STREAM RESTORATION

SWAT's Up, Doc?

The effects of StormWater And Transport on urban streams and estuaries

Mike Timperley and Gerda Kuschel

Every time it rains in the city, dirt and grime are washed off streets and buildings into the stormwater system and then into urban streams and estuaries. New research aims to find ways to help urban aquatic ecosystems recover from this contamination.

above:
Urban streams come in many forms including straightened "natural" channels and concrete-lined drains with grass or sealed riparian margins. (Photos: M. Timperley)

MOST STREAMS in our towns and cities have been piped and covered over to make way for buildings and roads, but the open stream sections that still exist are being increasingly regarded as valuable ecosystems in our urban environment. The problem is that many such sections have been structurally modified to improve their effectiveness as drains for stormwater. Even where these open channels look attractive and natural, the chances are that they contain only a fraction of the many and diverse plants and animals that normally inhabit natural streams.

NIWA's SWAT (StormWater And Transport) research on urban streams and estuaries came about because of escalating interest in restoring these ecosystems to something like their original forms.

It is usually fairly straightforward to identify what needs to be done to restore even the most severely modified stream to something at least *visually* similar to its natural state. For example, it might involve removing concrete channelling. However, the changes required to restore the stream to something *ecologically* similar to its natural state, with self-sustaining natural communities of animals and plants, are much more subtle and complex.

What's changed in urban streams?

The changes that have altered urban streams from their natural state can be broadly grouped into three types: physical, hydrological and chemical.

Physical changes include such things as removing shade (over-hanging vegetation), which causes the streamwater temperatures to increase above normal levels, and replacing the natural stream banks and beds with timber or concrete.

Hydrological (water flow) changes arise because urban catchments contain high proportions of impervious surfaces such as roads, car parks and roofs. This increases the rate at which rainwater runs off into the stormwater system and eventually into streams, causing flooding and high water velocities. It also reduces the amount of rainwater that can infiltrate the soil to keep streams flowing between rainfall events, and therefore streams dry up more often and for longer. These extremes make life very difficult for aquatic plants and animals.

Chemical changes are caused by the way we use our urban environment. When it rains, chemicals produced from transport, industrial, commercial and residential activities are washed from the atmosphere and the roads through the stormwater systems into the streams. Where urban development occurs around estuaries, most of these chemicals eventually end up in the estuarine sediments, where they can accumulate to concentrations high enough to damage the animals living there.

SWAT research

"Mitigating Contaminant Effects in Aquatic Habitats" is the formal name of NIWA's PGSF research programme on stormwater and transport (SWAT). The programme, which began in July 1998, focuses on the hydrological

and chemical problems in urban streams and estuaries and looks at the importance of transport activities as a source of chemical contaminants. The physical problems are addressed in other research programmes (e.g., see *Water & Atmosphere* 6(4) for an article on the effects of riparian changes on aquatic insects).

Over the next five years we aim to:

- determine the impact of contaminants from motor vehicles on urban aquatic ecosystems;
- find ways to reduce the harm contaminants do to aquatic life in urban streams;
- investigate options for managing high and low water flows to reduce the damage these cause to stream aquatic life;
- predict how chemicals from stormwaters affect life in urban estuaries.

What effect does transport have on urban streams?

Motor vehicles contaminate waterways through emissions to the air and deposits onto roads. Particles emitted into the air eventually settle out onto the ground. On roads they are joined by oil from engine leaks, material from brake linings, and rubber particles from tyre wear. When it rains, all of this material is washed through the stormwater system into urban streams and estuaries.

In the first year of SWAT research we developed and tested a system for collecting the information needed to compare the quantities of chemicals originating from vehicles with the quantities picked up in road runoff.

Our "test site" was near Avondale in Auckland. Here, all the stormwater from a known area of road surface drains through a single stormwater system.

A weir, flow recorder and an automatic water sampler were installed in the stormwater manhole. A mobile trailer parked on the roadside contained instruments to monitor rainfall, wind speed and direction, carbon monoxide and polycyclic aromatic hydrocarbon (PAH) concentrations, and to collect samples of fine particulate matter for later analysis. PAHs are produced from the combustion of fossil fuels, such as diesel and petrol in motor vehicles, and are also present in automotive oils and lubricants. We also installed traffic counters along with collectors to trap particles deposited from the atmosphere.

Most of this equipment was operated for seven weeks and an example of some of the data collected is shown in the figure on the right.

Our next task is to relate the quantities of contaminants leaving the road environment through the atmosphere and in the stormwater to vehicle numbers, type and speed and to various meteorological conditions. Eventually this will be incorporated into a user-friendly model that will be able to predict contaminant amounts reaching streams from any road system in New Zealand.

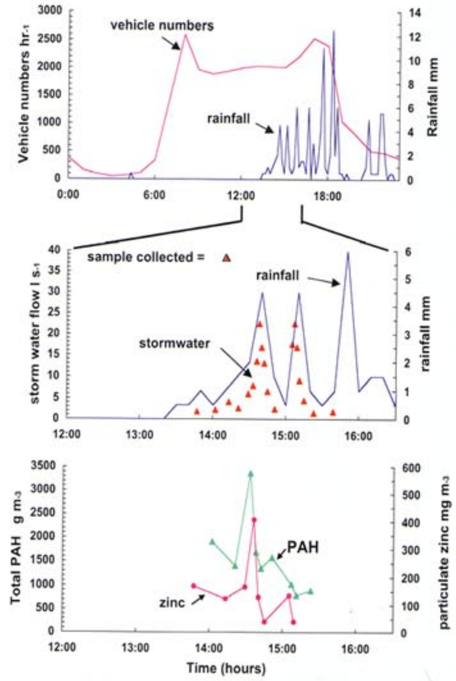
How can we reduce the effects of contamination in urban streams?

As well as the contaminants produced by traffic, stormwater contains metals – particularly zinc – washed from our house roofs. Oil and grease, metals, detergents and other cleaning chemicals, inks and industrial chemicals are washed from workplace floors and yards into the stormwater system. Small amounts of the pesticides and herbicides we use in our gardens also find their way into streams.

Over the past year, we have measured the range of concentrations of three key contaminants – copper, zinc and PAHs – in urban stream waters. Copper and zinc come from roofing, spouting and downpipes. Copper also comes from vehicle brake linings, and zinc is present in vehicle tyres.

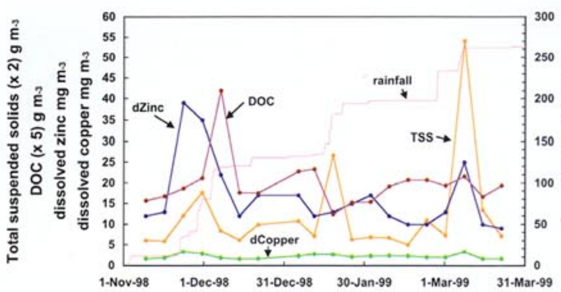
Urban stormwaters usually contain chemicals at high concentrations but stream life is exposed to these only briefly, for short periods immediately following rain. For the rest of the time, stream life is still exposed to chemicals but at lower "baseline" concentrations.

In the first year of the project we measured baseline concentrations in a range of different urban streams as a first step towards evaluating the extent of the contamination problem. Some of our sampling coincided with rainfall events so we also obtained an indication of the range of high stormwater concentrations.



Some of the data collected on one day (6 April 1999) during the transport study at Avondale in Auckland. (A) rainfall and the number of vehicles passing along the road during the day. (B) the first three rainfall peaks and the resulting flow of stormwater off the study section of road. The red points on the stormwater flow line indicate when samples of stormwater were collected. (C) concentrations of total PAHs and zinc attached to sediment in the stormwater samples.

left:
Transport activities contribute chemical contaminants to our urban environment. (Photo: G. Kuschel)



Some of the results for Botany Creek in Manukau City collected during the 20-week stream survey. Higher concentrations of the substances measured occurred following rainfall, but between rainfall events the baseline concentrations did not change much.

Water samples were collected each week for 20 weeks from each of 20 sites in 10 urban catchments in Auckland, Hamilton and Christchurch. The catchments ranged from relatively untouched native forest, to rural pasture, to purely residential, to a mix of residential with commercial and minor light industrial activities.

The graph above shows some of the results obtained for Botany Creek, which drains a residential development in Manukau City. The peaks in concentration generally correspond to rainfall events. For each of the 20 sites we took the median concentration as the best indicator of baseline concentrations.

For dissolved zinc, the lowest median concentration (5 mg/m^3) was recorded in the water draining the native forest catchment and the highest value (61 mg/m^3) was found in the stormwater from the most industrialised urban catchment. Total PAH concentrations followed a similar pattern.

The baseline concentrations of copper (range of median values: 0.5 to 2.5 mg/m^3) are close to the minimum values that have been found to cause adverse effects on aquatic life in studies worldwide. The concentrations of zinc are slightly above these minimum values.

Although our study was not designed specifically to detect the maximum concentrations that occur in stormwater, the results indicate that dissolved copper reaches at least 10 mg/m^3 whereas the peak dissolved zinc concentrations can be in excess of 300 mg/m^3. The effects of short-term exposure of stream life to these high concentrations are not well known at present.

We also looked at the production of dissolved organic matter (DOM) from the decomposition of different types of plants typically found in urban stream riparian margins. DOM – measured as dissolved organic carbon (DOC) – plays a major role in reducing the toxicity of dissolved metals and organic contaminants (e.g., PAHs) to aquatic life.

In future years, we aim to develop ways to manipulate natural instream and riparian zone processes involving DOM and other substances so that they minimise the harm done to aquatic life by chemical contaminants.

Managing stormwater flows

Although stormwater systems help to keep our feet dry and prevent flooding, their effects on urban streams result in poor habitats for stream insects, plants and fish. Faster flood flows destroy the nooks and crannies that aquatic animals inhabit and also wash away the animals and plants themselves. Channel modifications required to cope with flooding, such as lining channels with concrete, reduce habitat diversity and quality. Reduced streamwater flows between rainfall events can cause high water temperatures and low dissolved oxygen concentrations – conditions that are unsuitable for most aquatic animals.

Our aim is to produce a landuse–hydraulic interaction (LHI) model that can be used to determine the most effective way of reducing peak stormwater flows into urban streams and of increasing the amount of water entering the streams from the soil during dry periods. The model will be developed and tested using water flow data from three sites:

- Manukau Experimental Basin, Somerville. This site was first monitored 30 years ago but measurements stopped 16 years later when the catchment was built up. We will resume the monitoring to obtain an after-development record of the effects.
- Alexandra Stream, North Shore. This site already has a before- and after-development record.
- Okeover Stream, Ilam, Christchurch. This site contains a mixture of residential, park, and light commercial land use.

What happens to contaminants in estuaries?

All urban stormwater eventually finds its way to the sea. When the sea happens to be a sheltered estuary adjacent to the urban area, the chemical contaminants in stormwater tend to accumulate (see *Water & Atmosphere* 5(1): 8–10). In Auckland estuaries, for example, there has been a gradual increase of zinc, lead, copper and PAH concentrations in surface sediments as the surrounding catchments have become

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Estuaries accumulate many of the chemicals washed from coastal urban areas. (Photo: B. Williamson)

more and more built-up. Biological surveys in two of these estuaries indicate that present effects on ecosystems are slight. However, in 20–50 years, the predicted concentrations of zinc are likely to cause widespread biological effects unless steps are taken to minimise contaminant inputs to these estuaries.

The standard method for testing sediment toxicity involves exposing animals to artificially contaminated sediments. In the past, however, many of these tests failed because the animals responded to artefacts introduced by the physical and chemical modifications used to produce the contaminated sediments.

Our research involves developing procedures for producing contaminated sediments that don't have these artefacts and yet still retain their natural physical and other chemical characteristics. When we have achieved this, we will then be able to realistically predict the future effects of contaminated sediments on New Zealand estuarine animals.

As our SWAT research progresses we will gradually build up a full picture of how contamination from transport and other activities affects aquatic ecosystems in urban areas and how we can go about reducing these effects. The models and methods we develop will help in the quest for "natural" stream and estuarine habitats in our towns and cities. ■

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