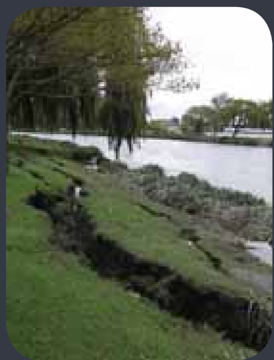
AQUATIC RESEARCH CONSULTANTS

Christchurch February Earthquake

EFFECT ON AQUATIC INVERTEBRATES

EOS Ecology Report No: 11010-CIV01-01 | June 2011
Prepared for: Environment Canterbury and Christchurch City Council
Prepared by: EOS Ecology; Alex James and Shelley McMurtrie







Environment Canterbury report no. U11/9
ISBN: 978-1-927195-86-4

Summary

The 22 February 2011 earthquake affected Christchurch's waterways through the inputs of liquefaction sand/silt, bank slumping, uplift of streambeds, and input of raw wastewater from broken sewage pipes. Such effects can have negative impacts on water quality, habitat condition, and the fauna of Christchurch's waterways.

EOS Ecology was asked to find out if these sewage and sand/silt inputs had impacted on the City's aquatic invertebrate communities; which are key indicators of ecosystem health. Nine sites were selected, three each belonging to the following impact categories; "no earthquake effect" (Waimairi Stream, Wairarapa Stream, & Montreal St): known "sand/silt" inputs (No. 2 Drain, Papanui Stream, & Jacksons Creek); and known "sand/silt & sewage" inputs (Victoria Square, Kilmore St, & Fitzgerald Ave). To determine if the earthquake had any negative impact on the City's aquatic invertebrates, pre and post earthquake invertebrate community data were compared. Sites were limited to the upper wadeable portion of the City's waterways, where before data was present.

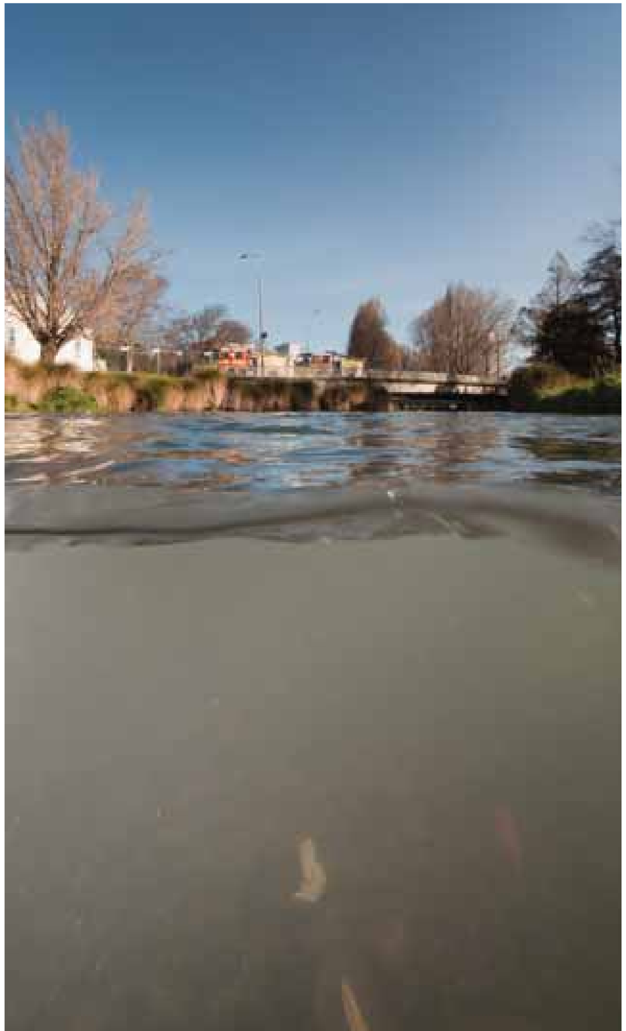
Fine sediment depth increased in all impact categories in the following order of magnitude; "sand/silt & sewage" >"sand/silt" >> "no earthquake effect". This increase was presumably as a result of the deposition of sediment mobilised by the earthquake. There is the potential this fine sediment smothered some of the interstitial space of cobbled areas of the streambed detrimentally affecting the populations of invertebrate taxa sensitive to fine sediment (e.g., some caddisfly taxa).

Of the three impact categories (no earthquake effect; sand/silt; sand/silt & sewage) none displayed any consistent major change to invertebrate communities. Instead, site specific changes (e.g., changes among crustacean taxa at Papanui Stm & Jacksons Ck and a decrease in caddisflies at Kilmore St) were observed, some of which were likely earthquake related.

The greatest earthquake-related impact was a large decrease in the abundance of caddisflies at the Kilmore St site; the only site to contain a significant population of pollution-sensitive invertebrate taxa. At all the other sites, shifts in the abundance of some taxa were observed but overall there were no mass changes to the core taxa present.

The overall lack of a major impact on the City's invertebrates (in the wadeable sections of the waterways) as a response to the earthquake sand/silt and sewage inputs is at least partially a result of the existing faunas of these waterways being dominated by taxa tolerant of degraded habitat and water quality. There are however, some management actions that are worthwhile, such as the removal of liquefaction from some sites (Jacksons Ck, Papanui Stm, & No. 2 Drain) to reduce the downstream transport of sediment, the repair of banks at the recently restored No. 2 Drain site to protect the bluegill bully population there, and the monitoring of caddisfly abundance at the Kilmore St site to determine if they recover.

Despite the lack of consistent and dramatic effects at our surveyed sites there are still waterways in Christchurch that have been severely impacted by the earthquake. Our study was limited to re-sampling those sites that had been surveyed prior to the earthquake, which by chance were not as impacted as other waterways in the city. The breadth and volume of sediment that has entered the City's rivers is unprecedented in the history of Christchurch, due to the input of such high volumes over such a small time frame and this occurring for a second time during the most recent 6.3 magnitude earthquake on the 13 June 2011. Tributary waterways of the Avon, Heathcote, and part of the Styx River should therefore be surveyed to plot the extent of liquefaction sand in these systems. Sand and silt will then need to be removed from areas of severe or extensive liquefaction, and the recovery of the aquatic biota monitored at key areas where liquefaction is most severe.



Turbid water and toilet paper at Kilmore Street

Effects of the February Earthquake on Christchurch Waterways

The devastation wrought by the 22 February 2011 earthquake extended to Christchurch's waterways. Large amounts of sediment were released that smothered the aquatic plants and riverbed which is habitat for many aquatic animals (Fig. 1). In places the banks slumped and the riverbed was uplifted altering physical habitat characteristics of the river (e.g., depth, water velocities, channel width, and substrate composition). Numerous broken wastewater pipes discharged untreated sewage to rivers (Fig. 1). Such organic material input can result in a spike in oxygen-demanding bacterial activity that can deplete dissolved oxygen levels and raise ammonia levels; and in extreme situations kill aquatic life.

FIGURE 1

FIGURE 1
Some of the physical effects of the earthquake on Christchurch's waterways that has the potential to also adversely affect the fauna that live in them.

Christchurch's Aquatic Invertebrates

Although we can't see them when we look at a waterway, our rivers and streams are packed with tiny invertebrates that make these ecosystems 'tick'. Aquatic invertebrates can be thought of as 'resource managers'; transferring the sun's energy collected by plants and making it available to animals higher up the food chain, such as fish and birds. Freshwater invertebrates also have species-specific tolerances to pollution and habitat degradation that makes them ideal indicators of environmental change. Throughout the world freshwater invertebrates are used to assess the health of rivers and streams.

Long before the recent earthquakes, Christchurch's waterways had already been impacted by urbanisation. With development a catchment becomes more impervious to stormwater run-off, causing flashier floods and lower summer flows (Suren & Elliott, 2004). Pollutants and fine sediment accumulate in the river sediment, while the addition of buildings, bridges, culverts, and light pollution impede dispersal and influence behaviour of adult aquatic insects (Suren, 2000; Blakely *et al.*, 2006). These factors detrimentally affect the health of our waterways and make them suitable for only a subset of the aquatic invertebrates that would usually be found there. While we do not have any quantitative data on aquatic invertebrates present prior to the development of Christchurch, we do know that some species have disappeared from the more urbanised Avon and Heathcote River catchments (e.g., mayflies, stoneflies, and sensitive caddisflies). Despite this, our waterways are still home to dozens of aquatic invertebrate species. In the Avon River catchment the invertebrate fauna consists of animals that are tolerant of urban stream conditions (such as snails, worms, crustaceans, and midge larvae), although a few caddisfly taxa still persist (Fig. 2).

FIGURE 2

Paracalliope fluviatilis (amphipod, 29%)
Potamopyrgus antipodarum (snail, 22%)
Ostracoda (seed shrimp, 10%)
Oligochaeta (worm, 9%)
Pycnocentrodes sp. (cased caddisfly, 9%)
Physa sp. (snail, 6%)

FIGURE 2
Some of the more common aquatic invertebrates in Christchurch and their relative abundance pre-earthquake (from McMurtrie, 2009). The caddisfly *Pycnocentrodes* is the only pollution-sensitive taxa found in moderate abundance.

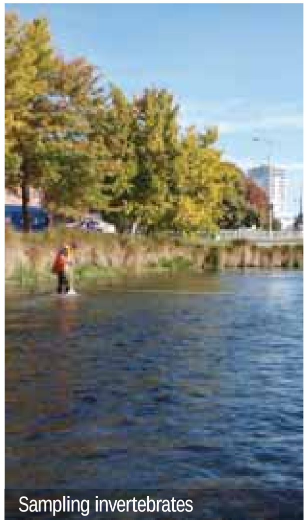
Assessing Earthquake Effects on Christchurch's Aquatic Invertebrates

EOS Ecology has invertebrate data from surveys undertaken before the February 2011 earthquake (i.e., McMurtrie *et al*., 2007; McMurtrie, 2009; James, 2010). Nine sites were selected, and resampled on the 13–15 April 2011 to compare pre and post earthquake invertebrate communities (Fig. 3 & 4). Sites were selected to have three replicate sites in each of three impact categories: no earthquake effect (Wairarapa Stm, Waimairi Stm, & Montreal St); known sand/silt inputs (No.2 Drain, Papanui Stm, & Jacksons Ck); and known sewage and sand/silt inputs (Victoria Sq, Kilmore St, & Fitzgerald Ave). Apart from Jacksons Ck (which is in the Heathcote River catchment), all sites were in the Avon River catchment. While there were liquefaction inputs into wadeable sections of the Heathcote River, sewage inputs were confined to the non-wadeable lower sections. We thus choose to concentrate on the Avon River catchment where both silt and sewage inputs occurred in wadeable sections with previously sampled invertebrate sites. Ideally we would have included sites further downstream of Fitzgerald Ave, where there were more sewage and sand/silt inputs. However, the Avon River is too deep for standard invertebrate sampling techniques downstream of Fitzgerald Ave and as such there is very limited pre-earthquake quantitative invertebrate community data for comparison.

To ensure consistency of sampling effort, the same methodology was used as pre-earthquake. At each site the instream habitat and invertebrates were semi-quantitatively sampled along three equally-spaced transects.

Aquatic benthic invertebrates were collected at each transect by disturbing the substrate across an approximate 1.5 m width immediately upstream of a conventional 500 μm mesh kicknet (Fig. 3). Samples were preserved in isopropyl alcohol. All invertebrates were counted and identified to the lowest practical level using a binocular microscope and several identification keys (Fig. 3). Sub-sampling was utilised for particularly large samples and the unsorted fraction scanned for taxa not already identified. Habitat data was also measured across each of the transects, including soft sediment depth and substrate composition.

FIGURE 3: METHODS PHOTOS


Sampling invertebrates

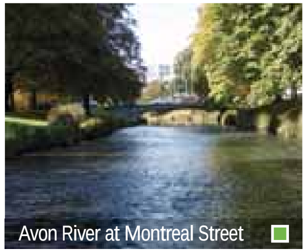

Measuring water velocity

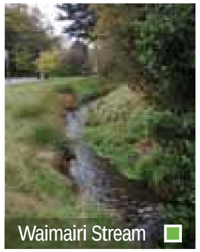

Washing a sample

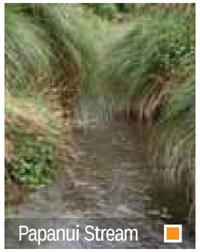

Identifying invertebrates

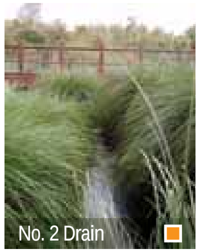
SITE PHOTOS


Wairarapa Stream


Avon River at Montreal Street


Waimairi Stream


Papanui Stream


No. 2 Drain


Jacksons Creek


Avon River at Victoria Square


Avon River at Kilmore Street


Avon River at Fitzgerald Bridge

FIGURE 4

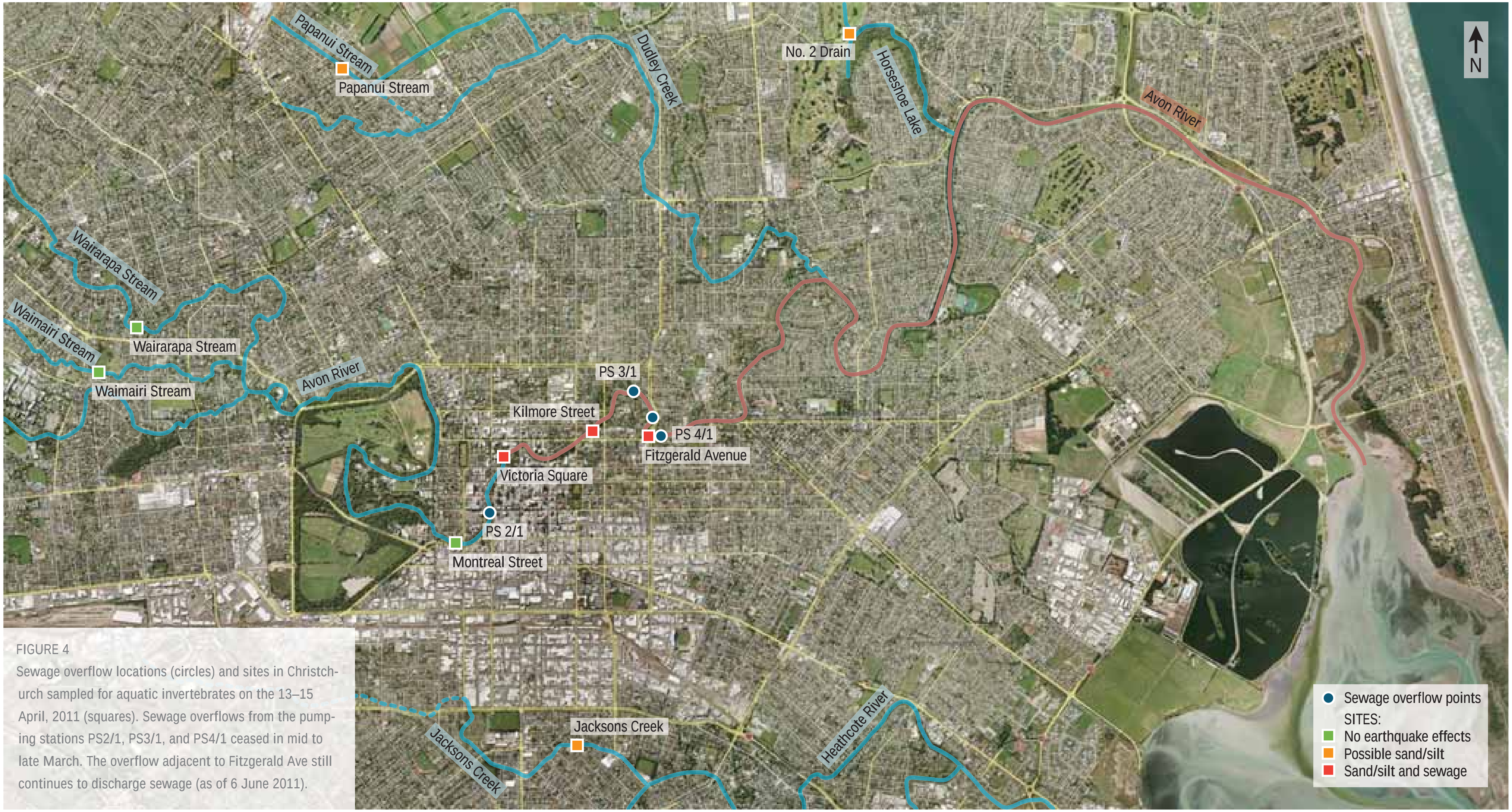


FIGURE 4
Sewage overflow locations (circles) and sites in Christchurch sampled for aquatic invertebrates on the 13–15 April, 2011 (squares). Sewage overflows from the pumping stations PS2/1, PS3/1, and PS4/1 ceased in mid to late March. The overflow adjacent to Fitzgerald Ave still continues to discharge sewage (as of 6 June 2011).

The substrate index is a method of converting substratum size measurements of a site to a single value. 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.

Sediment depth refers to the depth to which a 3 cm diameter pole can be pushed into the substratum with minimal resistance. Typically it is greatest in silt-bottomed streams and least in stony streams where measurements can be 0. It is of interest as fine sediment can smother larger substrates leading to a reduction in habitat quality.

Our Findings

Sediment depth was greater for all three categories of impact after the earthquake but the change was greatest for the "sand/silt & sewage" sites (Fig. 5). Of all the sites Fitzgerald Ave had the thickest layer of fine sediment and lowest substrate index value before and after the earthquake. This may be explained by the depositional nature of this site, which is slightly tidally influenced and so has slower water velocity during high tide. The smallest increase in sediment depth and change in substrate index was observed at the "no earthquake effect" sites (Fig. 5). Substrate index decreased at all the "sand/silt & sewage" sites after the earthquake but the response was more variable at the "sand/silt" sites; although there was still an average decrease in substrate size at these sites (Fig. 5). The small increases in fine sediment depth at one "no earthquake effect" site (Montreal St), all three "sand/silt" sites (No. 2 Drain, Papanui Stm, & Jacksons Ck), and the two other "sand/silt & sewage" sites (Victoria Sq & Kilmore St) may be enough to smother some of the interstitial space of cobbled areas of the streambed and potentially affect the populations of some invertebrates sensitive to fine sediment (e.g., some caddisfly taxa) if they are present.

FIGURE 5

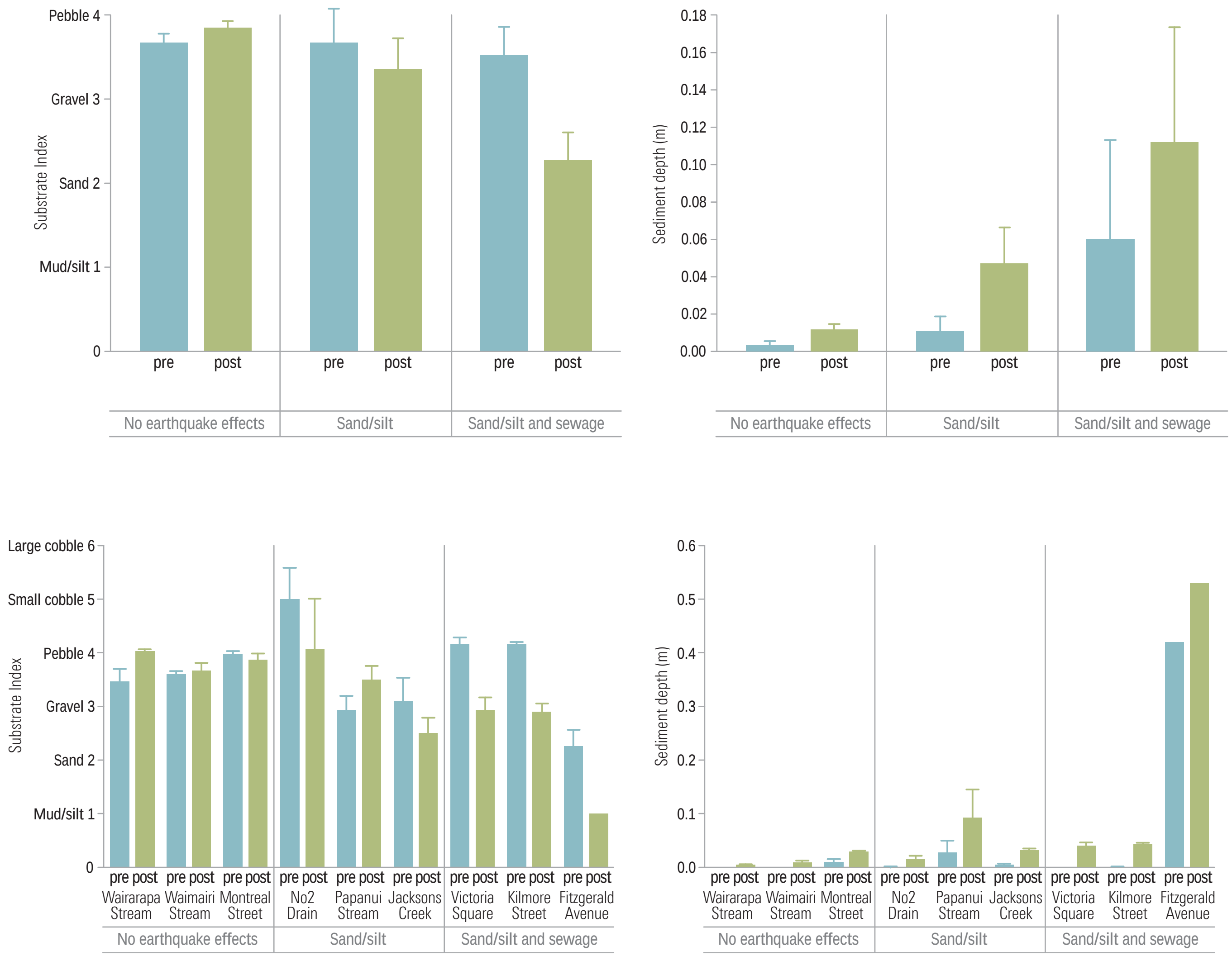
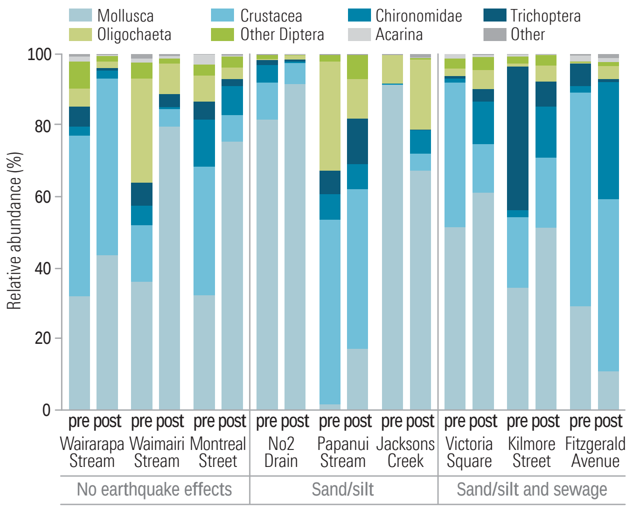


FIGURE 5
Sediment depth and substrate index grouped for each earthquake impact category (top) and for each individual site (bottom) before (pre) and after (post) the 22 February 2011 earthquake..

FIGURE 6



Relative contributions of higher-level taxonomic groupings to the total invertebrate community. Relative abundance graphs can show if there are shifts in the relative numbers of major taxonomic groups in response to some disturbance.

FIGURE 7

Overall the invertebrate communities of the sites sampled were dominated by snails (Mollusca) and crustaceans (Crustacea), with midges (Chironomidae), worms (Oligochaeta), and caddisflies (Trichoptera) being common at a few sites (Fig. 6 & 7). Pollution-sensitive EPT (Ephemeroptera – mayflies, Plecoptera – stoneflies, Trichoptera – caddisflies) invertebrates typically comprised a small-moderate (<10%) part of the total invertebrate community both before and after the earthquake. The exception to this was Kilmore St where around 40% of the pre-earthquake invertebrates were caddisflies (Trichoptera) including *Pycnocentrodes* sp., *Hudsonema amabile*, and *Hydrobiosis parumbripennis* (Fig. 7).

Some before-after earthquake shifts in community composition were observed, such as an increase in relative abundance of snails (Mollusca) post-earthquake at some sites not affected by the earthquake (Waimairi Stm & Montreal St), and a decrease in worms (Oligochaeta) post-earthquake at Papanui Stm that was affected by liquefaction (Fig. 6). At the three sites affected by sewage (Victoria Sq, Kilmore St, & Fitzgerald Ave) there was a post-earthquake increase in midges (Chironomidae) at the expense of snails (Mollusca) or crustaceans (Crustacea). Of note is the vast reduction in caddisflies (Trichoptera) post-earthquake at Kilmore St (dropping from 40% to less than 10%); the only site where caddisflies contributed a sizeable portion of the invertebrate community prior to the earthquake (Fig. 6).

FIGURE 6.
The relative abundance of aquatic invertebrate faunal groupings before and after the 22 February 2011 earthquake.

FIGURE 7.
Common invertebrates found in the current post-earthquake study and the more pollution-sensitive caddisflies (Trichoptera) that were found at the Kilmore St site.

Ordination of invertebrate community data showed that the "no earthquake effect" sites (Wairarapa Stm, Wairarapa Stm, & Montreal St) had invertebrate communities that clustered relatively closely together and did not change to any great extent after the earthquake (Fig. 8). These sites where characterised by having a coarse substratum, snails, amphipods, caddisflies, and mites.

Of the three sites that received sand/silt inputs (but no sewage) the invertebrate community of one (No. 2 Drain) was unchanged, while those of the other two (Papanui Stm & Jacksons Ck) displayed a distinct before-after earthquake separation in ordination space (Fig. 8). Along Axis 1 the post-earthquake Jackson Ck samples were distinct from all others and associated with worms, midge larvae, copepod microcrustaceans, and pea-calms. These are taxa that often are found in or on fine sediment, thus it would appear sediment inputs at this site may have shifted the community. Pre-earthquake samples from Papanui Stm were distinct and characterised by ostracod microcrustaceans (Fig. 8). After the earthquake the Papanui Stm samples had a higher abundance of amphipods which appeared to be at the expense of ostracods.

The sites that received sand/silt and sewage inputs (Victoria Sq, Kilmore St, & Fitzgerald Ave) displayed less community separation compared to the liquefaction affected sites (Papanui Stm & Jacksons Ck) (Fig. 8). Of these three sites Kilmore St and Fitzgerald Ave showed a greater community shift than Victoria Sq. The Fitzgerald Ave samples before and after the earthquake were distinct from the others along Axis 2 and characterised by midge larvae, ostracod microcrustaceans, and greater fine sediment depth.

Taxa richness remained similar before and after the earthquake for all impact categories (Fig. 9). For QMCI the "no earthquake effect" sites improved slightly after the earthquake, while the "sand/silt & sewage" sites decreased from the "fair" water quality category to the poor water quality category after the earthquake (Fig. 9). Pollution sensitive EPT taxa only comprised a significant component of the invertebrate community (i.e., greater than 10%) in the "sand/silt & sewage" sites, with this primarily being at the Kilmore St site where approximately 40% of the invertebrates were EPT taxa (mostly the cased caddisfly *Pycnocentrodes* sp.). After the earthquake the %EPT declined to around 10% at this site indicating a possible earthquake effect from either sand/silt deposition and/or sewage (Fig. 9).

FIGURE 8.
Non-metric multidimensional scaling (NMS) ordination of invertebrate community data before (A) and after (B) the 22 February 2011 earthquake. Invertebrate taxa and habitat variables correlated with the axes are shown.

FIGURE 8

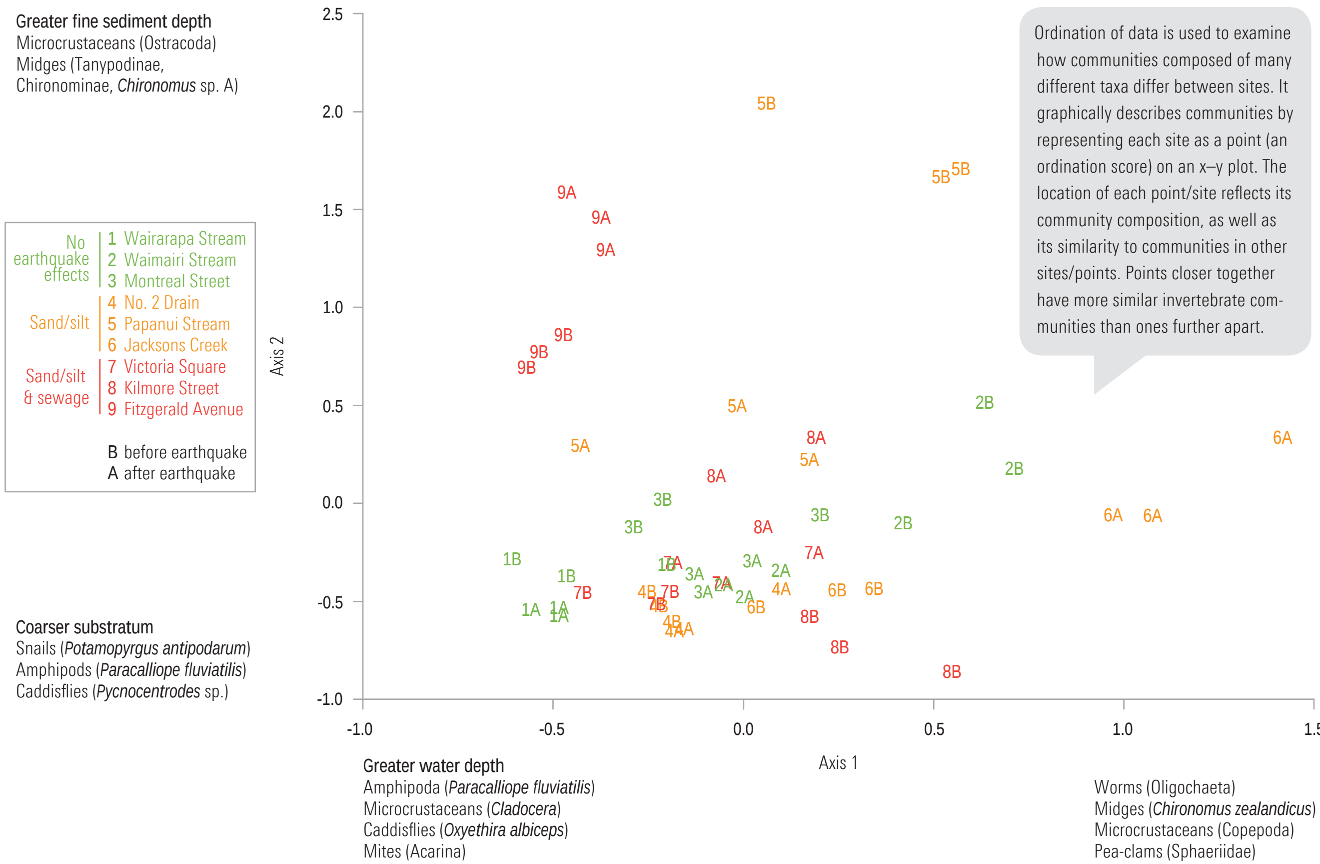
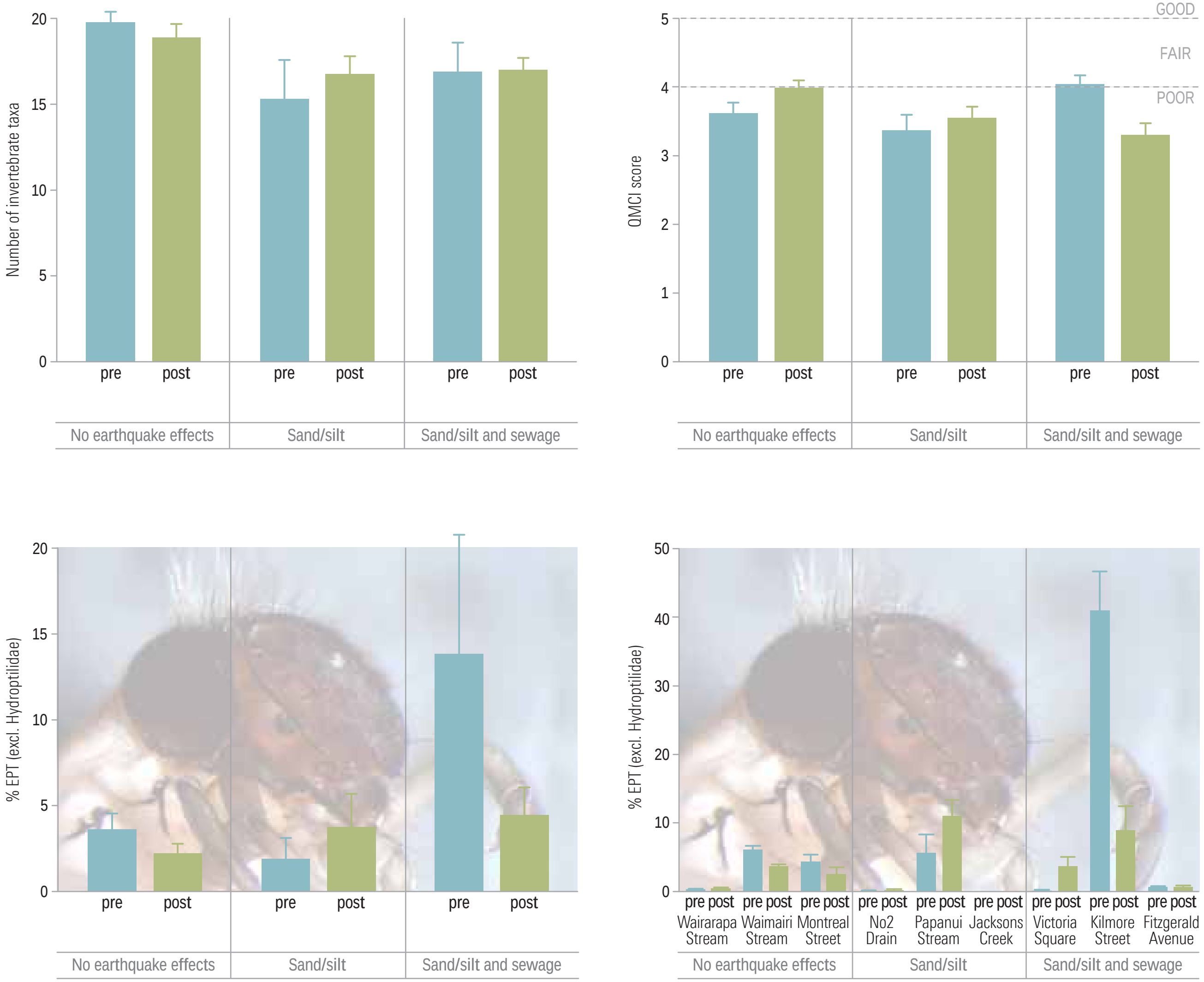


FIGURE 9

The number of taxa at a site refers to the number of different animals captured. A large decrease (or increase) in taxa as a result of some disturbance may indicate an effect. However, small differences often are a result of rare taxa being missed during sampling, rather than changes in the core taxa that make up most of the community at a site.



The Quantitative Macroinvertebrate Community Index (QMCI) is a metric derived from a pollution-tolerance score that has been assigned to all the commonly encountered aquatic invertebrates in New Zealand (Stark & Maxted, 2007). It gives an indication of organic pollution and is often used as a proxy for water quality. Higher scores indicate higher water quality (i.e., a community with a greater abundance of invertebrates that are sensitive to degraded water quality).

FIGURE 9.
Invertebrate community metrics for each impact category before (pre) and after (post) the 22 February 2011 earthquake (means + one standard error are shown). The QMCI graph has the water quality categories of Stark & Maxted (2007) superimposed. For %EPT the individual site means are also shown to highlight the effect at Kilmore St.

EPT refers to the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). Invertebrates from these orders are considered to be sensitive to pollution. Thus a higher percentage abundance of EPT invertebrates is a good indication of better water and habitat quality. The exception is the Hydroptilidae family of caddisflies (purse caddisflies) that thrive in high nutrient and algae conditions, and thus they are excluded from the %EPT calculation.

Conclusion and Management Actions

There were no consistent changes to invertebrate communities in the two earthquake impact categories. There were however some changes at a subset of sites that may be attributable to earthquake effects. At the three "sand/silt & sewage" sites (Victoria Sq, Kilmore St, & Fitzgerald Ave) there was a small post-earthquake increase in midges (Chironomidae) at the expense of snails (Mollusca) or crustaceans (Crustacea). This may be related to the increased fine sediment cover at these sites and/or an increase in sewage-derived nutrients increasing their food supply as midges are often seen to increase in abundance at sites downstream of sewage inputs. There was a decrease in the QMCI score at two of these sites after the earthquake indicating an increase in more pollution tolerant taxa at the expense of those less tolerant. At the Kilmore St site there was also a large drop in the relative abundance of caddisflies (mostly the cased-caddis *Pycnocentrodes* sp.). It is possible these algal grazers were adversely affected by the increase in fine sediment at this site or by the period of highly turbid water and associated sewage in the two weeks following the earthquake. This large decrease in caddisfly (*Pycnocentrodes* sp.) abundance at the Kilmore St site is of concern and should be monitored for improvement. Such taxa often exist in relatively isolated populations as much of the City's waterways no longer provide suitable habitat (because of siltation), while the cityscape reduces the ability of aerial adults to colonise new areas (because of light pollution, culverts, & buildings). Because of their isolation they are unable to easily recolonise and so are more susceptible to local extinction events.

Community shifts at the "sand/silt" impact sites (as shown by the ordination graph) were most dramatic at Jacksons Ck and Papanui Stm, and may have been the result of liquefaction inputs. There was still clear evidence of liquefaction almost two months after the earthquake and it is probable this was the remnants of greater quantities of liquefaction that had since been eroded or cleared away. A much greater area of the beds at these sites may have been smothered immediately after the earthquake leading to the community changes seen.

While there was some indication of an impact from the earthquake on both "sand/silt" and "sand/silt & sewage" sites, there were no major taxa extinction or colonisation events. The overall lack of a major impact on the City's aquatic invertebrate community (in the wadeable sections) as a response to the earthquake is at least partially a result of the existing faunas of these waterways being dominated by taxa tolerant of degraded habitat and water quality. Indeed the greatest earthquake effect was at the one site that supported more sensitive taxa; caddisflies at the Kilmore St site.

While the earthquake effects at the sites surveyed were not dramatic there are still some management actions that should be considered for these areas:

» Removal of liquefaction deposits from Jacksons Creek and Papanui Stm where practicable. Such deposits will affect downstream habitats through the transport of fine sediment. If required, the stony bed of some areas may need to be reinstated by adding appropriately sized coarse substrate.
» Removal of liquefaction deposits and repair of the collapsed banks in the recently restored section of No. 2 Drain. While the impact to the invertebrate community was not great, this site has a significant population of the declining bluegill bully which will be affected by this siltation. As such advice from a freshwater ecologist should be sought before any such works are undertaken.
» Monitoring of the caddisfly (*Pycnocentrodes* sp.) population at the Kilmore St site to determine if the decline observed persists and if so, investigate the possibility of reintroducing them from other parts of the catchment or the nearby Otukaikino River.

Despite the lack of consistent and dramatic effects at our surveyed sites there are still waterways in Christchurch that have been severely impacted by the earthquake. Our study was limited to re-sampling those sites that had been surveyed prior to the earthquake, which by chance were not as impacted as other areas in the city. However, a quick exploration of the city within days of the February earthquake by Associate Professor Jon Harding at the University of Canterbury provided photographic proof of streams smothered in liquefaction sand (in places up to 0.5 m deep) and suffering anoxic conditions (Fig. 10). These conditions would have been severe enough to kill most life in the stream within weeks of the earthquake. The most recent 13 June earthquake (magnitude 6.3) was sufficient to introduce further liquefaction sand and sewage into the city's waterways.

In light of these observations and the latest significant earthquake, we would recommend that tributary waterways of the Avon, Heathcote, and part of the Styx River catchments be surveyed so as to plot the extent of liquefaction sand in these systems (including a rough assessment of volume). Sand and silt will then need to be removed from areas of severe or extensive liquefaction to improve the local conditions and prevent this fine sediment from being redistributed into the lower reaches of the catchment. Recovery of the aquatic biota should be monitored at key areas where liquefaction is most severe.

Options for removal of the sand and silt will vary depending on the depth and extent of the liquefaction. Mechanical removal by digger will not be without its own impacts (through the release of silt and possible bank and bed damage), although this will still be less than the impact of leaving the fine sediment in the system. There are other viable options for smaller sections of waterway, including the use of a sand wand (like a water vacuum cleaner), which should be seriously considered for use in the upper catchment.

FIGURE 10

Corsers Stream seven days after the February earthquake

Liquefaction sand in Abberly Stream

Evidence of higher flows and liquefaction sand

Sand smothers the streambed even two months after the February earthquake

References

Blakely, T.J., Harding, J.S., McIntosh, A.R. & Winterbourn, M.J. 2006. Barriers to the recovery of aquatic insect communities in urban streams. *Freshwater Biology* 51: 1634-1645.

James, A.J. 2010. Long-term Monitoring of Aquatic Invertebrates in Christchurch's Waterways: Heathcote River Catchment 2010. EOS Ecology Report No. 06064-CCC02-03. 18 p.

McMurtrie, S. 2009. Long-term Monitoring of Aquatic Invertebrates in Christchurch's Waterways: Avon River Catchment 2009. EOS Ecology, Christchurch. EOS Ecology Report No. 06064-CCC02-02. 28 p.

McMurtrie, S., Burdon, F.J. & Taylor, M.J. 2007. Assessment of environmental effects: Impacts of the Fitzgerald Avenue Bridge widening on the aquatic ecology of the Avon River. EOS Ecology, Christchurch. EOS Ecology Report No. 06001-CCC01-01. 16 p.

Stark, J.D. & Maxted, J.R. 2007. A User Guide for the Macroinvertebrate Community Index. Cawthron Institute, Nelson. Report No. 1166. 66 p.

Suren, A. 2000. Effects of urbanisation. In: Winterbourn, M.J. & Collier, K.J. (ed). *New Zealand Stream Invertebrates: Ecology and Implications for Management*. New Zealand Limnological Society, Christchurch. Pp. 260-288.

Suren, A. & Elliott, S. 2004. Impacts of urbanisation on streams. In: Harding, J., Mosley, P., Pearson, C. & Sorrell, B. (ed). *Freshwaters of New Zealand*. New Zealand Hydrological Society Inc. and the New Zealand Limnological Society Inc., Christchurch. Pp. 35.1–35.17.

FIGURE 10

Unprecedented amounts of liquefaction sand has entered Christchurch streams following the 22 February and 13 June earthquakes. These sites were not surveyed due to lack of any 'before' biological data, but there is no doubt that the impacts to the stream biota would be severe, and without mitigation these impacts would persist. Photos courtesy of Assoc Prof Jon Harding, University of Canterbury.

eos ECOLOGY

EOS ECOLOGY | AQUATIC RESEARCH CONSULTANTS
P: 03 389 0538 | F: 03 389 8576 | info@eosecology.co.nz | www.eosecology.co.nz | PO Box 4262, Christchurch 8140, New Zealand