Ecological Assessment of the Lower Reaches of Cashmere Stream

Prepared for
Christchurch City Council

Prepared by
EOS Ecology

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environmental consultants

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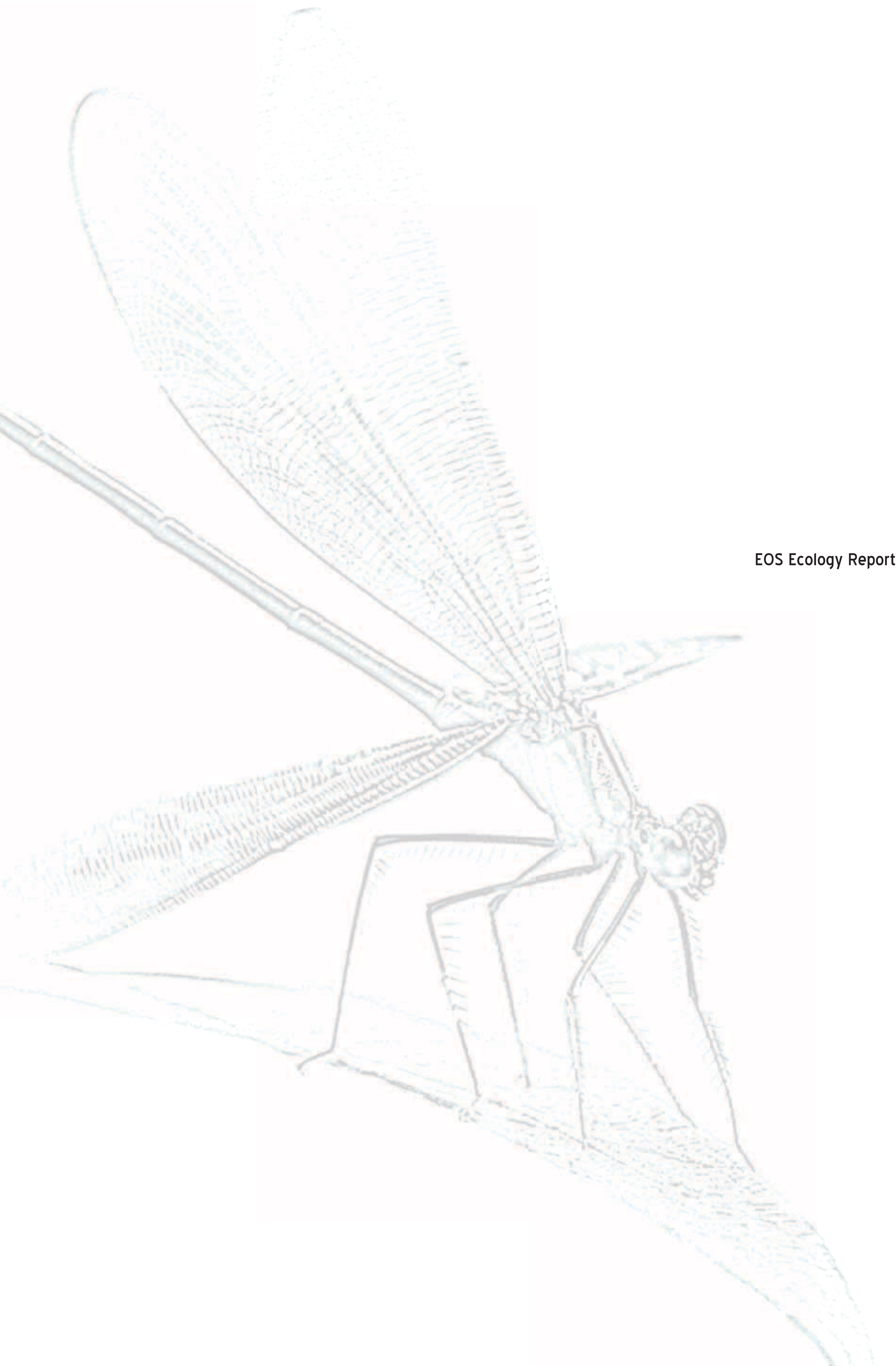

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EXECUTIVE SUMMARY

This survey was intended to address the requirements of a long-term monitoring programme for the lower reaches of Cashmere Stream, which is soon to undergo some restoration in conjunction with urban development on the southern side of the river. The main goal of this project was to provide baseline data that could be used in the future to accurately assess any change in instream environment, terrestrial environment, and biological communities over time.

EOS Ecology surveyed the instream habitat, riparian habitat, and aquatic invertebrate community at 12 sites between Worsleys Road and Penruddock Rise bridges, on the 1st to the 3rd of November 2005. In addition, the terrestrial invertebrate community (most specifically the adult phase of aquatic insects) was sampled at the same 12 sites using sticky traps (flight interception traps) placed out from the 8th to 14th of November 2005

The results indicated a habitat typical of a New Zealand lowland rural or peri-urban stream with a depauperate invertebrate fauna characterised by few EPT taxa and low ecological values. The total invertebrate diversity was 42 taxa, with the most abundant taxa being the seed shrimps (Crustacea: Ostracods; ca. 37%) followed by orthoclad midges (ca. 22%). The results indicated this section of Cashmere Stream had lower biological values than recently surveyed sites further upstream. The presence of Kakahi, the freshwater mussel, was a notable highlight, but preliminary data suggests that this is an ageing population with little or no recruitment of juveniles. However, further research is required to confirm this.

Sticky trapping reflected the low EPT diversity found in the aquatic habitat. However, the stream still contributed a relatively high density of insects to the adjacent riparian habitat, accounting for almost 44% of total invertebrate abundance. These adult aquatic insects were dominated by the non-biting midges (Diptera: Chironomidae) and hydroptilid caddisflies (Trichoptera: Hydroptilidae). A lack of adequate riparian vegetation in the section studied could help to explain the absence of certain caddisfly taxa present in the aquatic samples, but not found in the terrestrial samples. Sampling restored reaches of the Cashmere Stream where native plants are present could help establish how important riparian vegetation is for adult aquatic insects.

1 INTRODUCTION

Two areas of Cashmere Stream downstream of Francis Reserve on the southern side of the river are undergoing urban development. As part of the consent requirements, a 20 m riparian zone has been given over to the Christchurch City Council (CCC), which has enabled a riparian planting programme to be established. This survey was therefore intended to address the requirements of a long-term monitoring programme for this lower reach of Cashmere Stream. The main goal of this project was to provide baseline data that could be used in the future to accurately assess any change in instream environment, terrestrial environment, and biological communities over time.

More specifically, this project involves:

- Developing a monitoring programme that can be carried out prior to stream restoration, and several years after restoration.
- Sampling instream habitat, aquatic invertebrate communities, terrestrial habitat, and the adult terrestrial stage of aquatic invertebrates.

2 METHODS

2.1 Site selection

Twelve sites were surveyed along Cashmere Stream between Worsleys Road and Penruddock Rise bridges (Fig. 1). The location of each site was recorded via a hand-held Garmin GPS unit and relevant site photographs were taken (Appendix I). Each site had a transect across the stream channel and riparian zone. The stream and riparian habitat and aquatic invertebrate community was sampled on the 1st - 3rd of November 2005.

2.2 Habitat

The habitat survey followed the USHA methodology (Suren *et al.* 1998). We measured water (free-water and macrophyte) and soft sediment depth at approximately 10 equidistant points across each stream transect. The inorganic substrate was recorded at each of these points using a modified Wentworth classification scheme. This

Figure 1. The12 sites surveyed on the lower Cashmere Stream (between Worsleys Road and Penruddock Rise bridges) during November 2005.

incorporated silt (<0.5 mm), sand (>0.5-2 mm), gravels (>2-16 mm), pebbles (>16-64 mm), small cobbles (>64-120 mm), large cobbles (>120-256 mm) and boulders (>256 mm). Likewise, the organic material was quantified at these points under six defined classes: thin algal mats, filamentous algae, bryophytes (moss, liverworts), terrestrial material (e.g. terrestrial roots and detritus), emergent macrophytes, and submerged macrophytes. Mean water velocity (i.e. velocity at 0.4 x depth) was gauged at the same 10 points using an OTT meter (40 second recording interval).

Riparian conditions (vegetation type) were assessed along the stream transects on either side of the channel to a distance of five metres. For each bank, the presence of 15 different vegetation types were estimated at six points along the transect (i.e. at zero, one, two, three, four, and five metres). The vegetation was assessed three dimensionally at five height classes (0-0.5 m, 0.5-1 m, 1-2 m, 2-5 m, and >5 m) so as to incorporate different types of vegetation including the ground, shrub, and canopy cover levels. The vegetation categories, taken from the CREAS survey developed by NIWA and EOS Ecology, are provided in Appendix II.

2.3 Invertebrates

2.3.1 Benthic aquatic invertebrates

The aquatic invertebrate community was sampled at four kicknet widths across the stream-wide transect at each of the 12 sites (Fig. 2). At each transect one kicknet sample was collected. For each kicknet sample an effective combined area of approximately 1.2 m x 0.4 m (ca. four kicknet widths) was sampled. This entailed sampling a range of habitats (mid-channel, channel margins) across the transect until the effective sampling area was reached. Where the freshwater mussel *Hyridella menziesii* were found, a number of them were collected and had their shell length measured before being returned to the stream channel.

The invertebrate samples were preserved in the field in 60% isopropyl alcohol and taken to the laboratory for identification. The contents of each sample was sieved (minimum mesh size of 0.5 mm) and the invertebrates counted and identified to the lowest practical level using a binocular microscope and the keys of Chapman & Lewis (1976), Winterbourn (1973), Winterbourn *et al.* (2000), and Smith (2001).

2.3.2 Terrestrial invertebrates

The terrestrial invertebrate community was sampled along the stream channel using flight interception (sticky) traps (Fig. 2) from the 8th - 14th of November 2005. Two traps were used at each of the twelve sites surveyed. Each trap was suspended from two wooden stakes at a height of approximately 0.5 metres from the ground on a perpendicular orientation to the stream channel. A modified rectangular grid of garden mesh was used to give the traps strength and rigidity while not impairing their optical qualities. Two A4-size transparent plastic sheets were attached to this mesh grid by stapling them back to back. The mesh grid and plastic sheets were then attached to the wooden stakes with plastic cable ties. Once the traps were set up, Tanglefoot, an adhesive paste specifically manufactured for the purpose of capturing insects, was applied to the plastic sheet on the downstream facing side.

The traps were located adjacent to the stream channel not more that 0.5 m from the waters edge and always on the true left bank. Special attention was given to the location of the two traps at each site to reduce the chance of the downstream trap interfering with the catch of the upstream trap. The traps were left out for seven days from the 8th - 14th of November 2005. When the traps were collected the plastic sheets were removed from the mesh frame and the spare sheet from the upstream side of the frame was placed on top of the sheet with the adhesive and invertebrates. Both sheets were then placed in a plastic sealable bag.

Figure 2. Top: A site transect set up for the aquatic invertebrate and habitat survey. Bottom: Sticky traps used to sample the terrestrial invertebrates and adult aquatic insects present in the riparian zone,

The traps were kept frozen to ensure the samples did not deteriorate over time until processing in the laboratory. Each trap was divided into a grid of sixteen rectangles of an equal size. A stratified random approach was used to select half the grids (i.e. eight rectangles) and all the invertebrates present within each of those grids were counted and identified to the lowest practical level using a binocular microscope and the key of CSIRO (1991), with special attention given to the aquatic taxa present. To enable more accurate identification, specimens of certain taxa were removed from the traps using an appropriate solvent.

2.4 Data analysis

Invertebrate data were summarised by taxon richness, relative abundance, and frequency of occurrence (distribution). Biotic indices calculated were the number of Ephemeroptera-Plecoptera-Trichoptera taxa (EPT richness), % EPT, Macroinvertebrate Community Index (MCI) scores, Urban Community Index (UCI) scores, and the quantitative equivalent of the latter two; the QMCI and QUCI respectively.

EPT taxa are generally regarded as ‘clean-water’ taxa; i.e., they are relatively intolerant of organic enrichment or other pollutants. EPT richness and % EPT scores can therefore provide a good indication as to the health of a particular site. The disappearance and reappearance of EPT taxa also provides evidence of whether a site is impacted or recovering from a disturbance.

The MCI/QMCI is an index of community integrity that has been designed for use in stony riffles in New Zealand streams and rivers, and can be used to determine the level of organic enrichment for these types of streams (Stark 1985). It calculates an overall score for each sample, which is based on pollution-tolerance values for each invertebrate taxon. MCI scores less than 50 indicate extremely polluted sites, whereas scores > 150 indicate 'pristine' conditions (Stark 1993). MCI is calculated using presence/absence data, whereas the QMCI score incorporates abundance data and so gives a more accurate result by differentiating rare taxa from abundant taxa. The habitat characteristics of the survey sites were not ideal for the use of the MCI/QMCI, as they were mostly all run habitats with fine substrate. This index has therefore merely been used as an indicator of faunal change, rather than as an absolute descriptor of the biological health of the stream.

The habitat-based UCI and QUCI is a univariate index that combines tolerance values for invertebrates with either presence/absence (UCI) or abundance (QUCI) invertebrate data. It has been specifically developed for New Zealand urban streams, based on a multivariate analysis of 59 streams throughout the country (Suren *et al.* 1998). Negative scores are indicative of invertebrate communities tolerant of slow-flowing water conditions associated with soft-bottomed streams (and often choked with macrophytes), whereas positive scores are indicative of communities found in fast-flowing streams with coarse substrate (Suren *et al.* 1998). Because this biotic indice is indicative of habitat relationships, it was highly suitable for this study, given this section of the Cashmere Stream is characterised by run habitats with fine substrate which is not regarded as an ideal environment for many aquatic invertebrates.

The data describing the streambed composition was simplified by creating a substrate index, such that:

Substrate index = [(0.7 x % boulders) + (0.6 x % large cobbles) + (0.5 x % small cobbles) + (0.4 x % pebbles) + (0.3 x % gravels) + (0.2 x % sand) + (0.1 x % silt) + (0.1 x % concrete/bedrock)] / 10

Derived values for the substrate index range from 1 (i.e., a substrate of 100 % silt) to 7 (i.e., a substrate of 100% boulder); the larger the index, the coarser the overall substrate. In general, coarser substrate (up to cobbles) represents better instream habitat than finer substrate. The same low coefficients for silt and concrete/bedrock reflect their uniform nature and lack of spatial heterogeneity, and in the case of silt, instability during high flow.

3 RESULTS

3.1 Habitat

3.1.1 Stream habitat

The mean channel width of the transects sampled on the Cashmere Stream was 4.35 m (± 0.13; one standard error) (Table 1). The average free-water depth was 0.32 m (± 0.01), with the mean depth of macrophytes being 0.01 m (± 0.002). The mean depth of sediment on the channel bottom was 0.05 m (± 0.006). Fine sediment (i.e. silt) covered a majority of the streambed (Table 2), and as such there was a low mean substrate index (Table 1). The mean velocity of the water flow was 0.18 m/s (± 0.12).

Table 1. Summary statistics of key physical parameters measured across the Cashmere Stream channel. For channel width and the substrate index n = 12, but for all other parameters n = 123.

Variable	Mean	SD	SE	Max	Min	Median
Channel width (m)	4.35	0.44	0.13	5.10	3.80	4.35
Free-water depth (m)	0.32	0.12	0.01	0.55	0	0.34
Macrophyte depth (m)	0.01	0.03	0.002	0.18	0	0
Sediment depth (m)	0.05	0.06	0.006	0.54	0	0.02
Velocity (m/s)	0.18	0.12	0.01	0.63	0	0.18
Substrate index	1.3	0.3	0.1	1.9	1.0	1.2

The streambed was dominated by silt, generally either exposed (no organic material) or overlaid with filamentous algae and submerged macrophytes (Table 2). The dominant vegetative type recorded from the points along the transects was filamentous algae with 40% coverage. The majority of the points sampled were covered in some type of organic material (Table 2), although in the four most upstream sites (i.e. Sites 9-12) the abundance of aquatic plants (e.g. macrophytes and algae) was low.

Table 2. The relative abundance of inorganic and organic substrate units recorded from the streambed of Cashmere Stream (n = 123).

Substrate		Percentage
Inorganic	Silt	83
	Sand	11
	Gravels	2
	Pebbles	2
	Small cobbles	1
	Boulders	2
Organic	Filamentous algae	40
	Submerged macrophytes	10
	Terrestrial material	5
	Algal mats	2
	No organic material	43

Table 3. Percentage abundance of various riparian habitat categories recorded at six distances and five vertical heights from the water edge on both banks of Cashmere Stream. TRB: True right bank. TLB: True left bank.

Bank	Category	Height				
		0-0.5m	0.5-1m	1-2m	2-5m	>5m
TRB	Unvegetated	18	0	0	0	0
	Impervious surface	0	0	0	0	0
	Mown lawn/grazed pasture	7	0	0	0	0
	Grass/herb mix	75	11	0	0	0
	Low ground cover	0	0	0	0	0
	Rushes/sedges	0	0	0	0	0
	Exotic creeping vine	0	0	0	0	0
	Native shrub	0	0	0	0	0
	Exotic shrub	0	0	0	0	0
	Native tree	0	0	0	0	0
	Exotic evergreen tree	0	0	0	4	18
	Exotic deciduous tree	0	0	0	0	0
TLB	Unvegetated	38	0	0	0	0
	Impervious surface	4	0	0	0	0
	Mown lawn/grazed pasture	25	0	0	0	0
	Grass/herb mix	21	4	0	0	0
	Low ground cover	3	0	0	0	0
	Rushes/sedges	3	3	1	0	0
	Exotic creeping vine	0	1	4	4	0
	Native shrub	1	6	7	1	0
	Exotic shrub	0	1	0	0	0
	Native tree	1	0	6	8	4
	Exotic evergreen tree	4	6	10	26	28
	Exotic deciduous tree	0	0	3	7	0

3.1.2 Riparian habitat

In general, the riparian habitat on the true left bank was dominated by a grass/herb mix (Table 3), whereas the true right bank showed a greater diversity of riparian habitat categories. There were a greater variety of low ground vegetation types with unvegetated soil relatively abundant, and the upper canopy was dominated by exotic evergreen trees (e.g. macrocarpa and eucalyptus), particularly in the four most upstream sites (i.e. Sites 9-12). The relative abundance of native vegetation on both banks was low.

3.2 Benthic aquatic invertebrates

3.2.1 General faunal characteristics

A total of 42 invertebrate taxa were recorded from the kicknet samples taken from the stream in the survey area. The most diverse group were the true flies (Diptera; 16 taxa) and this included seven taxa in the dipteran family Chironomidae (non-biting midges). The second most diverse group were the caddisflies (Trichoptera; seven taxa), with three of these taxa coming from the family Leptoceridae, and two each from the families Hydroptilidae and Hydrobiosidae. The latter family did have an additional taxa identified under the family, but this was most likely just an early instar of one of the other two hydrobiosid genera recorded. The next most abundant group were the molluscs (Mollusca; six taxa) with three snails (Gastropoda) and three bivalve (Bivalvia) taxa recorded, including the freshwater mussel *Hyridella menziesii*. Five crustacean taxa were recorded, including three micro-crustaceans (Ostracoda, Cladocera, Copepoda), the amphipod *Paracalliope fluviatilis* (Amphipoda) and the freshwater shrimp *Paratya curvirostris* (Decapoda: Atyidae). Two mite taxa (Arachnida: Acari) were collected. The remaining groups represented by one taxa were the oligochaete (Oligochaetea) and nematode (Nematoda) worms, a type of freshwater anemone (Cnidaria: Hydra), tiny insect-like organisms known as Collembola (Hexapoda), and the damselfly *Xanthocnemis* (Odonata: Zygoptera).

The most abundant taxa (Fig. 3) recorded from the kicknet samples were the seed shrimps (Crustacea: Ostracoda) which made up 36.4% (± 4.1%; one standard error) of mean total abundance. Orthoclad non-biting midges (Diptera: Chironomidae: Orthocladiinae) made up 22.2% (± 2.7%) of mean total abundance, and the snail *Potamopyrgus antipodarum* (Mollusca: Gastropoda) was also abundant, with 16.5% (± 2.4%). Other abundant taxa included the hydroptilid caddisfly *Oxyethira albiceps* (5.3% ± 1.3%), the oligochaete worms (3.6% ± 1.0%) and the cnidarian hydra (3.4% ± 2.7%). The most abundant non-hydroptilid caddisfly was the leptocerid *Triplectides obsoletus* with 1.4% (± 0.4%) of mean abundance.

The taxa that were most widespread, being recorded at all 12 sites were the caddisflies *O. albiceps* and *T. obsoletus*, the oligochaete worms, the snails *P. antipodarum* and *Physella*, the fingernail clam Sphaerium, the orthoclad non-biting midges, and the seed shrimps (Ostracoda). Other widespread taxa included the amphipod *P. fluviatilis* (11 sites) and the Chironominae non-biting midges (10 sites).

There were 12 taxa which were only recorded at one site and these included the cased-caddisfly *Hudsonema amabile* (Trichoptera: Leptoceridae; Site 12), the atyid shrimp *P. curvirostris* (Site 1), and the crane fly *Limonia* (Diptera: Tipulidae; Site 7). See Figure 3 for images of these taxa.

3a. A seed shrimp (Ostracoda)

3b. An Orthocladinae non-biting midge

3c. The native snail *Potamopyrgus antipodarum*

3d. The stoney-cased caddisfly Hudsonema amablie

3e. The shrimp *Paratya curvirostris*

3f. The crane fly *Limonia*

Figure 3. Ostracods (3a), orthoclad non-biting midges (3b), and the native snail *Potamopyrgus antipodarum* (3c) accounted for over 70% of invertebrate abundance from the 12 sites surveyed along the lower reaches of Cashmere Stream during 1st - 3rd November 2005. Some of the rarer taxa were the stoney-cased caddisfly *Hudsonema* (4a), the shrimp *Paratya* (4b), and the crane fly *Limonia* (4c), which were among 12 taxa recorded from only one of the 12 sites. Photos 3c, d,e © Shelley McMurtrie. Photo 3b, f © Stephen Moore, Landcare Research.

3.2.2 Biotic indices

Although a total of 42 taxa were recorded from this section of the Cashmere Stream, the mean number of taxa collected from each site was 18.4 (± 1.4). The mean MCI score was 71.1 (± 1.3) and the mean UCI score was 0.9 (± 0.4). The quantitative equivalents of these indices, the QMCI and QUCI had mean scores of 2.9 (± 0.04) and -0.1 (± 0.03) respectively. The mean number of EPT taxa per site was 3.3 (± 0.3), although this dropped to 2.1 (± 0.3) when the hydroptilids were removed. Likewise, the mean percentage of EPT taxa was 6.9% (± 1.4%), but fell to 1.6 (± 1.3%) with the removal of the Hydroptilidae.

3.2.3 Freshwater mussels

The freshwater mussel or kakahi (Mollusca: Bivalvia: Unionidae: Hyriidae: *H. menziesii;* Fig. 4) was found at four sites (Sites 5, 6, 7, and 9) and made up 0.2% (± 0.1%) of mean total abundance. A total of 29 individuals were collected from the sites sampled, and measurements indicated a mean shell length of 9.08 cm (± 0.10 cm). A histogram of the size classes indicated that the mussels present were from a limited number of cohorts and were of a similar age (Fig. 5).

Figure 4. Photographs of kakahi, otherwise known as the freshwater mussel (*Hyridella menziesii*), which were found at four of the 12 sites surveyed along the lower reaches of Cashmere Stream during 1st - 3rd November 2005.

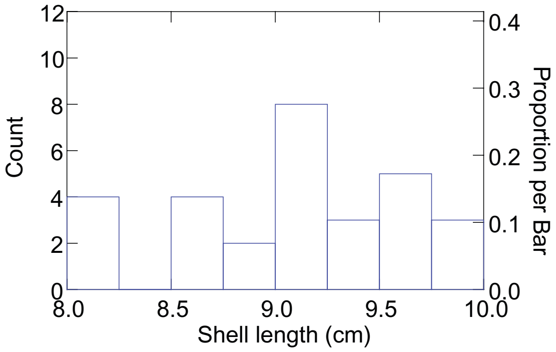

Figure 5. Histogram of size class frequencies for the freshwater mussel *Hyridella menziesii* collected from four sites in Cashmere Stream (n = 29).

3.3 Terrestrial invertebrates

A total of 51 invertebrate taxa were recorded from the sticky traps deployed in the survey area. The most diverse group were the true flies (Diptera; 27 taxa), followed by beetles (Coleoptera; 9 taxa), true bugs (Hemiptera; 3 taxa), and wasps (Hymenoptera; 3 taxa). The caddisflies (Trichoptera) were relatively depauperate with only two taxa recorded.

The most abundant order were the true flies (Diptera) which made up just over two-thirds (66.9% ± 2.0%; one standard error) of mean total abundance. The second most abundant order were the caddisflies (Trichoptera) with 14.7% (± 1.4%), but this was almost entirely dominated by hydroptilid micro-caddisflies (Hydroptilidae), with only a small fraction of individuals from another caddisfly family, the Leptoceridae. Other common orders included the true bugs (Hemiptera; 8.8% ± 0.9%) and the wasps, bees, and ants (Hymenoptera; 4.9% ± 0.5%). Although the beetles (Coleoptera) were a relatively diverse order, they had a low mean abundance of 2.1% (± 0.5%).

The most abundant taxa from the 'sticky traps' in the survey area were the non-biting midges (Diptera: Chironomidae) which made up 28.2% (± 2.7%) of mean total abundance. As mentioned above, hydroptilid caddisflies (14.7% ± 1.4%) were also highly abundant, as were the true flies (Diptera) from the families Mycetophilidae (12.4% ± 1.7%), Psychodidae (6.5% ± 1.5%), and Sciaridae (5.7% ± 1.0%).

The most widespread taxa were the true flies (Diptera) from the families Chironomidae (non-biting midges), Mycetophilidae, Psychodidae, and Stratiomyidae, and hydroptilid caddisflies (Trichoptera: Hydroptilidae), which were found on all 24 traps located across the 12 sites. Other common taxa (found on 23 traps) were small wasps (unidentified Hymenoptera: Apocrita), true flies (Diptera) from the families Phoridae and Sciaridae, true bugs (Hemiptera) from the family Cicadellidae, and tiny insects known as thrips (Thysanoptera).

There were seven taxa which were only recorded at one trap and these included the diving beetle *Rhantus* spp. (Coleoptera: Dytiscidae), a species of robber fly (Diptera: Asilidae), and a species of marsh fly (Diptera: Sciozymidae)

The invertebrates caught in the 'sticky traps' were evenly divided between having originated from an aquatic or terrestrial habitat. Taxa with an entirely terrestrial life history made up 44.6% (± 8.1%) of total abundance, whereas the taxa which had an aquatic larval stage made up 43.1% (± 4.1%). The remaining 12.3 % (± 2.6%) incorporated taxa which have both aquatic and terrestrial genera within their families and could not be distinguished with the taxonomic resolution employed in this study.

4 DISCUSSION

The aquatic invertebrate fauna of the lower Cashmere Stream is typical of a New Zealand lowland rural or peri-urban stream, with a depauperate invertebrate fauna of low ecological value and dominated by a few ubiquitous taxa; micro-crustaceans (Ostracods) and orthoclad midges. This section of Cashmere Stream appears to have lower biological values than recently surveyed sites further upstream (McMurtrie 2006). These upstream sites had a more diverse EPT taxa and higher EPT abundance. Likewise, the MCI and QUCI and their quantitative equivalents, the QMCI and the QMCI were all higher at these upstream sites.

4.1 Sedimentation and macrophytes

The depauperate aquatic invertebrate fauna in the lower reaches of Cashmere Stream is most likely a reflection of the silty/sandy habitat and absence of macrophytes. The Cashmere Stream has a history of sediment inputs, with a mixture of rural and urban catchment draining the leoss-covered Port Hills to the south, and a flat land to the north and west. Sediment sources range from natural leoss runoff to human-derived sources of bank collapse, stock damage, and urban stormwater. The Aidanfields discharge (McMurtrie 2006) was a particularly high profile event of the latter, but is certainly not the only source of sedimentation in this catchment. Fine sediment usually enters streams during the initial development and construction phase of urban areas, in 'mature' catchments where subdivision occurs, or as a result of stream-bank erosion caused by increased runoff derived from newly created impervious areas (Suren 2000). Some of the land on the true right bank has only recently been retired from grazing and has had problems in the past with bank slumping and erosion due to unfettered access by livestock to the stream margins; a situation that is still prevalent in the upstream reaches of this catchment. In addition, the new housing development on the true-right side of the stream near Penruddock Rise could have recently contributed sediment to the stream as a result of site excavations (Fig. 6), as has been the case for urban development in the upper catchment.

The adverse effects of suspended and settled fine sediment on benthic invertebrates are well-documented (e.g. Ryan 1991). It has been concluded that high sediment loads may reduce the abundance and diversity of invertebrates by smothering and abrading them, reducing their periphyton food supply and/or quality, and reducing available interstitial habitat (spaces between substratum) in a process known as colmation. High fine sediment loads can only support depauperate invertebrate communities with few or no EPT taxa (Quinn *et al.* 1992). Freshwater crayfish are especially vulnerable to heavy siltation and suspended sediment as it clogs their gills (Westman 1985, censu Usio & Townsend 2000). While small invertebrates will often drift out of areas to escape high suspended or settled sediment levels (Suren & Jowett 2001), crayfish are less mobile, and so could be more vulnerable to habitat deterioration. For fish, stream gravels must be kept clear of silt, or there will be a reduction in their refuge and spawning areas. If the substrate becomes blanketed in silt to a depth of more than a few centimetres, the fish fauna can become dominated by shortfin eels, often to the partial or complete exclusion of other fish species.

The relatively low coverage of aquatic macrophytes and the dominance of filamentous algae is most likely contributing to the depauperate invertebrate fauna of the study area. The abundance of macrophytes was significantly higher at the upstream sties surveyed by McMurtrie (2006). At some of the sites in this study (e.g., Sites 9 and 10), shading by large macrocarpas helps explain the low abundance of macrophytes, but the reasons for the overall lower coverage are unknown. Where the streambed is silted and thus providing little stable habitat, macrophytes are important to epibenthic invertebrates as they provide a complex three-dimensional architecture for colonizing invertebrates and can make available a variety of food sources, as well as refuge from predators (Kelly & McDowall 2004).

Figure 6. Sources of sediment input into Cashmere Stream during land clearance (top left) and bank works for the new subdivision off Penruddock Rise. Some sediment control measures were used for stormwater runoff sites (top right) but in other areas loose soil was pushed over the bank's apex and rolled into the stream (top right, above).

4.2 Freshwater mussels

A notable highlight in this study was the presence of kakahi (the freshwater mussel *Hyridella menziesii*) which were found at Sites 5, 6, 7, and 9. Previous site visits have also identified mussels just upstream of Site 8 (S. McMurtrie, pers. obs.). Observations made during recent CREAS surveys indicate that mussels could also be present near the confluence of Cashmere Stream with the Heathcote River and in the lower reaches of a tributary of Cashmere Stream, Ballintines Drain (Manfred Van Tippelskirch, CCC, pers comm.).

This large freshwater invertebrate could dominate the invertebrate community biomass, and it is likely that it is performing an important ecosystem service through filtering the water column and producing faeces that become available to aquatic producers and other consumers. Concerns have been raised in the last few years over the long-term viability of populations of this bivalve mollusc in New Zealand. The known or likely global causes of decline in freshwater mussels include influences on sediment type, food supply, water quality (pollution and eutrophication), water velocity, bed slope, and the reduction of fish hosts for the parasitic life stage (McDowell 2002). This latter factor is of interest given the unusual life cycle of kakahi, which, like most freshwater mussels, has a glochidium larva that is parasitic on fish in the early part of its life before moving to soft, sandy sediments in lake and river beds. McDowell (2002) postulated that a decline in suitable host fish, such as koaro (*Galaxias brevipinnis*), could be a factor in the decline of the kakahi. Nevertheless, other species of fish are listed as hosts for the glochidium larva including bullies and eels (Walker *et al.* 2001). The Freshwater Biodata Information System (FBIS) has entries for longfin and shortfin eels; and common, upland, bluegill, and giant bullies; all as recent as 2005 from Cashmere Stream. However, more research is required to determine the host specificity of *H. menziesii*, and the exact mechanisms involved in the dispersal of the larvae and survival of juveniles. Whilst the potential absence or low abundance of suitable host fish would affect the recruitment of kakahi in Cashmere Stream, the adverse effects of other factors such as sedimentation should not be discounted.

These questions of host specificity and sediment impacts are particularly pertinent given that all the mussels we found were over 8 cm in length, suggesting that there is little or no recruitment of new mussels into the population. However, the absence of small individuals in freshwater mussel populations is a common phenomenon and similar results were found by Grimmond (1968), James (1985), and Roper & Hickey (1994). Hunter (1964) noted that for *Unio* and *Anodonta* species, post-glochidial juveniles have rarely been found and that little is known about the development and ecology of these newly-metamorphosed mussels. Likewise, Green (1980) described a population of *Anodonta grandis* where individual younger than about 5 years were absent. Resampling this same population 13 years later showed a decline in growth rate, a shift to an older age structure, and a drop in population density, possibly as a result of anthropocentric impacts (Bailey & Green 1989). In New Zealand, James (1985) dismissed the effects of anthropocentric impacts on the absence of juveniles in Lake Taupo, and speculated that the ‘periodicity in age structure’ resulted from breeding characteristics (i.e. sporadic recruitment) and climatic conditions. However, the absence of juveniles in this study could be indicative of the global trend of decline in freshwater mussel populations.

Estimates of mussel longevity obtained by counting shell annual rings indicate that some individuals can live for at least 33 years (Winterbourn 2004), which could indicate that the mussel populations in Cashmere Stream are decades old. A more extensive survey focusing on kakahi in Cashmere Stream would help identify the range, size, and age class distribution of the population. This would be critical to establishing whether or not the population is in decline, and what factors could be contributing to this.

4.3 Terrestrial invertebrates

In addition to sampling the aquatic invertebrate community of Cashmere Stream, this study also sampled the terrestrial invertebrates and adult aquatic insects present in the adjacent riparian environment. The 'colonization cycle' proposed by Müller (1982) states that adult aquatic insects fly upstream and deposit eggs to compensate for larval displacement by downstream drift. In addition to flying upstream, stream insects are known to fly both downstream and laterally to the stream channel, although there is still a lack of understanding regarding the extent of this behaviour and what influences it (Collier & Scarsbrook 2000).

The contribution of aquatic insects to total terrestrial invertebrate abundance was relatively high, with the non-biting midges and hydroptilid caddisflies unsurprisingly common, reflecting their ubiquity in the kicknet samples. Moreover, given taxa were only identified to family in most cases, families with both aquatic and terrestrial genera were kept separate from being classified as either aquatic or terrestrial in origin. This meant that the proportion of taxa that were aquatic in origin could have been higher (as much as 55%). In addition, taxa that were terrestrial in origin could have been linked to the riparian zone because of the presence of desirable environmental conditions (e.g., the presence of specific plants or higher soil moisture levels).

The low diversity of EPT taxa in the aquatic samples was mirrored in the terrestrial trapping. Only caddisflies from two families, Hydroptilidae and Leptoceridae, were caught, with the latter most likely only representing one genera, the stick caddis *Triplectides*. However, the aquatic sampling did reveal a number of caddisfly taxa which were not caught in the sticky traps. These taxa were the hydrobiosids *Hydrobiosis parumbripennis* and *Psilochorema* (Hydrobiosidae) and the leptocerids *H. amabile* and *Oecetis unicolor*. There are a number of reasons that could explain why these taxa were not found in terrestrial samples.

Firstly, the presence of adult aquatic insects can vary through time, with typically a small synchronised peak in emergence during spring. However, Winterbourn *et al.* (1981) has suggested that New Zealand stream insects possess flexible, poorly synchronised life-histories with non-seasonal or weakly seasonal patterns of development, and extended flight and egg-hatching periods. Such characteristics have been shown in numerous studies of adult flight periods. Ward *et al.* (1996) reviewed the length of adult flight period in New Zealand Trichoptera (caddisflies) by using data from three sites (Waitakere Stream, Auckland; Turitea Stream, Manawatu; and Kawarau Gorge, Otago) for 66 species. For the majority of the species, the flight period was greater than six months, suggesting very little synchrony in emergence. As such, one would not expect the timing of sampling (early summer for this study) to have had a major impact on the presence of caddisflies that were not found as adults on the sticky traps but were found as larvae in the kicknet samples.

Secondly, caddisfly taxa only recorded in the kicknet samples all had very low relative abundances. As such, it is highly likely that a very large sampling effort would have been required to capture adults of these species. The use of 24 traps at 12 sites along the riparian margin was a reasonably extensive sampling design. However, given that sticky traps are primarily a passive trap, e.g. relying on flight interception; the use of light traps, which are known to attract caddisflies, could be a more appropriate technique to sample adult trichopteran diversity in systems like Cashmere Stream where the abundances of many of these taxa are low.

Thirdly, riparian zones can perform several functions for adult aquatic insects. Results from trapping indicates the presence of riparian cover may aid upstream dispersal by limiting the exposure of adults to prevailing winds (Collier & Scarsbrook 2000). Additionally, New Zealand adult caddisflies have been found in open *Eucalyptus* forest up to 200 m from the nearest stream, but not as great a distance in more dense native forest, suggesting that vegetation density plays a role in influencing dispersal direction and distances (Collier & Smith 1998). Riparian vegetation could provide sites for mating, completing metamorphosis, and sources of food (to enable the maturation of eggs or dispersal flights). Adult *Rakiura* caddisflies have been observed to congregate above kanuka, manuka, and gorse plants (Michaelis 1973), possibly using them as swarming markers. The riparian zone is also a theatre for predators such as spiders and birds to prey on adult aquatic insects, potentially providing an energy feedback loop to terrestrial foodwebs (Collier & Scarsbrook 2000). However, riparian vegetation might help to provide shelter from such predators. For example, Philips (1930) suggested that birds were a serious threat to adult mayflies given that “the riverbanks have [now] been cleared of bush in most places”.

Finally, the location of the sticky traps (all on the true left bank) may have influenced the types of caddisfly taxa that were caught due to vegetative differences to the opposite bank. The trapped side was predominantly in pasture, or in the case of the two most upstream sites, was devegetated due to excavation works for a new housing development. If the presence of riparian vegetation is important for the survival of certain adult aquatic insects, then the absence of adequate riparian vegetation on the side of Cashmere Stream sampled could help explain the low diversity of caddisfly taxa recorded. It would be interesting to sample for adult aquatic insects in a reach of Cashmere Stream where the riparian zone has been planted with natives (e.g. Francis Reserve). This could indicate the importance of native riparian vegetation to the survivability of adult aquatic insects and ultimately the persistence of these important taxa within this system. Such a study could help underline the importance of stream restoration, and provide a tangible benefit to assist managers to promote such projects.

Even though adult caddisfly taxa diversity was low, the contribution of aquatic insects to total terrestrial invertebrate abundance was relatively high, with the non-biting midges and hydroptilid caddisflies unsurprisingly common, reflecting their ubiquity in the kicknet samples. Moreover, given taxa were only identified to family in most cases, families with both aquatic and terrestrial genera were kept separate from being classified as either aquatic or terrestrial in origin. This meant that the proportion of taxa that were aquatic in origin could have been higher (as much as 55%). In addition, taxa that were terrestrial in origin could have been linked to the riparian zone because of the presence of desirable environmental conditions (e.g., the presence of specific plants or higher soil moisture levels).

4.4 Metapopulations

Section 5(2) (b) of the Resource Management Act requires that the life-supporting capacity of water and ecosystems be safeguarded, and that regard is given to the intrinsic values of ecosystems and habitat for trout (Section 7 [d and h]). This implies that a management goal for streams and rivers is the maintenance of ecosystem health (Collier *et al.* 2000). To have healthy streams, processes that regulate the distribution and abundance of organisms must be maintained (e.g. water flow, energy sources). An integral part of this requires managers to consider how populations of stream organisms persist at the local scale.

Ecological theory has evolved over time in an attempt to explain the persistence and extinction of populations of organisms at spatial and temporal scales. One theory, known as metapopulations states that local populations of organisms are subject to extinction and persist at the total population (metapopulation) level through recolonisation of habitat patches (Harrison & Taylor 1997). A fundamental of metapopulation theory is that persistence requires an adequate rate of migration between patches. The probability of metapopulation persistence also increases with the number of habitat patches and local populations. Additionally, heterogeneity in habitat quality can affect metapopulation dynamics. One idea is that dispersal from “source” populations in high-quality habitat may permit “sink” populations to exist in inferior habitat (Harrison & Taylor 1997). Unlike an island habitat which cannot support large populations because of its size, "sink" habitats are unable to provide positive population growth because of their poor quality. Such "sinks" range from marginal habitats that are only occupied during favourable years, to areas in which populations persist most of the time but cannot survive catastrophes (Harrison & Taylor 1997).

Metapopulation theory is important to stream communities because of the patchiness of the habitat (although streams and rivers can be longitudinally connected, they are always scattered across the landscape). Moreover, this theory is increasingly seen as relevant to how species persist, or fail to do so, in landscapes recently fragmented by humans (Harrison & Taylor 1997). These concepts are of particular interest as it would appear that urban waterways represent marginal (sink) habitats subject to catastrophic events (e.g. stormwater flood disturbance and pollution events) where there could be inadequate migration from source populations (or more simply, inadequate source populations in the urban environment) to maintain local populations of stream invertebrates.

The upstream sites of Cashmere Stream with higher EPT diversity could serve as source populations for a number of caddisfly taxa. Such populations are important in the event of urban restoration so as to provide a source of colonists. These colonists could naturally migrate to such urban sites by dispersal mechanisms such as downstream drift and adult flight. However, the proliferation of dispersal barriers to insects in the urban environment might impede the colonization cycle (Fig. 7). For example, roads and railways in an urban environment have been shown to be effective barriers to bumblebees, fragmenting their populations between plant patches (Bhattacharya *et al.* 2002). There are suggestions that barriers such as road culverts in the urban environment can adversely affect adult aquatic insect dispersal (Dr. Jon S. Harding, University of Canterbury, pers. comm.). Even sections of modified riparian zones could be a barrier to adult dispersal flight. Indeed, Suren & McMurtrie (2005) suggested that habitat isolation/fragmentation was a likely factor in the lack of change in invertebrate communities five years after habitat restoration in three Christchurch urban waterways, which were otherwise isolated from other suitable habitats. This means that special attention should be given to maintaining the habitat continuity of the stream and riparian zone, limiting the number of dispersal barriers, and where such barriers are necessary, using a dispersal friendly design (e.g. bridges instead of culverts).

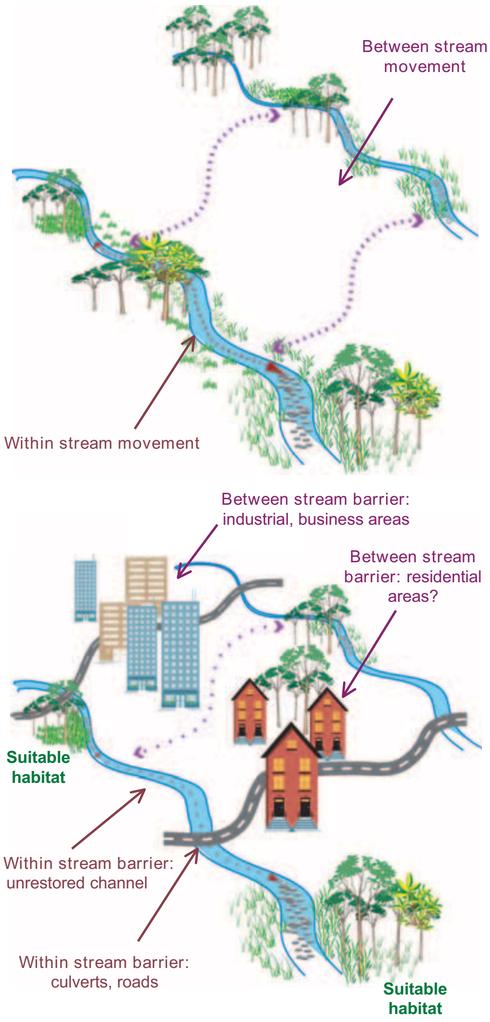

Figure 7. Change in land use from unmodified (top) to urban (bottom) creates many dispersal barriers that serve to fragment aquatic invertebrate populations. Many of these barriers (e.g. culverts) are seemingly innocuous to us but can represent a significant barrier to the terrestrial stage of adult insects trying to fly upstream to lay their eggs.

5 CONCLUSION

Sedimentation is one of the overriding factors limiting invertebrate communities in urban streams. Restoring the lower section of Cashmere Stream provides an opportunity to add coarse sediment, thereby locally improving instream conditions. However, this will most likely become smothered with fine silt unless there is some reduction in sediment inputs upstream, or alternatively, some form of flushing capacity can be integrated to help flush out accumulated sediment during times of high flow. The input of sediment into Cashmere Stream will continue unless in rural areas there is an integrated attempt to fence the mainstem and tributary waterways to keep stock out, and in urbanising areas, there is a more concerted effort to use effective sediment control measures during construction.

Although traditionally overlooked, more attention is now being given to the effect of terrestrial habitat on adult aquatic insects. It is now recognised that this component might be important in the successful restoration of degraded aquatic habitats by assisting the dispersal of aquatic insects. Moreover, recent studies have emphasised the significance of aquatic-terrestrial linkages in stream ecosystems. Studies have shown that adult aquatic insects make a significant prey contribution to terrestrial predators such as spiders and birds which inhabit the riparian zone (Burdon 2004). This means that riparian areas should be viewed as wildlife corridors that affect both the aquatic and terrestrial biota present and the linkages that bind those two systems together.

Maintaining a continuous riparian zone will therefore be integral to maintaining instream community integrity for aquatic insects. The restoration of the lower reach of Cashmere Stream should therefore promote a riparian zone with a good representation of native species, and which serves to recreate a good canopy cover on the northern banks where the old macrocarpas and eucalyptus trees have been recently removed.

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8 APPENDICES

8.1 Appendix I: Site photographs

Site 1: Looking upstream.

Site 2: Looking upstream.

Site 3: Looking upstream.

Site 4: Looking upstream.

Site 5: Looking upstream.

Site 6: Looking upstream.

Site 7: Looking upstream.

Site 8: Looking upstream.

Site 9: Looking upstream.

Site 10: Looking upstream.

Site 11: Looking upstream.

Site 12: Looking upstream.

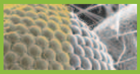
8.2 Appendix II: Riparian vegetation categories

Code	Name	Description
imp	impervious	roads and tarsealed/concreted paths, buildings.
unv	unvegetated	earth, rocks, gravel.
mos	bryophytes	moss/liverworts
law	lawn	manicured lawn of grass & herb mix. Mown, VERY regularly.
ghm	grass & herb mix	unmanaged and managed, short and long
low	low ground cover	herbaceous (and other) low growing plants, general small garden-variety, and vines/ivy (e.g. aluminium plant, nasturtium). Excl ‘grass & herb mix’.
ferr	ferns	ground ferns, both native and exotic
rst	rush/sedge/tussock	both native and exotic.
cvn	coarser veg - native	flax, raupo, toe toe
cve	coarser veg - exotic	general larger garden-variety plants (e.g. gunnera, pampas, lily, irises, bear’s breaches, arum lily, fox glove, bamboo, etc), vegetables
shn	shrubs - native	hebes, coprosmas, shrub daisies, native brooms, divaricating shrubs.
she	shrubs - exotic	rhododendron, camelias, hydrangeas, roses, gorse, broom, etc
trn	native trees	incl. cabbage trees, tree ferns, native conifers (kahikatea, matai, totara) and trees (kowhai, wine berry, ribbonwood, tree fuchsia).
ted	exotic deciduous	willow, poplar, elm, walnut, maple, chestnut.
tee	exotic evergreen	pine, macrocarpa, eucalyptus, acacia.

ASSESSMENT AND MONITORING

RESTORATION DESIGN

LABORATORY SERVICES



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