicability. However, it is acknowledged and agreed that a minimum number of 15 Gordon River sites, 16 tributary sites and 11 out of catchment sites are required to be monitored by the Licensee under this Agreement, and that, subject to logistical practicalities, they must be in representative of the biological zones corresponding to the sites above.



Map 1.4. Locations of sampling sites (including reference sites) for the fish monitoring program.

3.9.3 Field Methods

Backpack electrofishing methods will be used, with at least 1200 seconds (20 minutes) of actual shocking time carried out at each site. Electrofishing effort will be standardised by shocking time as counted by the backpack electrofisher's battery timer.

The fish captured must be identified to species, counted, and measured for fork length (mm), and released at the site. Type specimens for unidentifiable species will be retained for identification at a later time.

3.9.4 Data Analysis and Reporting

A database must be established to enable CPUE summaries to be produced for a variety of different site groupings. All CPUE figures will be calculated as the total catch (each species treated separately) for a site (or group of sites) divided by the total electrofishing battery time and standardised to 1200 seconds (20 minutes) shock time.

Ordination of site fish community data, ANOVA and other statistical analyses must be conducted. Data must be analysed to assess changes over time in comparison to reference sites by conducting ANOVAs with time (year) and location (Gordon zones vs reference rivers) as factors, and abundance (CPUE) of each species and overall diversity as test statistics.

The outputs of the analysis must be included in the relevant Gordon River Basslink Monitoring Annual Report.'

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A2 Hydro Tasmania responses to comments raised by the WHACC on the Draft Basslink Baseline Report

Hydro Tasmania was required in its Water Licence to provide the Draft Basslink Baseline Report (BBR) to the World Heritage Area Consultative Committee (WHACC) for comment prior to finalizing this report.

The following comments on the Draft Basslink Baseline Report were received from the World Heritage Area Consultative Committee (WHACC) on October 28 2005.

The Committee notes the essential requirements of the report:

1. Present trends from all consolidated data collected subsequent to the IIAS investigations;
2. Evaluate the adequacy of the Gordon River Basslink Monitoring Program, and if necessary, propose refinements;
3. Evaluate the appropriateness of the proposed mitigation measures based on this further data;
4. Consider and, if appropriate and practicable, propose 'limits of acceptable change' for each of the key scientific disciplines; and
5. Respond to any written comments on the Draft Basslink Baseline Report received from the WHACC.

A2.1 Presentation of trends

The WHACC accepts that the data and analysis provided in the Basslink Baseline Report (BBR) provides the best available information on which to identify trends in the environmental parameters important for monitoring potential impacts of Basslink.

RESPONSE: Noted.

A2.2 Adequacy of the Gordon River Basslink Monitoring Program

The WHACC accepts that the data and analysis provided in the Basslink Baseline Report (BBR) provides appropriate and adequate information on which to proceed with the monitoring program. WHACC endorses continued monitoring at all pre-Basslink test and reference sites for all variables. The addition of algal cover (now including reference sites) provides useful insights and a variable demonstrating short-term response to important hydro-geomorphic processes.

RESPONSE: Noted.

A2.2.1 Sampling regime

Will the Basslink demand cycles impact on the schedules of the monitoring program? That is, can the same seasonal time-windows apply?

RESPONSE: The schedules of the monitoring program will not change post-Basslink, and the same seasonal windows will apply. Each of the disciplines will undertake monitoring trips twice a year, with the timing dependent on the discipline. Geomorphology, karst, macroinvertebrate and algae monitoring is conducted in autumn and spring; riparian vegetation and fish monitoring is conducted in autumn and summer.

A2.2.2 The descriptive model

WHACC suggests that further work should be undertaken to increase understanding of the basic descriptive model under both pre- and post-Basslink conditions. This might include further post-hoc analysis of historical evidence (provided by pre-dam photographs for example) to provide insights on geomorphological change since damming. This could provide qualitative evidence in support of, for example, in stream geomorphic processes over the 30-year period since construction of the Gordon Dam and enhance interpretation of the trends observed in the pre-Basslink monitoring phase.

RESPONSE: The suggestion is noted, and opportunities to advance the present understanding of the basic descriptive model will be considered as they arise. Further work was not able to be undertaken between receipt of these comments and finalization of the BBR. With regard to geomorphic change, considerable effort was made during the IIAS to obtain and evaluate historical evidence of pre-dam river condition, and all of this understanding is captured in the IIAS reports and in the pre-Basslink conceptual model. Evidence on which to assess geomorphic change since damming, such as photograph and historical cross-section, has been unfortunately limited, as locations of photos cannot be determined, and cross-sections are only at the dam sites that were under consideration. Hydro Tasmania is attempting to get a full set of river cross-sections prior to the commencement of Basslink. The Three-Year Basslink Review Report will have a re-visit of the basic descriptive model under post-Basslink conditions.

A2.2.3 Time frames

WHACC is concerned that the suggestion (p. 70) that 'some judgements about the sources of change may have to wait for up to six years of Basslink operation' implies that values in excess of the limits of acceptable change (as outlined in section 13) will not be acted upon until such time has elapsed. The essence of adaptive management is informed experiment, not reaction to certainty.

RESPONSE: This is not a statement that we have to wait six years to determine if change has occurred or if action should be taken as a result of that change. It arises after evidence of change has been detected and is a statement about determining the nature of the change in cases where the change is presumed to be in terms of a change in trend. It is generally not possible to decide on the form of the change in trend until there are several years of post-change data. This is unrelated to adaptive management which would presumably be considered when a departure is first detected.

A2.2.4 Evolving and changing 'baselines'

WHACC believes the proposal to incorporate monitoring data into an evolving 'baseline' analysis is risky. We suggest that as data is accumulated over the years, alternative scenarios using original baseline data and integrated or revised data should be considered.

RESPONSE: It is believed that this comment is not in response to content of the Draft BBR reviewed by the WHACC, but to a suggestion made during discussion at a WHACC meeting on the BBR and approaches that would be taken to assess Basslink change. The only sense in which an 'evolving baseline' is being considered is in respect of additional ***pre-Basslink*** *data from Spring 2005 that were not available for inclusion in the final report. No post-Basslink data are being used to set baselines. The pre-Basslink baseline is that which is presented in this report, and will be supplemented by the final pre-Basslink datasets which will be presented in the 2005-06 Gordon Basslink Annual Monitoring Report. Section 1.5 of the BBR provides clarification of the status of the BBR and further documents.*

A2.2.5 Specific minor queries

- p. 59 there is an apparent internal contradiction in the paragraph immediately before section 1.4.2;
- 2.1.2. not all HEC disturbances were excluded from the WHA (e.g. Lake Pedder);
- 7.1.4. Eucalyptus simmondsii is the old name for E. nitida. E. delegatensis is as almost as common in the catchment as E. obliqua. It is buttongrass not button grass;
- 9.4.2.2. (p. 248) Anopterus glandulosus is a tall shrub to small tree, not a small to medium-sized shrub;
- p 218 Map 10.2 does not show algal reference sites;
- p 229 'Table 10.7' should read Table 10.5; and
- p 233, last para. Re 'Proportion of macroinvertebrates as EPTCC species falls well below reference sites values upstream of the Denison confluence' appears to be unsupported in fig10.3 p 226.

RESPONSE: These items from the Draft BBR have been corrected in the Final BBR.

A2.3 Appropriateness of proposed mitigation measures (chapter 12)

A2.3.1 Compliance site

A fundamental issue lies in the location of the compliance site, site 65, just above the Denison confluence. This site is potentially flawed as a reliable location to provide evidence on compliance with operating provisions for two significant reasons. Firstly, the site lies a considerable distance downstream from the Gordon Dam and captures 'free' environmental flow from tributaries including the Orange and Albert rivers. Secondly the Denison river, immediately downstream from the compliance site, is likely to act as a significant hydrological control at site 65 at times of high flow in the Denison system. These two factors seriously compromise the compliance monitoring.

RESPONSE: The purpose of the minimum flow is to ensure a continuously available habitat area as a refuge for biota during times when the Gordon Power Station is not generating power. The location of the compliance site was agreed by the Joint Advisory Panel assessing Basslink, with recognition that it captures a certain level of non-power station derived water. The compliance requirement is that Hydro Tasmania continuously ensures a minimum flow level at this location, 19 $m^3\ s^{-1}$ in summer-autumn and 38 $m^3\ s^{-1}$ in winter-spring, by supplementing natural 'pick-up' as required. Compliance will be verifiable because flow data at this location is continuously recorded and instantaneously fed back to Hydro Tasmania system control to inform whether the Gordon Power Station needs to adjust its discharge, and this flow data will be provided to DPIWE. There will be backwater effects of the Denison River on the compliance site when the Denison is in flood but not at low river levels when the power station needs to discharge to meet the minimum flows; when the Denison is in flood and acts as a hydrological control the other tributaries will also be in flood and Gordon River levels at the compliance site are well above the minimum targets.

A2.3.2 Environmental flow provisions

The proposed variation of environmental flow provisions is totally inadequately justified. Such a variation is said to be allowed for a period of three years 'on a trial basis provided it does not increase environmental risk'. The term 'trial' implies that there is some baseline to vary from, in the context of Basslink operations. WHAAC is concerned about interpretations of words that violate their common sense meaning and is alarmed that no attempt is made to detail the likely differences in environmental outcomes with a 10/20, rather than the prescribed 19/38, environmental flow prescription. A comparison with the effects of earlier flow regimes, including the natural, seems strangely beside the point. Surely, the only justification for having a trial variation from a non-existent 'normal' regime would be that data suggest that the variation would provide better outcomes than the 'normal' regime. Otherwise, it would be possible to suspect that the science is being used as a smokescreen for decisions made on economic grounds.

The flow duration curves for environmental flow scenarios (fig 12.1) suggest that for more than 40 % of the time, the environmental flow will be exceeded. While exceeding the minimum flows may advantage some ecosystem components, during high flow regimes bank toe erosion may be negatively affected. Loss of a low summer flow may deprive biotic elements of the ecosystem of a crucial life-history trigger. The complex relationships between flow regimes and evidence from the environmental monitoring program under will require constant review under Basslink. The focus should be on environmental outcomes, not simply compliance with a minimum flow provision.

RESPONSE: These comments are in response to references in the Draft BBR to Hydro Tasmania's intended application for approval for a lower environmental flow of 10 m^3 s^{-1} in summer-autumn and 20 m^3 s^{-1} in winter-spring for a defined period. Hydro Tasmania is committed to achieve the objectives of the minimum environmental flow and maintain its commitment to sustainability, and as a commercial business it will explore cost-efficient methods to do so. Maintenance of a 10/20 rather than 19/38 m^3 s^{-1} minimum flow at the compliance site has been a particular proposal under consideration, as it would represent a considerable cost saving by making more water available for generation at energy efficient discharge levels and optimal market periods. Any proposal such as the 10/20 requires Ministerial approval, and will need to verify that it can adequately mitigate Basslink impacts and not cause unacceptable environmental risk.

A2.3.3 Redfin perch

The discovery of redfin perch in the Gordon in Zones 1 and 2 is a matter of concern. Since this invasion of a pest species appears to be quite recent, its populations are unlikely to have reached equilibrium in the river. It is clearly a threat to native galaxiids and could spread (p280). Already it is the dominant species immediately below the dam. One possible reason for the transfer of this species from Lake Gordon is escape through the turbines during times when the lake levels have been relatively low and the intake closer to the surface.

Has any consideration been given to the potential for Basslink operations to exacerbate the problem of continuing transfer of this species downstream, either through lake level intake issue or by providing more suitable habitat below the dam enabling populations to thrive?

WHACC urges Hydro Tasmania, aside from any Basslink consideration, to further investigate redfin perch in the Gordon River and Gordon impoundment (and elsewhere in the catchment) with a view to control or eradication and prevention of any further colonization via the Gordon Dam.

RESPONSE: Redfin perch populations will continue to be monitored and the implications of their presence assessed. Since the Draft BBR upon which these comments were made, additional information on redfin perch has been provided in Section 11.4.2.

A2.4 Consider 'limits of acceptable change'

The BBR has cast the notion of limits of acceptable change as trigger values for indicator variables. This is a useful way of formalizing and articulating limits.

The WHACC endorse the general position of 'no net Basslink impact' and supports the efforts to provide scientific and statistically valid data to inform decisionmaking.

RESPONSE: Noted.

A2.4.1 Responsibility for decision making

The responsibility for making decisions in the adaptive management process needs to be spread more widely than the management agency. Otherwise, it would be possible to suspect that any decisions were based solely on the economic impact on the HEC.

The WHACC has repeatedly urged a more independent process to evaluate the environmental impacts of Basslink.

RESPONSE: Responsibility for decision-making post-Basslink rests with the Minister administering Hydro Tasmania's Water Licence under the Water Management Act. Mitigation measures have been identified for environmental purposes to ensure no net Basslink impact, and trigger values are set to provide an indication as to whether a Basslink impact may have occurred. The use of trigger values based on a rigorous monitoring program over the four years prior to Basslink commencement provides an objective process to identify and assess Basslink effects. The Scientific Reference Committee provides independent scientific review of the monitoring findings, and includes representatives of the Commonwealth Department of Environment and Heritage. Trigger values and monitoring results are to be made available to the public through the Annual Reports on Hydro Tasmania's website (www.hydro.com.au).

A2.4.2 Trigger values

It appears that the statistical analysis will be undertaken on combined data with the exception of fluvial geomorphology (section 13.3.1) for which trigger values are provided at a zone scale. Other variables are not so referenced.

WHACC believes that it would be unacceptable to combine data from all test sites, because this could disguise or mask changes or trends in separate zones or by seasons. Trigger values must be set at zone scale as a minimum in order to have any validity. If this is not statistically possible, spatial patterns of change should be examined. Spatial statistics could be used to test for the significance of such variations. For example, there may be no overall change, but deleterious change concentrated in zone 3 and a beneficial change in zone 1. It may be possible to modify operations to stabilize zone 3, while not disrupting zone 1.

RESPONSE: Since production of the Draft BBR, the use of pooling of data has been more clearly explained in the Final BBR. The reader is referred to Section 4.4.5 in the Design and Inference chapter for a general discussion, and the final sections of each of the discipline specific chapters (6-11) to provide clear explanation for how data has been grouped for each discipline. It was recognised at the November 2005 meeting of the Gordon River Basslink Scientific Reference Committee (SRC) that the trigger values in the Final BBR would benefit from further statistical exploration to rigorously examine how data pooling can be optimally used, and as a consequence the BBR trigger values will be considered interim trigger values until further statistical exploration of the data and incorporation of the final set of pre-Basslink data can occur. Hydro Tasmania has committed to further engagement of its consulting *statistician to work with the researchers between January and March 2005 to develop a proposed final set of trigger values, and these will be presented, reviewed and agreed to at a special meeting of the SRC in April 2006. These trigger values will be available to the public in the 2005-06 Annual Monitoring Report, and will be formally reviewed in the three-year post-Basslink Review Report.*

A2.4.3 Trend analysis for fluvial geomorphology

Figure 13.1 (p310) shows the temporal pattern in bank retreat during the monitoring period. It also shows the extrapolation made for setting limits for acceptable change, which is linear, which is said to be 'conservative'. Yet, the data points indicate a decline in the rate of increase in erosion through time, a not totally unpredictable outcome given that the years of monitoring had a more severe flow regime for erosion than the earlier years in which the power station was in operation. The implication of the 'conservative' linear extrapolation is that a higher increase in the rate of erosion would be required to set off adaptive management alarms than if a quadratic or polynomial line of best fit had been fitted to the data points. This is 'conservative' in relation to economic values, but 'radical' in relation to environmental values. We suggest that alternative best fit analyses should be considered in place of the linear extrapolation.

RESPONSE: This issue can be considered in the further statistical exploration of the data that will be undertaken early in 2006.

A2.4.4 Interpreting the changes in indicator variables

It is vital to look at variables in an integrated fashion. While caveats are placed on statistical interpretation and confidence, the evidence of changes in variables should not be taken in isolation. An integrated approach to interpretation can be used with greater confidence where interrelationships between variables are better understood. Hence the importance of continued efforts to refine the underlying conceptual model. There may be value in the next stages of monitoring and interpretation to develop some rule sets based on the conceptual model to complement the statistical analyses. For some indicator variables, values outside the norm may represent a positive change in environmental or ecosystem quality.

RESPONSE: Fully agreed. Opportunities to look at the variables in an integrated fashion will be explored, as will continued refinement of, and guidance from, the conceptual model.

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A3 Water quality

A3.1 Introduction

The water quality monitoring program has collected a large amount of information relating to the water quality of Lakes Pedder and Gordon, as required by Hydro Tasmania's Special Licence (see appendix 1). This information is of value in terms of ensuring that the lakes remain in a relatively pristine condition.

The lakes have little influence on the water quality of the downstream Gordon River. It is only at the intake site in Lake Gordon that lake water quality plays a part in determining the quality of the water released from the power station. Consequently, the discussion pertinent to the water quality of the middle Gordon River, as presented in the water quality chapter (chapter 6), includes only summary information about the lake's water quality. This appendix provides a more detailed listing of the methods, values, ranges and trends identified for the various lake water quality parameters measured during the pre-Basslink monitoring.

A3.2 Methods

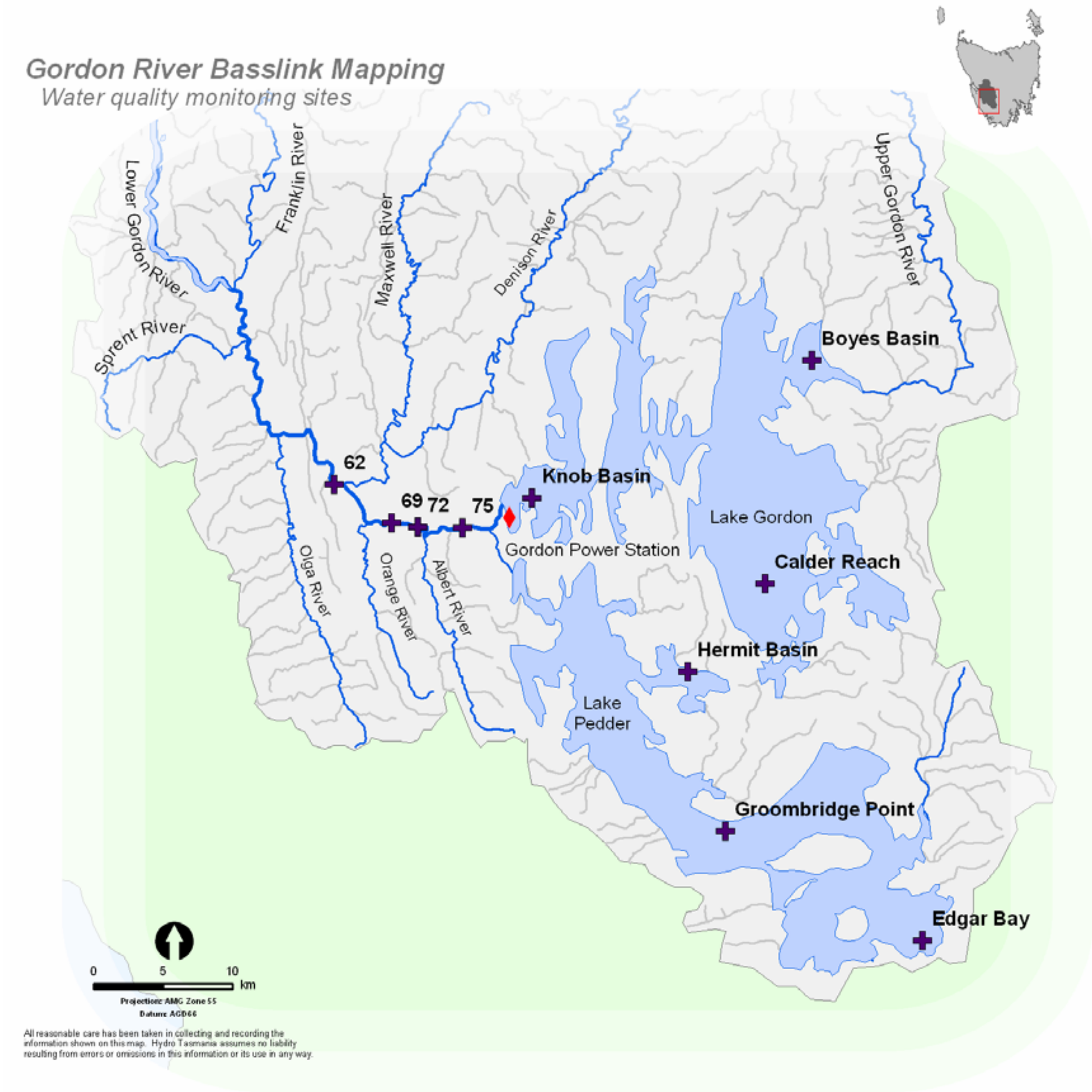
Water quality parameters were monitored in Lakes Pedder and Gordon, and in the Gordon River. Map 3.1 shows the Gordon catchment, including the location of the lakes, the power station, and the Gordon River, as well as the monitoring sites.

In Lake Pedder, three sites (Edgar Basin, Hermit Basin, and Groombridge Point) were monitored quarterly for surface physico-chemical parameters. Groombridge Point was also monitored for metals and nutrients, and depth profiles of physico-chemical parameters were also taken. At a similar frequency, three sites in Lake Gordon (Boyes Basin, Calder Basin and the power station intake) were monitored for surface physico-chemical parameters, metals and nutrients. Depth profiles of physico-chemical parameters were also taken at each site. Map 3.1 shows the location of the lake monitoring sites.

Surface and depth profile physico-chemical parameters (water temperature, dissolved oxygen, conductivity, pH, and turbidity) were measured using field instruments. For each of the metals and nutrients water samples, the following parameters were measured by laboratory analysis:

- total phosphorus (TP) and dissolved reactive phosphorus (DRP);
- nitrite, nitrate, total Kjeldahl nitrogen (TKN), ammonia;
- chlorophyll-*a*;
- metals (iron, manganese, zinc, cadmium, copper, aluminium, cobalt, chromium, nickel and lead);

- sulphate;
- alkalinity; and
- dissolved organic carbon (DOC).



Map 3.1 Map of the Gordon catchment showing the location of monitoring sites in Lakes Pedder and Gordon and the Gordon River.

The Gordon River was monitored continuously for water temperature and dissolved oxygen at the tailrace. Water temperature was also monitored continuously at sites 75 (Gordon River at Abel Gorge) and 62 (Gordon River downstream of the Denison confluence). Additional water temperature data were available from sites 72 (Gordon River downstream of Albert confluence) and 69 (Gordon River upstream of the Splits). Map 3.1 shows the location of these sites.

A3.3 Lake Pedder surface parameters

A3.3.1 Water temperature

Surface water temperatures varied seasonally, with winter lows around 6 °C and summer highs above 20 °C. No unusual values were recorded at any of the Lake Pedder sites.

A3.3.2 Dissolved oxygen

Surface dissolved oxygen values also demonstrated a seasonal pattern, because of the close association between water temperature and oxygen solubility. Table 3.1 lists the dissolved oxygen statistics recorded for the three Lake Pedder monitoring sites. These show that the dissolved oxygen levels in Lake Pedder were within a normal range and stable over time and throughout the lake.

Table 3.1 Surface dissolved oxygen values recorded in Lake Pedder.

Location	# of samples	Date range	Value range (mg L^{-1})	Median value (mg L^{-1})	Trend/pattern
Edgar Basin	34	Sep 96–Apr 05	7.9–12.1	9.9	Seasonal
Hermit Basin	32	Aug 99–Apr 05	7.4–11.4	9.8	Seasonal
Groombridge Pt	50	Jan 94–Apr 05	7.6–11.6	9.8	Seasonal

A3.3.3 pH

The pH values recorded for Lake Pedder were relatively even across the lake and through time, although Hermit Basin tended to record generally lower values than the other sites. Table A2.2 shows the statistics for pH values recorded in the lake. These values indicate that the lake remains slightly acidic, which is common to lakes in this area.

Table 3.2 Surface pH values in Lake Pedder.

Location	# of samples	Date range	Value range	Median value	Trend/pattern
Edgar Basin	33	Sep 96–Apr 05	5.8–7.4	6.3	none apparent
Hermit Basin	32	Aug 99–Apr 05	5.2–6.8	5.7	none apparent
Groombridge Pt	48	Oct 93–Apr 05	5.7–7.3	6.1	none apparent

A3.3.4 Conductivity

Conductivity values were generally even throughout the lake and have been stable over time at around 40 $\mu S\ cm^{-1}$ (range 30-50 $\mu S\ cm^{-1}$). These values are typical of lakes in this region. The main pattern apparent is for some years (1996-97 and 1999) to have generally lower conductivity values (30-35 $\mu S\ cm^{-1}$) than others. Table 3.3 shows the statistics for conductivity values recorded in the lake.

Table 3.3 Surface conductivity values in Lake Pedder.

Location	# of samples	Date range	Value range	Median value	Trend/pattern
Edgar Basin	32	Sep 96–Apr 05	31.1–48.7	39.5	none apparent
Hermit Basin	22	Aug 99–Apr 05	33.1–45.1	41	none apparent
Groombridge Pt	36	Oct 93–Apr 05	30.4–46.0	39.4	none apparent

A3.3.5 Turbidity

The turbidity values in Lake Pedder were uniformly low. Table 3.4 shows the statistics for the turbidity values recorded throughout the lake over time.

Table 3.4 Surface turbidity values in Lake Pedder.

Location	# of samples	Date range	Value range (NTU)	Median value (NTU)	Trend/pattern
Edgar Basin	51	Nov 96–Apr 05	0.6–4.5	1.2	none apparent
Hermit Basin	48	Aug 99–Apr 05	0.6–3.7	0.8	none apparent
Groombridge Pt	61	Oct 93–Apr 05	0.4–4.1	1.0	none apparent

A3.3.6 Chlorophyll-*a*

The chlorophyll-*a* values were very low, as would be expected in a lake in this region and demonstrated a seasonal pattern, with lower values in winter-spring and higher values in summer-autumn. Table 3.5 shows the statistics for chlorophyll-*a* values recorded in the lake.

Table 3.5. Surface chlorophyll-a values in Lake Pedder.

Location	# of samples	Date range	Value range ($\mu g\ L^{-1}$)	Median value ($\mu g\ L^{-1}$)	Trend/pattern
Edgar Basin	36	Oct 93–Apr 05	0.28–2.07	0.88	Seasonal
Hermit Basin	24	Aug 99–Apr 05	0.48–2.79	0.99	Seasonal
Groombridge Pt	38	Oct 93–Apr 05	0.04–1.83	0.89	Seasonal

A3.3.7 Nutrients and metals

Water samples for laboratory analysis of nutrients and metals were taken at Groombridge Point in Lake Pedder. Table 3.6 shows the parameters, number of samples, date and value ranges, and median values recorded for this site. Of the results shown in Table 3.6, the data indicated continuing low nutrient levels in Lake Pedder., with no apparent trends. One high ammonia value of 0.075 mg L^{-1} was recorded in May 1997. All other readings were below 0.033 mg L^{-1}, in closer concordance with the median value.

Alkalinity values showed peaks in December 2000 and over the winter of 2003, but the long-term trend of values between 4–6 mg L^{-1} is continuing. Dissolved organic carbon recorded low values over the winter of 2001 and its long-term trend of values around 6 mg L^{-1} is also continuing. Sulphate values were relatively stable around the median of 1.1 mg L^{-1}.

Several of the metals values were at or below the detection thresholds for these parameters. These included chromium, cobalt, copper, lead, manganese, nickel and zinc. Iron values continued their long-term trend close to the median value of 0.26 mg L^{-1}. Aluminium values were relatively stable over time, close to the median value of 0.11 mg L^{-1}.

Table 3.6 Surface nutrient and metals values at Groombridge Point, Lake Pedder.

Location	# of samples	Date range	Value range (mg L^{-1})	Median value (mg L^{-1})	Trend/pattern
Total phosphorus	31	Oct 93–Apr 05	0.002–0.016	0.005	None apparent
Dissolved reactive phosphorus	24	Oct 93–Apr 05	<0.001– 0.006	0.002	None apparent
Total Kjeldahl nitrogen	31	Oct 93–Apr 05	0.14–0.32	0.22	None apparent
Ammonia	31	Oct 93–Apr 05	<0.005–0.075	0.019	None apparent
Nitrite	31	Oct 93–Apr 05	<0.001–0.005	0.003	None apparent
Nitrate	31	Oct 93–Apr 05	0.009–0.079	0.053	None apparent
Dissolved organic carbon	19	Aug 99–Apr 05	2.1–8.1	5.7	None apparent
Alkalinity	19	Aug 99–Apr 05	3.8–20.0	6	None apparent
Sulphate	19	Aug 99–Apr 05	0.5–1.4	1.1	None apparent
Aluminium	13	Dec 00 –Apr 05	0.093–0.128	0.11	None apparent
Cadmium	19	Aug 99–Apr 05	<0.001–<0.02	<0.001	All below detection limit
Chromium	13	Dec 00 –Apr 05		<0.001	All below detection limit
Cobalt	13	Dec 00 –Apr 05		<0.001	All below detection limit
Copper	19	Aug 99–Apr 05	<0.001–<0.05	<0.001	All below detection limit
Iron	31	Oct 93–Apr 05	0.18–0.55	0.25	None apparent
Lead	13	Dec 00 –Apr 05		<0.005	All below detection limit
Manganese	31	Oct 93–Apr 05	<0.005–<0.02	0.006	All at or near detection limit
Nickel	13	Dec 00 –Apr 05	<0.001–0.002	<0.001	All at or near detection limit
Zinc	19	Aug 99–Apr 05	<0.001–<0.03	0.004	All at or near detection limit

In summary, none of the nutrient or metals values shows any great divergence from values expected of lakes in this region.

A3.4 Lake Pedder depth profiles

A3.4.1.1 Water temperature depth profiles

The water temperature profiles recorded at Groombridge Point from March 2001 to April 2005 were uniform to the maximum depth of 16 m. Water column values ranged from 6 °C in July 2004 to 17 °C in March 2001. Occasionally in summer, the top two metres of the water column were 2–3 °C higher than the water column. Figure 3.1 shows the water temperature profiles recorded since September 2000.

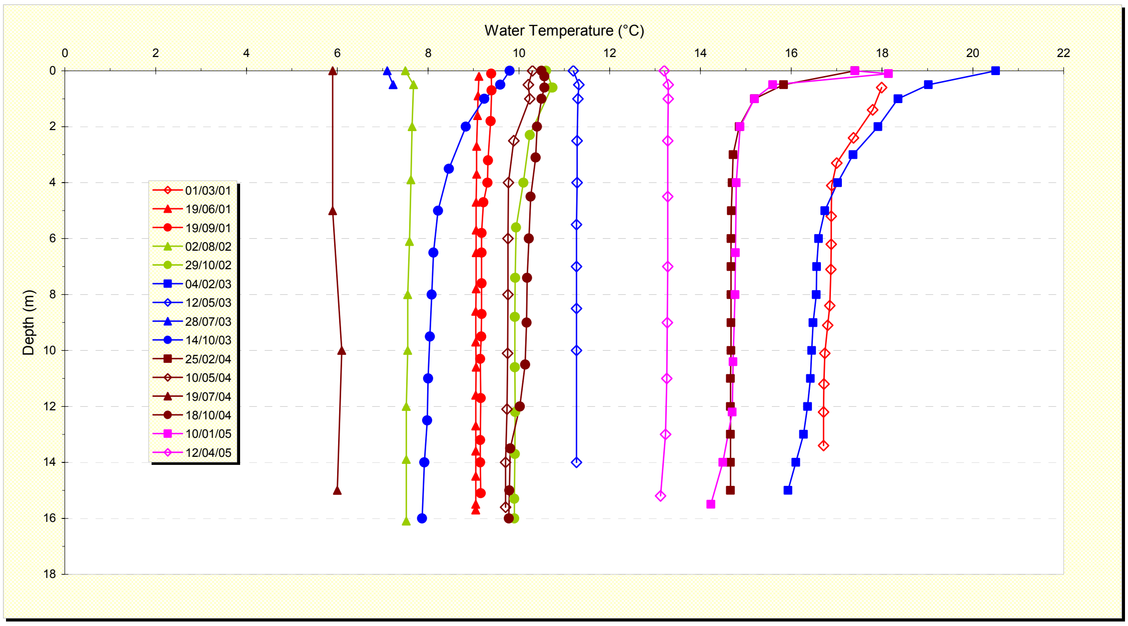


Figure 3.1 . Water temperature depth profiles at Groombridge Point, Lake Pedder. Differing colours indicate years. Filled squares indicate summer profiles, open diamonds: autumn, filled triangles: winter and filled circles: spring profiles.

A3.4.1.2 Dissolved oxygen depth profiles

The dissolved oxygen profiles were similar to those of water temperature, with constant values at all depths throughout the profile and no indication of stratification. Figure 3.2 shows the profiles for oxygen concentration. Values ranged from 7.9 to 11.7 mg L^{-1}. Oxygen ranged from 74 to 106 % saturation between 2001 and 2005.

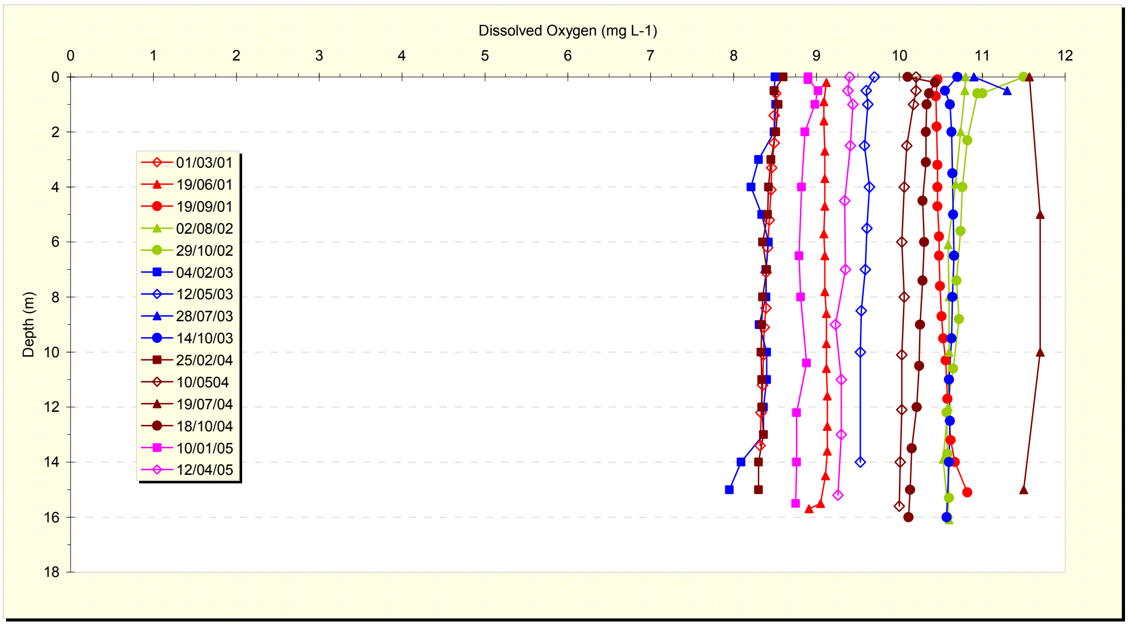


Figure 3.2 Depth profiles of dissolved oxygen concentration at Groombridge Point, Lake Pedder.

A3.4.1.3 pH depth profiles

The pH profiles at Groombridge Point (Figure 3.3) were similar to those of dissolved oxygen and water temperature, being even through depth with no indication of stratification. Values were slightly to moderately acidic, ranging from 5.5 to 6.6.

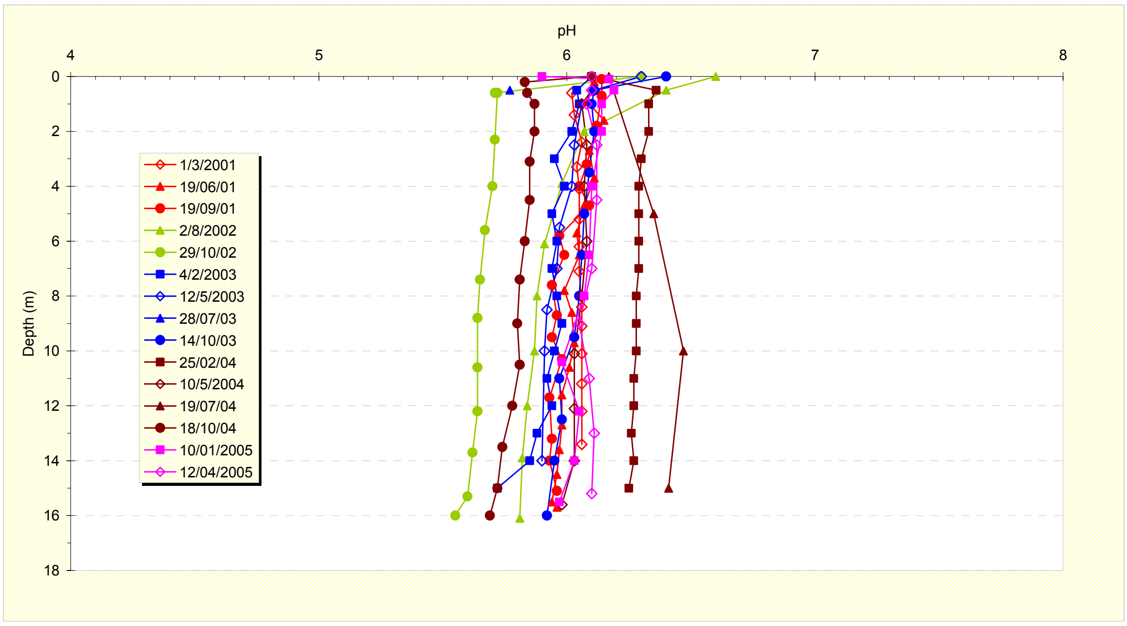


Figure 3.3 Depth profiles of pH at Groombridge Point, Lake Pedder.

A3.4.1.4 Conductivity depth profiles

The conductivity profiles (Figure 3.4) were even through depth, with no indication of stratification and ranged from 33-46 µS cm^{-1}.

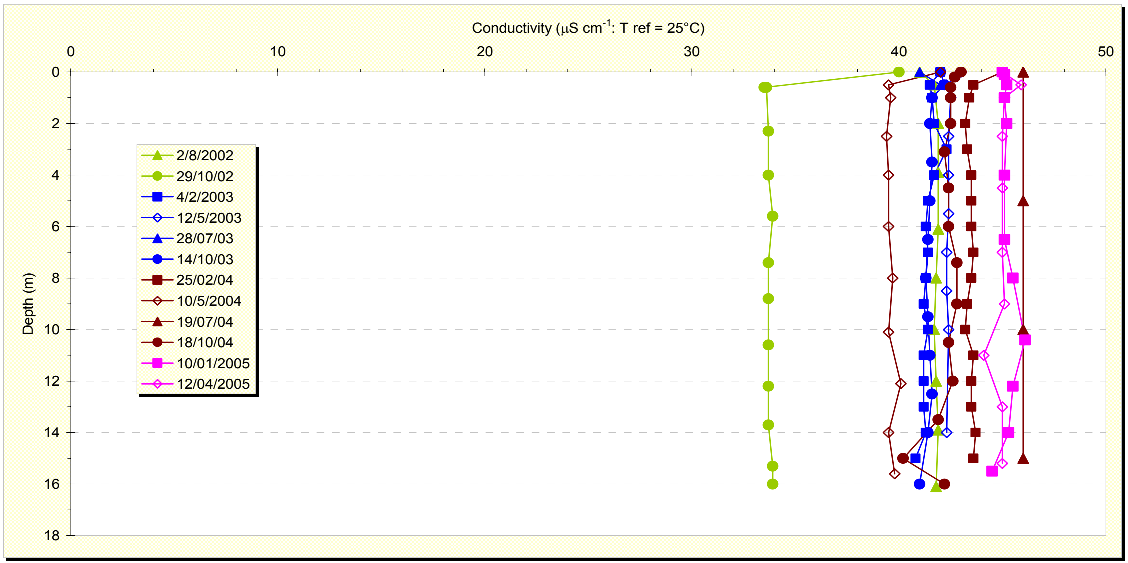


Figure 3.4 Depth profiles of conductivity at Groombridge Point, Lake Pedder.

A3.5 Lake Gordon surface parameters

A3.5.1.1 Water temperature

Surface water temperatures varied seasonally, with winter lows around 5 °C and summer highs above 20 °C. No unusual values were recorded at any of the Lake Gordon sites.

A3.5.1.2 Dissolved oxygen

Surface dissolved oxygen values demonstrated a seasonal pattern. Table 3.7 lists the dissolved oxygen statistics recorded for the three Lake Gordon monitoring sites. These show that the dissolved oxygen levels in Lake Gordon were within a normal range and stable over time and throughout the lake.

Table 3.7 Surface dissolved oxygen values in Lake Gordon.

Location	# of samples	Date range	Value range (mg L^{-1})	Median value (mg L^{-1})	Trend/pattern
Boyes Basin	39	Sep 96–Apr 05	7.5–10.9	8.9	Seasonal
Calder Reach	49	Jan 94–Apr 05	7.8–10.9	9.4	Seasonal
Intake	35	Jan 96–Apr 05	7.6–11.1	8.5	Seasonal

A3.5.1.3 pH

The pH values recorded for Lake Gordon were relatively even across the lake and through time, although Hermit Basin tended to record generally lower values than the other sites. Table 3.8 shows the statistics for pH values recorded in the lake. These values indicate that the lake remains slightly acidic, which is common to lakes in this area.

Table 3.8 Surface pH values in Lake Gordon.

Location	# of samples	Date range	Value range	Median value	Trend/pattern
Boyes Basin	38	Sep 96–Apr 05	5.8–7.5	6.4	none apparent
Calder Reach	48	Oct 93–Apr 05	5.5–7.4	6.3	none apparent
Intake	36	Jan 96–Apr 05	5.4–7.0	6.1	none apparent

A3.5.1.4 Conductivity

Conductivity values were generally even throughout the lake and have been stable over time at around 40 $\mu S\ cm^{-1}$ (range of 28–67 $\mu S\ cm^{-1}$), although almost all readings were below 50 $\mu S\ cm^{-1}$. This range of values is typical of lakes in this region. The Boyes Basin and Calder Reach sites recorded high values on 25 September 1996, at 64 and 67 $\mu S\ cm^{-1}$, respectively. Table 3.9 shows the statistics for conductivity values recorded in the lake.

Table 3.9 Surface conductivity values in Lake Gordon.

Location	# of samples	Date range	Value range	Median value	Trend/pattern
Boyes Basin	39	Sep 96–Apr 05	29.2–63.7	39.9	none apparent
Calder Reach	51	Oct 93–Apr 05	29.0–67.2	39.9	none apparent
Intake	37	Jan 96–Apr 05	27.9–44.2	40.0	none apparent

A3.5.1.5 Turbidity

The turbidity values in Lake Gordon were relatively low, with median values between 1.4 and 2.8 NTU. Table 3.10 shows the statistics for the turbidity values recorded throughout the lake over time. At the Boyes Basin and Calder Reach sites, unusually high turbidity values (8.8 and 9.4, respectively) were recorded on 1 August 2002.

Table 3.10 Surface turbidity values in Lake Gordon.

Location	# of samples	Date range	Value range (NTU)	Median value (NTU)	Trend/pattern
Boyes Basin	53	Nov 96–Apr 05	0.7–8.8	2.6	none apparent
Calder Reach	60	Oct 93–Apr 05	1.0–9.4	2.8	none apparent
Intake	50	Jan 96–Apr 05	0.6–1.8	1.4	none apparent

*A3.5.1.6 Chlorophyll-*a

The chlorophyll-*a* values were very low, as would be expected in a lake in this region and demonstrated a seasonal pattern, with lower values in winter–spring and higher values in summer–autumn. Table 3.11 shows the statistics for chlorophyll-*a* values recorded in the lake.

At Boyes Basin, an unusually high chlorophyll-*a* value of 15.1 μg L^{-1} was recorded in February 2004. This is the only record, to date, of a value greater than 6 μg L^{-1} at this site.

Table 3.11 Surface chlorophyll-*a* values in Lake Gordon.

Location	# of samples	Date range	Value range (μg L^{-1})	Median value (μg L^{-1})	Trend/pattern
Boyes Basin	40	Oct 93–Apr 05	0.1–15.1	1.1	Seasonal: low values in winter/spring, high values in summer/autumn.
Calder Reach	38	Oct 93–Apr 05	0.1–1.4	0.5	As above
Intake	29	Aug 99–Apr 05	0.1–2.0	0.5	None apparent

A3.5.1.7 Nutrients and metals

Water samples for laboratory analysis of nutrients and metals were taken at Boyes Basin, Calder Reach, and the power station intake in Lake Gordon. Table 3.12 shows the parameters, number of samples, date and value ranges, median values recorded for the Boyes Basin site, while Table 3.13 and Table 3.14 show these for Calder Reach and the intake site, respectively.

Table 3.12 Surface nutrient and metals values at Boyes Basin, Lake Gordon.

Parameter	# of samples	Date range	Value range (mg L^{-1})	Median value (mg L^{-1})	Trend/pattern
Total phosphorus	21	Aug 99–Apr 05	0.004–0.055	0.006	None apparent The high value in February 2004 is related to a high chlorophyll-*a* value (see A3.5.1.6)
Dissolved reactive phosphorus	14	Aug 00–Apr 05	<0.002–0.003	0.002	None apparent
Total Kjeldahl nitrogen	21	Aug 99–Apr 05	0.17–0.33	0.216	None apparent
Ammonia	21	Aug 99–Apr 05	0.003–0.032	0.011	None apparent
Nitrite	21	Aug 99–Apr 05	0.002 –0.006	0.003	None apparent
Nitrate	21	Aug 99–Apr 05	0.037–0.091	0.053	None apparent
Dissolved organic carbon	21	Aug 99–Apr 05	4.1–8	7.1	None apparent
Alkalinity	21	Aug 99–Apr 05	4.4–20	8	None apparent
Sulphate	21	Aug 99–Apr 05	0.5–1.3	0.94	None apparent
Aluminium	15	Aug 00–Apr 05	0.119–0.243	0.184	None apparent
Cadmium	21	Aug 99–Apr 05		<0.001	All below detection limit
Chromium	15	Aug 00–Apr 05	<0.001–0.002	<0.001	Most below detection limit
Cobalt	15	Aug 00–Apr 05		<0.001	All below detection limit
Copper	21	Aug 99–Apr 05	<0.001–0.006	<0.001	Most below detection limit
Iron	21	Aug 99–Apr 05	0.401–0.692	0.52	None apparent
Lead	15	Aug 00–Apr 05		<0.005	All below detection limit
Manganese	21	Aug 99–Apr 05	<0.005–0.021	0.009	None apparent
Nickel	15	Aug 00–Apr 05	<0.001–0.002	<0.001	Most below detection limit
Zinc	21	Aug 99–Apr 05	<0.001–0.011	0.003	None apparent

Table 3.13 Surface nutrient and metals values at Calder Basin, Lake Gordon.

Parameter	# of samples	Date range	Value range (mg L^{-1})	Median value (mg L^{-1})	Trend/pattern
Total phosphorus	23	Oct 93–Apr 05	0.003–0.009	0.005	None apparent
Dissolved reactive phosphorus	23	Oct 93–Apr 05	<0.001–0.006	0.002	None apparent
Total Kjeldahl nitrogen	23	Oct 93–Apr 05	<0.01–0.29	0.21	None apparent
Ammonia	23	Oct 93–Apr 05	<0.005–0.034	0.021	None apparent
Nitrite	23	Oct 93–Apr 05	<0.001–0.008	0.003	None apparent
Nitrate	23	Oct 93–Apr 05	0.059–0.078	0.065	None apparent
Dissolved organic carbon	11	Aug 02–Apr 05	3.9–7.2	6.1	None apparent
Alkalinity	11	Aug 02–Apr 05	5–10	7	None apparent
Sulphate	11	Aug 02–Apr 05	1.0–1.4	1.2	None apparent
Aluminium	11	Aug 02–Apr 05	0.157–0.33	0.2	None apparent
Cadmium	11	Aug 02–Apr 05		<0.001	All values below detection limit
Chromium	11	Aug 02–Apr 05		<0.001	All values at or below detection limit
Cobalt	11	Aug 02–Apr 05		<0.001	All values below detection limit
Copper	11	Aug 02–Apr 05	<0.001–0.007	<0.001	most values below detection limit
Iron	23	Oct 93–Apr 05	0.35–0.81	0.49	None apparent
Lead	11	Aug 02–Apr 05		<0.005	All values below detection limit
Manganese	23	Oct 93–Apr 05	<0.005–0.019	0.01	None apparent
Nickel	11	Aug 02–Apr 05		<0.001	All values at or below detection limit
Zinc	11	Aug 02–Apr 05	<0.001–0.017	0.002	None apparent

Table 3.14 Surface nutrient and metals values at the power station intake, Lake Gordon.

Parameter	# of samples	Date range	Value range (mg L^{-1})	Median value (mg L^{-1})	Trend/pattern
Total phosphorus	12	Sep 01–Apr 05	<0.005–0.013	0.006	None apparent
Dissolved reactive phosphorus	12	Sep 01–Apr 05	<0.002–0.005	0.002	None apparent
Total Kjeldahl nitrogen	12	Sep 01–Apr 05	0.165–0.287	0.21	None apparent
Ammonia	12	Sep 01–Apr 05	0.002–0.021	0.017	None apparent
Nitrite	12	Sep 01–Apr 05	<0.002–0.003	0.003	None apparent
Nitrate	12	Sep 01–Apr 05	0.002–0.074	0.066	None apparent
Dissolved organic carbon	12	Sep 01–Apr 05	2.2–7.2	6.3	None apparent
Alkalinity	12	Sep 01–Apr 05	5–11	8	None apparent
Sulphate	12	Sep 01–Apr 05	0.79–2.3	1.05	None apparent
Aluminium	12	Sep 01–Apr 05	0.13–0.278	0.161	None apparent
Cadmium	12	Sep 01–Apr 05		<0.001	All values below detection limit
Chromium	12	Sep 01–Apr 05	<0.001–0.001	<0.001	Most values below detection limit
Cobalt	12	Sep 01–Apr 05		<0.001	All values below detection limit
Copper	12	Sep 01–Apr 05	<0.001–0.006	<0.001	Most values below detection limit
Iron	12	Sep 01–Apr 05	0.43–1.62	0.638	None apparent
Lead	12	Sep 01–Apr 05		<0.005	All values below detection limit
Manganese	12	Sep 01–Apr 05	0.005–0.064	0.011	None apparent
Nickel	12	Sep 01–Apr 05	<0.001–0.001	<0.001	Most values below detection limit
Zinc	12	Sep 01–Apr 05	<0.001–0.016	0.002	None apparent

A3.6 Lake Gordon depth profiles

A3.6.1 Water temperature depth profiles

The water temperature profiles at Boyes Basin showed a tendency for thermal stratification in the summer and early autumn profiles. The stratification was not strong and bottom (30–40 m) temperatures ranged from 4.5–11 °C. This unusually large range is attributed to the effects of inflow from the upper Gordon River water (see discussion about dissolved oxygen, in section A3.6.1.1). Figure 3.5 illustrates the water temperature profiles for the Boyes Basin site.

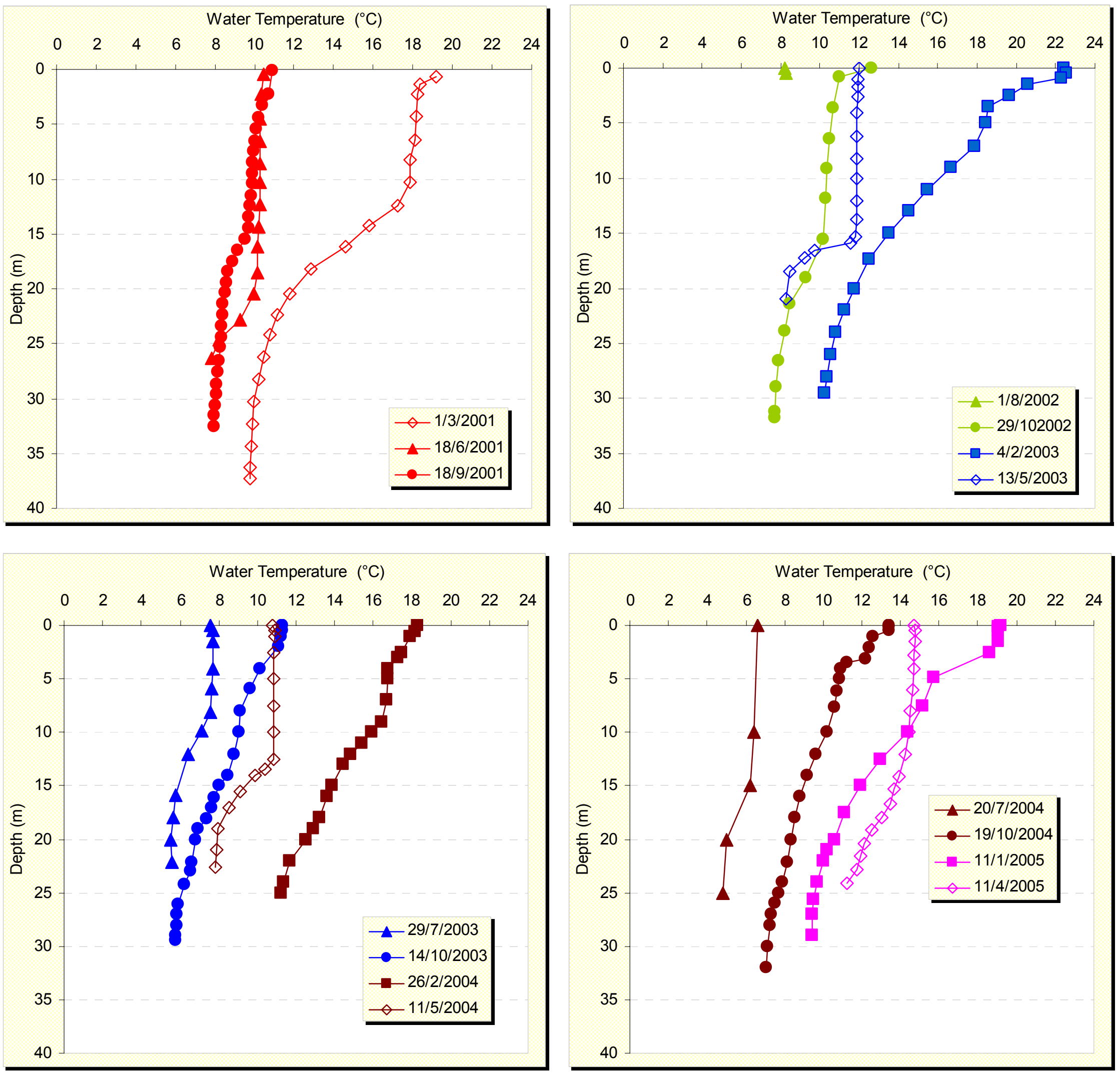


Figure 3.5 Water temperature profiles for the Boyes Basin site, Lake Gordon for the years 2001, 2002–03, 2003–04 and 2004–05.

The Calder Reach water temperature profiles were consistent with the site's 55 m depth and are shown in Figure 3.6. Winter and early spring profiles were relatively uniform with depth, while summer and autumn profiles showed marked thermal stratification. Surface temperatures ranged from 8–24 °C, while bottom temperatures ranged from 7.6–10 °C. Stratification depth varied between years from around 10-32 m.

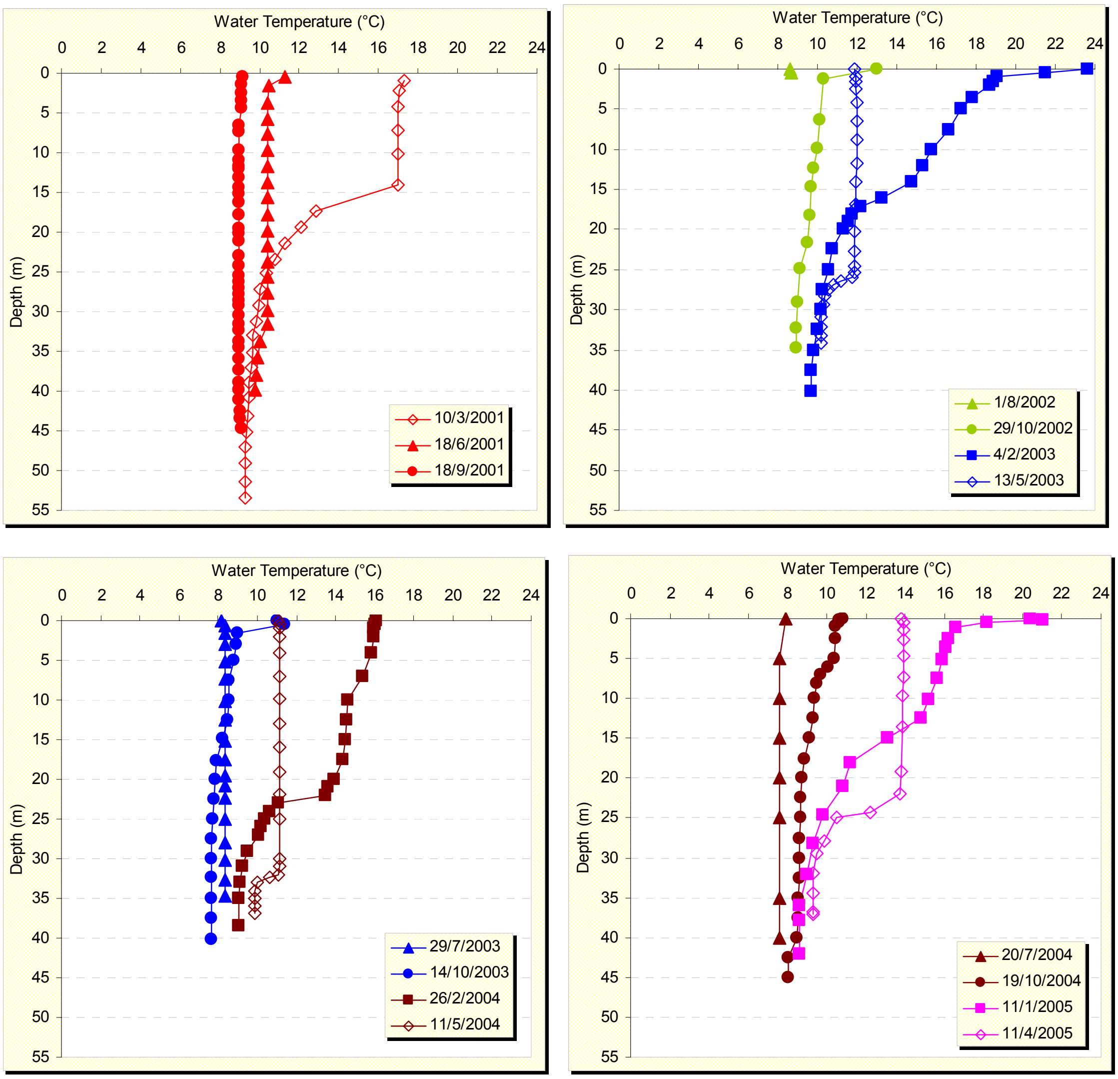


Figure 3.6 Water temperature profiles for the Calder Reach site, Lake Gordon for the years 2001, 2002–03, 2003–04 and 2004–05.

The intake site is the deepest of the three at around 100 m. Stratification was seasonal, being most pronounced in summer and early autumn and breaking down to a uniform profile in winter and spring. Figure 3.7 shows the water temperature profiles for the power station intake site since 2001. Surface temperatures ranged from 8-19 °C, bottom temperatures ranged from 7-9 °C, and stratification depth varied from 10-30 m.

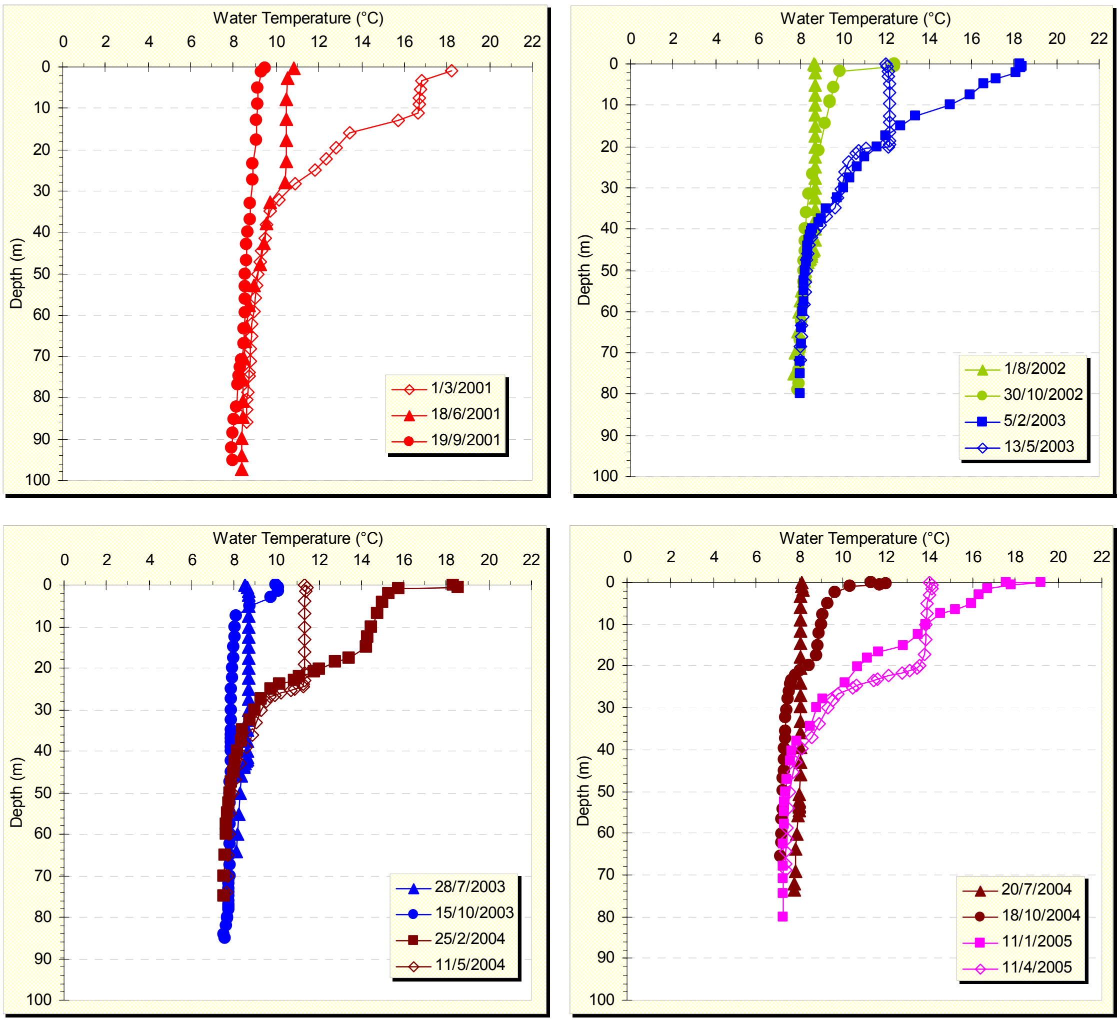


Figure 3.7 Depth profiles of water temperature at the power station intake, Lake Gordon, for the years 2001, 2002–03, 2003–04 and 2004–05.

A3.6.1.1 Dissolved oxygen depth profiles

The Boyes Basin dissolved oxygen profiles indicated varying degrees of stratification, with low dissolved oxygen levels recorded below 20 m in the early autumn of 2001 and the summers of 2003 and 2005. Figure 3.8 shows the dissolved oxygen concentration profiles recorded at the site.

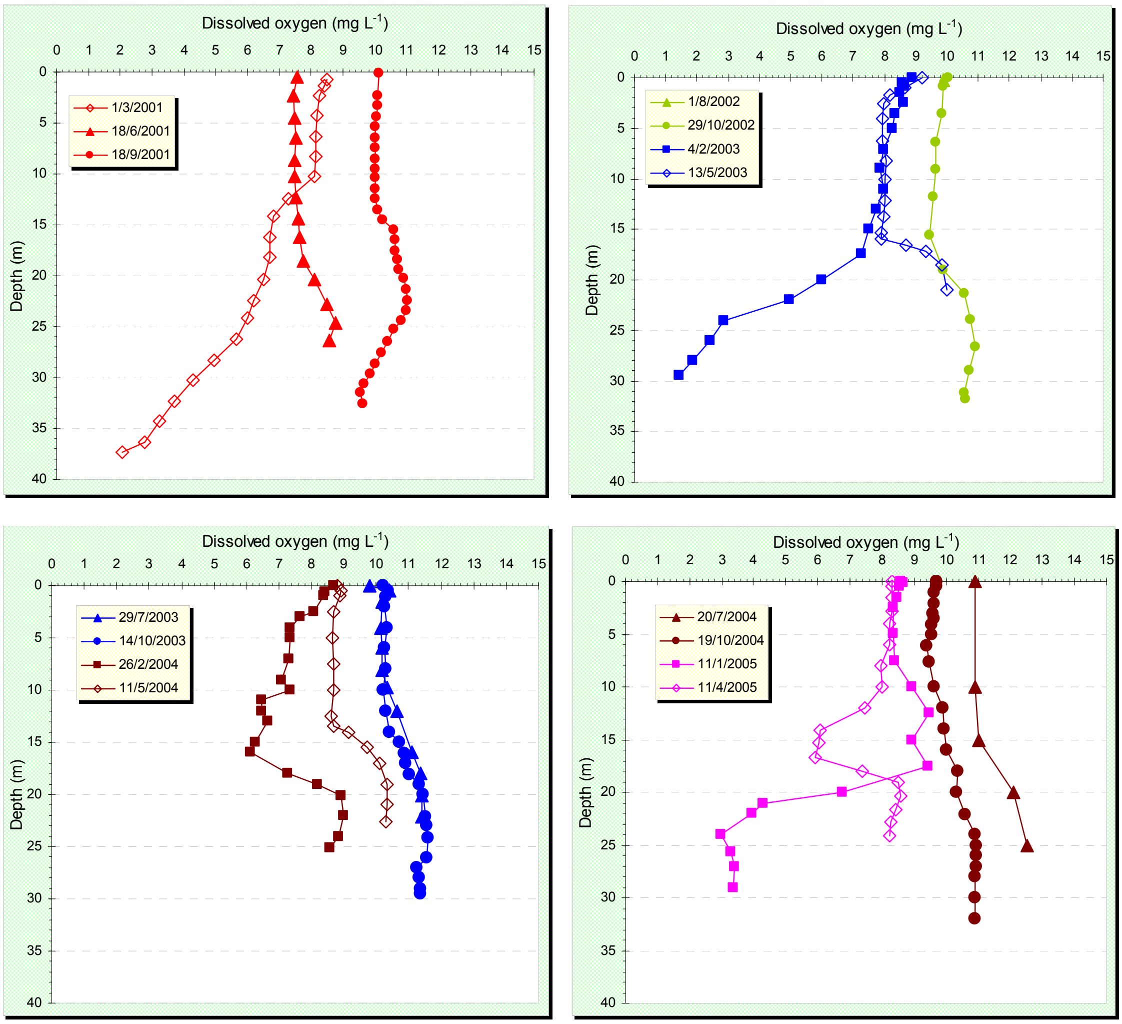


Figure 3.8 Depth profiles of dissolved oxygen concentration at Boyes Basin, Lake Gordon, for the years 2001, 2002–03, 2003–04 and 2004–05.

A more unusual pattern was evident, often in the late autumn through to spring profiles, where the dissolved oxygen concentrations increased with depth (at around 15 m). It was noted earlier (section A3.6.1) that the water temperature variation at this site was unusually large. Both of these patterns are attributed to the effects of the adjacent inflow from the upper Gordon River, where cooler, more-oxygenated water enters Lake Gordon. It appears that the river water did not immediately mix with the lake water. This effect was evident at depths between 15–30 m and strongest at about 20 m during the months when inflow would be substantial. This is an interesting artefact first reported by Steane and Tyler (1982) and it is sometimes detected as far as the dam wall. It does not affect the overall water quality of the lake or the water entering the power station intake.

The Calder Reach dissolved oxygen profiles showed distinct oxygen stratification, at around 25 m, in most autumn profiles. The stratification was less marked in the summer profiles, and not apparent in the winter and spring profiles. Anoxic values (<2 mg L^{-1}) were recorded only once (June 2001), although they approached this value in most autumn profiles. Figure 3.9 shows the dissolved oxygen concentration profiles recorded at the site.

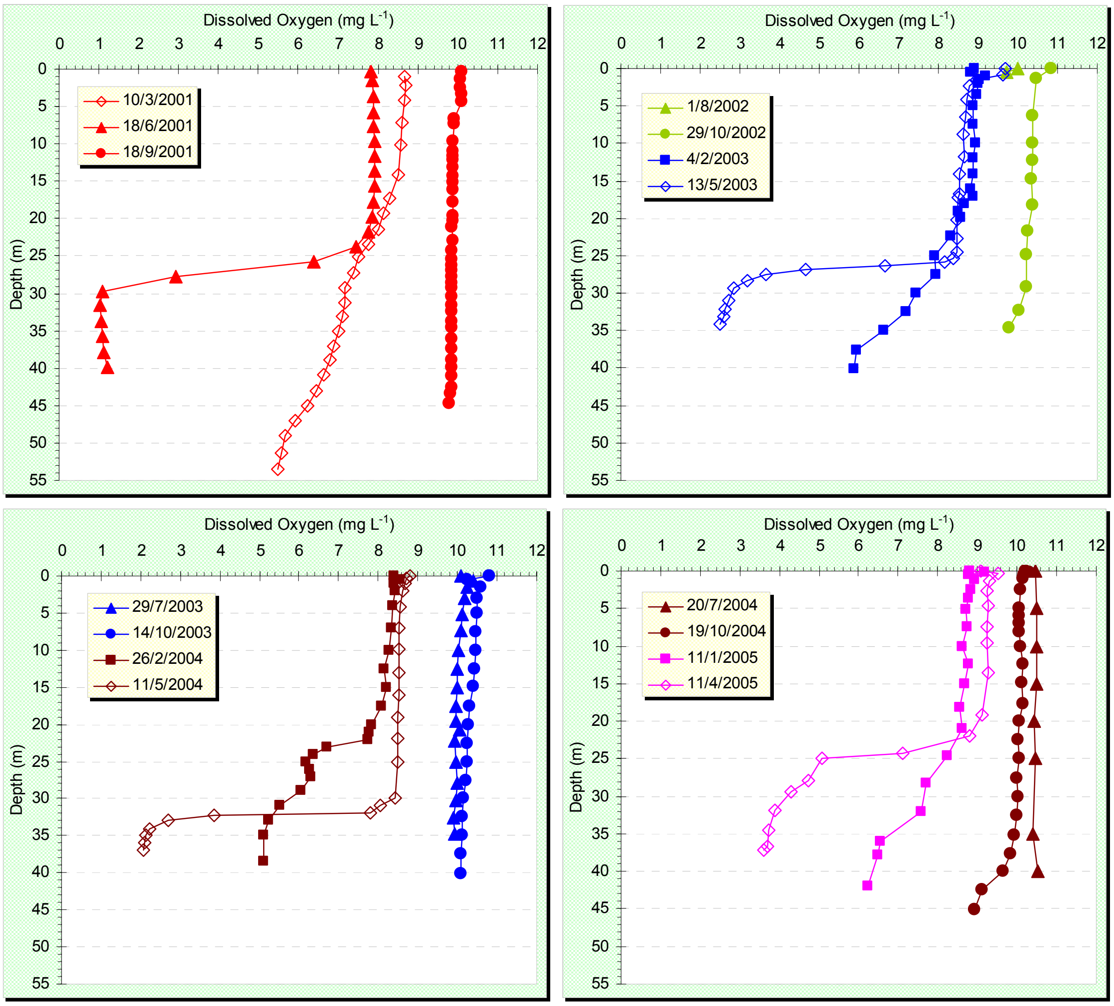


Figure 3.9 Depth profiles of dissolved oxygen concentration at Calder Reach, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

The intake dissolved oxygen profiles were much more strongly stratified than either of the other two Lake Gordon sites. Figure 3.10 shows the dissolved oxygen concentration profiles recorded at this site. Almost all profiles showed some degree of oxygen stratification, with stratification depth varying from 20 to 70 m. Most profiles recorded anoxic values (<2 mg L^{-1}) at depths ranging from 35 to 80 m. In a broadly seasonal pattern, which varied from year to year, stratification tended to develop during the warmer months, extending to its shallowest depths in late autumn. As the surface temperatures decreased over winter, the profile became more vertical, with the oxycline moving to its greatest depths in spring.

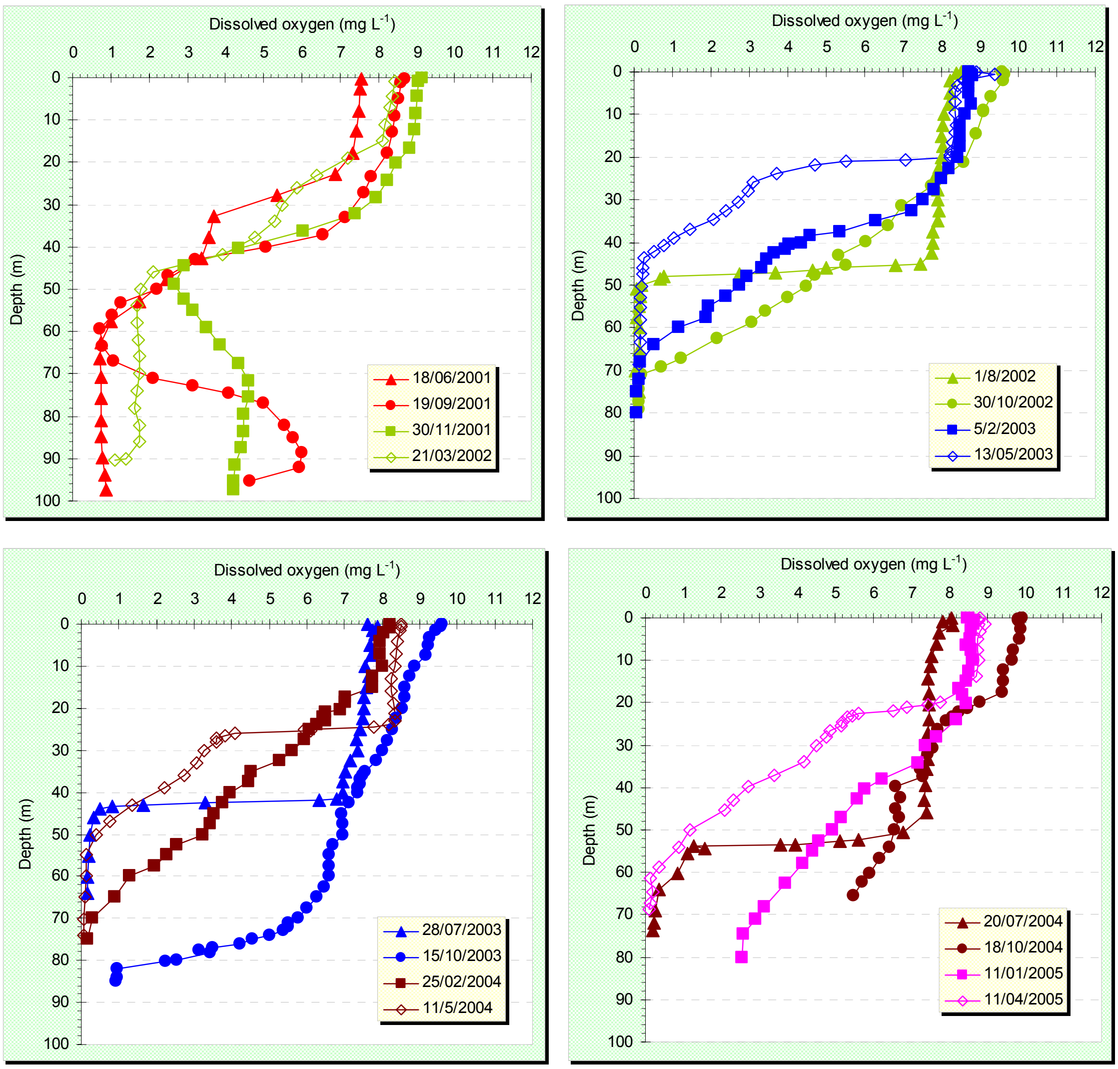


Figure 3.10 Depth profiles of dissolved oxygen concentration at the power station intake, Lake Gordon, for the years 2001-02 to 2004-05.

The profile for 19 September 2001 differs from the usual pattern at depths below 64 m, by showing an increase in oxygen concentration which reached a maximum of 6 mg L^{-1} at a depth of 89 m. This is an indication of an 'underflow' effect which is occasionally evident at the downstream end of Lake Gordon and which was first reported in Steane and Tyler (1982). This phenomenon was also recorded in Bowles (1998). It is apparently the result of more-dense, oxygenated Gordon River water flowing down the old river channel below the less-dense, anoxic layer of the lake. The distinct dissolved oxygen profiles recorded at Boyes Basin (Figure 3.8) appear to mark the commencement of this phenomenon as the water flows into the lake. The profile for 30 November 2001 shows this pattern weakening (at about 50 m) and, by 21 March 2002, it was approaching the anoxic pattern more usual at this site.

A3.6.1.2 pH depth profiles

The pH profiles at Boyes Basin were variable. Some summer profiles showed a decline in value with depth at around 15 m, while others showed variability associated with the unusual dissolved oxygen profiles for this site (see A3.6.1.1). Values were slightly to moderately acidic, with surface values ranging from 5.8 to 6.9 and bottom values ranging from 5.1 to 6.5. Figure 3.11 shows the pH profiles recorded at this site.

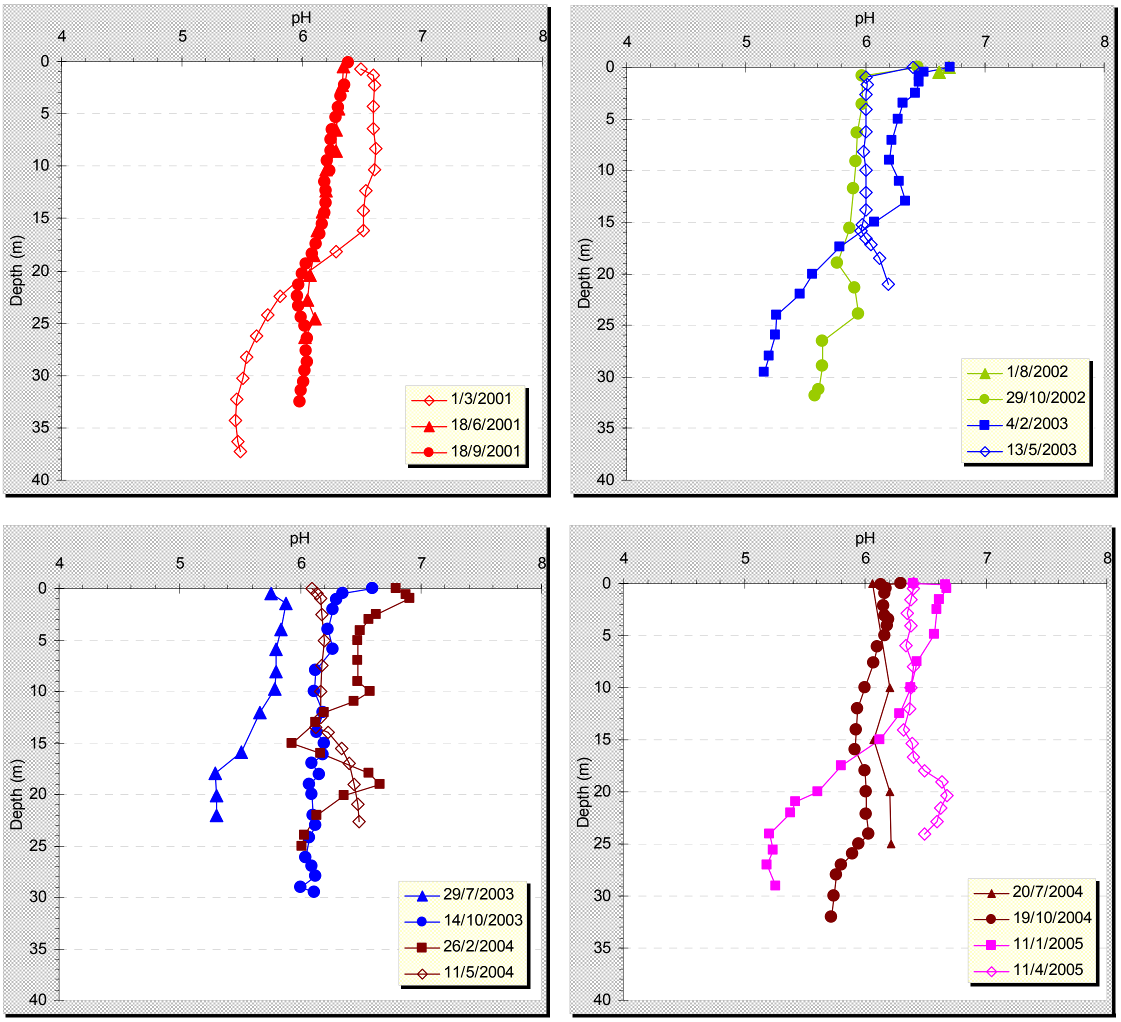


Figure 3.11 Profiles of pH values at Boyes Basin, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

The Calder Reach pH profiles reflected the patterns of both water temperature and dissolved oxygen, with clines in pH values evident in most summer and autumn profiles. The site recorded a surface range of 5.5 to 6.9 and a bottom range of 5.1 to 6.2, as shown in Figure 3.12.

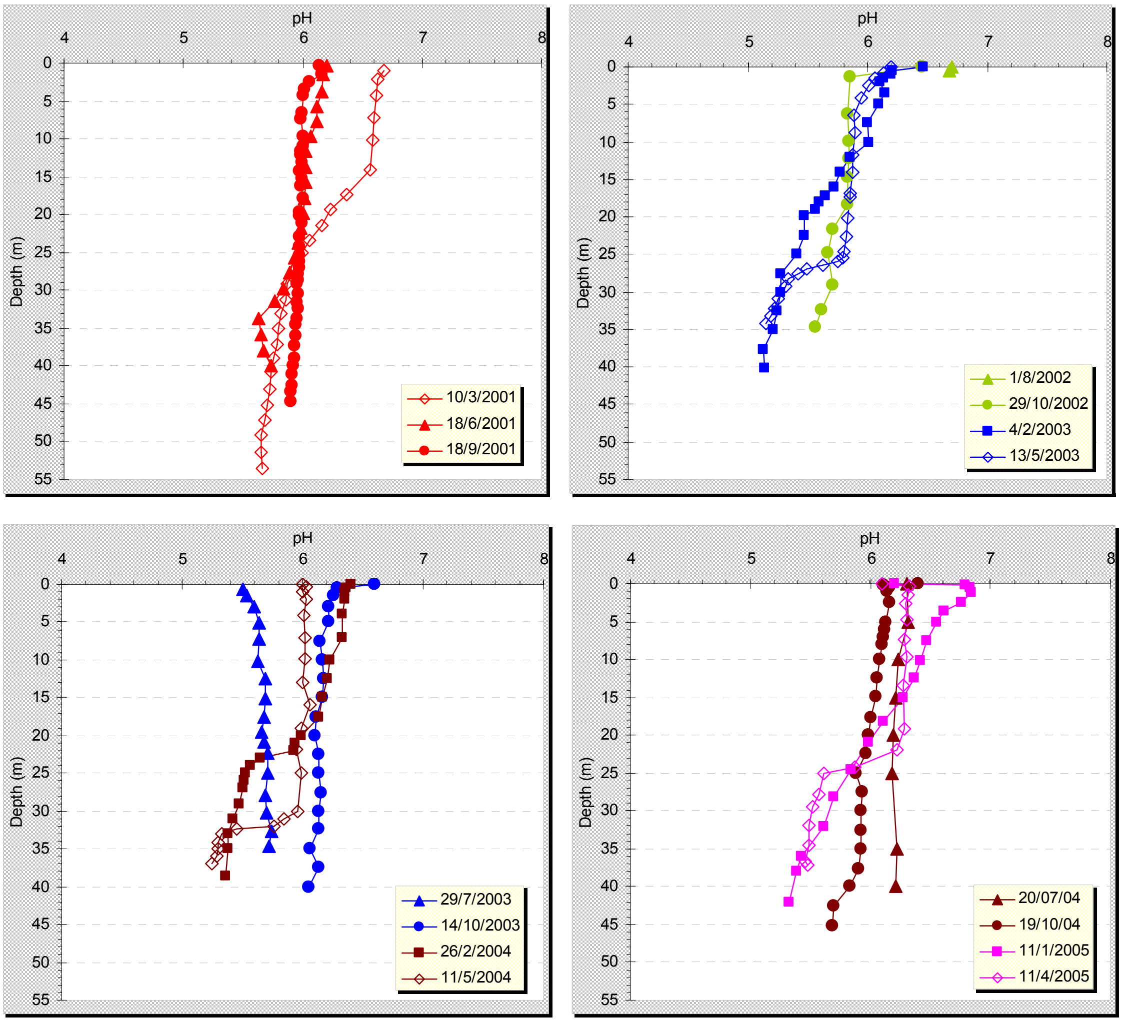


Figure 3.12 Profiles of pH values at Calder Reach, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

The intake pH profiles extended the patterns recorded at the other two sites to a greater depth. Figure 3.13 shows the pH profiles recorded at the intake site. The profiles demonstrate the decline in pH with depth, to a depth of around 50-60 m, after which the values began to rise with further depth. Sharp declines in pH were associated with similarly sharp declines in dissolved oxygen concentrations. Surface values ranged form 5.4-6.4. At 80 m, the values ranged from 4.7-5.9.

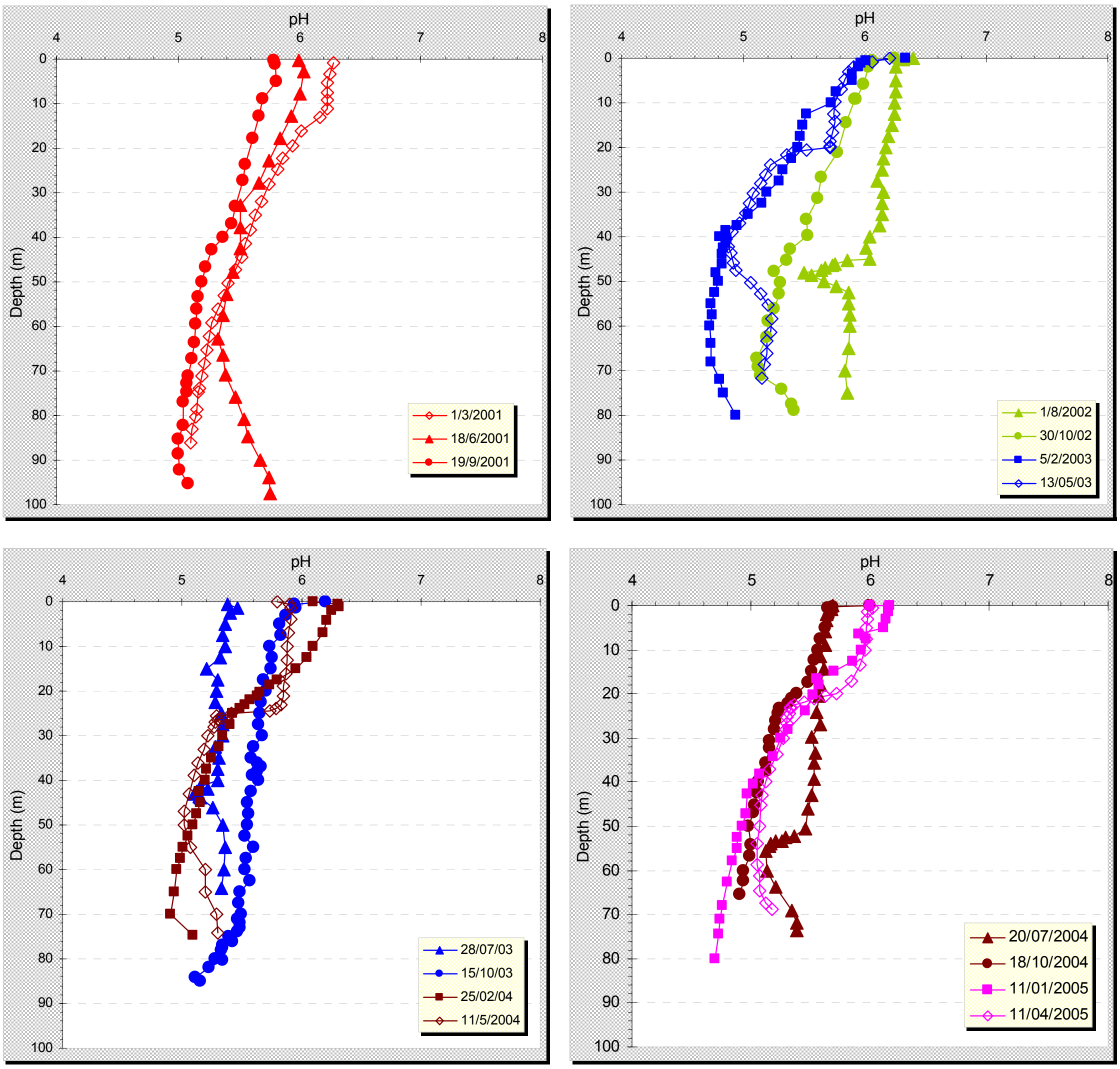


Figure 3.13 Depth profiles of pH at the power station intake, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

A3.6.1.3 Conductivity depth profiles

The Boyes Basin conductivity profiles showed a large amount of variation similar to those of water temperature and dissolved oxygen, which are likely to result from the same cause: that of inflowing upper Gordon River water. Figure 3.14 shows the conductivity profiles recorded at this site. Summer profiles tended to show conductivity increases of up to 20 µS cm^{-1} between 10–20 m, while some winter-spring profiles recorded decreases of around 10 µS cm^{-1}. These variations are relatively small in a low conductivity impoundment and none would indicate any kind of water quality issue for the lake.

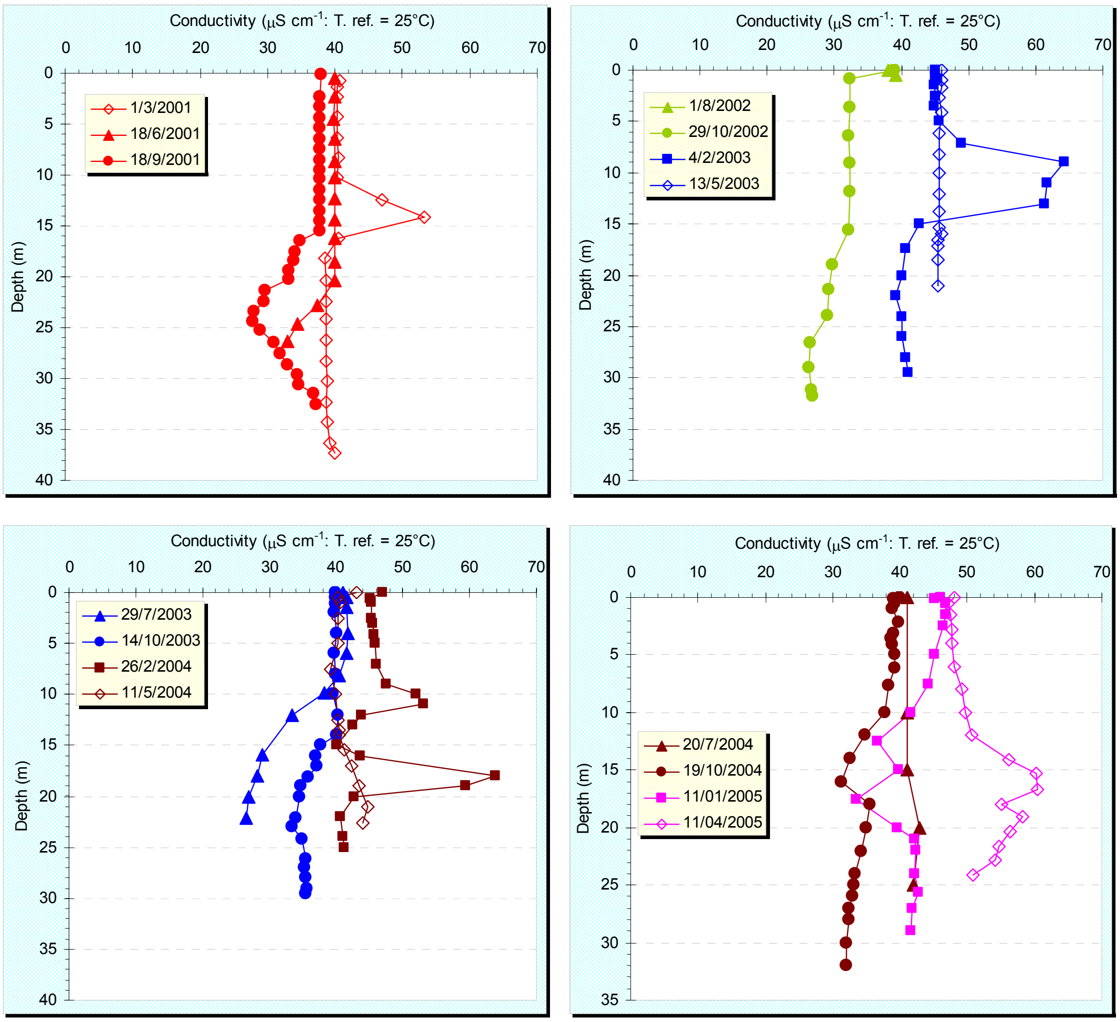


Figure 3.14 Depth profiles of conductivity at Boyes Basin, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

The Calder Reach conductivity profiles were even with depth and ranged from 33-49 μS cm^{-1}. Figure 3.15 shows the conductivity profiles recorded at this site.

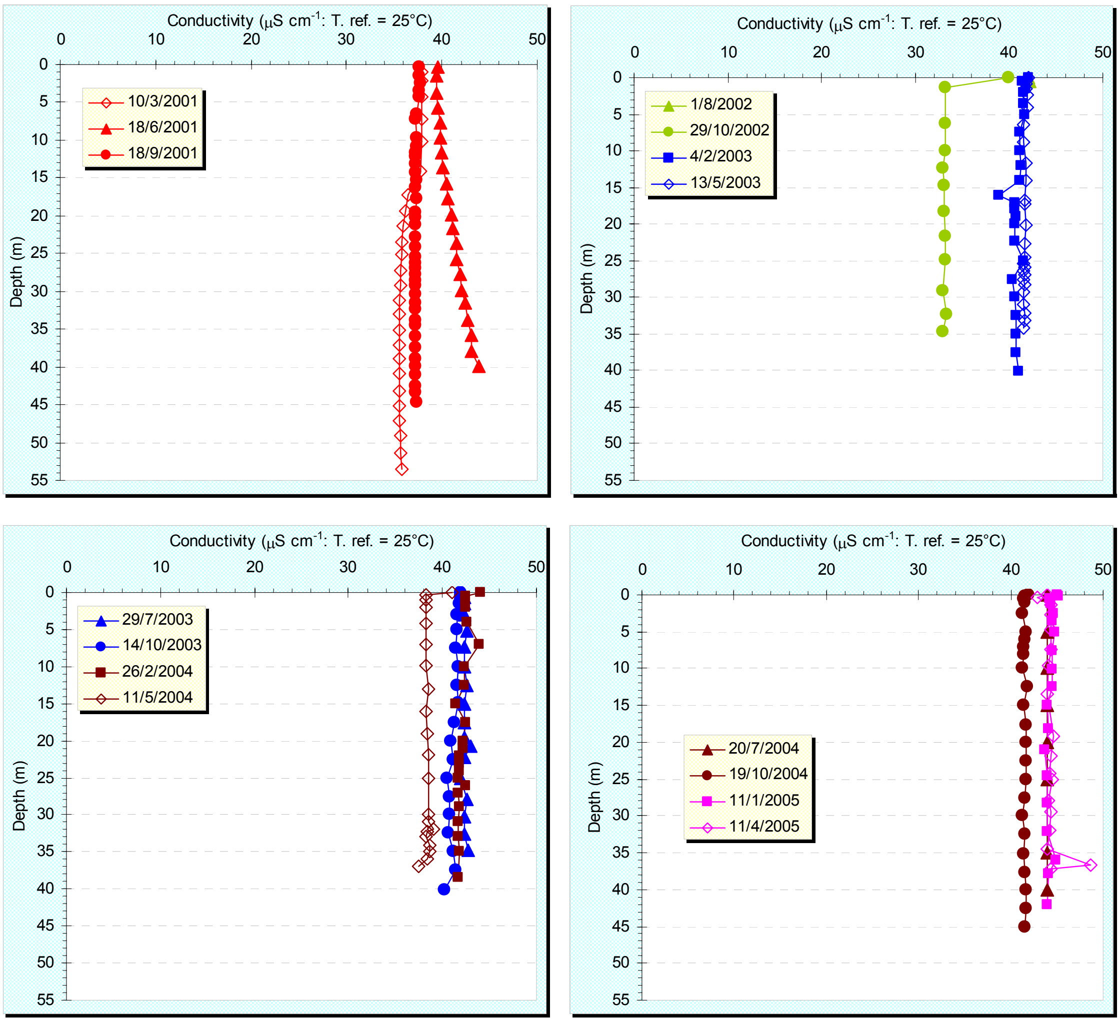


Figure 3.15 Depth profiles of conductivity at Calder Reach, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

The intake site's conductivity profiles were uniform until a depth similar to that at which anoxic conditions were reached (see section A3.6.1.1), below which conductivity tended to rise slightly. Values ranged from 31 to 50 μS cm^{-1} (Figure 3.16).

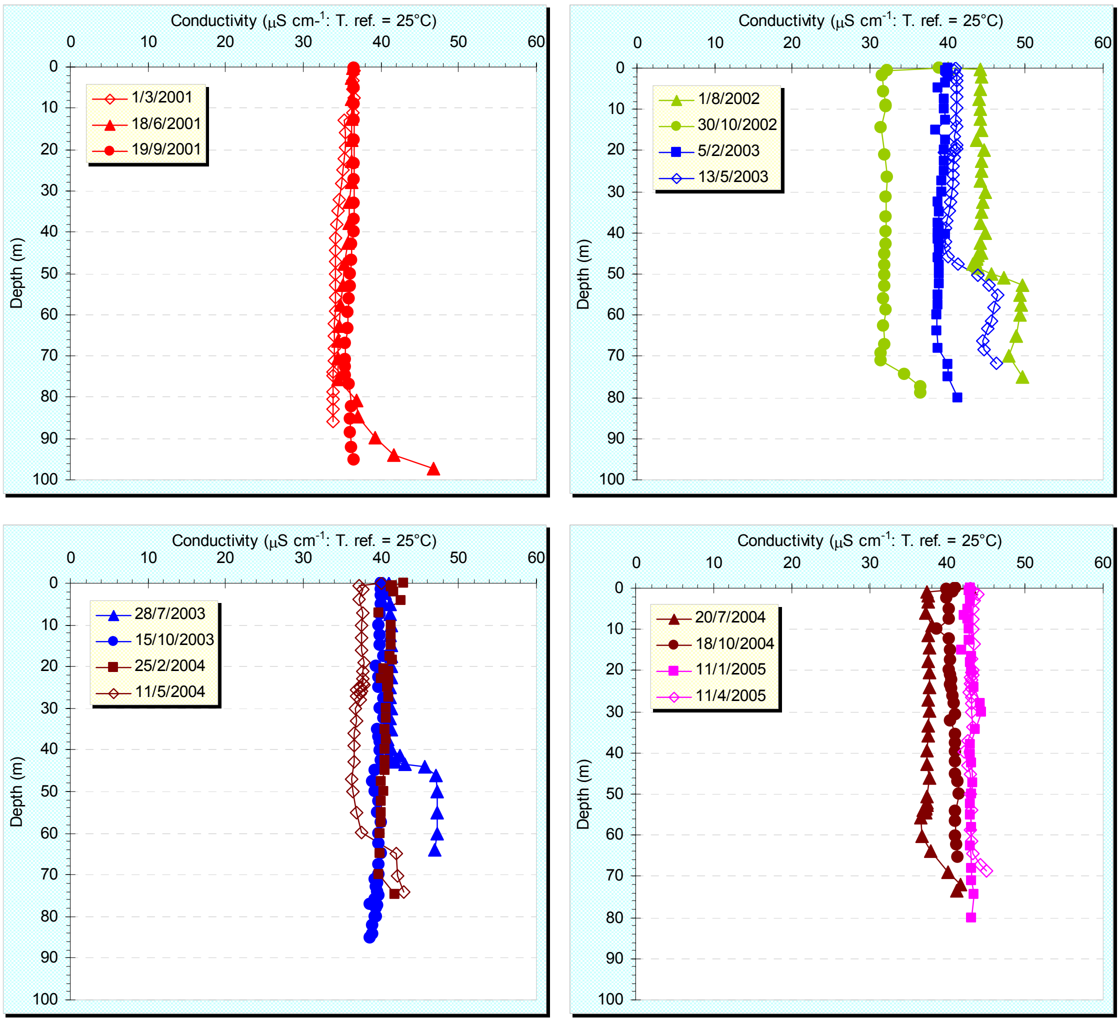


Figure 3.16 Depth profiles of conductivity at the intake site, Lake Gordon, for the years 2001, 2002-03, 2003-04 and 2004-05.

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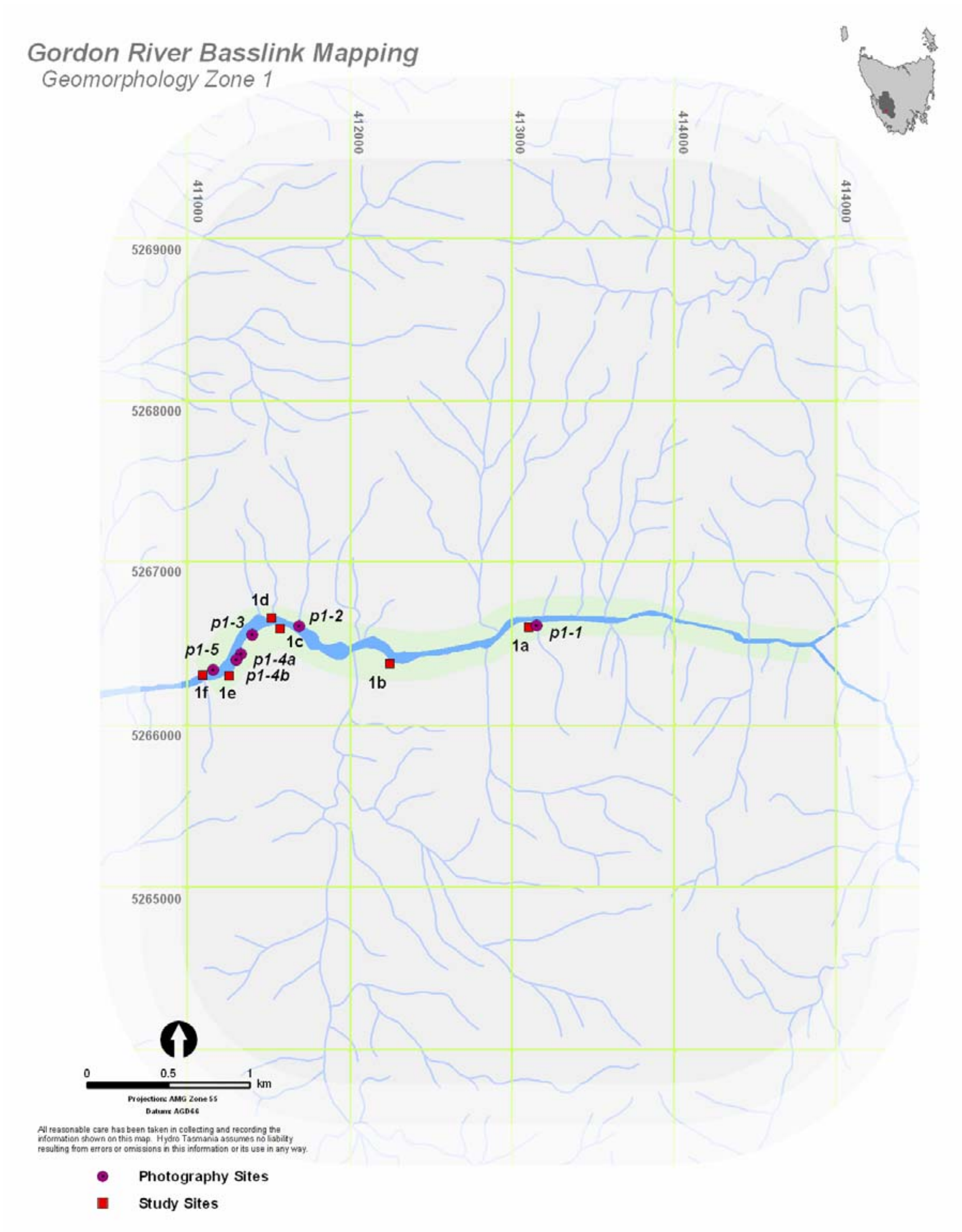
A4 Fluvial geomorphology A

A4.1 Zone 1

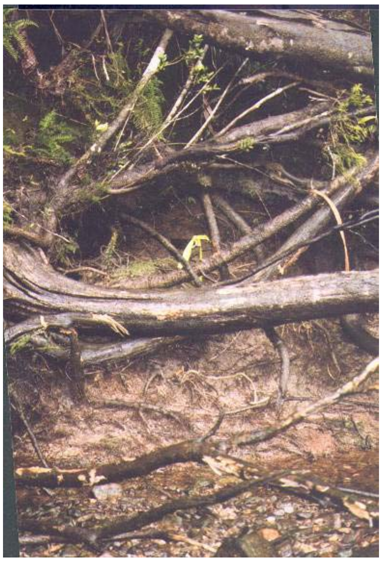


Site 1A: LB pins located in longitudinal transect in colluvium behind cobble bar.

Site 1A behind cobble bar on left bank. Photo shows site a 1-turbine operation, algae line on face of bar indicates 2-turbine, and vegetation line on top of bar indicates 3-turbine water level.

Pin1A/1 and scour chain 1 (December 1999)

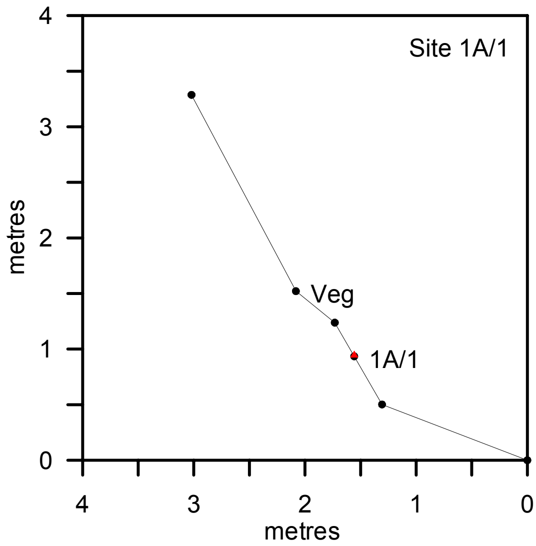
Pin 1A/5 (December 1999)

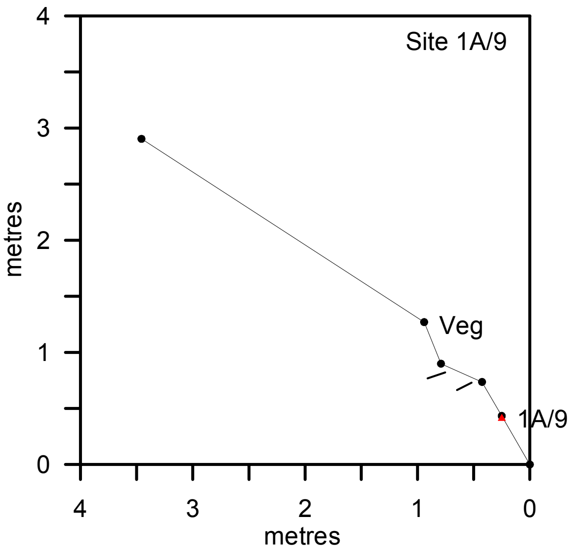


Pin 1A/6 (December 1999)

'Pins" (pipes) 1A/8a (top pipe) and 1A/8b (December 1999)

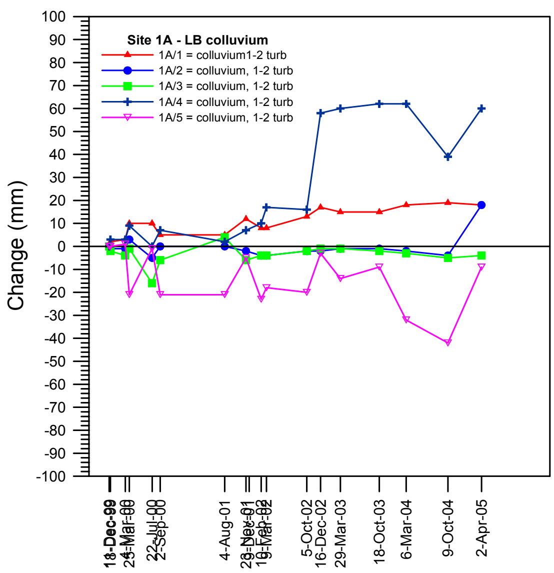
Pin 1A/9 (December 1999) d/s end of bar

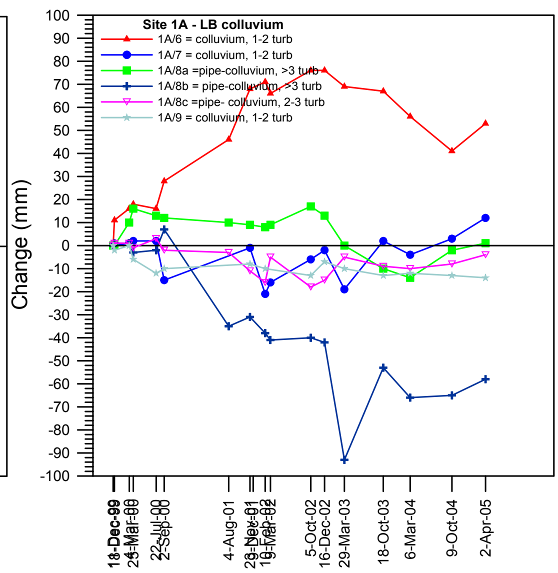




Site is composed of pins inserted along length of colluvial bank behind lateral cobble bar. Base of profile is cobble bar, not power station off water level. Profiles October 2004

Pins P2-P7 and P8c (lowest pipe) also on lower bank face, similar to P1 and P9 as indicated on site 1A/9 profile. Pins 8b (middle pipe) and 8a (top pipe) are located above the break in slope as shown in photo and on profile.





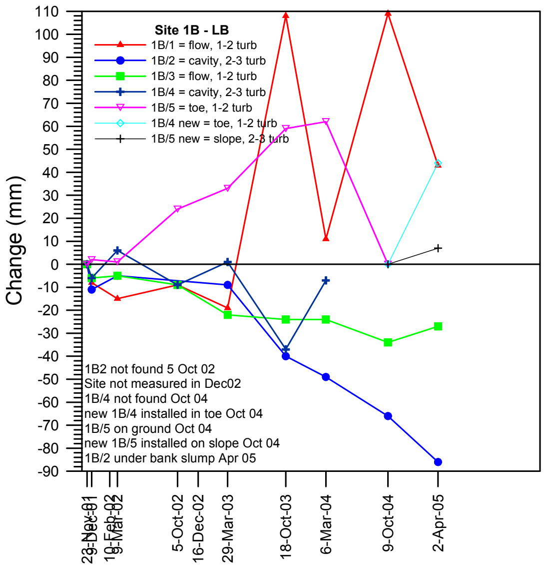
Deposition recorded by pins reflects downslope movement of root mat and bank over pin, not fluvial deposition

Site 1B: LB, sandy alluvium over bedrock in back eddy area.

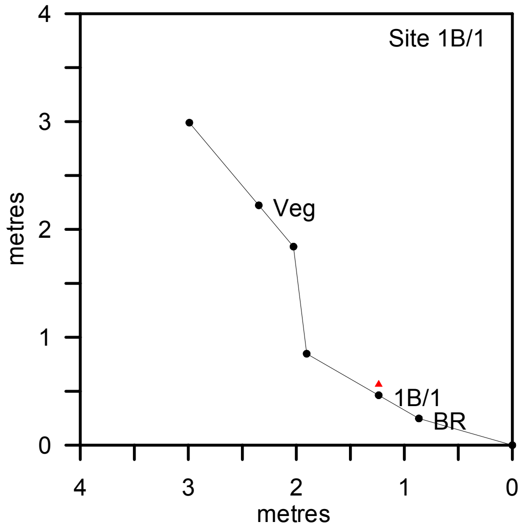
Overview of site 1B, 12 December 1999

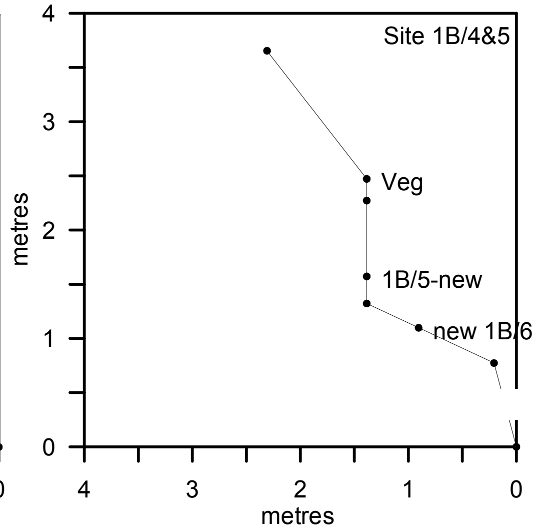
Pin 1B/1 in sediment flow over bedrock

(Left) Pins 1B/2 (on left side of photo below leaves) and 1B/; (Right) Pin 1B/5



Site prone to seepage erosion. Pin 1B/5 was originally in the toe of the bank. It was found lying on ground on October 2004, and re-inserted upslope in a cavity, as shown in the profile. A new pin (1B/6) was also inserted in the flow downslope of the cavity (new). 1B/2 and 1B/4 (not found October 2004) are located in cavities at approx. the same height as 1B/5-new. Pin 1B/3 in similar position to 'new'.


Site 1B/1
Veg
1B/1
BR
metres
metres
4
3
2
1
0

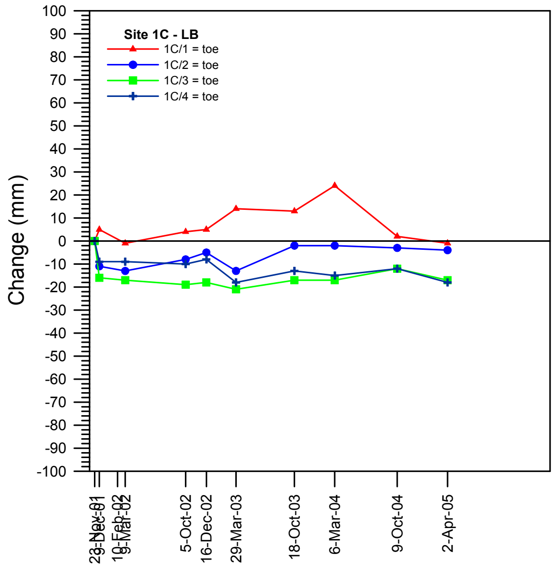

Site 1B/4&5
Veg
1B/5-new
new 1B/6
metres
metres
4
3
2
1
0

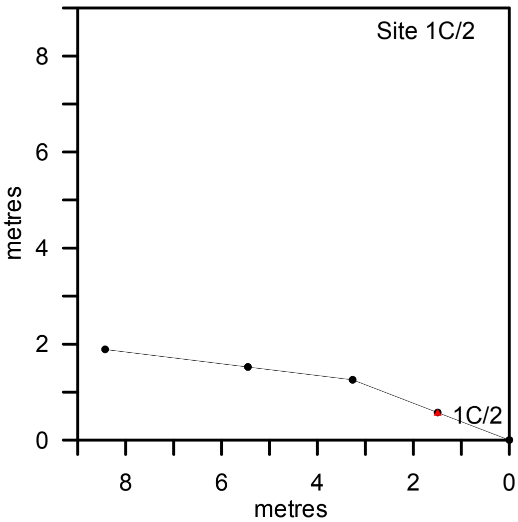
Site 1C. LB, transect of 4 pins along bank toe. Bank consists of sandy alluvium over cobbles, with tea tree.

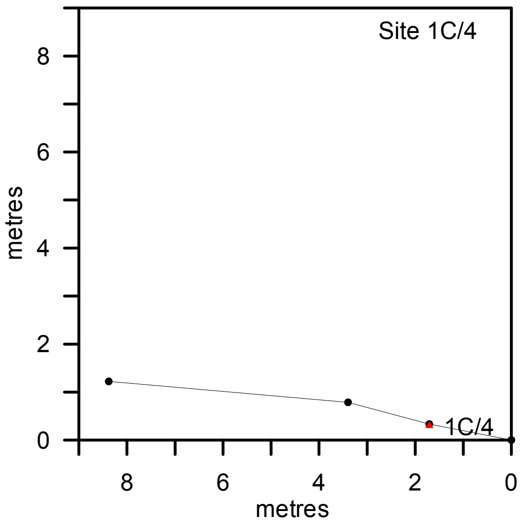
Overview of site 1C

Pin 1C/2

Pin 1C/4







Pins 1C/2 and 1C/3 situated at similar positions on the bank.

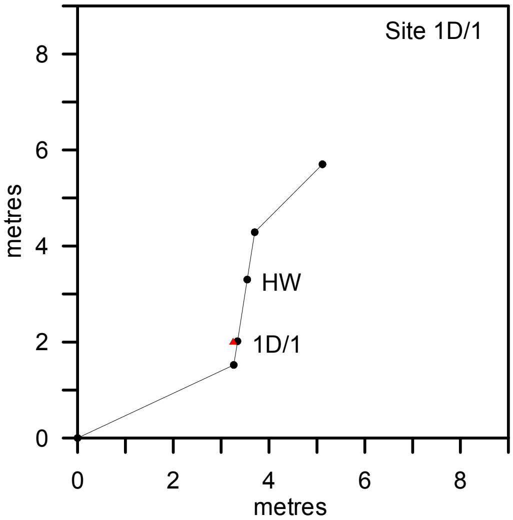
Site 1D: RB sandy alluvium over cobbles and bedrock

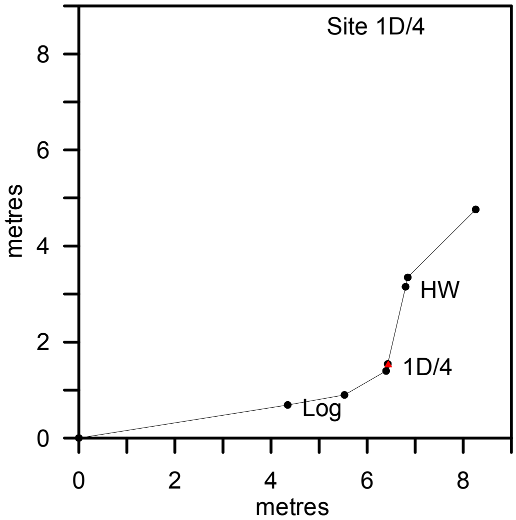
Overview 1D

Pin 1D/1

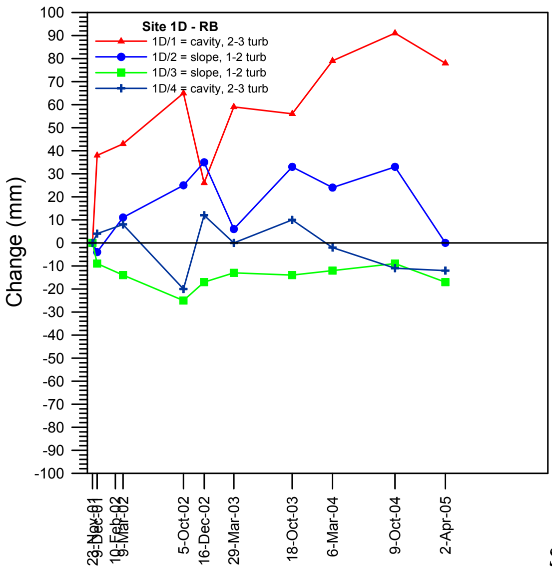
Pin 1D/2

Pin 1D/4





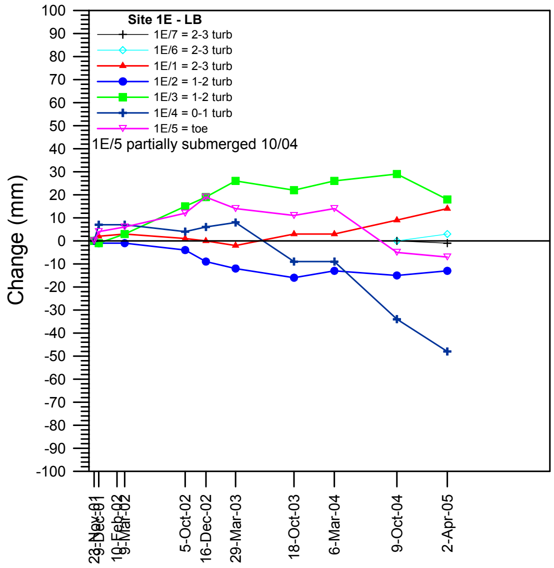
1D/1 and 1D/4 are in cavities, pins 1D/2 and 1D/3 are on the slope below the cavities. Not considered 'toes' because of cobbles at base of site.

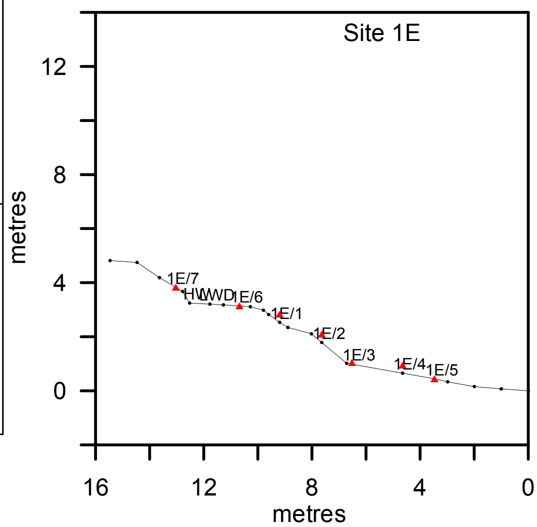


Site 1D

Site 1E: LB, transect of pins up alluvial bank

Site 1E





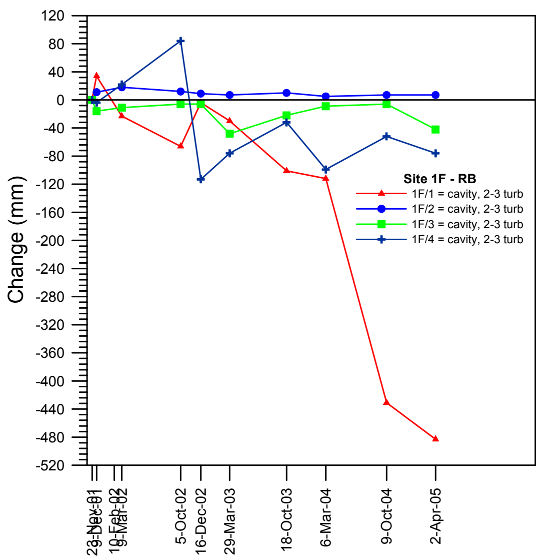
Note-pins 1E/6 and 1E/7 established in December 2005.

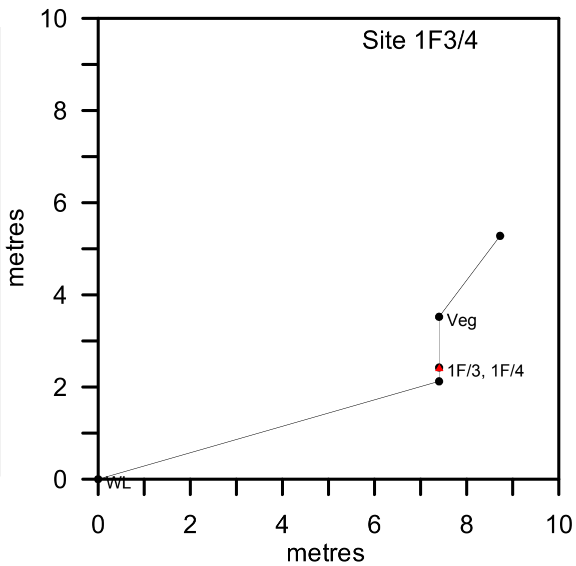
Site 1F: RB alluvium over bedrock at entrance to Abel Gorge

Pin 1F/1

Pin 1F/2

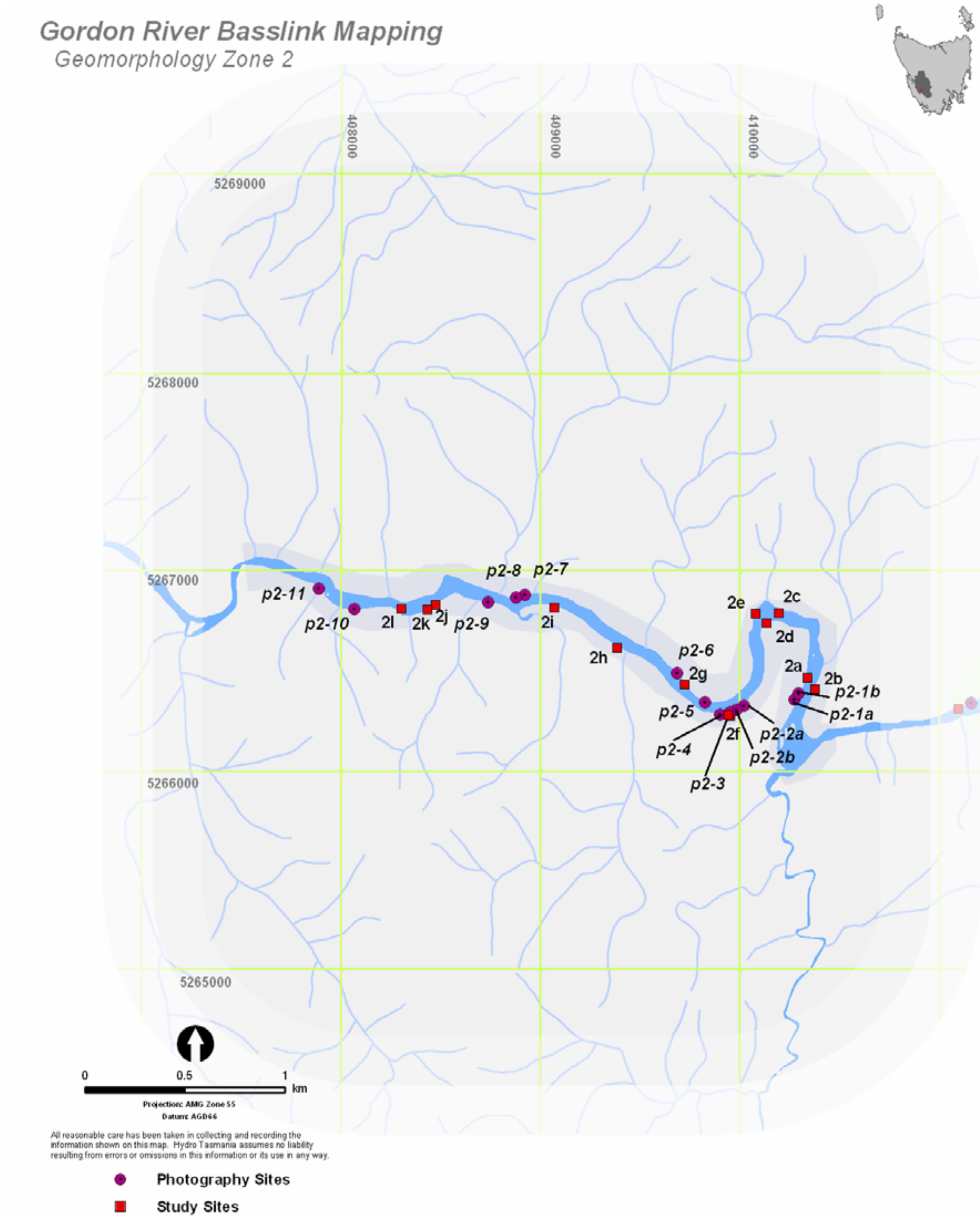
Pins 1F/3 and 1F/4 in cavities



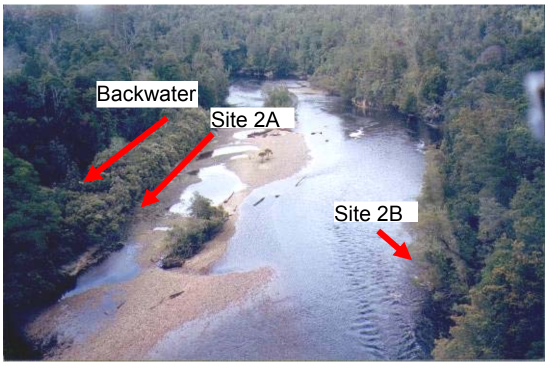


Pins 1F/1 and 1F/2 are located in cavities at approximately the same height as 1F/3 and 1F/4.

A4.2 Zone 2


Gordon River Basslink Mapping
Geomorphology Zone 2
408000
409000
410000
5269000
5268000
5267000
5266000
5265000
p2-11
p2-10
2l
2k
2j
p2-9
p2-8
p2-7
2i
2h
p2-6
2g
2e
2c
2d
2a
2b
p2-1b
p2-1a
p2-5
2f
p2-2a
p2-2b
p2-4
p2-3
0
0.5
1
km
Projection: AMG Zone 55
Datum: AGD66
All reasonable care has been taken in collecting and recording the information shown on this map. Hydro Tasmania assumes no liability resulting from errors or omissions in this information or its use in any way.
Photography Sites
Study Sites

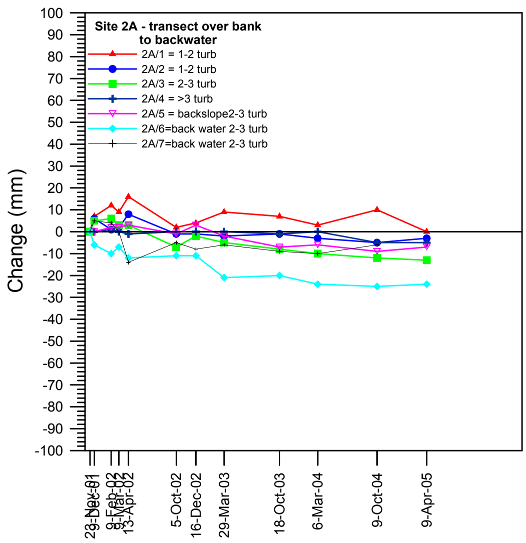
Site 2A: Downstream of Albert River behind cobble bar, LB transect over bank crest into back water.

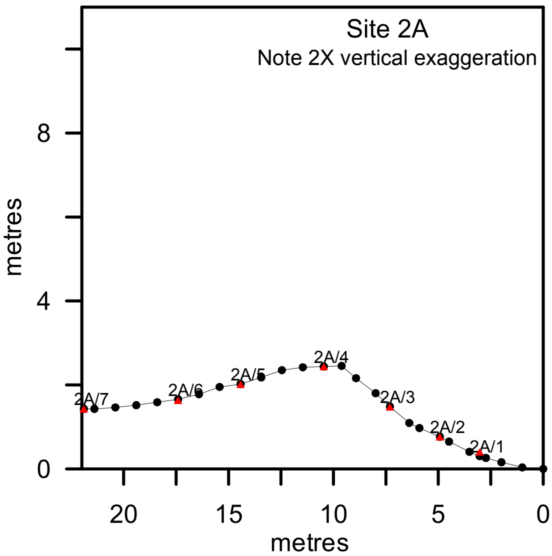


Aerial view of 2A on RB behind cobble bar

River side of site 2A

Backwater side of site 2A from crest looking downslope (left, November 2001) and from backwater looking downstream (December 1999 - photo taken prior to placement of pins)



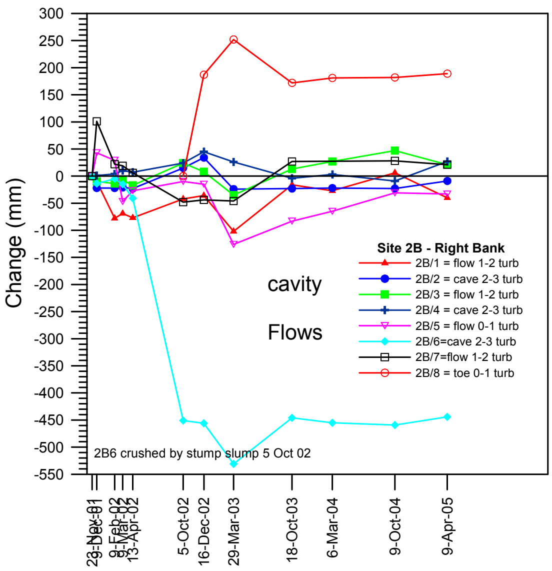


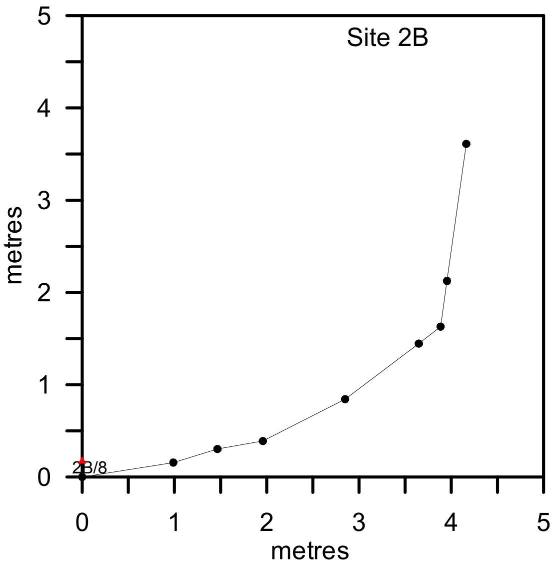
Site 2B: RB sandy alluvium across and slightly upstream of 2A.

2B Pins 1-3 (November 2001)

Pins 2B4-7 (November 2001)

2B after collapse of root mat (October 2002)



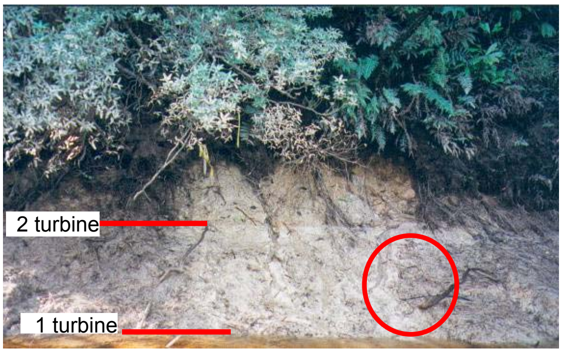


Pins in longitudinal transect along bank in cavity / flow section. Pins 2B/2, 2B/4, 2B/6 in cavity zone, pins 2B/1, 2B/3, 2B/5 and 2B/7 in flow zone. 2B/8 shown on profile.

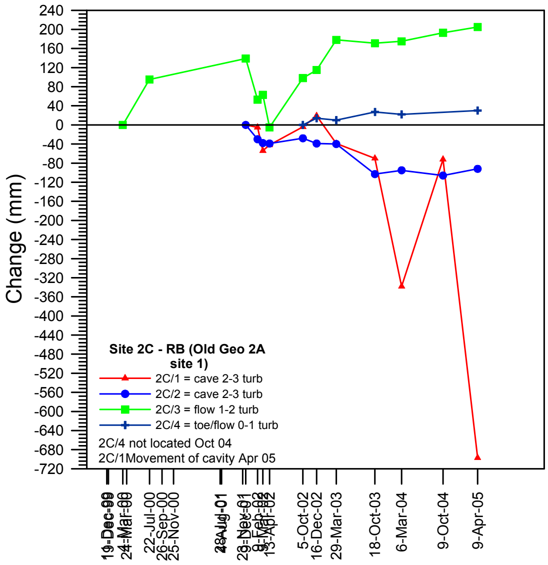
Site 2C: RB sandy alluvium in 'pocket' between dolomite outcrops. Highly prone to seepage erosion

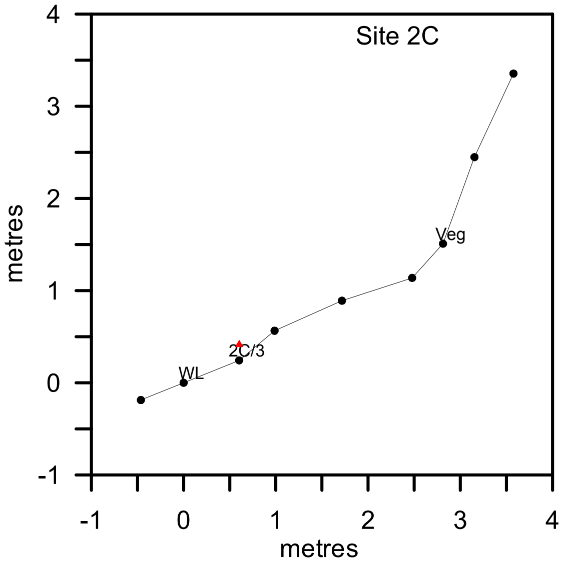
Overview of site 2C

Site 2 C



Left: 2C on 4 March 2000 showing saturated bank and disturbance by monitoring. Right: 2C on 2 September 2000 during 1-turbine operation, with 2-turbine level visible as water line. Note downslope movement of branch.

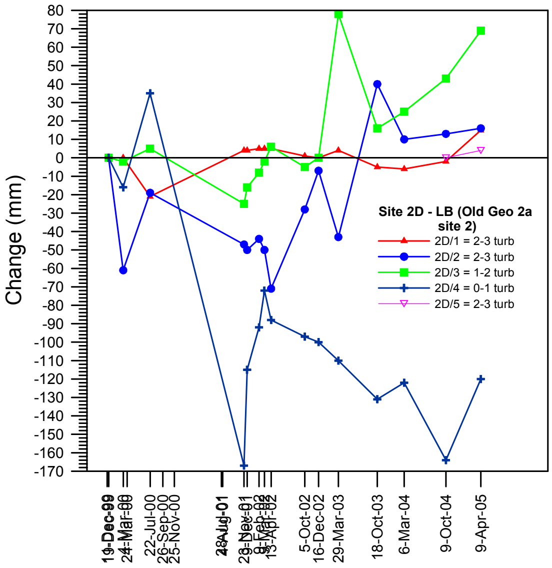


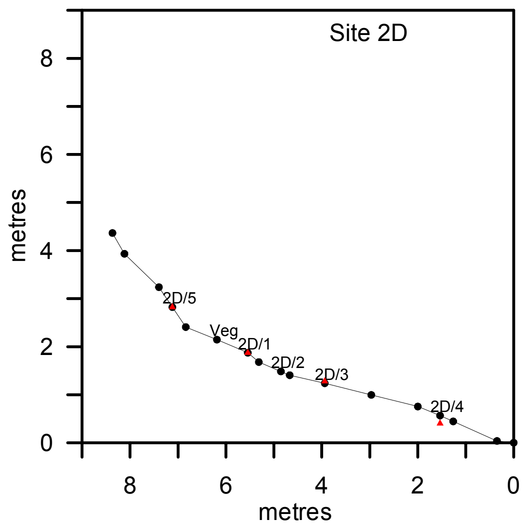


Pins 2C/1 and 2C/2 in cavity area below 'veg'. Toe pin (2C/4) below water level in profile.

Site 2D: LB sandy alluvial bank opposite 2C and 2E on inside bend

Overview of site 2D December 1999

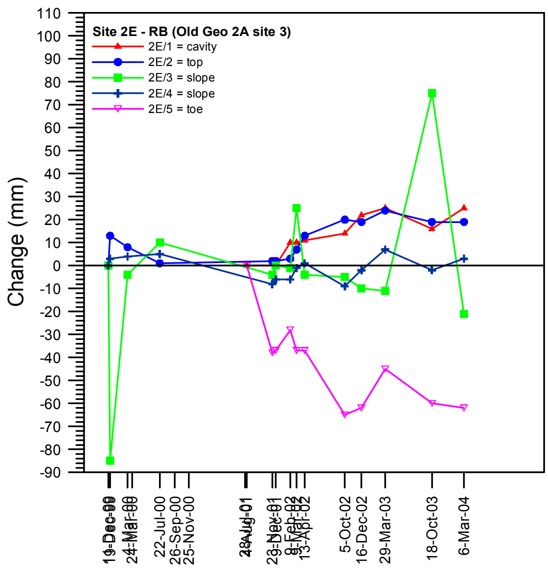


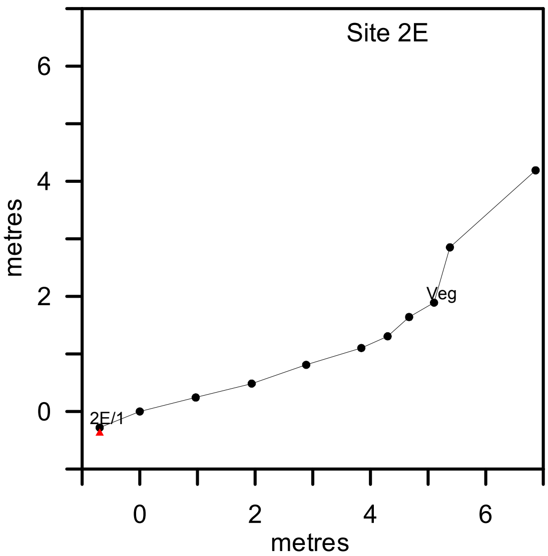


Note-2D/5 installed in December 2005.

Site 2E: RB in alluvial 'pocket' in dolomite downstream from 2C, opposite 2D.

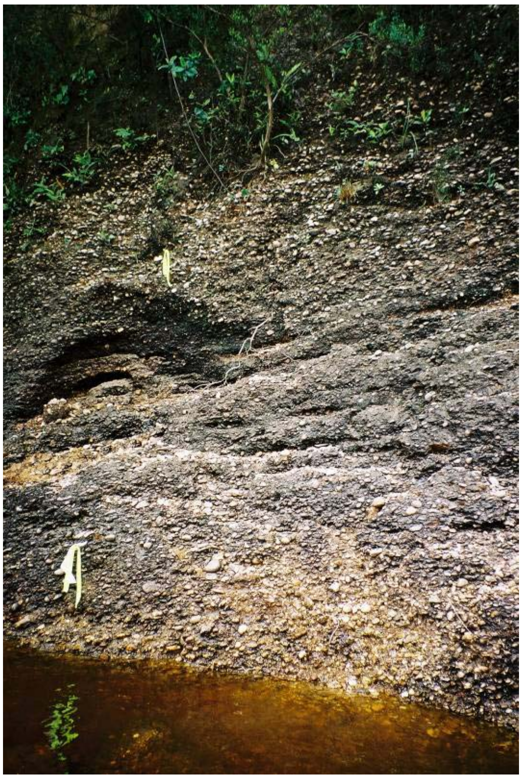
Site 2E

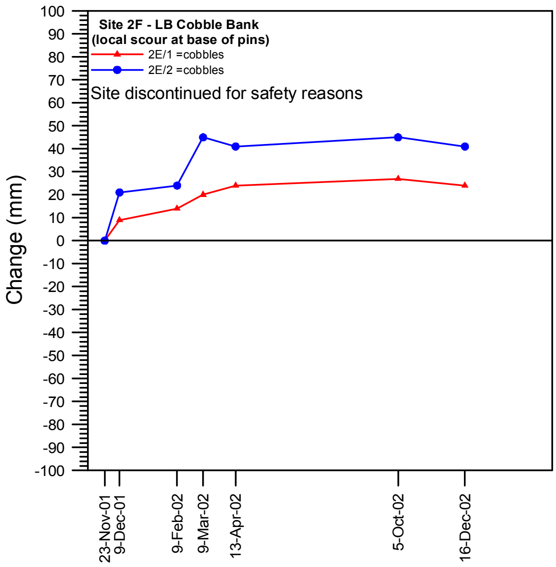




2E/1 on steep slope above 'veg'. 2E/2 below break in slope at 'veg'. 2E/3 and 4 on slope.

2F: LB cobble bank. Not monitored due to dangerous overhang of vegetation



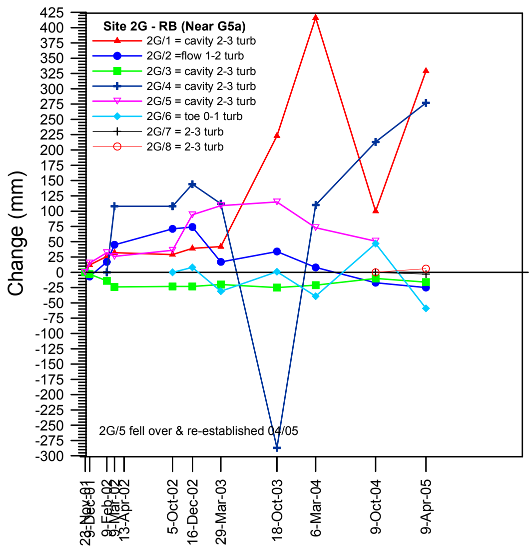


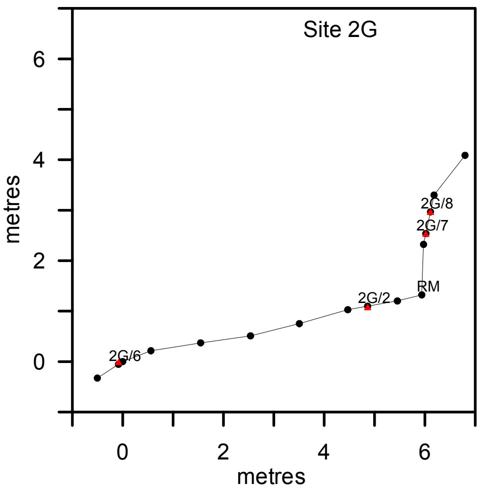
Site 2G: RB, sandy alluvium over cobbles, just upstream from piezometer site

November 2001

October 2003

March 2002

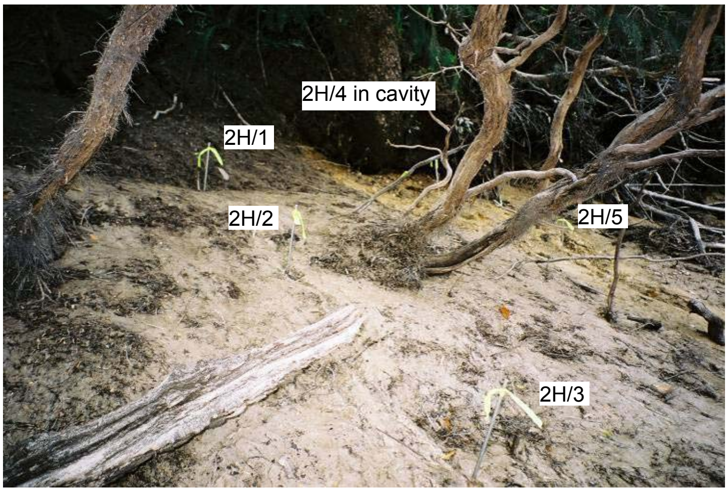




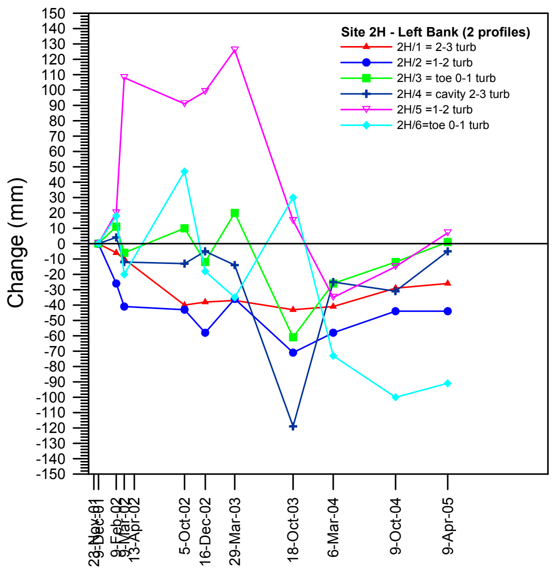
Pins 2G/1, 3, 4, 5 in cavity zone above break in slope marked by root mat (RM).

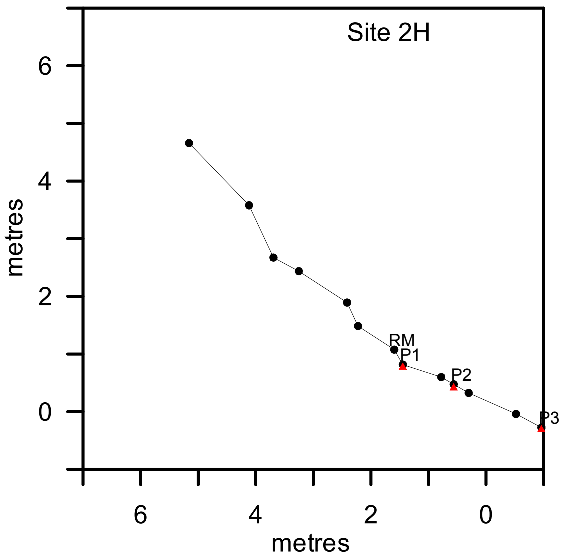
Pins 2G/6 and 7 installed December 2004

Site 2H

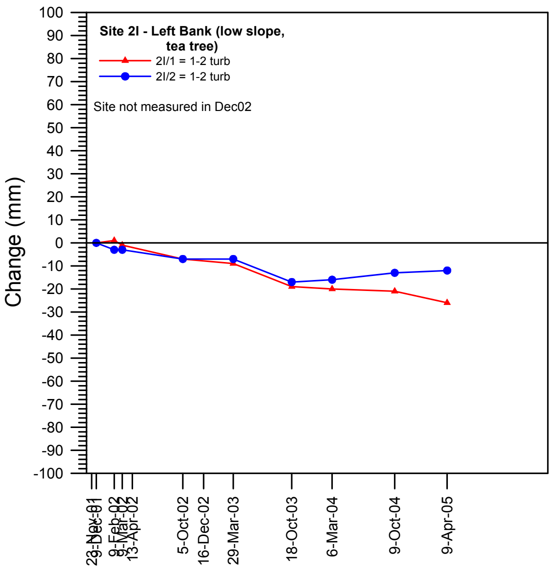


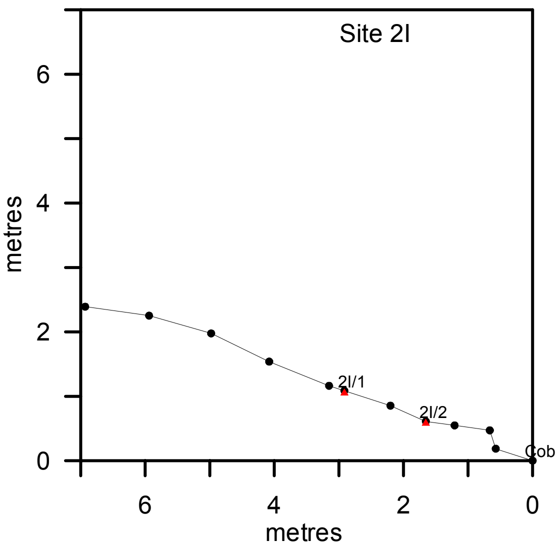
Two rows of erosion pins ~2 m apart. Closest row in tea tree, second row in orange seepage zone. Pin 2H/6 in toe off photo.





Site 2I: Two pins on gently sloping tea tree bank upstream of 'Bathtub Creek'

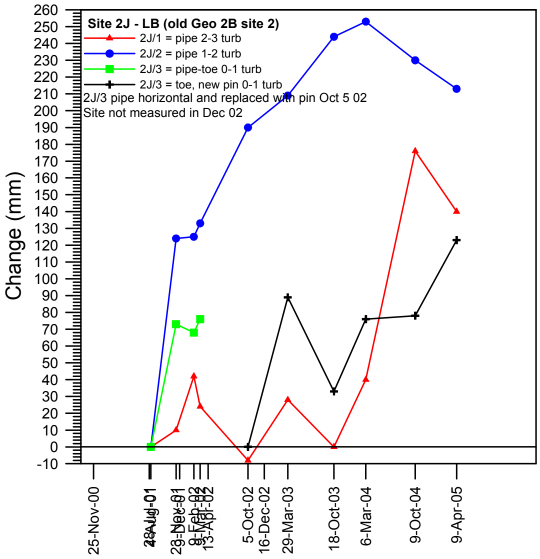


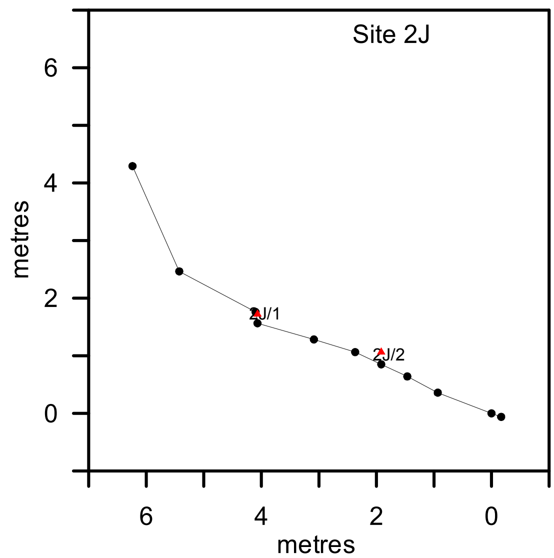


Site 2J: Left bank sandy alluvium, upstream from Splits

Site 2J initially installed as a potential piezometer site, but probes never inserted in casings (pipes). Pipes measured as erosion pins, and new toe pin inserted October 2002.

Site 2J December 1999





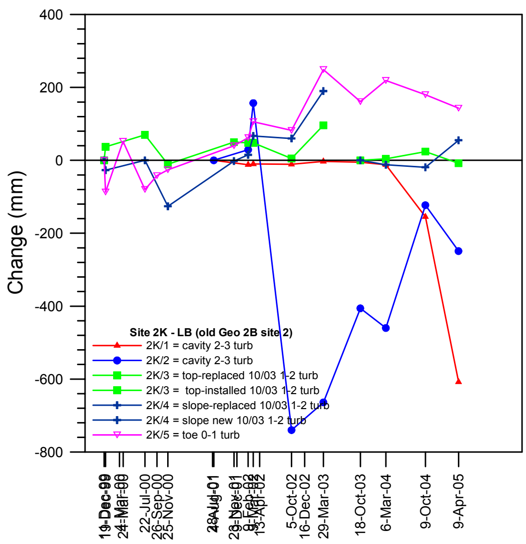
Site 2K

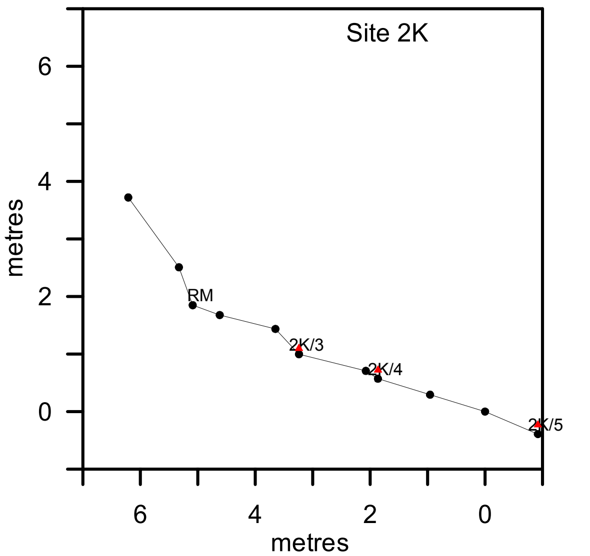
Site 2K December 1999 when site established

site 2K March 2000 – note rilling and angle of tree stump in left side of photos.

Scour chain 1 m upslope from 2K/5

Scour chain showing deposition March 2000.





Pins 2K/1 and 2K/2 in cavity above break in slope indicated by root mat (RM). Scour chain located 1 m upslope of 2K/5. In December 2004 additional an attempt to insert additional pins above root mat (RM) level were unsuccessful, as zone above RM consists of vegetation drape with no firm bank

Site 2L: RB at downstream end of lateral cobble bar, immediately upstream of the Splits.

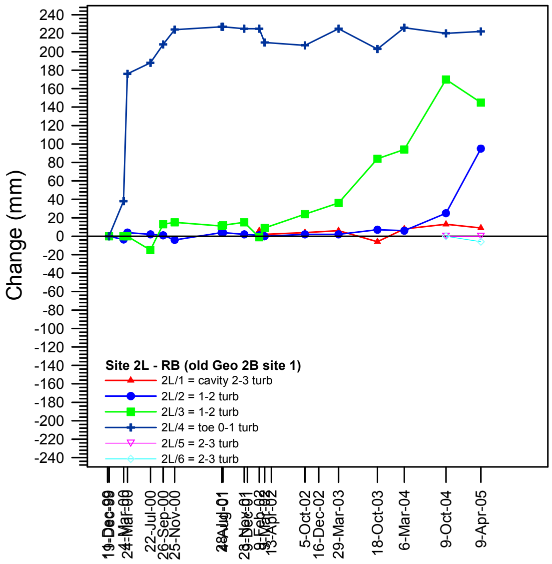
December 1999

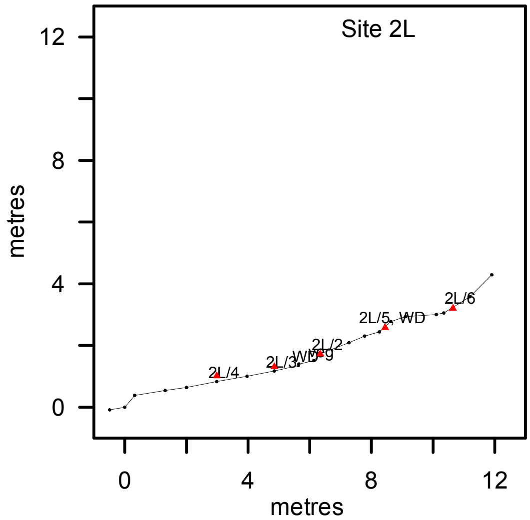
March 2000

July 2001

October 2004

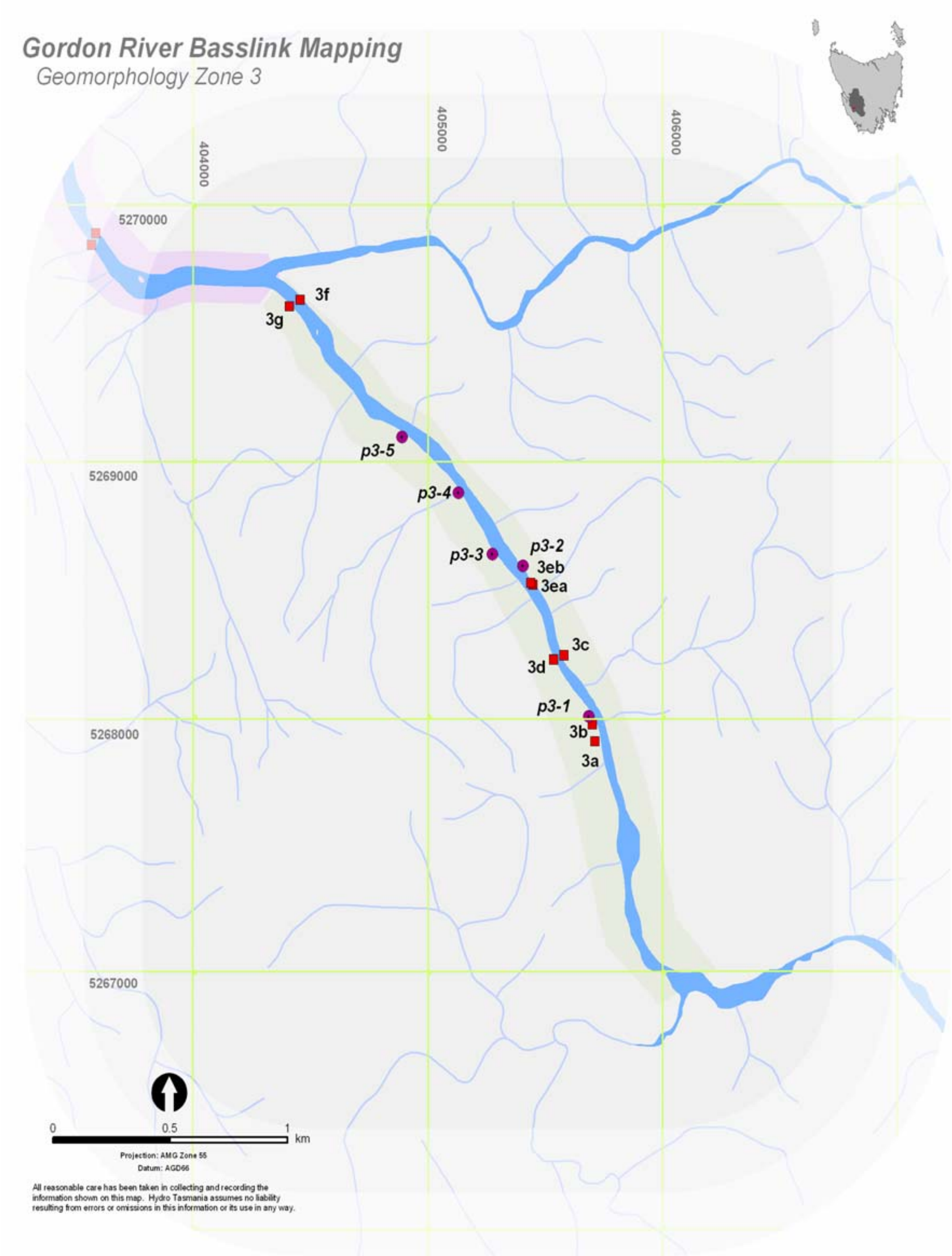
Mud deposit present at base of star picket in December 1999 and March 2000 disappeared by July 2001.





Pin 2L/1 upstream of profile location in cavity at break in slope indicated by woody debris (WD) in profile.

A4.3 Zone 3


Gordon River Basslink Mapping
Geomorphology Zone 3
404000
405000
406000
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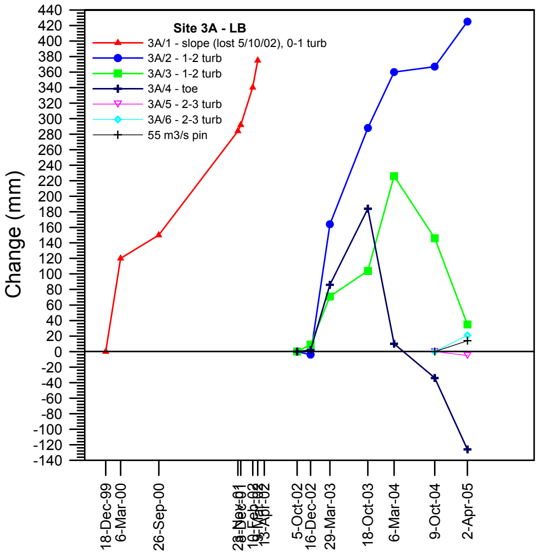
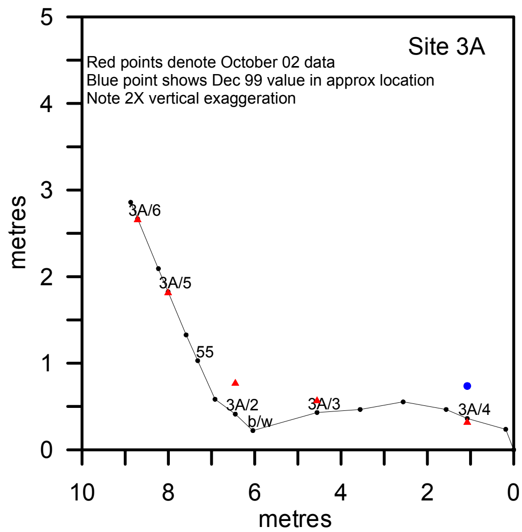
5268000
5267000
3f
3g
p3-5
p3-4
p3-3
p3-2
3eb
3ea
3c
3d
p3-1
3b
3a
0
0.5
1
km
Projection: AMG Zone 55
Datum: AGD66
All reasonable care has been taken in collecting and recording the information shown on this map. Hydro Tasmania assumes no liability resulting from errors or omissions in this information or its use in any way.

Site 3A


Installation of site 3A, December 1999. Note Ian Rutherfurd standing on log exposed in October 2002


Site 3A October 2002 (left) red circles indicate same log in each photo, showing erosion of bank slope. Site 3A October 2004 (right), note deposition on log in foreground. High water level in October 2004 created backwater (arrow).





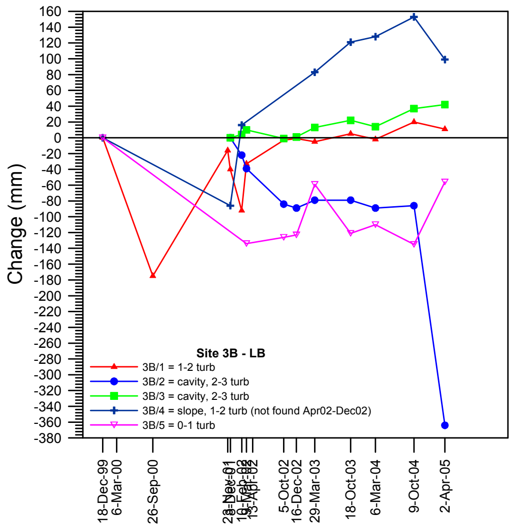
Pins 3A/5 and 3A/6 installed in December 2005. '55' denotes level of 55 m^3/s environmental Flow.

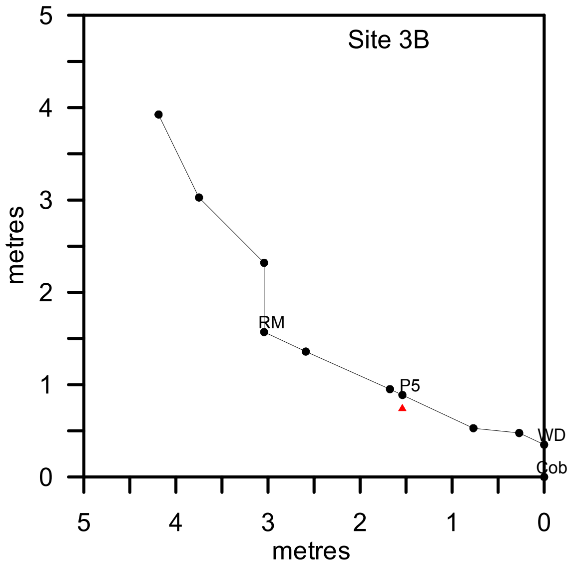
Site 3B

Site 3B December 1999

Pin 3B/1 and scour chain December 2001

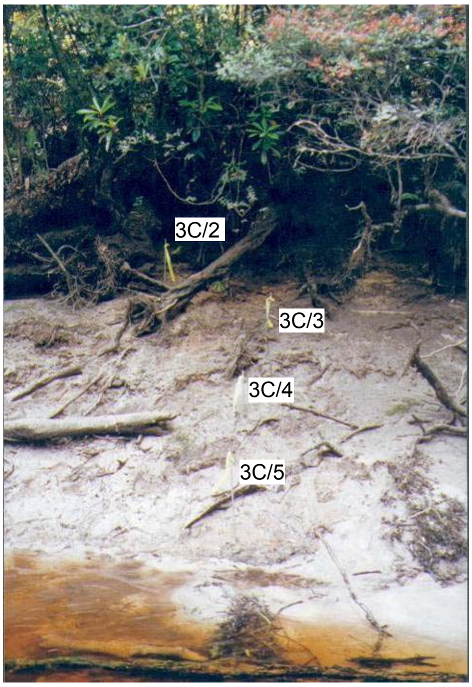
December 2001



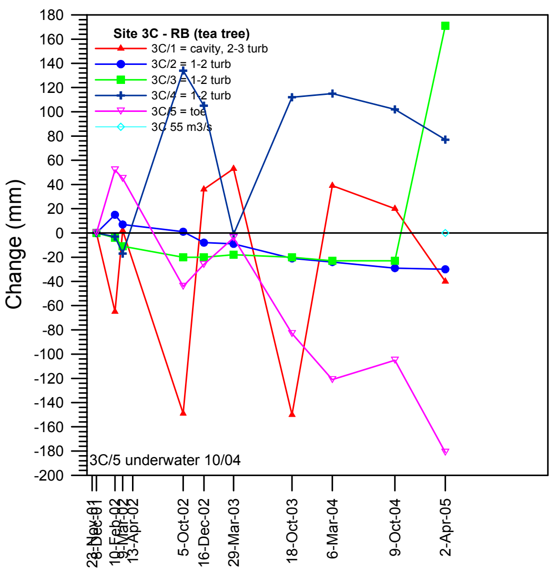


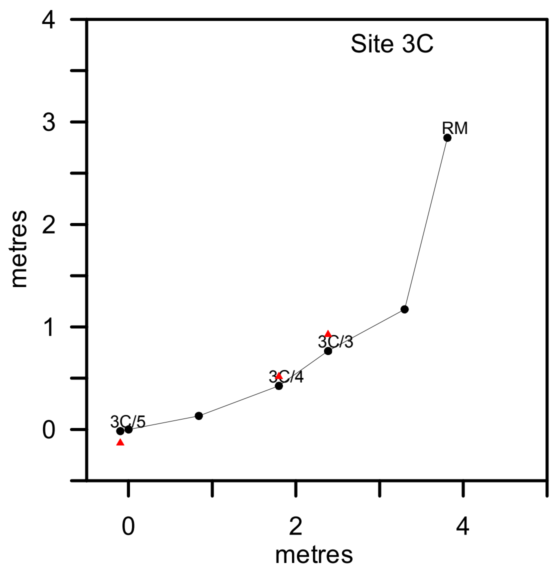
Blue labels on profile indicate relative position of Pins 3B/1-4 on bank profile.

Site 3C: RB, Sandy alluvium with tea tree.



Site 3C December 2001

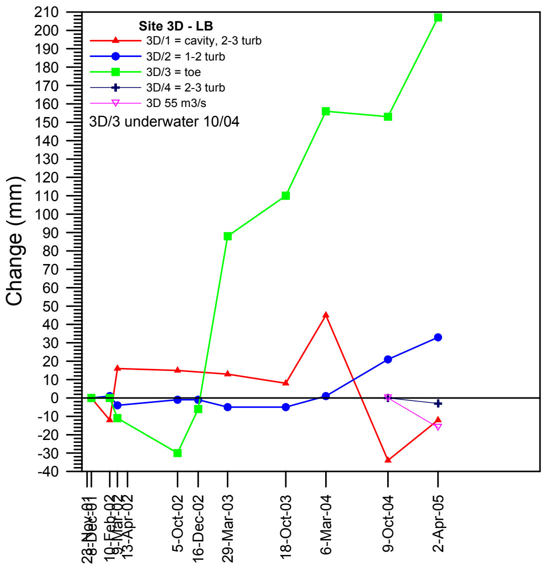


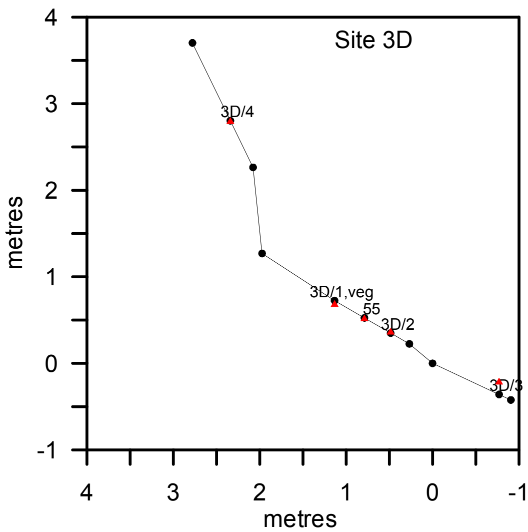


3C/1 in cavity above break in slope and below root mat; 3C/2 below break in slope, as shown in photo. Pin in cavity very difficult to measure due to 3 m length.

Site 3D: LB opposite site 3C. Sandy alluvium with cobbles at depth, upstream of compliance site.

Site 3D December 2001



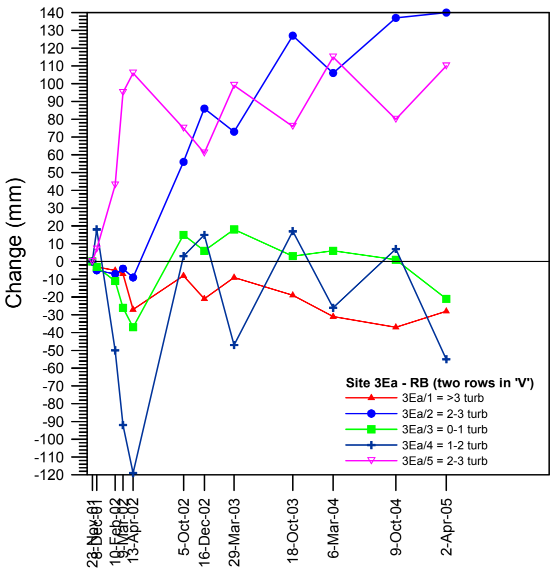


Pin 3D/4 installed December 2005

Site 3Ea: RB, gully in sandy alluvium. Pins set in V-formation up both sides of gully.

Site 3Ea – back channel

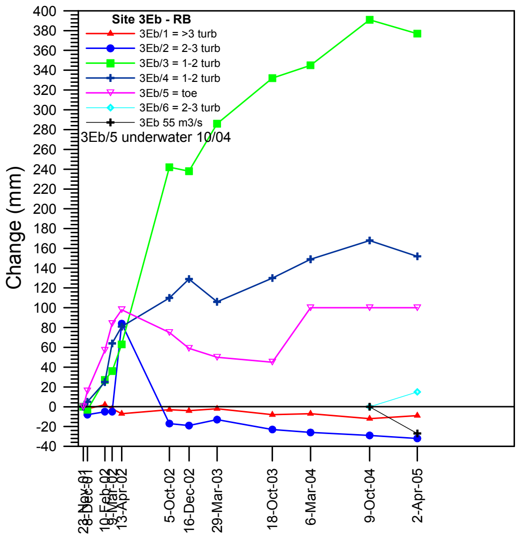
No profile collected.

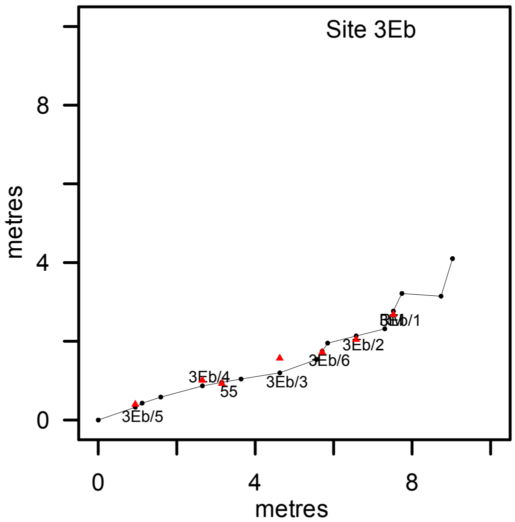


Site 3Eb: RB, large sandy beach immediately downstream of 3Ea. Pins arranged in a profile.

Site 3Eb general vies

Site 3Eb

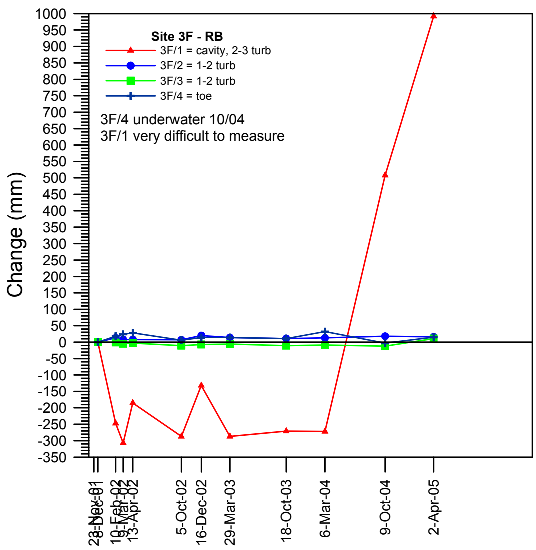


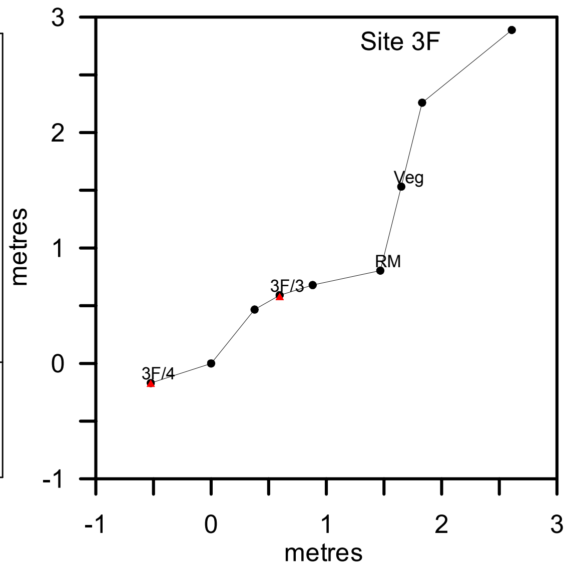


Pin 3Ea/6 installed December 2004.

'55'denotes level of proposed environmental flow

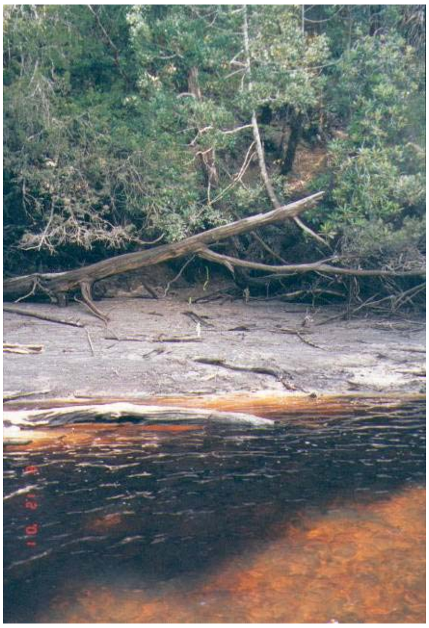
Site 3F

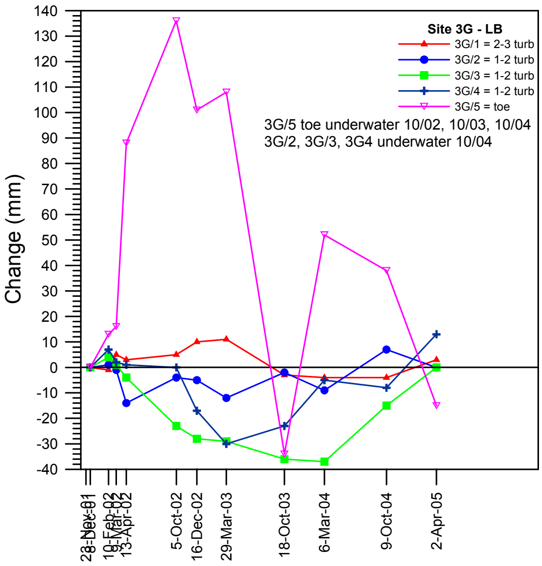




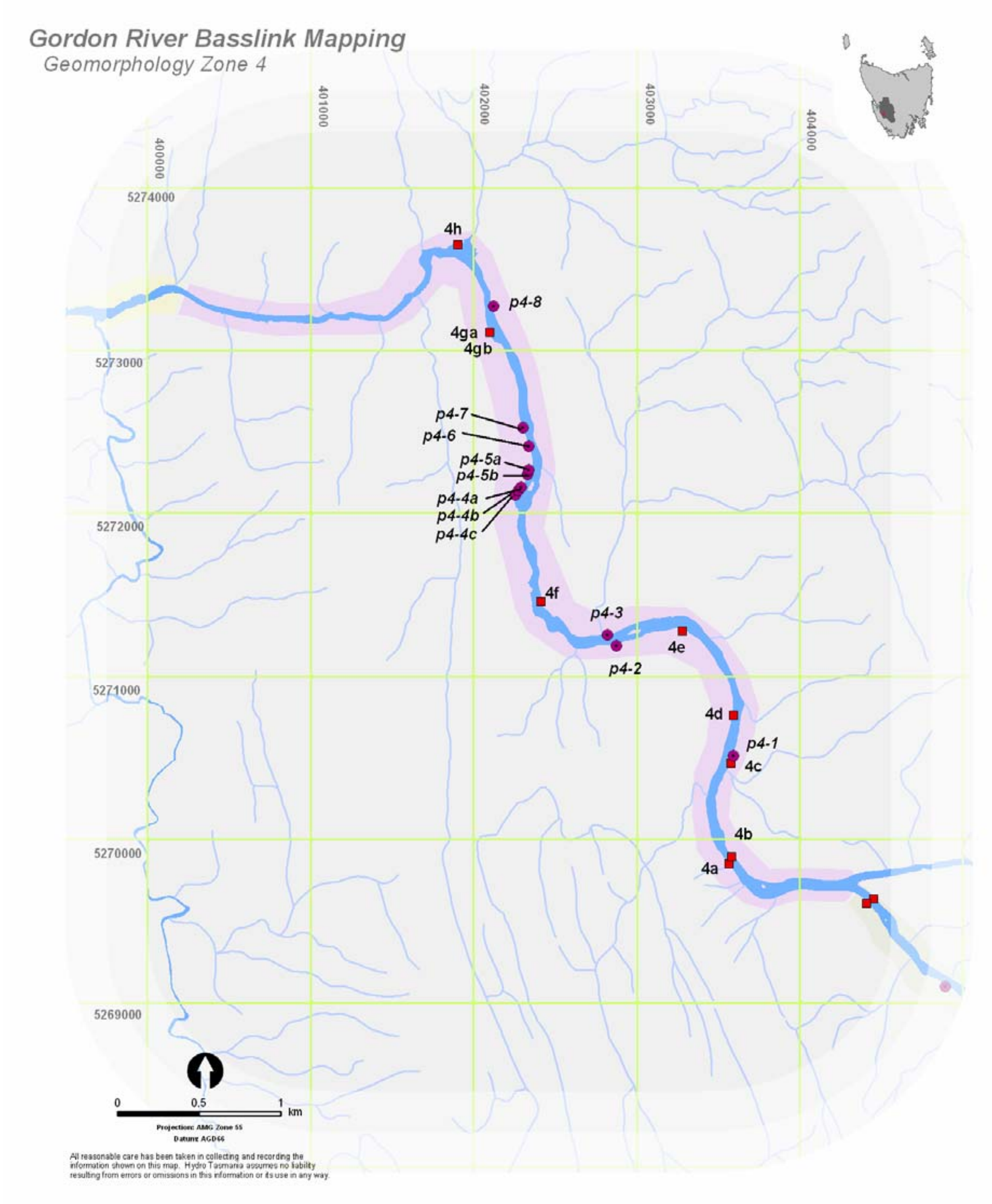
Pin 3F/1 in cavity on steep bank face between 'veg' and root mat (RM); Pin 3F/2 immediately below slope break,

Site 3G: RB immediately upstream of confluence with Denison River





A4.4 Zone 4


Gordon River Basslink Mapping
Geomorphology Zone 4
400000
401000
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403000
404000
5274000
5273000
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5271000
5270000
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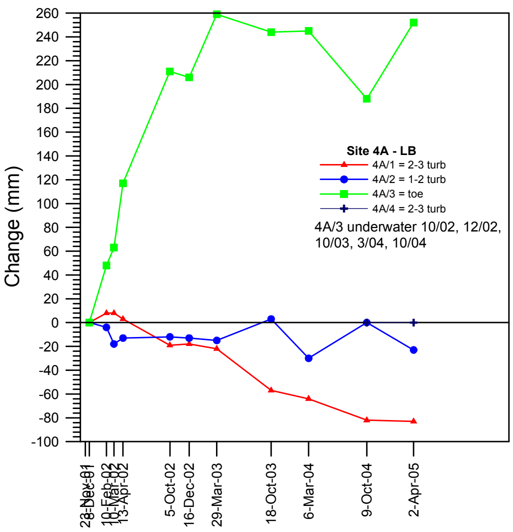
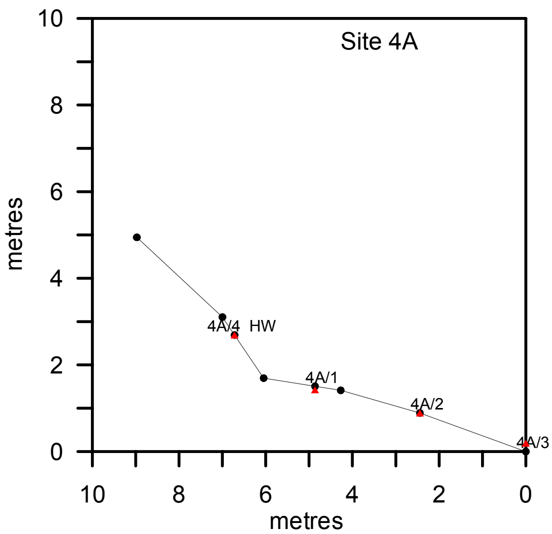
p4-8
4ga
4gb
p4-7
p4-6
p4-5a
p4-5b
p4-4a
p4-4b
p4-4c
4f
p4-3
p4-2
4e
4d
p4-1
4c
4b
4a
0
0.5
1
km
Projection: AMG Zone 55
Datum: AGD66
All reasonable care has been taken in collecting and recording the information shown on this map. Hydro Tasmania assumes no liability resulting from errors or omissions in this information or its use in any way.

Site 4A: LB. Sandy alluvial bank in straight reach, opposite site 4B.

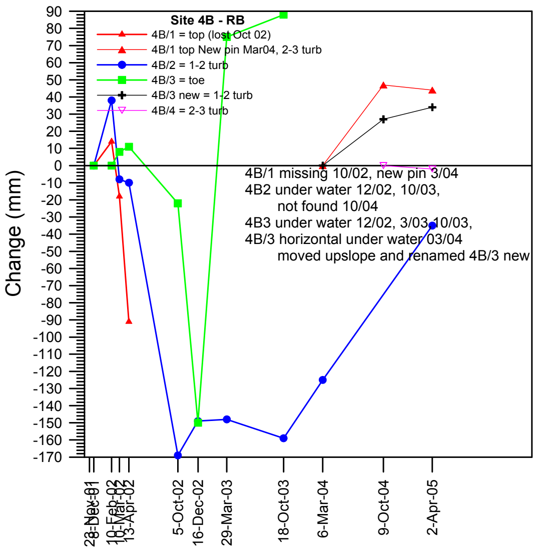


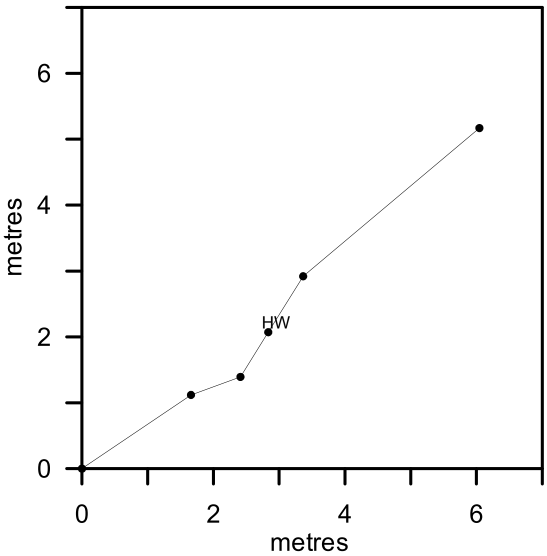


Site 4B: RB. Sandy alluvial bank in straight reach, opposite site 4B. Very active site with respect to downslope movement of bank material.

Site 4B December 2001. Pins 2 and 2 shown in photo

Site 4B (Pin 4B/2) March 2002 with higher water level





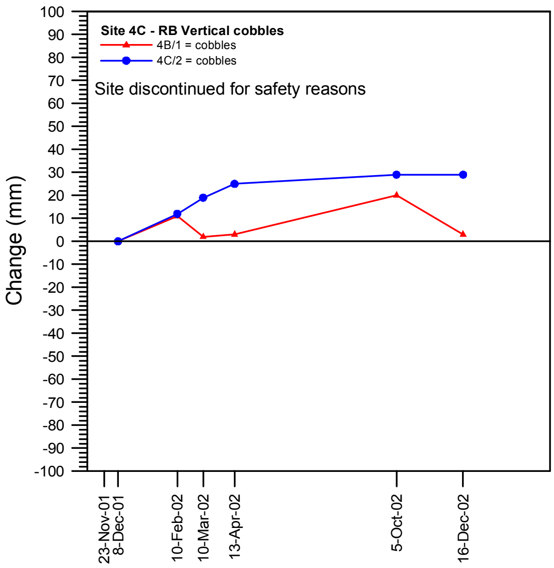
December 2001 erosion pin data not able to be placed on profile because pins have been lost and moved. Approximate position of original pins shown on profile. Bank is prone to downslope mass movement. Pin 4B/4 installed in December 2004.

Site 4C: RB. Vertical cobble bank with over hanging vegetation. Site judged not to be safe to monitor, so it is included in the yearly photo monitoring.

Site 4C overview, March 2000

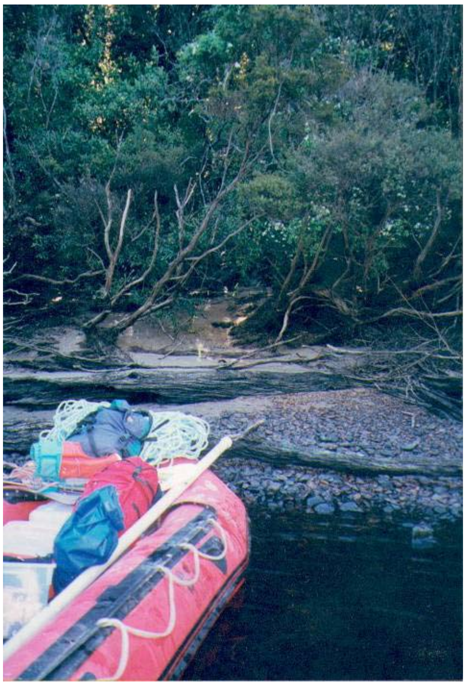
Site 4C, March 2002

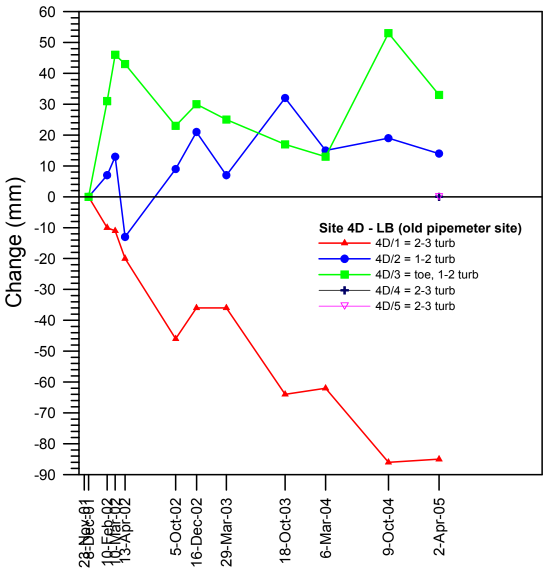
Site 4C close up December 2001

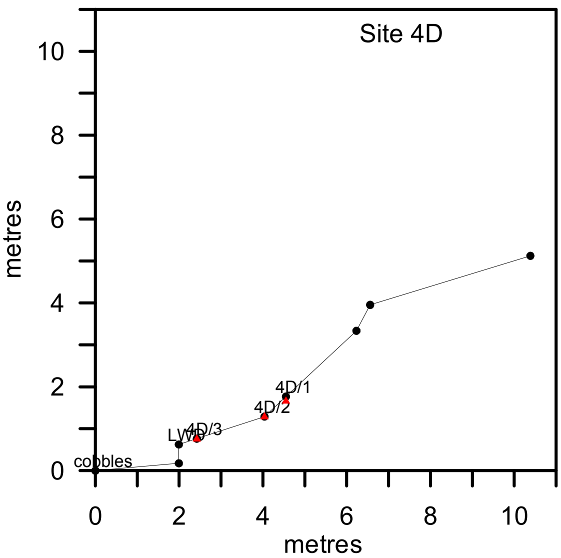


No profile available because site is only photographed.

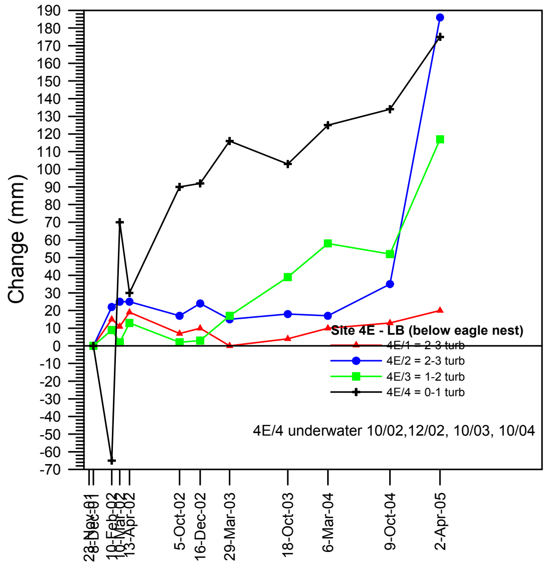
Site 4D: LB, old Geo 4 pipe-meter site. Sandy alluvium over cobbles with large log buttressing toe of bank.

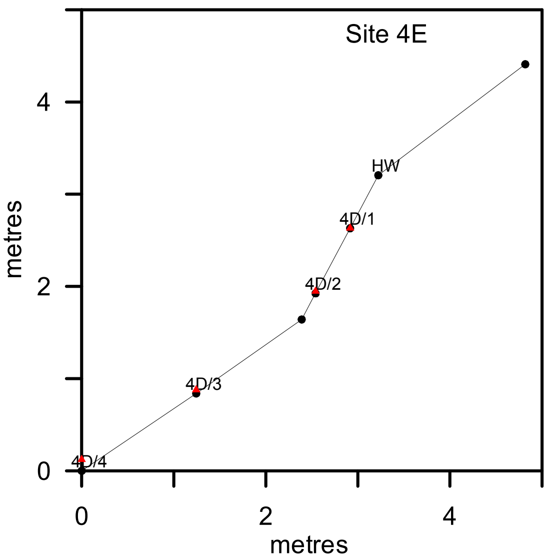




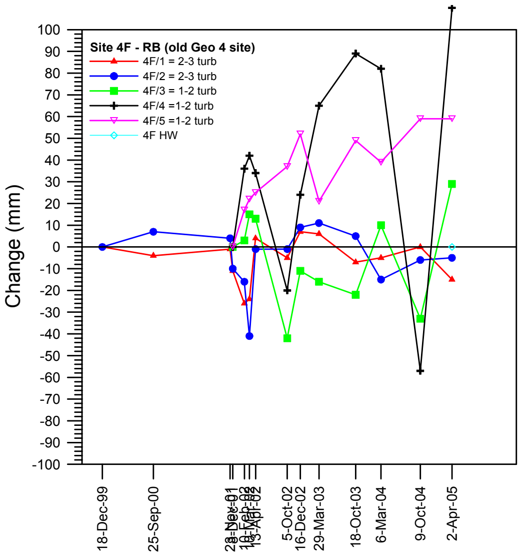


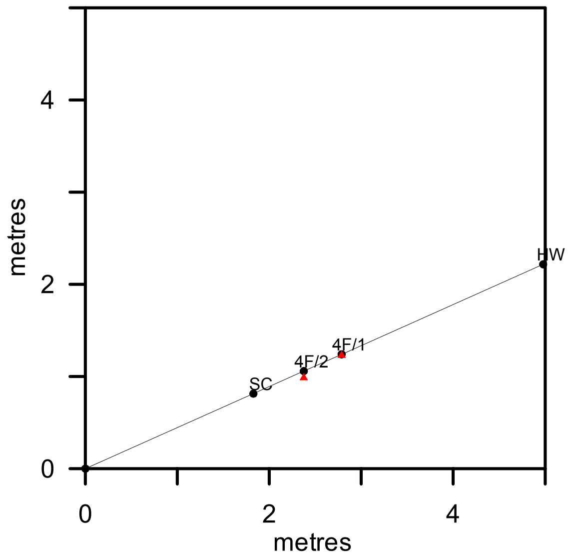
Site 4E: LB. Steep alluvial bank on inside bend with tea tree and LWD.





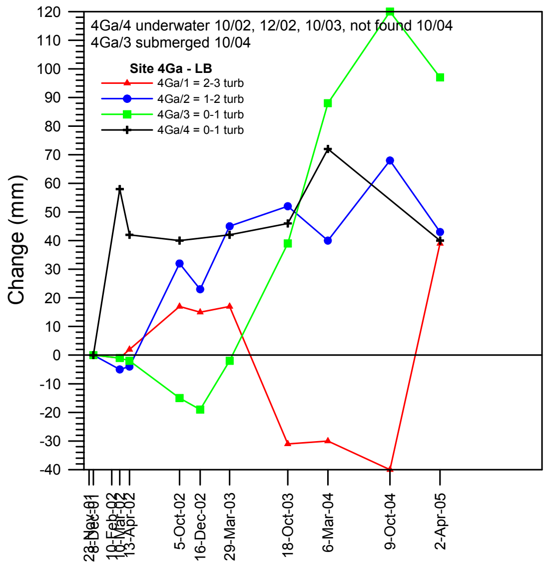
Site 4F: RB. Old Geo4 site. Sandy alluvium over bedrock, and over cobbles.

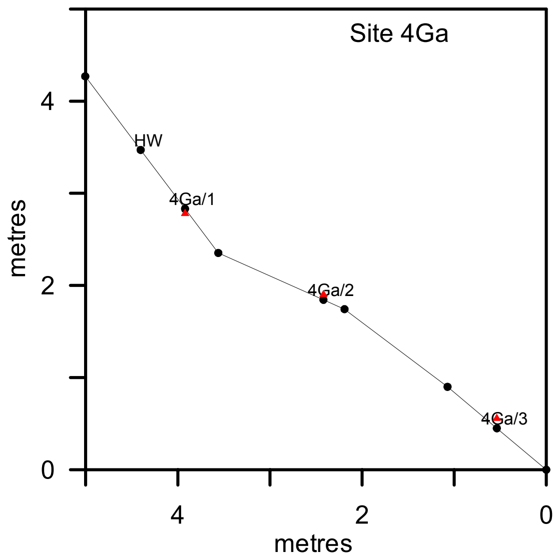




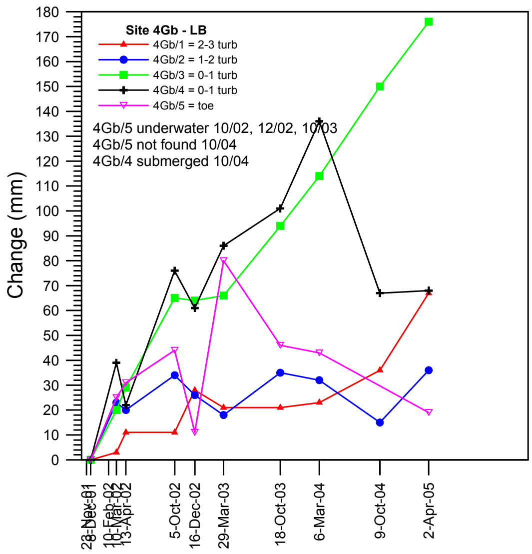
Pins 4F3-5 are located at toe of bank, downstream from this profile

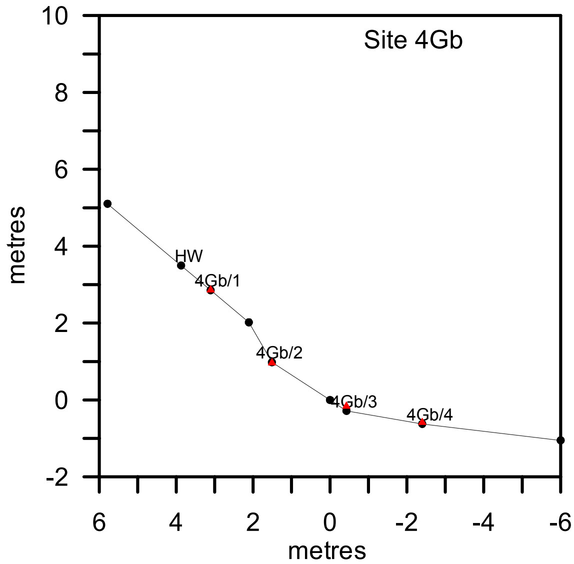
Site 4Ga


4Ga/4 underwater 10/02, 12/02, 10/03, not found 10/04
4Ga/3 submerged 10/04
Site 4Ga - LB
4Ga/1 = 2-3 turb
4Ga/2 = 1-2 turb
4Ga/3 = 0-1 turb
4Ga/4 = 0-1 turb
Change (mm)
5-Oct-02
16-Dec-02
29-Mar-03
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05

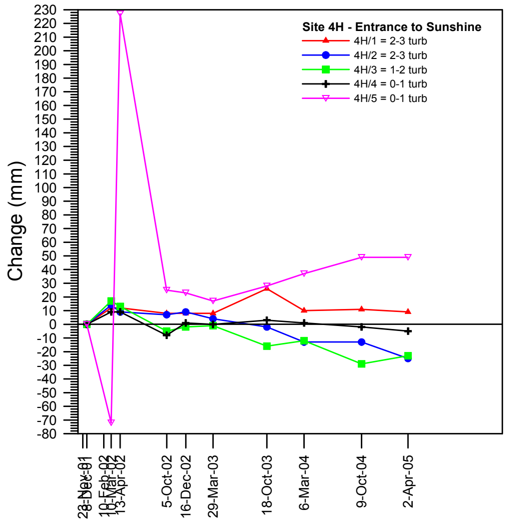

Site 4Ga
HW
4Ga/1
4Ga/2
4Ga/3
metres
metres

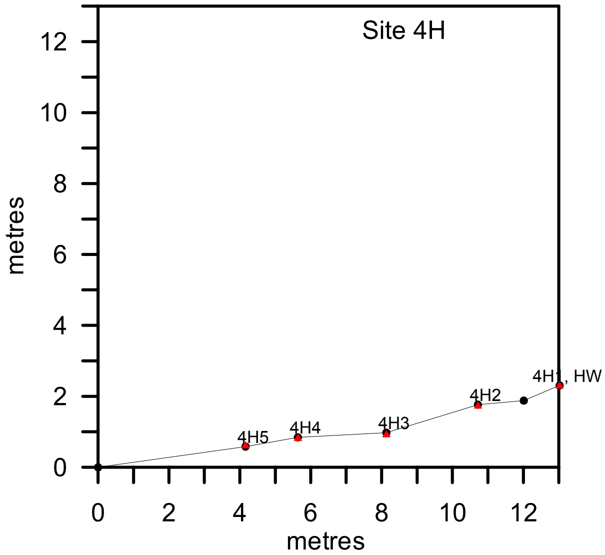
Site 4Gb


Site 4Gb - LB
4Gb/1 = 2-3 turb
4Gb/2 = 1-2 turb
4Gb/3 = 0-1 turb
4Gb/4 = 0-1 turb
4Gb/5 = toe
4Gb/5 underwater 10/02, 12/02, 10/03
4Gb/5 not found 10/04
4Gb/4 submerged 10/04
Change (mm)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
8-Dec-01
10-Feb-02
10-Mar-02
13-Apr-02
5-Oct-02
16-Dec-02
29-Mar-03
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05

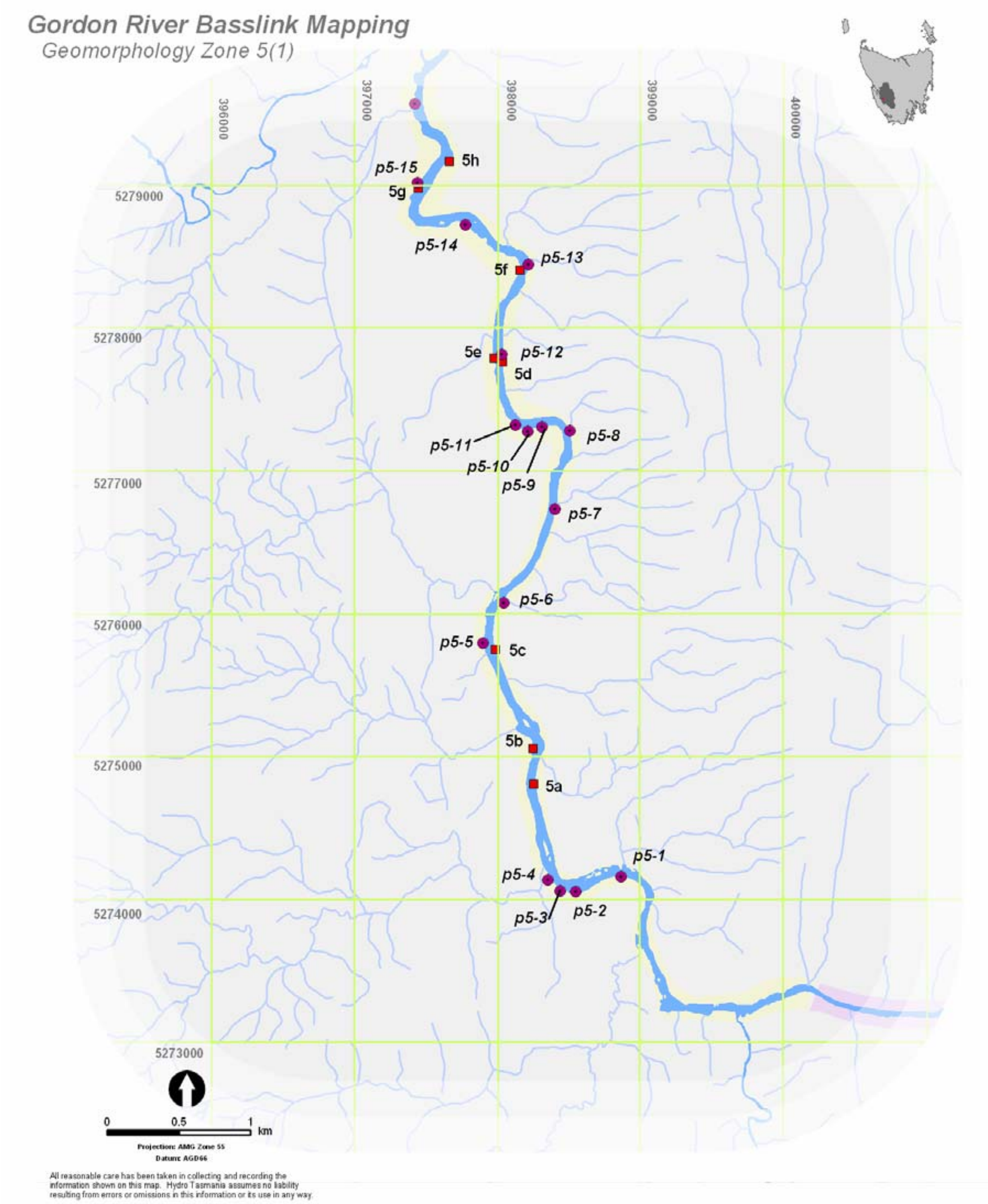

Site 4Gb
HW
4Gb/1
4Gb/2
4Gb/3
4Gb/4
metres
metres
10
8
6
4
2
0
-2
6
4
2
0
-2
-4
-6

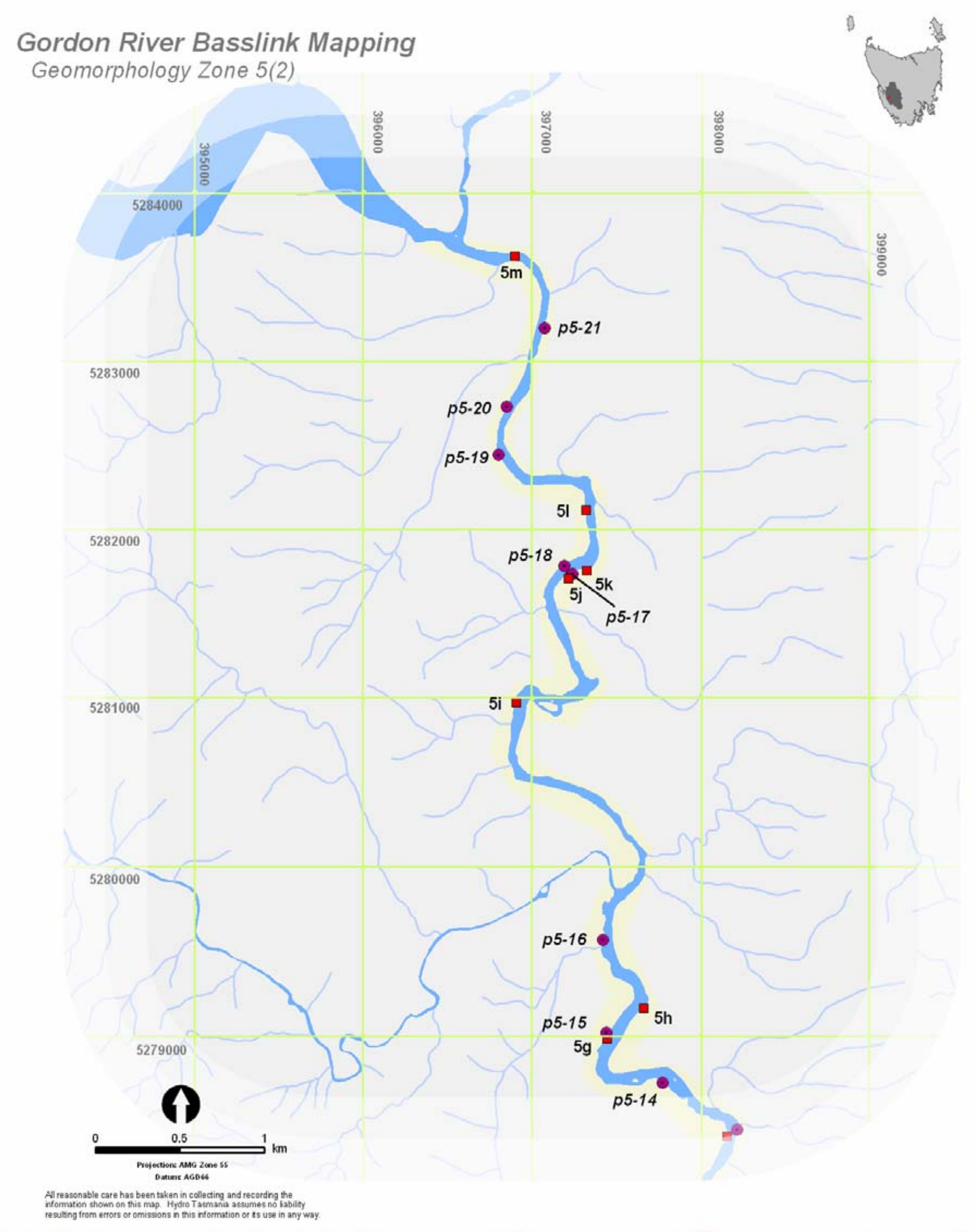
Site 4H


Site 4H - Entrance to Sunshine
4H/1 = 2-3 turb
4H/2 = 2-3 turb
4H/3 = 1-2 turb
4H/4 = 0-1 turb
4H/5 = 0-1 turb
Change (mm)
5-Oct-02
16-Dec-02
29-Mar-03
18-Oct-03
6-Mar-04
9-Oct-04
2-Apr-05

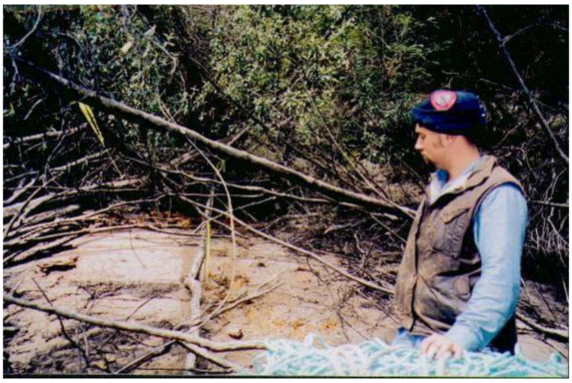

Site 4H
metres
metres
4H5
4H4
4H3
4H2
4H1, HW

A4.5 Zone 5


Gordon River Basslink Mapping
Geomorphology Zone 5(1)
396000
397000
398000
399000
400000
5279000
5278000
5277000
5276000
5275000
5274000
5273000
5h
p5-15
5g
p5-14
5f
p5-13
5e
p5-12
5d
p5-11
p5-10
p5-9
p5-8
p5-7
p5-6
p5-5
5c
5b
5a
p5-4
p5-3
p5-2
p5-1
0
0.5
1
km
Projection: AMG Zone 55
Datum: AGD66
All reasonable care has been taken in collecting and recording the information shown on this map. Hydro Tasmania assumes no liability resulting from errors or omissions in this information or its use in any way.


Gordon River Basslink Mapping
Geomorphology Zone 5(2)
395000
396000
397000
398000
399000
5284000
5283000
5282000
5281000
5280000
5279000
5m
p5-21
p5-20
p5-19
5l
p5-18
5k
5j
p5-17
5i
p5-16
5h
p5-15
5g
p5-14
0
0.5
1
km
Projection: AMG Zone 55
Datum: AGD66
All reasonable care has been taken in collecting and recording the information shown on this map. Hydro Tasmania assumes no liability resulting from errors or omissions in this information or its use in any way.

Site 5A. RB sandy alluvium downstream end of long straight reach, high incidence of woody debris.

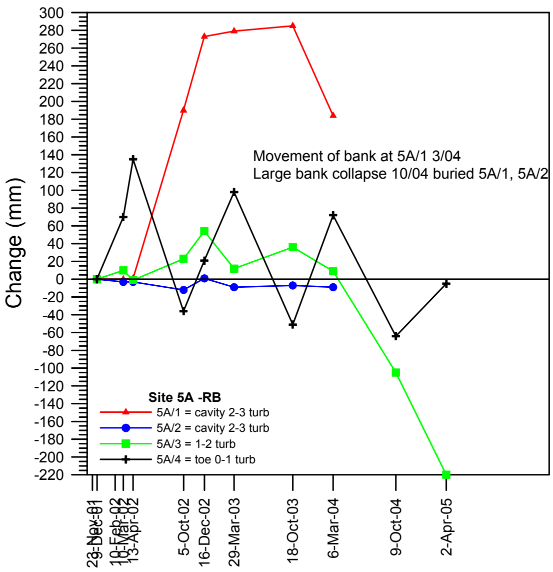


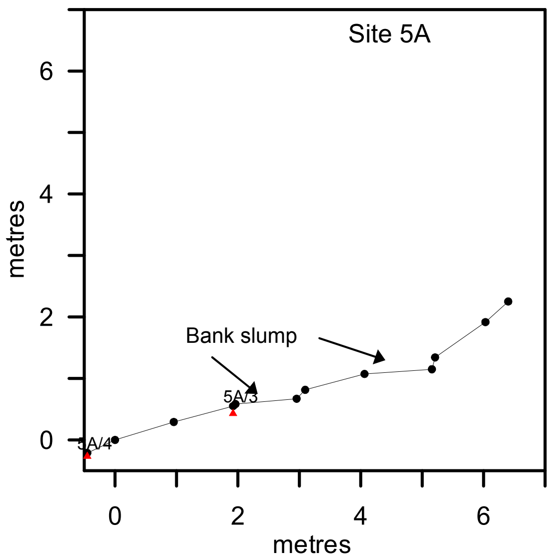
Site 5A December 2001

After bank collapse October 2004

Scarp created by bank collapse

Scarp created by bank collapse

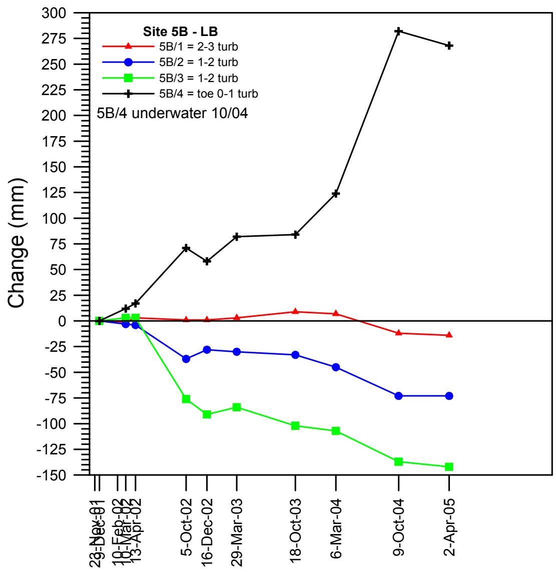


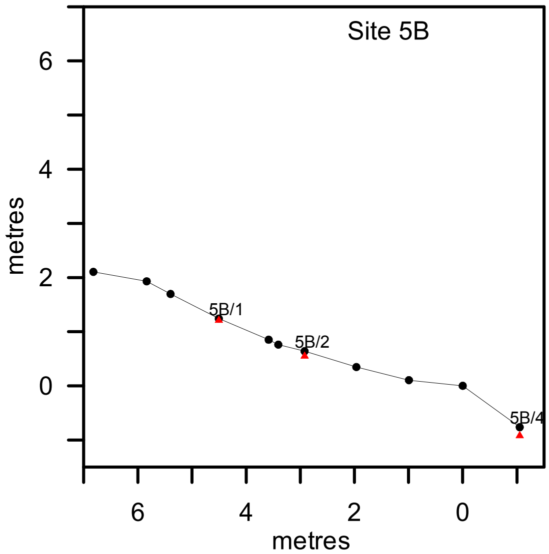


Pins 5A/1 and 5A/2 initially in break in slope below recent bank slump.

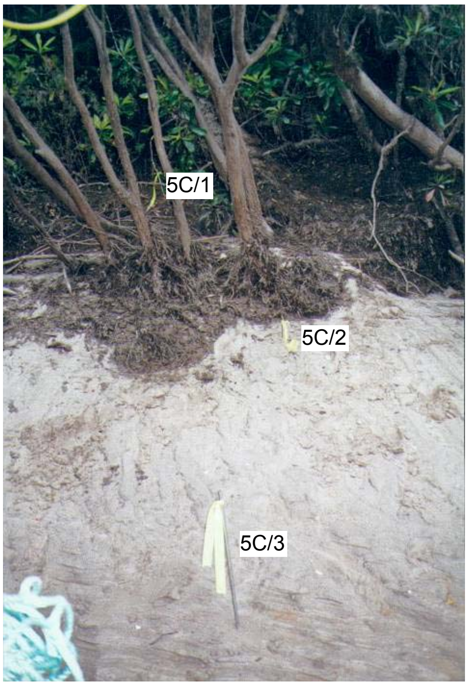
Site 5B: LB, sandy alluvium on inside bend upstream of riffle.

Site 5B December 2001.

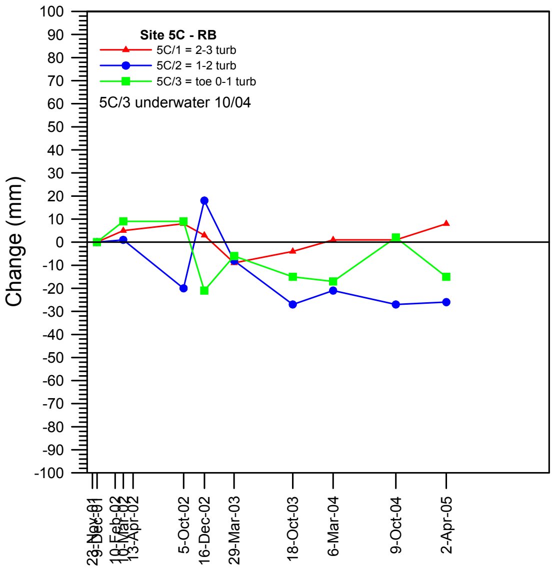


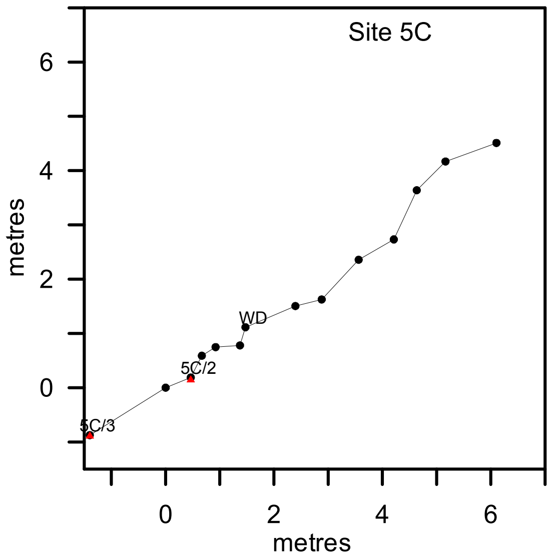


Site 5C. RB, sandy alluvium on inside bend.



Site 5C December 2001

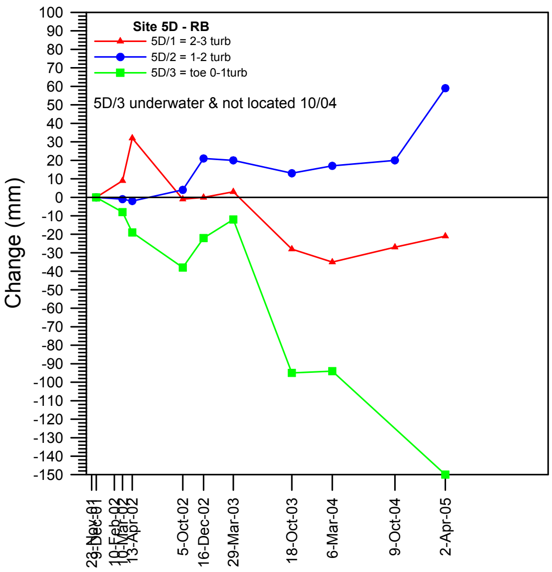


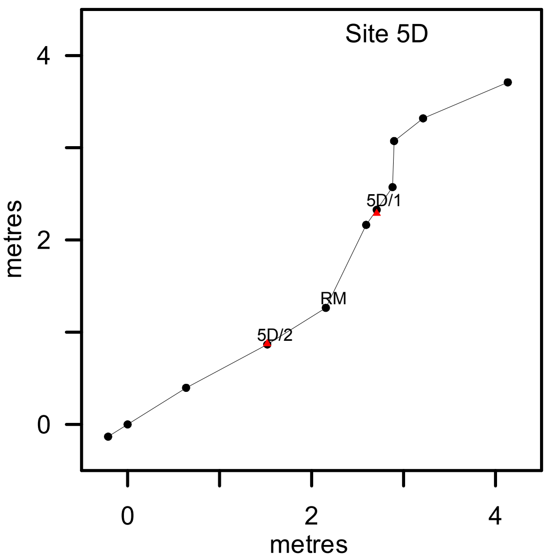


Pin 5C/1 upslope of woody debris (WD) (visible in photo).

Site 5D: RB, sandy alluvium along straight reach

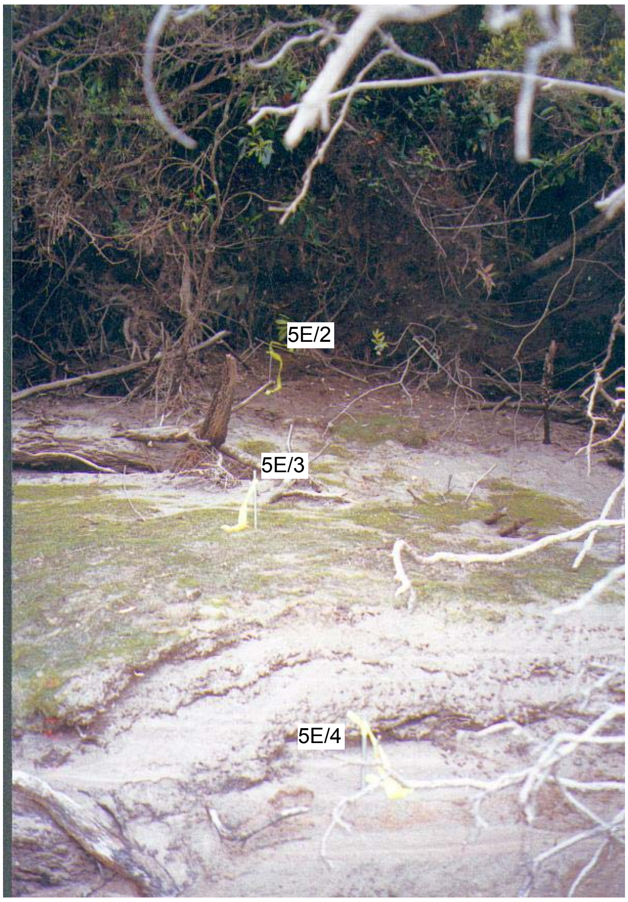
Site 5D. December 2001

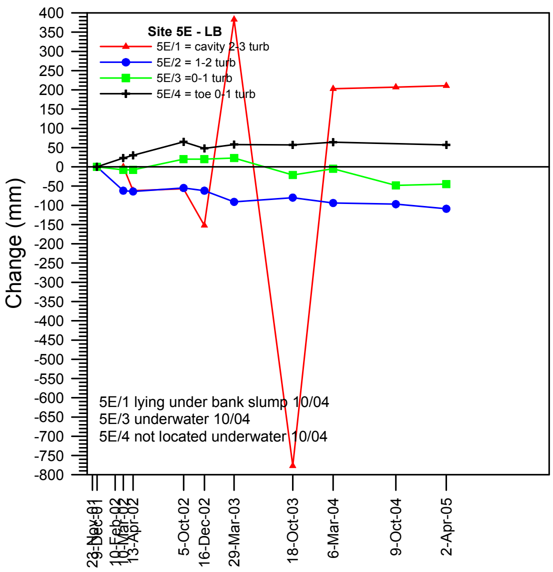


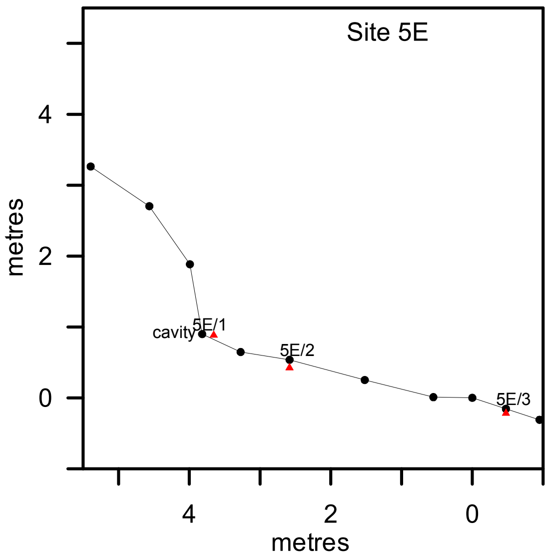


Pin 5D/3 on toe below water level of October 2004.

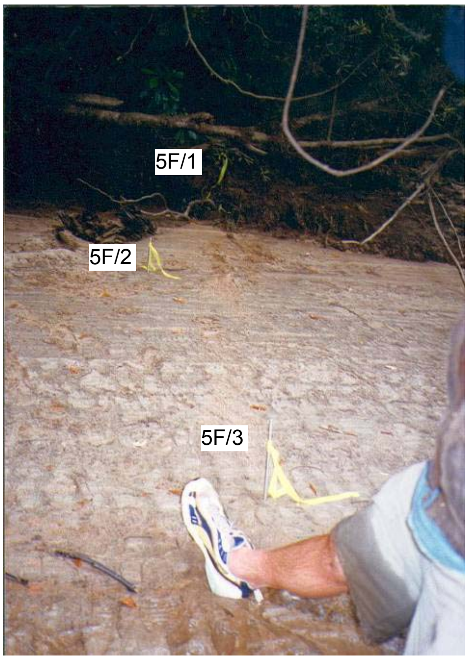
Site 5E: LB, sandy alluvium supporting grasses

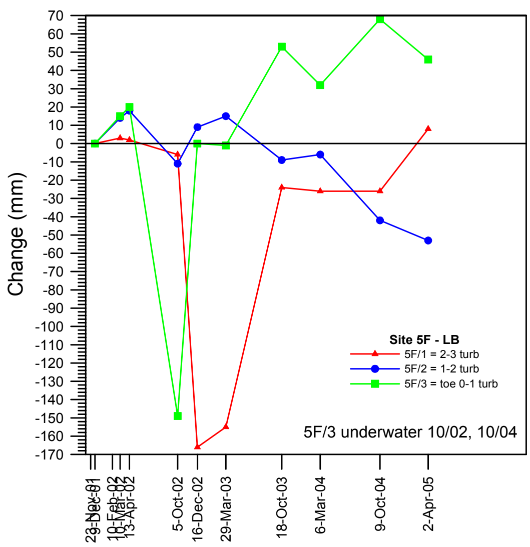


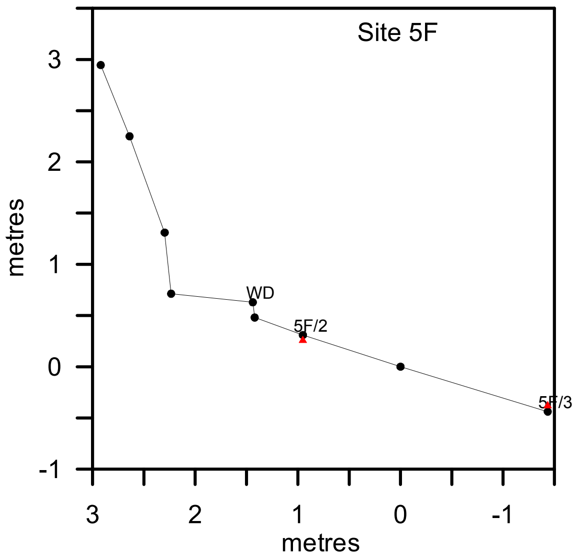




Site 5F: LB, sandy alluvium along straight reach

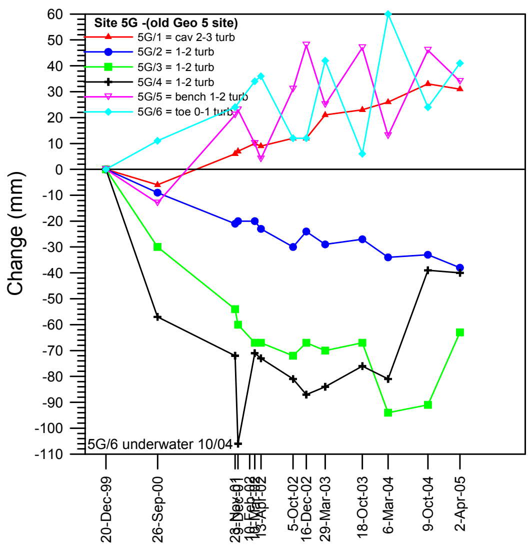


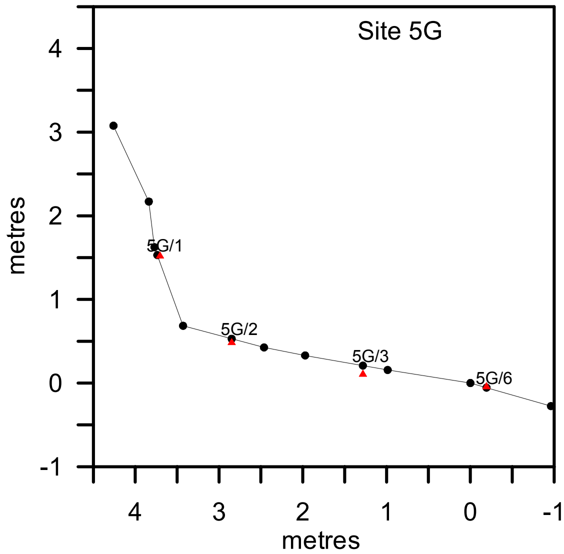




Pin 5F/1 in root mat upslope of woody debris (WD)

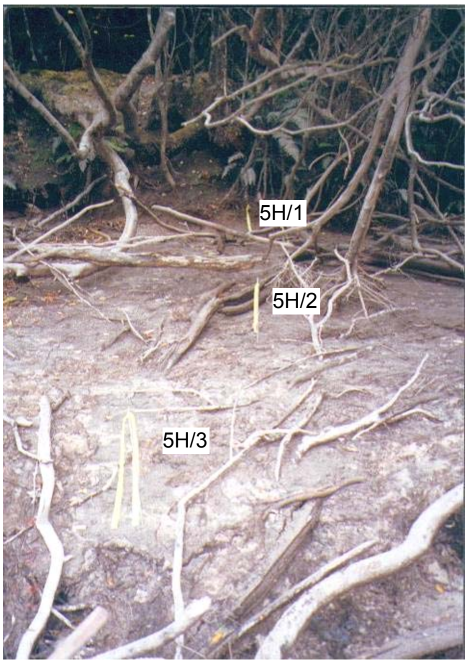
Site 5G: Old Geo 5 site. Sandy alluvium over cobbles on LB behind cobble bar.

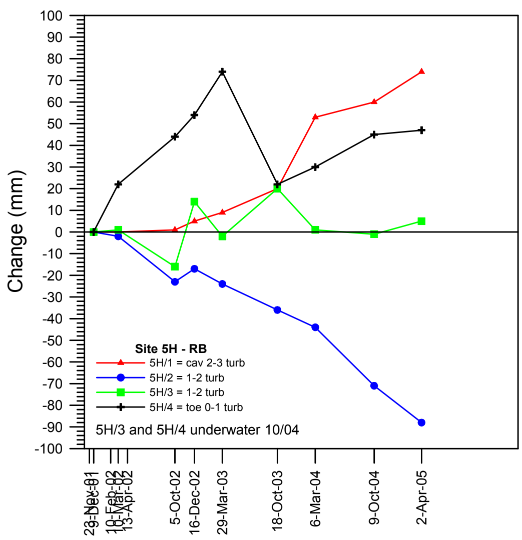


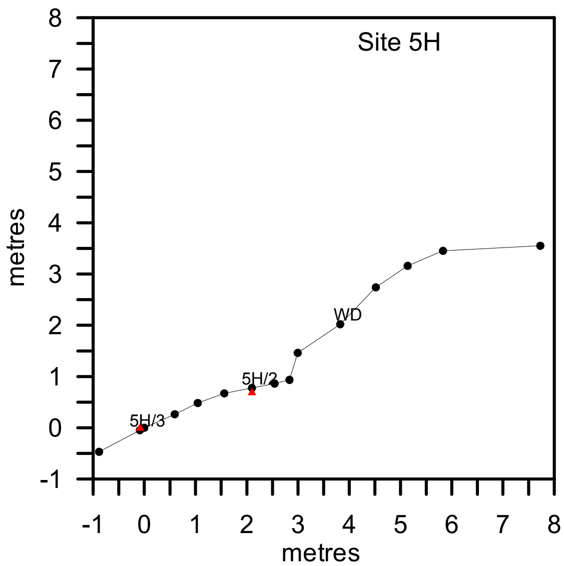


Pin 5G/4 and 5 on 'bench' on right side of photo. 5G/4 behind Huon.

Site 5H: RB, sandy alluvium on outside bend.



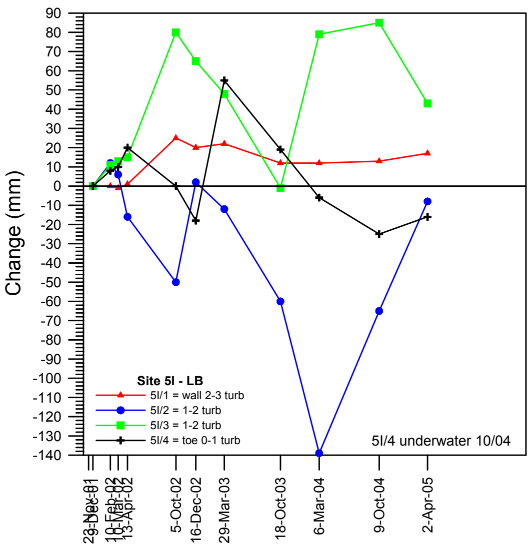


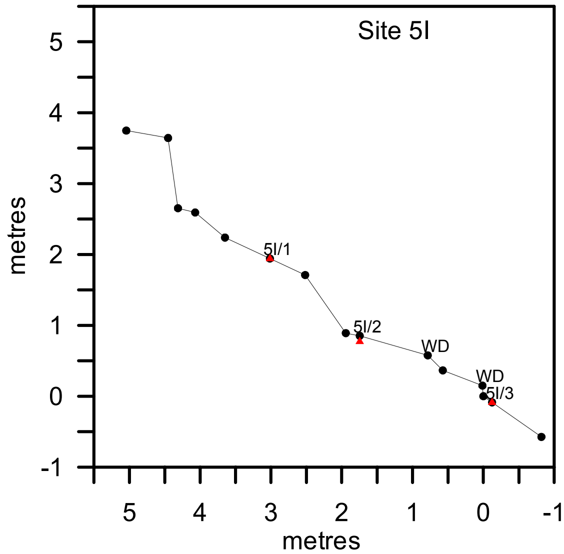


Pin 5H/1 in cavity in steep part of bank upslope of 5H/2.

Site 5I: LB, upstream of cobble bar at Gordon above Franklin gauging site

Site 5I, December 2001

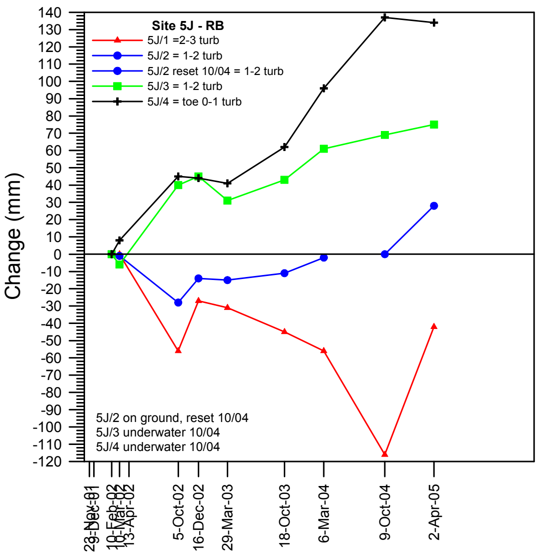


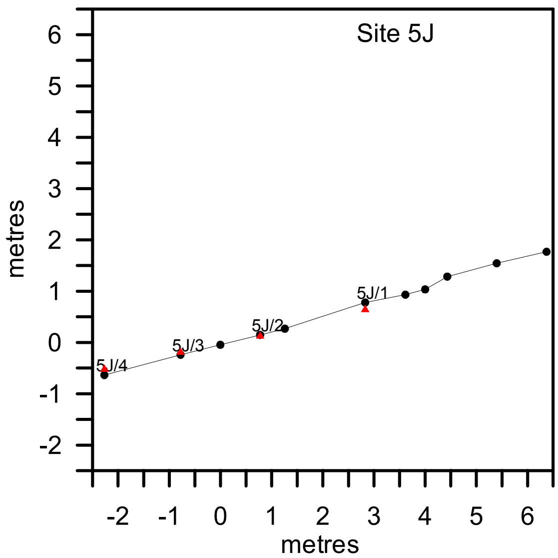


Pin 5I/4 on toe below water level – approximately at start of profile

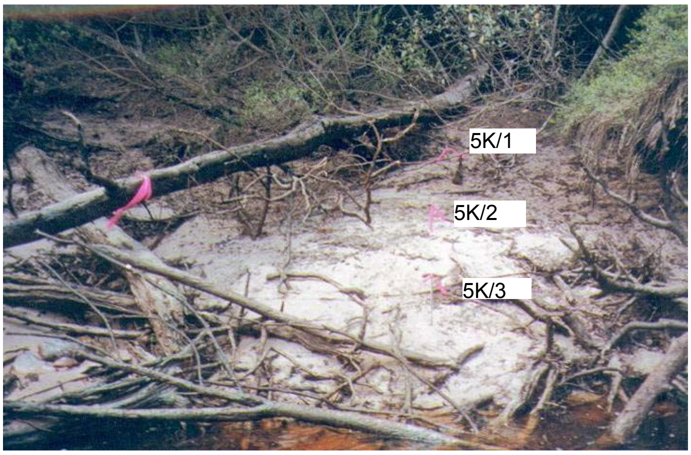
Site 5J: RB, downstream end of long inside bend. Sandy alluvium over bedrock.

Site 5J, December 2001

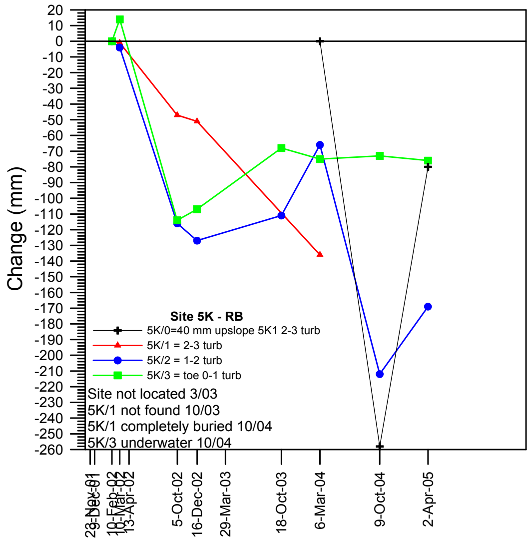


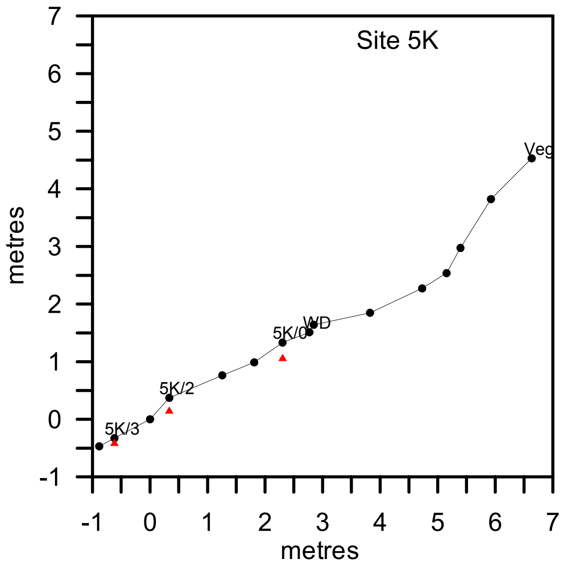


Site 5K.



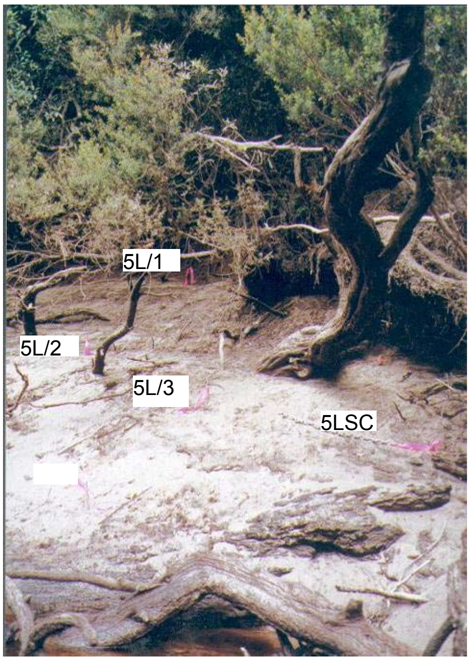
Site 5K, February 2002



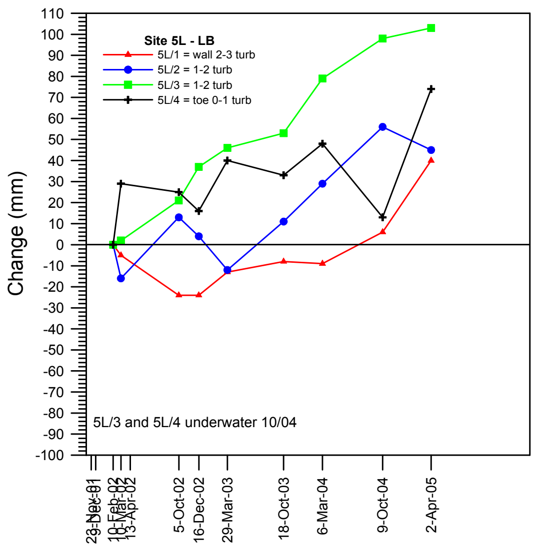


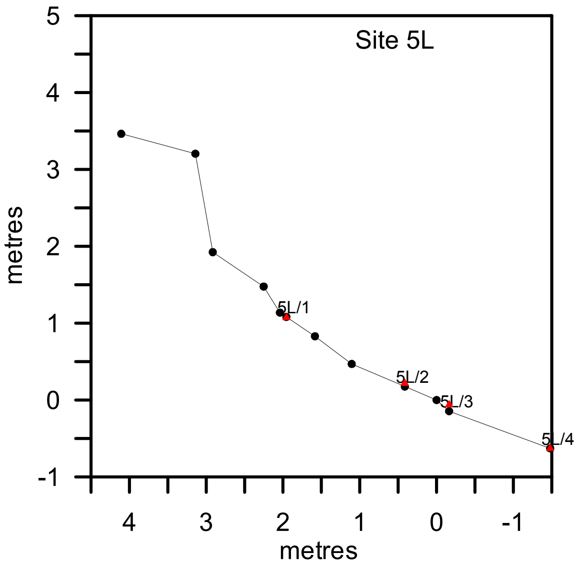
Pin 5K/0 inserted to continue record of 5K/1, which was completely buried October 2004

Site 5L: LB, sandy alluvium along straight reach



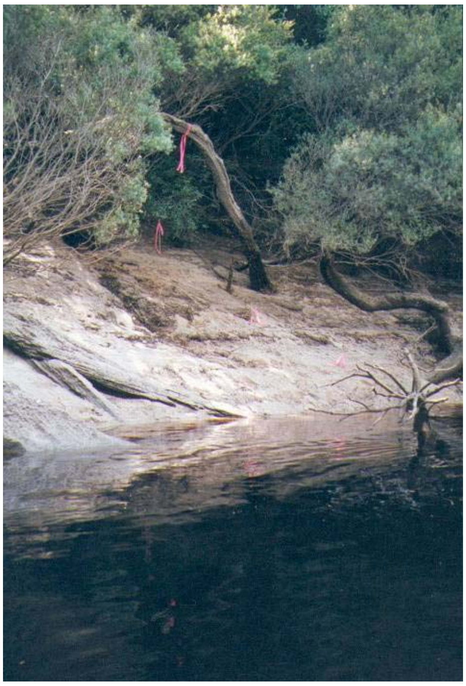
Site 5L, February 2002



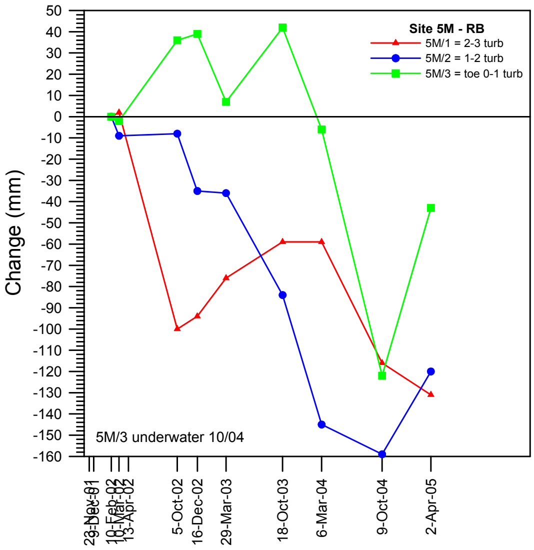


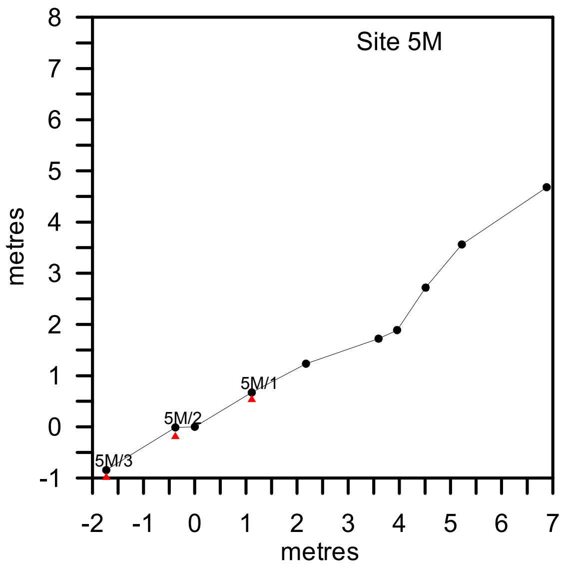
5L/1 and 5L/2 off set upstream of 5L/3 and 5L/4.

Site 5M: RB upstream of Franklin River



Site 5M, February 2002





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A5 Fluvial geomorphology B

A5.1 Distribution of erosion pins

Table 5.1 Distribution of erosion pins by bank materials, river location and turbine level

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

Zone	Turbine Level	Bank Material - Colluvial	Bank Material - Alluvial	Bank Material - Alluvial over cobbles or bedrock	Location - Inside bend	Location - Outside bend	Location - Straight reach	Turbine level Totals
	>3			2A/4			2A/4	1
Bank type, location totals		0	43	13	15	8	33	
Zone 3	<1		32A/1, 3A/4, 3A/5, 3C/5, 3D/3, 3Ea/3, 3Eb/5, 3F/4, 3G/5	3B/5	3C/5	3D/3	32A/1, 3A/4, 3A/5, 3B/5, 3Ea/3, 3Eb/5, 3F/4, 3G/5	10
	1-2		3A/2, 3A/3, 3C/2, 3C/3, 3C/4, 3D/2, 3Ea/4, 3Eb/3, 3Eb/4, 3G/2, 3G/3, 3G/4	3B/1, 3B/4, 3F/2, 3F/3,	3C/2, 3C/3, 3C/4	3D/2	3A/2, 3A/3, 3B/1, 3B/4, 3Ea/4, 3Eb/3, 3Eb/4, 3F/2, 3F/3, 3G/2, 3G/3, 3G/4	16
	2-3		3A/5, 3A/6, 3C/1, 3D/1, 3D/4, 3Ea/2, 3Ea/5, 3Eb/2, 3Eb/6, 3G/1	3B/2, 3B/3, 3F/1	3C/1	3D/1, 3D/4	3A/5, 3A/6, 3B/2, 3B/3, 3Ea/2 3Ea/5, 3Eb/2, 3Eb/6, 3F/1, 3G/1	13
	>3		3Ea/1, 3Ea/6, 3Eb/1				3Ea/1, 3Ea/6, 3Eb/1	3
Bank type, location totals			34	8	5	4	33	
Zone 4	<1		4A/3, 4B/3, 4E/4, 4Ga/3, 4Ga/4, 4Gb/3, 4Gb/4, 4Gb/5, 4H/4, 4H/5		4E/4	4H/4, 4H/5	4A/3, 4B/3, 4Ga/3, 4Ga/4, 4Gb/3, 4Gb/4, 4Gb/5	10
	1-2		4A/2, 4B/2, 4E/3, 4Ga/2, 4Gb/2, 4H/3	4D/2, 4D/3, 4F/3, 4F/4, 4F/5	4E/3, 4F/3, 4F/4, 4F/5	4D/2, 4D/3, 4H/3	4A/2, 4B/2, 4Ga/2, 4Gb/2	11
	2-3		4A/1, 4A/4, 4B/1, 4/B/4, 4E/1, 4E/2, 4Ga/1, 4Gb/1, 4H/1, 4H/2	4D/1, 4D/4, 4F/1, 4F/2,	4E/1, 4E/2, 4F/1, 4F/2,	4D/1, 4D/4, 4H/1, 4H/2	4A/1, 4A/4, 4B/1, 4/B/4, 4Ga/1, 4Gb/1	14
	>3			4F/HW	4F/HW			1
Bank type, location totals			26	10	10	9	17	
Zone 5	<1		5A/4, 5B/4, 5C/3, 5D/3, 5E/3, 5E/4, 5F/3, 5G/6, 5H/4, 5I/4, 5J/4, 5K/3, 5L/4, 5M/3		5B/4, 5C/3, 5F/3, 5J/4, 5K/3	5H/4, 5I/4, 5M/3	5A/4, 5D/3, 5E/3, 5E/4, 5G/6, 5L/4	14

Zone	**Turbine Level**	**Bank Material - Colluvial**	**Bank Material - Alluvial**	**Bank Material - Alluvial over cobbles or bedrock**	**Location - Inside bend**	**Location - Outside bend**	**Location - Straight reach**	**Turbine level Totals**
	1-2		5A/3, 5B/2, 5B/3, 5B/5, 5B/6, 5C/2, 5D/2, 5E/2, 5F/2, 5G/2, 5G/3, 5G/4, 5G/5, 5H/2, 5H/3, 5I/2, 5I/3, 5I/6, 5J/3, 5J/2, 5K/2, 5L/2, 5L/3, 5M/2		5B/2, 5B/3, 5B/5, 5B/6, 5C/2, 5F/, 5J/3, 5J/2, 5K/2	5H/2, 5H/3, 5I/2, 5I/3, 5I/6	5A/3, 5D/2, 5E/2, 5G/2, 5G/3, 5G/4, 5G/5, 5L/2, 5L/3, 5M/2	24
	2-3		5A/1, 5A/2, 5B/1, 5C/1, 5C/4, 5D/1, 5E/1, 5F/1, 5G/1, 5H/1, 5I/1, 5I/5, 5J/1, 5J/5, 5J/6, 5K/0, 5K/1, 5L/1, 5M/1		5B/1, 5C/1, 5C/4, 5F/1, 5J/1, 5J/5, 5J/6, 5K/0, 5K/1	5H/1, 5I/1, 5I/5	5A/1, 5A/2, 5D/1, 5E/1, 5G/1, 5L/1, 5M/1	19
	>3							
Bank type, location totals			57	0	23	11	23	

A5.2 Results

Table 5.2 Average erosion in pins showing erosion relative to 23 November 2001, normalised to mm yr^{-1}

Sampling Date	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
9 March 2002	20.7	54.6	138.9	79.5	49.9
5 Oct 2002	9.6	45.5	75.8	41.7	28.3
29 March 2003	9.3	43.7	64.2	34.2	24.4
18 Oct 2003	7.2	30.9	48.6	26.4	15.0
6 March 2004	7.6	25.2	44.3	24.1	16.1
9 Oct 2004	4.6	25.5	34.7	23.7	21.0
9 April 2005	4.9	22.2	32.1	22.6	16.2

Table 5.3. Average deposition in pins showing deposition relative to November 23, 2001, normalised to mm yr^{-1}

Sampling Date	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
9 March 2002	-26.6	-89.8	-53.5	-65.4	-37.5
5 Oct 2002	-12.2	-23.1	-18.6	-24.3	-43.2
29 March 2003	-12.5	-21.7	-10.6	-11.4	-17.7
18 Oct 2003	-6.4	-12.9	-12.5	-16.8	-16.3
6 March 2004	-6.6	-12.0	-12.7	-12.7	-18.0
9 Oct 2004	-6.0	-7.6	-9.5	-14.8	-17.6
9 April 2005	-4.5	-7.2	-13.7	-10.5	-15.1

Table 5.4. Net change in pins in zones 1-5 relative to November 23, 2001, normalised to mm yr^{-1}.

Sampling Date	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
9 March 2002	-9.0	-8.6	38.8	38.1	17.1
5 Oct 2002	-1.3	4.8	35.0	20.5	-7.1
2 March 2003	-2.1	11.6	25.3	22.0	5.7
18 Oct 2003	0.1	9.0	19.3	17.1	-2.4
6 March 2004	-0.8	6.9	19.3	13.6	-1.6
9 Oct 2004	-1.8	8.9	17.0	11.8	-1.9
9 April 2005	-1.0	8.5	14.9	14.3	-1.2

Table 5.5. Net change in pins in zones 1-5 relative to previous monitoring season, normalised to mm yr^{-1}.

Sampling Date	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
9 March 2002	-9.0	-8.6	38.8	38.1	17.1
5 Oct 2002	2.6	11.6	33.1	11.6	-19.4
29 March 2003	-3.5	23.9	7.8	24.7	28.9
18 Oct 2003	5.3	2.7	4.7	5.4	-22.0
6 March 2004	-5.0	-3.4	19.1	-4.1	2.3
9 Oct 2004	-5.9	16.6	8.4	5.0	-2.8
9 April 2005	3.6	6.2	2.4	28.7	2.7

Table 5.6. Average erosion in pins showing erosion relative to November 23, 2001 by turbine level, normalised to mm yr^{-1}

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	98.4	58.3	56.1
5 Oct 2002	59.6	36.0	33.9
29 March 2003	51.4	29.5	26.8
18 Oct 2003	31.5	24.6	25.4
6 March 2004	32.8	21.6	20.9
9 Oct 2004	28.8	21.7	21.9
9 April 2005	28.7	18.2	21.4

Table 5.7. Average deposition in pins showing deposition relative to November 23, 2001 by turbine level, normalised to mm yr^{-1}

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	-56.1	-67.3	-35.3
5 Oct 2002	-38.4	-23.9	-16.8
29 March 2003	-8.8	-18.2	-11.4
18 Oct 2003	-14.5	-13.4	-11.8
6 March 2004	-12.1	-13.2	-11.3
9 Oct 2004	-10.3	-12.0	-10.0
9 April 2005	-9.5	-11.5	-8.4

Table 5.8. Net change in pins relative to November 23, 2001 by turbine level, normalised to mm yr^{-1}.

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	50.0	-2.6	17.7
5 Oct 2002	20.4	4.5	13.6
29 March 2003	32.4	5.2	12.3
18 Oct 2003	13.9	7.8	8.0
6 March 2004	16.9	4.4	7.0
9 Oct 2004	11.5	5.5	8.1
9 April 2005	10.7	5.7	9.5

Table 5.9 Net change in pins in zones 2 and 3 relative to November 23, 2001, normalised to mm yr^{-1}.

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	68.3	-18.5	30.7
5 Oct 2002	20.1	13.9	27.4
29 March 2003	31.5	10.6	23.9
18 Oct 2003	4.5	15.5	20.6
6 March 2004	11.7	11.2	18.3
9 Oct 2004	5.1	13.6	20.3
9 April 2005	4.6	12.8	17.0

Table 5.10. Net change in pins in zones 4 and 5 relative to November 23, 2001, normalised to mm yr^{-1}.

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	60.4	20.9	6.7
5 Oct 2002	30.1	-5.2	3.9
29 March 2003	46.9	0.4	3.6
18 Oct 2003	28.3	0.8	-2.0
6 March 2004	28.4	-2.4	-2.0
9 Oct 2004	23.2	-1.7	-1.8
9 April 2005	22.2	-0.9	3.8

Table 5.11. Net change in pins in zones 2 and 3 relative to previous season, normalised to mm yr^{-1}.

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	68.3	-18.5	30.7
5 Oct 2002	-4.3	30.3	25.7
29 March 2003	52.1	4.6	17.6
18 Oct 2003	-60.9	27.3	12.7
6 March 2004	47.3	-10.0	6.6
9 Oct 2004	-20.2	22.9	28.1
9 April 2005	1.4	8.5	-2.3

Table 5.12. Net change in pins in zones 4 and 5 relative to previous season, normalised to mm yr^{-1}.

Sampling Date	<1-turbine	1-2 turbine	2-3 turbine
9 March 2002	60.4	20.9	6.7
5 Oct 2002	14.8	-18.4	2.5
29 March 2003	77.3	10.6	3.1
18 Oct 2003	-16.9	1.7	-15.6
6 March 2004	29.2	-18.3	-2.3
9 Oct 2004	3.3	1.1	-0.7
9 April 2005	16.4	3.6	36.0

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A6 Karst geomorphology

A6.1 Program rationale and methods

A6.1.1 Importance of karst

Karst areas represent an important facet of the earth's geodiversity. They are unique environments which are dynamic and can be potentially very sensitive to disturbance. Caves support remarkably diverse faunas which, having developed in specific restricted environments, are of special evolutionary, biodiversity and natural heritage significance. The sediments found in caves often provide a unique record of landscape evolution, of environmental and climatic change, and of biological evolution on both a local and regional scale, particularly when analyses of the actual constituents of the sediments are combined with morphological studies. One of the unique values of cave sediments is that the subsurface environment provides protection from erosional and depositional processes occurring at the surface which can otherwise obliterate or obscure the record.

The integrity of karst areas depends on a complex interactive relationship between land, water and air and a minor change in any one of the variables can have a significant impact on the balance of the entire system. In practice, the maintenance of the characteristics of a karst system often hinges upon the retention of natural water flows and water chemistry.

A6.1.2 Background to the development of the karst monitoring program

The Gordon River karst pre-Basslink Monitoring Program has largely been in place since December 2001 although some improvements have been made over time. The program arose out of the recommendations from the initial Basslink karst investigation carried out between June and September 2000 (Deakin *et al.* 2000).

The initial investigation assessed the potential impacts of the proposed Basslink power station operating regime on the three karst areas downstream of the Gordon Power Station which are affected by the Gordon River: the Gordon-Albert karst area which is closest to the power station, the Nicholl's Range karst area downstream of the Denison River, and the Gordon-Sprent karst area in the vicinity of the Franklin River confluence. While all three karst areas are inundated by the Gordon River water being located at river level, and hence are influenced by the power station operations, the study focussed on the Gordon-Albert and Nicholl's Range karst areas because the impacts of the station on the Gordon-Sprent area were found to be relatively low and the caves in that area were relatively robust. At the commencement of the monitoring program a new cave (GA-X1) was found in the Gordon-Albert area and this was added to the program.

Within the Gordon-Albert area, the primary potential management issues associated with Basslink changes to power station operations are:

- Changes in the inundation regime in GA-X1. This could lead to increased disturbance of cave sediments, changes in habitat or food for any biological communities, or changes to the physical structure of the cave. This cave is important because it is the only known cave in these rocks in this area; and
- Increased transfer of sediment from the base of the dolines[1] due to the increased number of wetting and draining events associated with the increased number of on-off sequences. This could potentially lead to further collapse of the dolines and destabilisation of the surrounding vegetation.

The potential management issues within the Nicholl's Range area are:

- Changes to the inundation regimes in Bill Neilson Cave and Kayak Kavern which could significantly change the hydrological regime within the caves, disturb habitats and food sources, and change the geomorphological development of the caves;
- Changes in sediment transfer processes in Bill Neilson Cave and in Kayak Kavern which could impact on the habitats of the cave adapted species and their food sources, and change the geomorphological development of the caves; and
- Changes to the maximum peak flow events in Bill Neilson Cave if full gate power station operations coincide with high tributary flow. This could increase the range of inundation of the dry sediment bank located just before the large bend in the middle of the cave. The dry sediment bank is important as there are calcite features forming on top of the sediment, they provide habitat for the only known true cave adapted species in the cave and they may be significant in terms of recording the evolutionary history of the area.

During the original karst investigation phase, all the karst features were subjected to a preliminary conservation value assessment using the National Estate Criteria and the principles of geoconservation to assist in determining any potential mitigation measures and an appropriate monitoring regime. The Nicholl's Range karst was found to be 'Representative at a local scale' on the basis of the available information. Almost all of the National Estate Criteria are ranked 'low',

[1] Dolines are karst features which present as depressions or collapses of the land surface. They are of variable size and can reach up to tens of metres in diameter. Dolines are formed when a solution cavity in the underlying rock becomes enlarged enough for overlying sediment to collapse into it.

with the exception of one 'medium' in light of the potential importance of the dry cave sediments in Bill Neilson Cave.

The Gordon-Albert karst is largely still unknown as investigations to date have mainly focussed on the river channel, and dolomite karst is not as well known in Tasmania as limestone karst. GA-X1 is considered to be 'Significant' as it is the only cave found in the Gordon-Albert dolomite and it is tentatively considered to be 'Representative at a local or regional scale'. When compared to other caves in other dolomite karst areas, GA-X1 would appear not to be of particularly high conservation value based on its sediments or formations. However, as this is the only significant cave found in the Gordon-Albert Karst area to date, and the nearest karst area is some 10 km distant, it is possible that there could be locally endemic species of cave fauna which have developed.

The relatively low significance of these karst areas from the preliminary conservation assessment, and the relatively robust nature of the features, led to no specific mitigation measures being recommended in the initial karst investigations that were required to be addressed in the Basslink monitoring program.

A6.2 Sampling strategy

In designing the monitoring program, the karst team was very mindful that karst environments are typically relatively pristine and can be highly sensitive to human induced impacts. The Australian Speleological Federation Minimal Impact Caving Code 1995 states that all cave visitors (whether recreational or scientific) should try to minimise their impacts on the cave environment at all times. While the caves being monitored are considered relatively robust, the monitoring equipment installed as part of this program has been kept to a minimum in order to achieve a balance between carrying out the assessments and being consistent with the Code.

The sampling methodology and rationale for site selection is described for each site in the following sections under the broad headings of the Gordon-Albert karst area and the Nicholl's Range karst area.

A6.2.1 Gordon-Albert karst area

There were four different monitoring sites within the Gordon-Albert Karst area (sites 1-4) which include Channel Cam, GA-X1 Cave and two dolines.

A6.2.1.1 Site 1: Channel Cam

Monitoring in Channel Cam, being a relatively minor element of the monitoring program, was limited to regular measurements of two erosion pins combined with photo-monitoring. Two pins were considered adequate given the relatively small size and low energy environment of the feature.

The river level at which the channel becomes inundated was determined in the initial investigation phase using surveying techniques and the flow record at G5 which is adjacent to the site. These flow data, together with the erosion pin data, were used to determine the inundation regime and associated sediment changes.

A6.2.1.2 Site 2: GA-X1

Monitoring in GA-X1 comprised measuring sediment changes at three erosion pins inside the cave and two in the doline at the cave entrance, and recording the inundation regime inside the cave using a temporary water level recorder.

The pins were located in the soft sediment in the base of the cave at low, middle and high points in the profile to determine the effects of different levels of inundation at various power station outputs. The pins installed in the doline at the entrance to the cave were primarily used to determine whether the mouth of the cave was likely to be a major source of sediment input to the cave.

The recorder in GA-X1 was surveyed relative to the Gordon River and recorded the mid to upper range of the Gordon River inundation in the cave. As this sort of temporary instrumentation can be unreliable, and as it measured only a portion of the inundation regime in the cave being only 1 m in length, a secondary objective was to correlate the water level data from within the cave with those from the nearby G5 stream gauging station and the sediment bores at G5a, to determine any relationships that could be used to extend the dataset.

The water level changes in the cave were also manually recorded and related to Gordon River changes during an inundation event, to determine more precisely the effects of changes in the river level on the cave.

A6.2.1.3 Site 3: Doline adjacent to GA-X1

Two dolines were selected for inclusion in the monitoring program. The first of these, at site 3, is located adjacent to, and along the same north-south geological line of weakness as GA-X1, approximately 25 m from the river channel and 6 m above the level of the river with the power station turned off. As the cave has developed along this line of weakness at this location, it was considered that there was good potential for this doline to also be in hydraulic connection with the river. This doline was therefore selected for monitoring as a site with a relatively high probability of being affected by the river fluctuations and hence any potential Basslink changes.

Four erosion pins were installed in a vertical profile from the base of the feature up the side to close to the rim. The pins were used as survey markers to determine whether there were any structural changes occurring over time in the shape and depth of the doline. The distances between the pins and their heights above ground level were measured on each trip and comparative photos were taken from a standard photo-monitoring site.

A6.2.1.4 Site 4: Doline adjacent to Channel Cam

The second of the dolines (site 4) was selected as one which was less likely to be in direct hydraulic connection with the river so that it could provide some control in as much as that is possible with dolines. It is located approximately 25 m in from the river bank and approximately 5 m above the level of the river with the station turned off. Its location to the west of the river, and hence off-line with any north-south geological lineaments, meant that it was less likely than site 3 to be affected by river fluctuations.

Three erosion pins were installed as survey markers in a similar vertical profile in the doline, with a further two being added towards the end of the program to assist in assessing any changes during the post-Basslink phase. Photo-monitoring was also used to support the pin data.

A6.2.2 Nicholl's Range karst area

There were two principal monitoring sites within the Nicholl's Range karst area: Kayak Kavern and Bill Neilson Cave, although the latter was subdivided into a number of sites as the cave is 0.5 km long.

A6.2.2.1 Site 5: Kayak Kavern

Sediment transfer in Kayak Kavern was monitored initially by way of four erosion pins at various locations throughout the silt bank in the cave. Due to the significant displacement of two of the pins, two additional pins were added to the array towards the end of the program so that monitoring could be continued in the post-Basslink phase. The pins were supported by photo-monitoring data and, from midway through the program, additional monitoring of changes in the height of the silt bank relative to the rock roof along a transect at a number of points along the profile. The survey transect was added to the program in response to the relatively major changes that were occurring at two of the pins and was designed to pick up any macro changes that might be occurring in the profile of the bank.

The purpose of the monitoring was twofold: to understand the sediment transport processes in Kayak Kavern in its own right; and to provide a reference for understanding the role of the Gordon inundation waters in sediment transfer processes in Bill Neilson Cave.

A6.2.2.2 Site 6: Bill Neilson Cave

Three principal sub-sites in Bill Neilson Cave were the focus of the sediment transfer studies: Site 6A located in the wet sediment bank in the large entrance chamber to the cave; site 6B, also in a wet sediment bank located 5-10 m further back into the cave; and site 6C in the dry sediment bank located approximately 175 m into the cave just before the major bend. Sites 6A and 6B were selected to monitor the effects of the Gordon River inundation waters on the sediment banks that are regularly inundated within the cave. Three pins were installed at each site at different heights within the profile, low, middle and high, to take account of potential effects of the cave stream and different river levels. Site 6C was expected to be outside the range of the majority of inundation events and just two pins were installed.

Two water level recorders were installed in the cave at the beginning of the program and were supported by a third in October 2003. The first recorder was located upstream of the limit of inundation by the river and measured cave stream flow only. The second recorder was located in the middle reaches of the cave close to the dry sediment bank and measured a combination of cave stream flow and Gordon River inundation water. The third recorder was installed at the cave entrance in the wet sediment bank between sites 6A and 6B to measure Gordon River inundation water in a location close to the sediment monitoring sites. The middle and entrance recorders were surveyed in relative to a reference point at the cave entrance and are directly comparable with each other and with other water level reference points generated during the original investigation. These data were used in conjunction with the Gordon below Denison flow data and the tailrace flow data to determine the different components of the water regime in the cave.

As the water level recorders were of a relatively limited range, the middle recorder was moved about within the middle reaches of the cave to capture different parts of the hydrograph. Each time the recorder was moved it was surveyed from its old location to its new location so that all data was relative to the same reference point.

A6.3 Impacts of uncharacteristic flow events preceding a monitoring trip

Comparison of the river flow data for the last six weeks before each monitoring trip shows that the flows in the periods immediately before the summer 2003-04 and the winter 2004 sampling trips were somewhat uncharacteristic in the context of the usual seasonal trends (Figure 6.1). Power station operations were unusually low for approximately three weeks in the lead up to the March 2004 sampling trip, probably due to a period of heavy rainfall across the state which would have prompted the switch to the run of river stations for generation of power. The high rainfall also resulted in some higher than usual natural flows in the Denison which would have brought some extra sediment into the system. Similarly, in the weeks before the October 2004 sampling trip, there was a two week period when power station operations were unusually high with some uncharacteristic 3-turbine events. The flow conditions during these periods have given rise to results in the erosion pin data that do not fit the usual trends and this needs to be taken into consideration in analyzing the results.

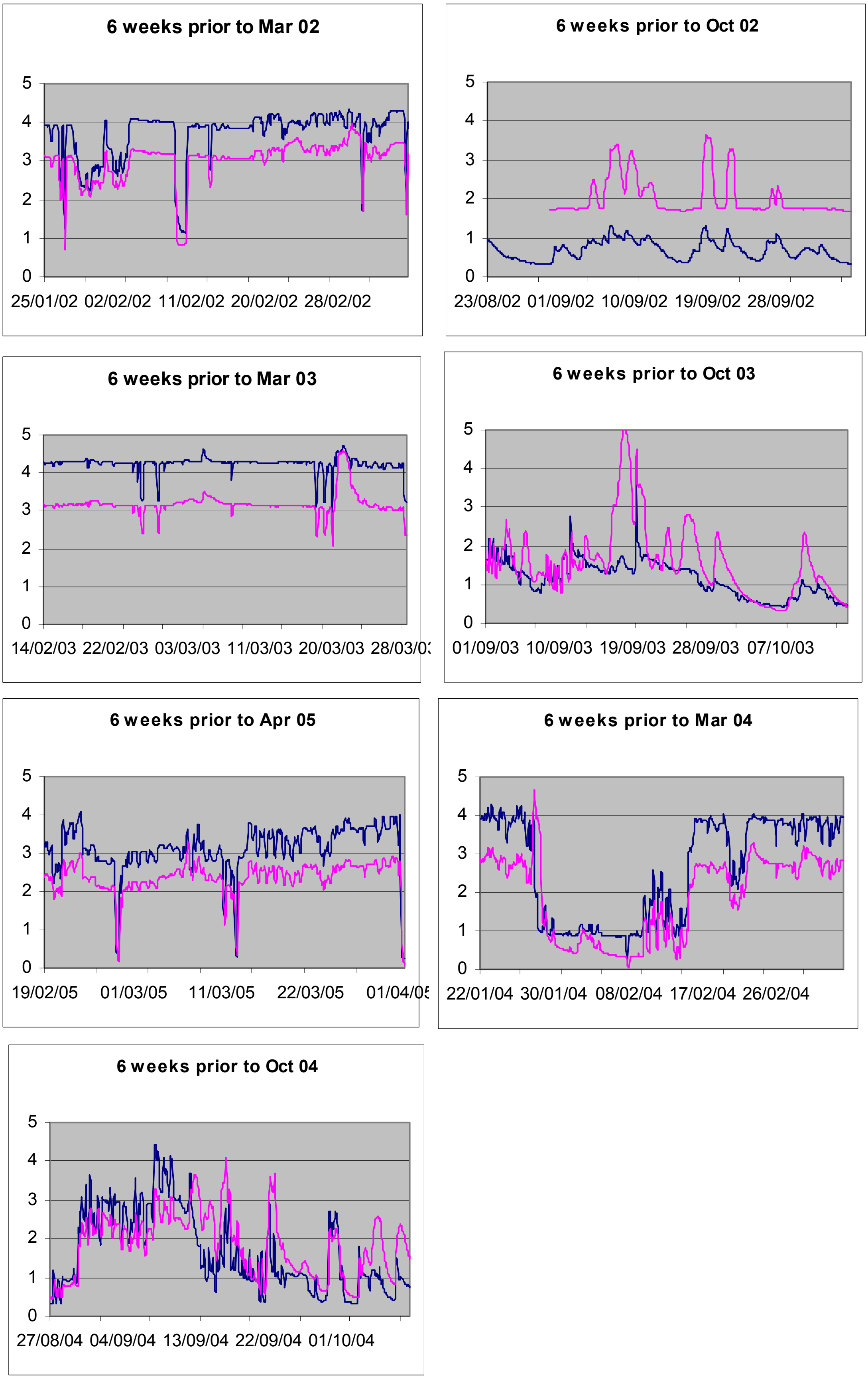


Figure 6.1. Flow data for G5 (darker colour) and Gordon River below Denison (lighter colour) for the six week periods prior to each of the monitoring trips

A6.4 Effects of sediment buffering on water level fluctuations at site 71 (G5a)

The base of the doline at site 4 is choked with approximately 0.73 m of loose organic soil and leaf litter underlain by at least 30 mm of sand. The sandy material is likely to be a significant sediment buffer that will temper the effects of the fluctuations. This is demonstrated by a sample of water level data for two piezometers located at a site just downstream of the dolines at G5a, one close to the river and the other some 25 m inland, which is a similar distance from the river as the dolines (Figure 6.2). The graph shows the significantly lower effects of the power station operations on the water level at the more inland of the piezometer sites. This reduction in effect is also likely to occur in the dolines.

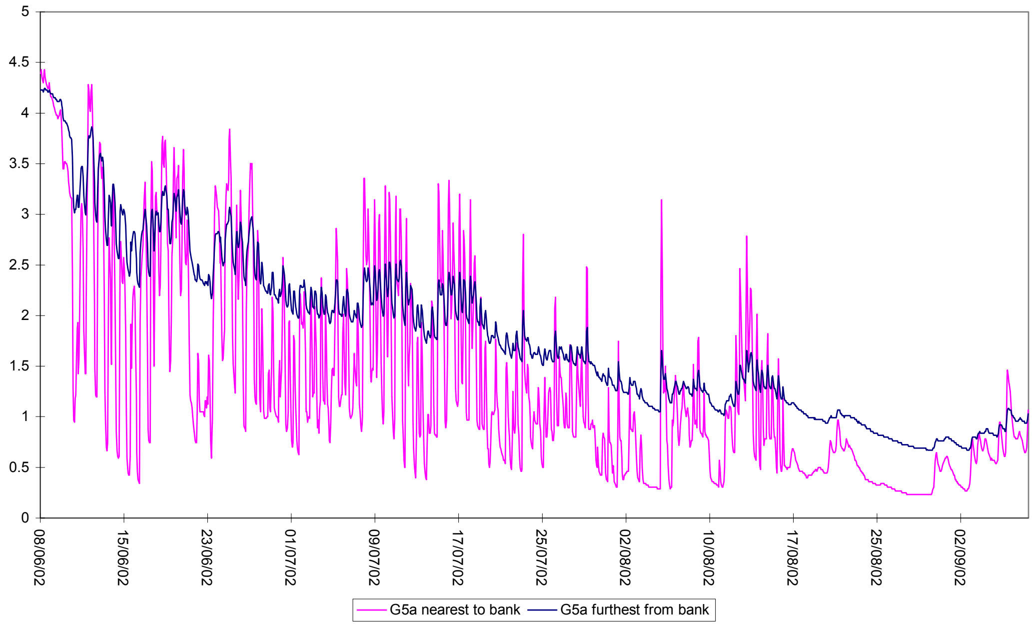


Figure 6.2. Water level data from two piezometers located just downstream of the dolines at G5a. The bores were located in the sediment at the river bank and some 25 m inland. The data reflect the effects of river level fluctuations. All data in meters above arbitrary reference levels.

A7 Riparian vegetation

A7.1 Riparian vegetation dynamics and the influence of flow regulation

Riverbanks are dynamic and highly changeable environments that respond to a range of disturbance types and frequencies. Riverside, or *riparian* vegetation is made up of plant species that can inhabit the active riverbanks between the low water mark and high flood levels. Plant life forms range from mosses to tall trees, and individual species have a variety of survival strategies for coping with the environmental variability and disturbance regimes. The riparian vegetation community responds to many environmental factors, including stream energy, bank and valley steepness, geology, sediment loads and the variability in river flows.

Riparian vegetation corridors are widely considered to provide an important corridor for the dispersal of plant species (Gregory *et al.* 1991, Nilsson *et al.* 1994). Riparian vegetation has importance for in-stream habitat and nutrient supply, as well as playing a major role in maintaining lateral bank stability, by diminishing the erosive effects of the flowing water (Abernethy and Rutherfurd 1999). It follows that the health and condition of riparian vegetation is an important factor in the ecological soundness of the in-stream and nearby terrestrial habitat areas.

A regulated river has a flow pattern that is changed from natural. The regulation, usually in the form of impoundment or abstraction, alters the downstream hydrological and riparian habitat conditions. This alteration may impact on the riparian vegetation communities, and the nearby communities dependent on the riparian zone. If the continuity of the riparian zone is altered or interrupted by regulating structures such as dams and weirs, downstream riparian communities may be affected. This is most marked if the community relies on recruitment from upstream communities to maintain its population. This recruitment may be in the form of viable seeds or twigs washing downstream, a common riparian plant life reproduction strategy. Dams are known to be a fragmenting influence on a riparian corridor and often act as a barrier to long-distance downstream plant dispersal (Jansson *et al.* 2000) and subsequently impact on species composition.

The species richness of riparian communities is often significantly lower in regulated rivers than in unregulated rivers (Jansson *et al.* 2000). Downstream impacts from river regulation include changed water levels, which may mean extended periods of inundation or extended periods of very low flows, and in many cases, both. These alterations to the natural river hydrology may increase erosion rates, alter soil water levels and potentially produce environmental conditions outside the tolerance levels of the riparian species. This may lead to plant death and/or failure of plant recruitment, leading to changes in the vegetation community. If the disturbance regime is too frequent or too severe, the riparian vegetation may be removed entirely.

The impacts of river regulation on riparian communities have been widely studied throughout the world; however, the relationships between changed river flows and losses in ecological integrity remain poorly understood (Jansson *et al.* 2000). The impact of regulation on the Gordon River in comparison to near-by unregulated rivers has been investigated as part of the Basslink Integrated Impact Assessment by Davidson and Gibbons (2001).

A7.2 Methods

A7.2.1 Measures of cover

Percentage overlapping cover values estimated to the nearest percent were recorded for ground cover species, small shrubs (<1 m), bare ground, litter, root exposure, rock and mosses.

A7.2.2 Tree and shrub density and stem size

Measures of tree and large shrub density were obtained by stem counts within a belt transect located within the quadrat area and up to 5 m into the adjacent vegetation. The position (along the tape) and size of trees and large shrubs rooted within 1.5 m of the central tapeline were recorded forming a 3 m belt transect of varying length. These data were classified into size classes representing the diameter (width) of the stem at the base: 1-5 cm; 6-10 cm; 11-20 cm and >20 cm.

A7.2.3 Condition of vegetation

The relative health of the vegetation within the quadrat was assessed through visual detection of indicators of poor health from factors such as inundation and waterlogging. Presence of indicators including chlorosis (yellowing) of older leaves, premature leaf fall, growth of adventitious roots and wilting were noted for woody species, in particular, tea tree.

A7.2.4 Ground conditions and litter

Measurements of ground conditions and species were taken along each permanent transect running perpendicular to the river. Ground conditions were classified into the following classes:

- FF - Forest with floor litter intact (not regularly inundated);
- MD - Moderately disturbed - some inundation apparent; and
- HD - High disturbance little or no vegetation cover.

A7.2.5 Seedling recruitment

Recruitment was assessed within quadrats by counting and measuring seedlings of all species and grouping these within three height classes (<5 cm; 5 <10 cm; 10 <15 cm). Some seedlings were not readily identifiable to species and have been recorded as dicotyledons or monocotyledons. These data were recorded as number of seedlings within each quadrat. Where numbers of seedlings for a species were very high and exceeded 10, the measure was recorded as >10 and an average height given.

A7.2.6 Data analysis

A7.2.6.1 Ordination and vector fitting

Ordination is an exploratory tool that orders vegetation samples in space in relation to each other depending on similarity of species composition and environmental factors. The similarities of the quadrats are calculated and plotted in space as a point in a coordinate system and represented in 'scatter diagrams' (Kent and Coker 1994). These diagrams are commonly in two or three dimensions. The further apart, or greater the 'distance', between a pair of points, then the more they differ in the species composition of the sites; conversely the closer together sites are, the more similar they are in species composition.

Ordination diagrams therefore also display similarities between sites. Similar sites will have a tendency to cluster together. In this way, data can be explored to assess if expected groupings are occurring; such as differences between quadrats according to their position on the bank or location within a zone.

The relationship between trends in the ordinations and environmental variables, such as river or quadrat type, can be explored using vector fitting. Vector fitting shows whether the species data is responding in a systematic way to an environmental variable (Kent and Coker 1994).

Indirect gradient analysis was used to produce non-metric multidimensional scaling (NMS) ordinations of species composition for all quadrats. Analyses were undertaken in PC-ORD using the 'slow and thorough' autopilot setting (400 iterations, starting at six dimensions with 40 real runs and 50 randomised runs) using the robust Bray-Curtis dissimilarity co-efficient (Bray and Curtis 1957, Faith *et al.* 1987, Minchin 1987) for all ordinations (McCune and Mefford 1999). The optimal ordination solution was selected by assessing the number of dimensions at which subsequent reductions in stress were small on a stress versus dimensionality plot (McCune and Grace 2002). Stress figures are given in PC-ORD scale; this scale should be divided by 100 when comparing with the 'rules of thumb' for acceptable stress solutions developed by Kruskall (1964) and Clarke (1993). Solutions with stress values greater than 20 (0.2) have been rejected in the present study due to increasing likelihood of misleading interpretations above this level (Clarke 1993).

The PRIMER multivariate statistics software package was used to analyse the vegetation data compiled. The SIMPER program was then used to determine which, if any, species or taxa vegetation were contributing most to the degree of similarity and dissimilarity within and between groups of sites on the basis of that abundance.

A7.2.6.2 .Correlations between erosion and seedling density

Correlations between the mean erosion change measured from erosion pins and the mean density of seedlings was undertaken for all seasons using the Spearman's rho non-parametric correlation. Spearman's rho is a rank-order correlation coefficient which measures association at the ordinal level. This is a nonparametric version of the Pearson correlation based on the ranks of the data rather than the actual values. Data for the correlations were grouped into the geomorphic zone units presented in chapter 7 which group zones 2 and 3 and zones 4 and 5.

A7.2.6.3 Analysis

Belt transect tree data were stratified into two 3 m wide zones based on regulated water level and standardised to provide a total density per 9 m^2 (plot) measurement. For species recorded in sections of the bank normally inundated at regulated flow were classified as the 'below regulated flow' area and trees rooted in the areas above this were classified as the 'above regulated flow' area. These data were analysed tested for different effects between years using ANOVA with post-hoc tests using Tukey's HSD test if appropriate.

Vegetation cover data analyses were stratified by quadrat type due to obvious and substantial differences in disturbance regimes and periods of inundation. For most analyses, the channel data from the lowest position on the bank were excluded due to the high frequency of zeros in the data particularly for vegetation cover variables.

Species and ground cover data were analysed using repeated measures analysis of variance (ANOVA) to test the effect of year and zone (Quinn and Keough 2002). Zone was added as a between subjects factor in all ANOVA analyses. Polynomial contrasts were examined for significant interactions to determine the nature of any significant trends in the data, that is, whether trends were linear, quadratic or cubic. Following analysis, residuals were plotted against estimated values for a normal distribution to ensure test assumptions were fulfilled.

All other data were explored for normality and, where necessary, skewed distributions and outliers in the species data were corrected using a $\log_{10}$ transformation. Because $\log_{10}$ transformation converts zeros to missing values that would bias analyses, a constant value (1) was added to all data prior to transformation (Quinn and Keough 2002). Arcsine transformations proved more effective in correcting the percentage cover data for the dependent variables 'total vegetation cover' and 'total bare substrate'.

Species richness data were tested for different effects between years using ANOVA with post-hoc tests using Tukey's HSD test where appropriate. If data could not be corrected with transformations or failed Levene's tests, the non-parametric equivalent of one-way ANOVA, the Kruskal-Wallis test was undertaken on data with greater than two factors or groups (Dytham 2003). Post-hoc testing was done using Mann-Whitney tests on all permutations of the pairs.

Seedling data were grouped into total seedling numbers for statistical analyses due to the sparseness of individual species data and high frequency of zeros. Data were stratified into quadrat type groups and analysed using repeated measures ANOVA. Multiple patterns were present in these data including strong seasonal, year and zone effects. Due to the complexity of these patterns and the possibility of further undetected patterns in the data, ratios of seedlings between the above high water quadrats and other quadrats were analysed. Chapter 4 Design and inference (volume 1) provides a detailed rationale of this approach. All analyses were undertaken in the statistical package SPSS version 13.

A7.3 Results

A7.3.1 Riparian vegetation photo-monitoring - examples of differences in photos

A7.3.1.1 Contraction of ground layer 2002-04

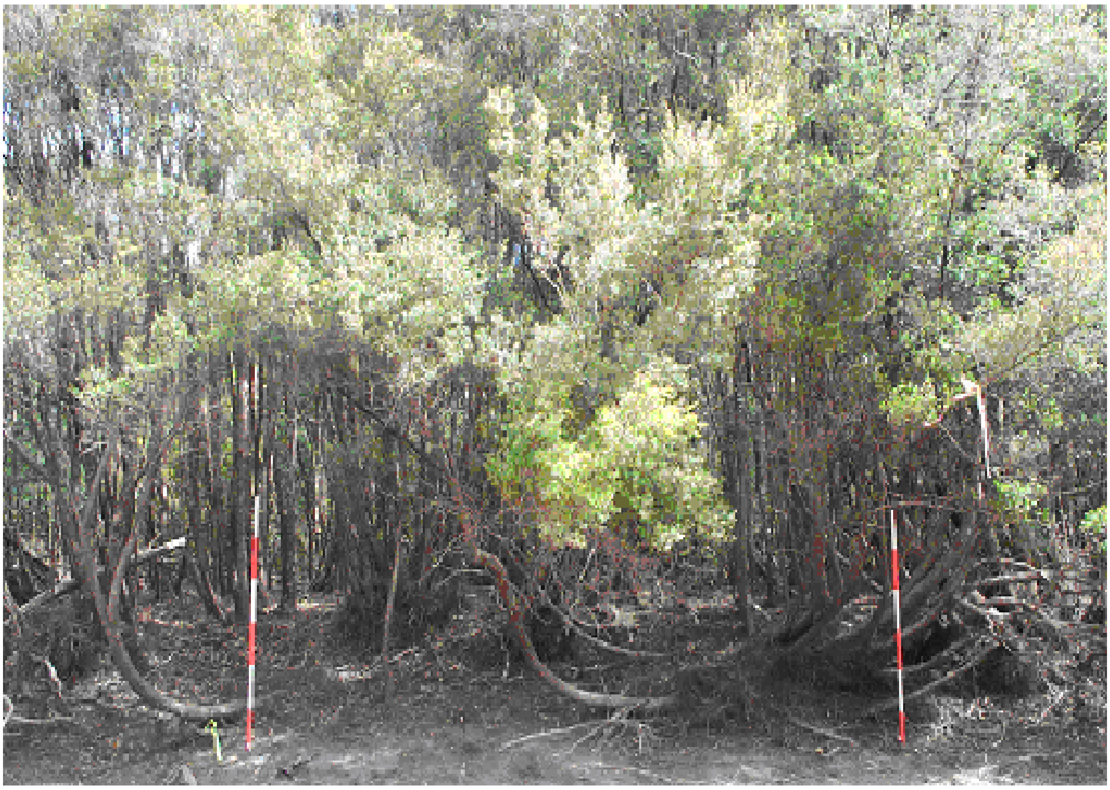
Site 4, zone 3, December 2002

Site 4, zone 3, December 2003

Site 4, zone 3, December 2004

A7.3.1.2 Contraction of canopy layer 2002-04

Site 11, zone 2, December 2002



Site 11, zone 2, December 2003

Site 11, zone 2, December 2004

A7.3.1.3 Expansion of ground layer 2002-04

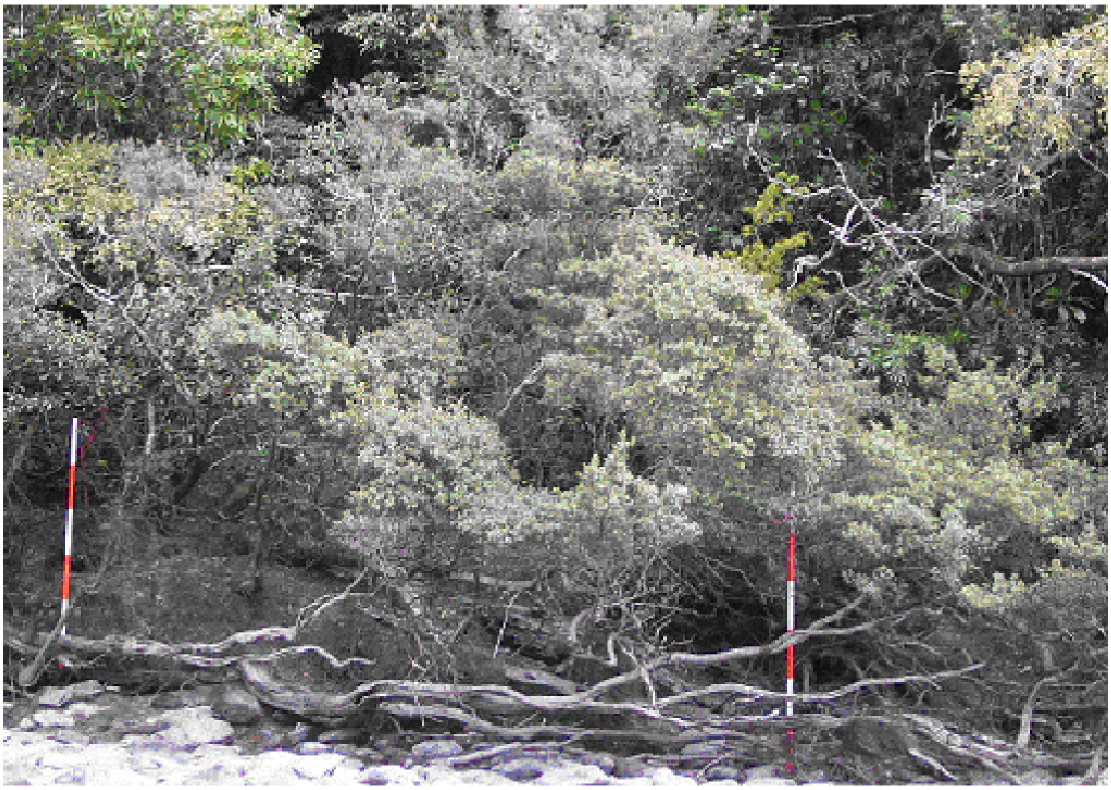
Site 6, zone 5, December 2002

Site 6, zone 5, December 2003

Site 6, zone 5, December 2004

A7.3.1.4 Expansion of canopy layer 2002-03 and 2003-04

Site 5, zone 5, December 2002



Site 5, zone 5, December 2003

Site 5, zone 5, December 2004

A7.3.2 Results for the Gordon River

A7.3.2.1 Trees and large shrubs

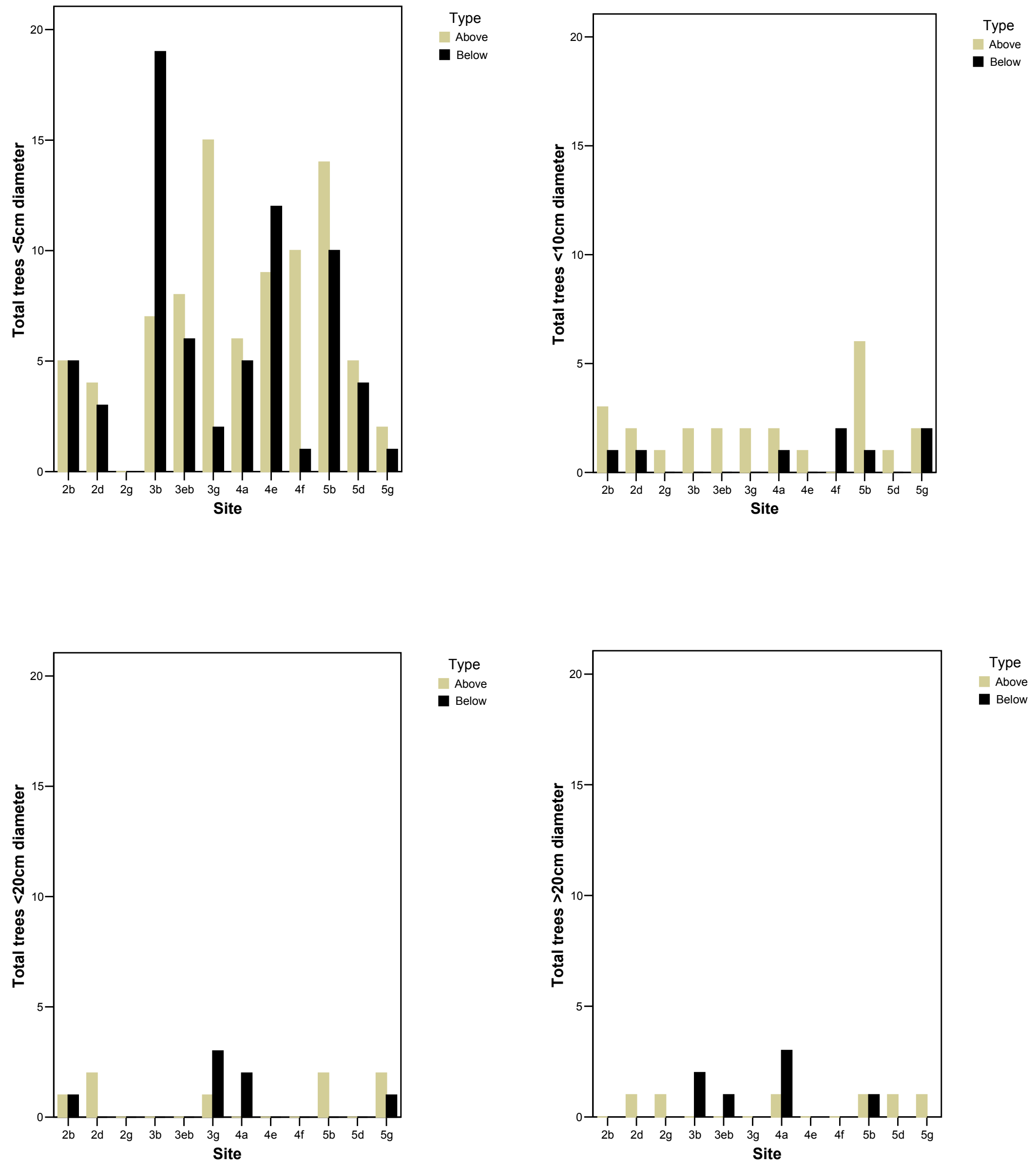


Figure 7.1. Total numbers of tree and large shrub species in four size classes in the Gordon River by site.

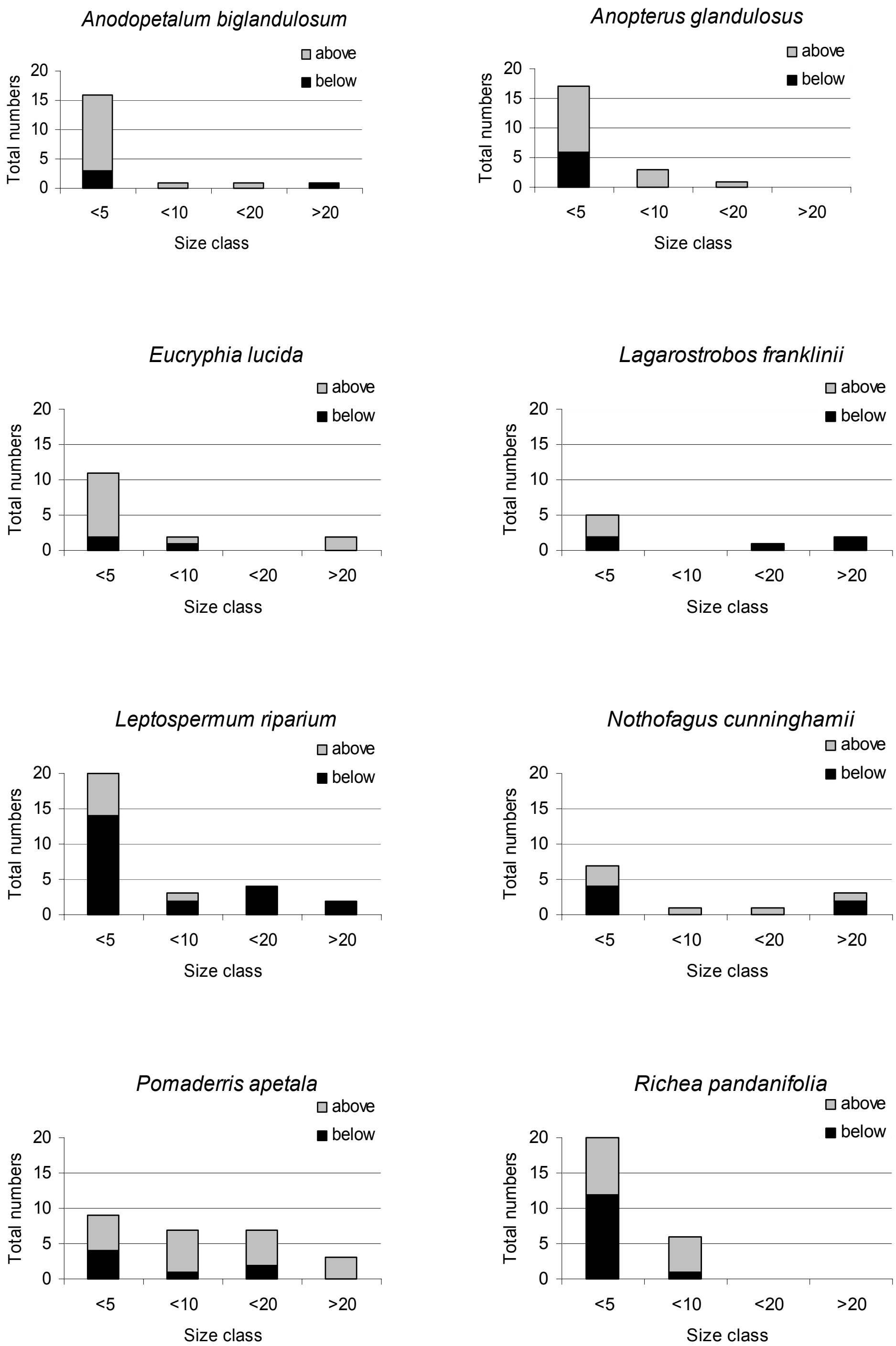


Figure 7.2 Size class distribution (cm) of most abundant tree and shrub species measured in belt transect for ‘above regulated water level’ (above) and ‘below regulated water level’ (below) quadrats.

Total vegetation cover, bryophytes, ferns, small shrubs, graminoids, grasses and herbs

Table 7.1. Summary of life form cover data by all zones in the Gordon River.

		Monitoring event									
		April 2002		April 2003		April 2004		April 2005		Total	
Zone		Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean
2	Bryophytes	5.80	2.70	4.72	2.13	3.04	1.12	4.18	2.14	4.43	1.04
	Ferns	7.97	1.76	7.63	1.86	4.92	1.22	5.42	1.09	6.48	.76
	Graminoids	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	Grasses	.09	.06	.21	.12	.17	.10	.18	.17	.16	.06
	Herbs	.00	.00	.00	.00	.04	.04	.01	.01	.02	.01
	Shrubs	.25	.17	.67	.42	1.13	.41	.37	.22	.60	.17
	Trees	2.17	1.02	1.21	.65	1.42	.55	.84	.48	1.41	.35
3	Bryophytes	21.47	6.08	19.51	5.23	13.54	4.21	22.48	5.63	19.25	2.65
	Ferns	3.78	1.34	2.34	1.08	2.38	1.04	3.73	1.83	3.06	.67
	Graminoids	.86	.64	1.27	.70	1.58	1.01	1.51	1.08	1.31	.43
	Grasses	.01	.01	.00	.00	.04	.04	.00	.00	.01	.01
	Herbs	.44	.26	.10	.08	.13	.09	.09	.08	.19	.08
	Shrubs	1.58	.63	.78	.39	1.25	.41	.94	.35	1.14	.23
	Trees	.55	.16	1.10	.40	.96	.45	1.80	1.03	1.10	.30
4	Bryophytes	4.13	1.67	7.99	1.77	8.87	2.68	15.01	4.28	8.92	1.37
	Ferns	3.02	1.27	6.11	1.68	3.33	1.48	4.97	2.22	4.49	.85
	Graminoids	1.47	.65	.61	.31	1.08	.54	.24	.13	.83	.22
	Grasses	.80	.36	.10	.05	.88	.35	.60	.33	.56	.14
	Herbs	.50	.20	.23	.09	1.04	.26	.34	.17	.50	.09
	Shrubs	8.42	2.66	5.12	1.58	8.38	2.29	9.93	2.80	7.74	1.14
	Trees	1.23	.51	.21	.14	1.08	.35	1.47	.46	.94	.19
5	Bryophytes	12.52	4.35	9.31	2.93	11.38	4.28	9.44	3.38	10.66	1.87
	Ferns	1.85	.97	1.80	1.11	.83	.55	2.21	1.32	1.68	.51
	Graminoids	.02	.01	.21	.21	.04	.04	.48	.42	.19	.12
	Grasses	2.27	1.05	1.98	1.08	6.42	3.20	1.30	.68	2.99	.91
	Herbs	.67	.39	1.13	.62	1.25	.52	1.08	.68	1.03	.28
	Shrubs	4.28	1.71	3.32	1.53	4.75	1.55	2.27	1.42	3.66	.77
	Trees	1.26	1.13	1.18	1.04	2.21	1.36	.05	.04	1.17	.51

Table 7.2. Summary of ground cover data by all zones for the Gordon River.

		Monitoring event									
		April 2002		April 2003		April 2004		April 2005		Total	
Zone		Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean	Mean	Std. Error of Mean
2	Coarse woody debris	6.79	1.87	7.50	1.32	9.29	2.49	9.04	2.16	8.16	.99
	Litter	33.42	6.21	28.42	5.17	25.46	5.47	19.88	5.35	26.79	2.78
	Total Bare Substrate	53.30	7.65	62.55	7.00	60.58	7.01	66.68	6.55	60.78	3.51
3	Coarse woody debris	2.71	.69	6.29	1.46	8.21	2.03	6.71	1.45	5.98	.76
	Litter	13.42	4.13	10.55	3.51	7.42	3.12	10.36	3.32	10.44	1.76
	Total Bare Substrate	76.21	7.91	71.71	6.51	71.04	6.51	61.89	6.83	70.21	3.47
4	Coarse woody debris	1.67	.70	4.51	1.41	6.96	2.29	11.83	4.38	6.11	1.26
	Litter	4.04	1.96	11.83	3.56	12.46	4.68	11.18	3.46	10.03	1.80
	Total Bare Substrate	61.92	5.94	68.17	5.05	69.75	6.25	53.72	6.33	63.76	2.94
5	Coarse woody debris	8.96	2.08	9.01	2.29	8.75	2.48	7.12	1.91	8.46	1.09
	Litter	10.58	2.00	15.67	3.13	17.58	5.09	19.76	4.33	15.90	1.91
	Total Bare Substrate	67.35	5.89	62.75	5.71	55.96	7.32	57.67	6.25	60.93	3.14

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A8 Macroinvertebrates and benthic algae

A8.1 Benthic macroinvertebrates

A8.1.1 Sampling

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

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

Two sets of RBA samples and one set of quantitative surber samples were collected at each site, from riffle habitat in or immediately adjacent to the main river flow.

All surber samples from a site were pooled and preserved (10 % formalin) prior to lab processing. Samples were elutriated with a saturated calcium chloride solution and then sub-sampled to 20 % using a Marchant box subsampler, and random cell selection. The subsamples were then hand picked and all fauna identified to family level with the exception of Oligochaetes, Turbellaria, Hydrozoa, Hirudinea, Hydracarina, Copepoda and Tardigrada. Chironomids were identified to sub-family.

All RBA samples were live-picked on site for 30 minutes, with pickers attempting to maximise the number of taxa recovered. All taxa were identified to the same taxonomic levels as described above.

A8.1.2 Habitat variables

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

A8.1.3 Data analysis

All RBA data was analysed using the combined-season Hydro RIVPACS models developed by Davies *et al.* (1999). O/Epa and O/Erk values were derived using the RBA macroinvertebrate data in combination with key 'predictor' habitat variables. Data from the RBA samples were also analysed using single-season (autumn and spring) Hydro RIVPACS models developed for this program during 2001, from the original reference site data sets used to develop the combined season models (see methods in Davies *et al.* 1999).

A suite of multivariate and univariate data analyses will be conducted following the completion of the post-Basslink phases of the program to evaluate changes associated with Basslink operations.

A8.2 Algal sampling

A8.2.1 Gordon River sites

All algal assessment at Gordon River sites was conducted by measuring % area of cover at fixed distances along existing transects across the river, with one transect assessed at each site. All Gordon River data was collected as follows:

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

The transect was also divided into broadly similar 'zones', characterised by consistency of benthic substrate composition. Zones were defined following visual inspection of the channel substrate, and defined in terms of their dominant substrate composition (cobble/gravel, sand/silt, sand/snags, bedrock)

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

A8.2.2 Reference sites

Sampling at reference sites commenced in 2004. Plant cover was assessed at 30 randomly chosen locations across the channel on the dominant substrate (typically cobbles and boulders) using the same quadrat procedure described above. It should be noted that bedrock substrate and backwater features were not sampled. Data comparability between these sample sets and those for the Gordon River is therefore restricted to filamentous benthic algae only.

A8.2.3 Data analysis

A suite of multivariate and univariate data analyses will be conducted following the completion of the post-Basslink phases of the program to evaluate changes associated with Basslink operations.

A9 Fish

A9.1 Establishing capability of fish monitoring to detect Basslink change

Data are provided in the form of catch (number of fish) and effort (length of stimulus) of fish classified into species over six collection periods comprising three consecutive summers and following autumns.

The points of collection comprise sites in five zones of the Gordon River. For some zones additional data are provided from sites in tributaries that are presumed to be influenced by water flow patterns in the main river.

For the purpose of statistical analysis the low density of fish necessitated two forms of combination – data from all sites within a zone were pooled to provide a single catch and single measure of effort within each zone at each time of collection, and results for different species were combined into four groupings (all fish, native fish, trout and galaxiids).

The variable employed in all statistical analyses is the catch per unit effort (CPUE).

As a precursor to establishing the capability of using CPUE values from the combination of five zones at six times of measurement per zone an analysis is performed to determine if there is a temporal trend evident for any grouping. It is established:

- For trout and galaxiids there is evidence of a trend and evidence that the trend varies among zones. Given the fact that there is no replication at zone level it is concluded that the tests for the presence of a Basslink effect cannot be based on trout and galaxiids since it is not possible to separate a real change after Basslink from sampling variation; and
- For "all fish" and "native fish" there is no evidence of a temporal trend[2]. Hence the CPUE for these quantities is suitable for testing for a Basslink effect.

Power analysis establishes that based on the CPUE values collected over three years pre- and three years post-Basslink monitoring:

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[2] The fact that trends evident in trout and galaxiids are not evident in the data for native fish and all fish would suggest that there is perhaps a correlation between levels of different species such that larger numbers of one species are associated with lower numbers of others.

- for “all fish” there is a high probability (0.8) that testing can detect a change as small as a doubling or halving in fish numbers; and
- for “native fish” there would need to be between a three and four-fold change in numbers to have a high probability (0.8) of detection of the change.

A9.2 Scope

Data are provided in the form of catch and effort for selected sites in Gordon River zones and tributaries for a number of fish species over the pre-Basslink monitoring period that covers three summer and three autumn monitoring periods from December 2001 to April 2004.

For the purpose of detecting Basslink-related changes the statistical modeling and analysis focuses on the data collected at sites in zones 1 to 5, with data from tributary sites included with the associated river zone sites where it is anticipated that the tributary sites are affected by altered flow rates from the dam.

A9.3 Variable and data

The variable employed in the analysis is the catch per unit effort (CPUE) which is formed as the ratio of total catch to total effort in a common monitoring period at the collection of sites within each zone.

It is noted that while the design allows for individual sites to be the basic units, the generally low catch rates necessitate the pooling of data from sites in a common zone.

Pooling is also necessary across species because of low catch rates. On the advice of the fish expert (Dave Andrews) the following groupings are employed for the purpose of statistical analysis:

- All natives (G. *brevipinnis*, G. *maculatus*, G. *truttaceus*, A. *australis*, G. *australis* and M. *mordax* present in all zones);
- Galaxiids (*G. brevipinnis*, *G. maculatus* and *G. truttaceus*, consistently present in zones 4 and 5, with isolated occurrences further upriver); and
- Trout (*S. trutta*, present in all zones)

Additionally, a variable formed by combining the catches of all fish is employed on the grounds that variability is reduced by pooling.

For statistical purposes the data structure is as follows with each "x" representing a CPUE value:

Monitoring time	**1**	**2**	**3**	**4**	**5**	**6**
Year	2001-02		2002-03		2003-04	
Season	Summer	Autumn	Summer	Autumn	Summer	Autumn
Zone 1	x	x	x	x	x	x
Zone 2	x	x	x	x	x	x
Zone 3	x	x	x	x	x	x
Zone 4	x	x	x	x	x	x
Zone 5	x	x	x	x	x	x

A9.4 Aims

- **Pre-Basslink trends.** To determine if there is evidence of a trend over time in any zone; and
- **Capability of detecting a Basslink effect.** To construct power curves based on the assumption of a step-change after the implementation of Basslink.

A9.5 Statistical models and modeling

A9.5.1 Transformation of CPUE values

For statistical purposes the CPUE values are transformed to a logarithmic scale since it is determined that additive models and standard methodology can be then applied. The symbol y employed for responses in the following models represents logarithms of CPUE values.

A9.5.2 Pre-Basslink trends

A model is fitted to the data that assumes a linear relation between log CPUE and time of sampling and allows for possible differences in the intercepts and slopes of lines among zones. This we refer to as the "full model".

The model equations are:

$$y_{ijk} = \alpha_{ij} + \beta_{ij} t_{ijk} + e_{ijk} \quad \text{for } i = 1,2,\ldots,5;\ j = 1,2;\ k = 1,2,3,\ldots \quad (1)$$

where y_{ijk} is log CPUE in zone i, season j of year k, t denotes monitoring time, α and β are the intercept and slope with subscripts defining combinations of zone and season, and e is the unexplained component.

If there is no evidence of trend across time at any site, the "minimal" model equations are

$$y_{ijk} = \alpha_{ij} + e_{ijk} \quad \text{for } i = 1,2,\ldots,5;\ j = 1,2;\ k = 1,2,3, \qquad (2)$$

where the α_{ij} terms represent the combined effect of differences in mean CPUE among zones and seasons.

There is potential for both spatial and temporal correlation. In fact the correlation structure could possibly be complex if there is migration of fish up the river because the spatial correlation would then have a temporal component. Given the limited amount of data and lack of information from previous studies the view is taken that it is not practical to attempt to model the correlation structure. Hence, for the purpose of analysis the e_{ijk}-terms are presumed independent. They are also assumed to have been generated from identical Normal distributions.

Standard regression analysis is employed in the course of model fitting. Models are fitted sequentially commencing with the full model (1), and with terms associated with the slope component progressively removed as they prove to be not significant following path that ends with the minimal model (2). In effect the term β_{ij} is decomposed into the following components:

$$\beta_{ij} = \beta_0 + \beta_{1i} + \beta_{2j} + \beta_{3ij}$$

Components are examined one at a time commencing with the term on the right-hand side. A term is removed if the associated p-value is less than 0.05. Each time a term is removed a new model is fitted with that term excluded.

A9.5.3 A model that includes a Basslink effect

On the assumption that there is no trend in the pre-Basslink period but there may be a step change with the introduction of Basslink[3], the model that is fitted is based on the following model equations:

[3] To determine the ability of statistical analysis to detect a change, the nature of the possible change must be identified. In the model employed in this document it is presumed that the post-Basslink change is reflected in a constant average increase or decrease in CPUE. Another possibility would be that the Basslink effect is reflected in an increasing or decreasing effect over time. If required a power analysis under a different choice of alternative model could be constructed.

$$
\begin{aligned}
y_{ijk} &= M + Z_i + S_j + (Z.S)_{ij} + e_{ijk} && \text{for } i = 1,2,\ldots,5; j = 1,2; k = 1,2,3 \\
&= M + \delta + Z_i + S_j + (Z.S)_{ij} + e_{ijk} && \text{for } i = 1,2,\ldots,5; j = 1,2; k = 4,5,\ldots,r
\end{aligned}
\quad ,\ldots \text{ (2)}
$$

where y_{ijk} is log CPUE in zone i, season j and year k; M is the long-term mean, Z and S allow for zone and season differences and (Z.S) allows for the possibility that seasonal differences are not the same in all zones; δ is the change in mean level in the post-Basslink period that is present in years 3,4,..,r; and e is the unexplained component. Distributional assumptions are as described above.

A9.6 Statistical methods

Analysis of variance is employed with F-tests to test hypotheses.

Assuming the model that contains the model equations in (2) a test for a Basslink effect is a test of the hypothesis δ=0 versus the alternative $\delta \neq 0$. The power of the test is determined as

$$\beta = \Pr[F(1, \nu, \lambda)] > F_\alpha(1, \nu),$$

where

$F(1,\nu,\lambda)$ is a non-central F variate with degrees of freedom 1 and ν and non-centrality parameter $\lambda = \delta^2 / [\sigma^2 (1/n_1 + 1/n_2)]$ where n_1 is the number of pre-Basslink observations (6 in this study), n_2 is the number of post-Basslink observations (two, four or six in this study, i.e., one, two or three years of monitoring post-Basslink), and σ^2 is the variance of y, an estimate of which is supplied by the residual mean square of the minimal model fitted for the purpose of power analysis.

$F_\alpha(1,\nu)$ is the tabulated value for an F distribution with 1 and ν degrees of freedom that satisfies $\Pr[F > F_\alpha(1,\nu)] = \alpha$ Thus α is the type 1 error rate.

A power curve is constructed as the graph of β versus δ.

A9.7 Results

A9.7.1 Tests for a pre-Basslink trend

Note: The fit of models that produce the following results are accompanied by model and data checking based on fitted values and residuals. Unless otherwise stated, these checks establish that (i) the linearity assumption is reasonable, and (ii) the Normality assumption and equality-of-variance assumptions are reasonable.

A9.7.1.1 All fish

The fit of the full model provides the following output.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Time	1	0.304679	0.304679	1.558569	0.24
Zone	4	6.743675	1.685919	8.62422	0.00
Season	1	0.038013	0.038013	0.194455	0.67
Time:Zone	4	0.653159	0.16329	0.835299	0.53
Time:Season	1	0.199884	0.199884	1.022494	0.34
Zone:Season	4	0.408934	0.102234	0.52297	0.72
Time:Zone:Season	4	0.438097	0.109524	0.560265	0.70
Residuals	10	1.954865	0.195487		

Progressive elimination of time-based components in the model yields the minimal model that fits the data. This model requires no trend across time.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Zone	4	6.743675	1.685919	10.06275	0.00
Season	1	0.121124	0.121124	0.722956	0.41
Zone:Season	4	0.525697	0.131424	0.784432	0.55
Residuals	20	3.35081	0.167541		

There is strong evidence of zonal differences but not of seasonal differences.

The residual mean square (0.1675) is employed as the variance estimate in the construction of power curves below.

A9.7.1.2 Trout

Residual analysis based on the logarithm of CPUE indicates that variability increases with increasing means. This is illustrated in Figure 9.1.

The variability is most pronounced in zone 3 and zone 4 spring results.

Table 9.1. CPUE results for zone/season combinations.

Zone	Season	Year	CPUE
3	Autumn	2002	1.62
3	Autumn	2003	3.47
3	Autumn	2004	2.30
3	Spring/Summer	2001/02	7.50
3	Spring/Summer	2002/03	1.59
3	Spring/Summer	2003/04	13.36
4	Autumn	2002	2.26
4	Autumn	2003	2.62
4	Autumn	2004	2.18
4	Spring/Summer	2001/02	3.24
4	Spring/Summer	2002/03	0.77
4	Spring/Summer	2003/04	3.12

Further analysis was restricted to the subset of data from zones 1, 2 and 5. This revealed temporal trends in the data which were different among the three zones.

Given that there is insufficient data to analyse data separately for each zone, the conclusion is reached that the use of trout as a single species may not be able to provide a reliable indicator of a Basslink effect.

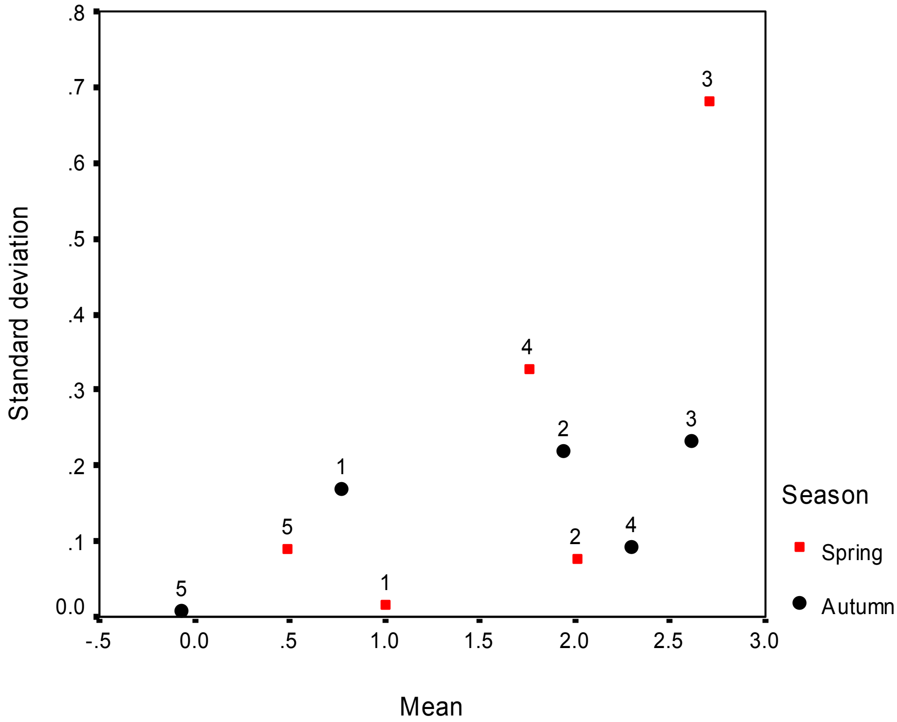

Figure 9.1. Plot of standard deviation versus mean where the standard deviations are computed from residuals derived from fitting the full model.

A9.7.1.3 Native fish

The fit of the full model provides the following output.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Time	1	1.359215	1.359215	2.291389	0.16
Zone	4	34.53664	8.634159	14.55562	0.00
Season	1	0.032852	0.032852	0.055382	0.82
Time:Zone	4	1.373841	0.34346	0.579011	0.68
Time:Season	1	1.524714	1.524714	2.570389	0.14
Zone:Season	4	0.536359	0.13409	0.226051	0.92
Time:Zone:Season	4	1.112281	0.27807	0.468776	0.76
Residuals	10	5.931839	0.593184		

Progressive elimination of time-based components in the model yields the minimal model that fits the data. This model requires no trend across time.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Zone	4	34.53664	8.634159	15.94737	0.00
Season	1	0.26485	0.26485	0.48918	0.49
Zone:Season	4	0.777931	0.194483	0.359211	0.83
Residuals	20	10.82832	0.541416		

There is strong evidence of zonal differences but not of seasonal differences.

The residual mean square (0.5414) is employed as the variance estimate in the construction of power curves below.

A9.7.1.4 Galaxiids

Galaxiid numbers are only sufficient for analysis in zones 4 and 5. The fit of the full model provides the following output.

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Time	1	0.005677	0.005677	0.032805	0.87
Zone	1	3.895287	3.895287	22.51081	0.01
Season	1	0.278028	0.278028	1.606723	0.27
Time:Zone	1	0.888506	0.888506	5.134664	0.09
Time:Season	1	0.059752	0.059752	0.345307	0.59
Zone:Season	1	0.342157	0.342157	1.97732	0.23
Time:Zone:Season	1	1.555292	1.555292	8.988011	0.04
Residuals	4	0.692163	0.173041		

The fact that the "time × zone × season is significant indicates that there are trends across the three years in galaxiid numbers and these trends are not consistent in zones 4 and 5.

Given that there is insufficient data to analyse data separately for each zone, the conclusion is reached that the use of galaxiids as a group may not be able to provide a reliable indicator of a Basslink effect.

A9.7.2 Power analyses

Power curves are presented in Figure 9.2. In each plot there are power curves for detection of a change after one, two or three years of post-Basslink data and assuming three years of pre-Basslink data. All curves are based on a type 1 error rate of 0.05.

The use of "all fish" will require the smallest change in mean CPUE levels for a high probability of detection of change. Adopting a power of 0.8 as a yardstick, then a doubling or halving in trout numbers over three years of post-Basslink monitoring would provide sufficient evidence of change.

Native fish require a larger change to detect a Basslink effect. Adopting a power of 0.8 as a yardstick, then more than a three-fold change in native fish numbers over three years of post-Basslink monitoring would provide sufficient evidence of change.

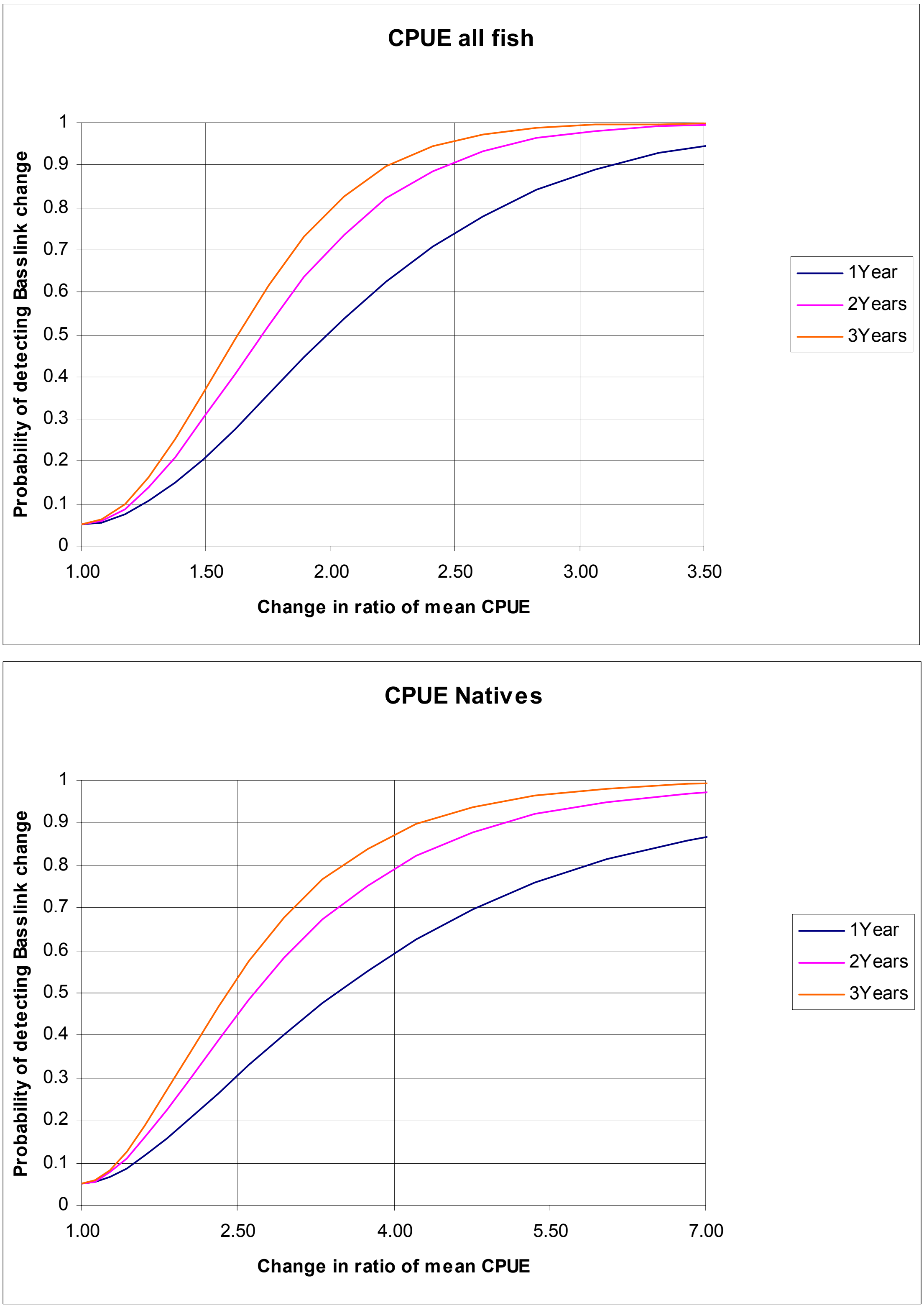

Figure 9.2 Power analyses for detection of Basslink changes.

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