INTRODUCTION TO STORMWATER ISSUES

4. *Stormwater contaminants*

4.3: Effects of stormwater contaminants

The following overview considers the generic effects of the primary road related contaminants.

Litter

It is estimated that approximately 6.5 million tonnes of litter and rubbish ends up in the ocean globally each year. While this litter comes from a number of sources, studies have shown that in coastal areas, litter has generally been found to originate from land based wet weather discharges, and not from marine sources (such as shipping). A survey undertaken by the American Academy of Science has estimated that 60-80% of the total rubbish floating on the ocean surface is indeed land sourced, and that most of this is plastic. Figures from the Waitemata Harbour Clean Up Trust indicate the volume of litter able to be collected in harbours across the Auckland Region (refer to Table 4.3.1).

Table 4.3.1: Harbour Litter Collection Volumes – Auckland Region

Period	Litter Volume Collected (Litres)					
	Auckland	Manukau	North Shore	Waitakere	Island Care	Total Region
April – June 2006	12,225	18,400	8,050	24,650	7,000	70,325
April – June 2009	16,350	19,200	11,550	21,650	53,450	122,200
Jan 03 – June 06	199,713	82,076	86,128	144,563	103,220	615,700
June 06 – June 09	301,661	239,403	146,675	272,675	230,500	1,190,914

Litter surveys conducted by the New York City Department of Sanitation in 1984 and 1986 found that 70% of the street litter items consisted of food and drink wrappers and containers (60%), and the paper and plastic bags (10%) used to carry these items. The early studies also found that litter levels on the streets and footpaths were about 20 to 25% higher in the afternoon than in the morning. Similar surveys in 1993 found that twice as much floatable litter was located on footpaths compared to the streets, and that land use had little effect on the litter loadings (except in some areas where enhanced street cleaning and litter control resulted in improved control).

Floatable litter can significantly degrade the aesthetics and general community enjoyment of receiving waters. The control of '**floatables'** is therefore often a common community goal. The USEPA has identified that one of the major problems with the aesthetic degradation of receiving waters in urban areas is a consequential and general lack of respect for local waterways.

The USEPA notes that such effects lead to a continued degradation of urban watercourses and other water quality problems. Whereas in areas where stormwater is considered a beneficial component of the urban water system, the USEPA notes that the abovementioned problems are "*not as severe, and inhabitants and visitors enjoy the local waterscape*".

Problems that are common to neglected waterways include:

- Low flows;
- Contaminated sediments;
- Additional rubbish (e.g. from illegal dumping);
- Floatables from discharges of litter;
- Unnatural riparian areas;
- Unnatural channel modifications;
- Malodourous water and sediment;
- Rotting vegetation and dead fish; and
- Objectionable sanitary wastes from wastewater overflows.

In addition to aesthetic effects, litter can alter the hydraulics within a watercourse (or reticulated stormwater system), and cause direct effects on fish and bird life. Plastic may be a greater cause of death among the world's marine mammals than any other marine pollutant. It is estimated that 100,000 marine mammals and one million seabirds die each year of plastic entanglement or ingestion. Additionally, studies have shown that the accumulation of microscopic plastic fibres in sand may leach out toxins such as **PCBs** and heavy metals that could then be absorbed by micro-algae and bio-accumulate within the food chain (Thompson and Hoare, 1997). The suspension of tiny plastic fibres in the water column is thought to also potentially affect small invertebrates (Thompson et al, 2004).

Albatross chick carcass with ingested plastic
Source: mindully.org

- **Rubber and plasticisers:**

New Zealand roads are reportedly particularly abrasive and result in relatively high levels of tyre wear. This wear can bind to pavement surfaces (creating issues such as reduced skid resistance), and can introduce rubber and other contaminants into road runoff. Tyres have been found to comprise approximately 55% rubber, 27 % carbon black, lesser amounts of oils, resins, curing and anti-aging agents, and trace levels of zinc oxide (Kennedy, undated presentation notes). These materials include traces of heavy metals (particularly zinc), and a range of organic substances including **PAHs**. The effect of particulates arising from tyre wear is addressed as part of the discussion on sediment. Specific hydrocarbon and heavy metal effects are discussed separately below.

Plasticisers will be released into the environment from roads, largely in association with litter (the bulk of which consists of plastics). As such, these would be expected to be released as part of leaching and / or the breakdown of the plastic over time. Whilst **phthalates** in water generally break down into other chemicals between approximately 2 and 20 days, the presence of phthalate esters (a common plasticiser) is routinely detected within organic soil screens within urban areas, including sediments near stormwater discharge points. As such, the phthalates are now considered to be ubiquitous in urban areas.

Phthalates are an additive within some insecticides as these are known repellents. The Australian National Pollution Index (**NPI**) advises that dibutyl phthalate is known to be highly toxic to aquatic life, but that the toxicity of dibutyl phthalate on plants, birds, and land animals has not been determined. The NPI also notes that dibutyl phthalate will bio-accumulate in the tissues of fish and shellfish.

- **Hydrocarbons**:

Petroleum hydrocarbons are discharged onto roads from a number of sources. These can include engine leaks and drips, burst hydraulic lines, failed valves, spills, and illegal discharges. Hydrocarbons may therefore discharge in a number of forms; from aerosols, to droplets, through to larger scale spills, in solution, as a free liquid, or adsorbed onto sediments. The form of the discharge will depend both on the characteristics of the substance lost to the environment, and the conditions or treatment at the time of discharge. For example:

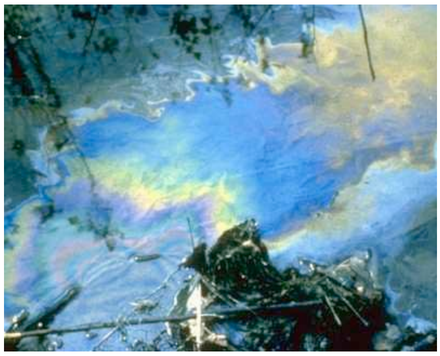
- Where the substance has lighter fractions, the substance may evaporate before reaching the stormwater system or may be partially soluble and therefore pass through a conventional treatment system (as in a petrol spill for example);

- Where the substance is heavier (e.g. fuel / lube oil), its higher **viscosity** may enable containment or cleanup prior to it reaching the stormwater system, or the use of high pressure hoses or detergents may create an **emulsion** which increases the solubility of the substance (which may therefore pass through a conventional treatment system).

Formerly, hydrocarbons were analysed using a test for 'oil and grease' (monitoring reports still occasionally include this screen). In addition to petroleum compounds, the screen detected a range of natural oily substances that did not necessarily result in toxic effects. Hydrocarbon concentrations are now assessed by screening for total petroleum hydrocarbons (**TPH**). This assesses petroleum hydrocarbons with carbon chain lengths of between 7 and 36, and is a more useful indicator of pollution.

Oil boom deployment
Source: Environment Waikato

This screen does not, however, detect all hydrocarbons of interest; particularly lighter fractions (which dominate substances such as petrol, for example) and the very heavy fractions (which may dominate a substance such as bitumen) will not be detected. Care and common sense is required when monitoring for hydrocarbons off roads as TPH may not be an appropriate indicator of hydrocarbon concentrations in all instances (e.g. after a crash where petrol may have been discharged). **PAHs** are a subset of the TPH screen, and some of these compounds are highly toxic and are also known human **carcinogens**. In addition to toxic effects, hydrocarbon spills may cause the clogging of fish gills, smother filter feeders, or damage bird feathers.



Oil sheen on water
Source: purdue.edu

Relatively small hydrocarbon discharges can result in highly visible iridescent sheens. However, not all sheens are a result of petroleum hydrocarbons, and may have a biological origin. The Ministry for the Environment (**MfE**) has released *Guidelines for Assessing and Managing Petroleum Hydrocarbon Contaminated Sites in New Zealand* (1999). However these guidelines do not provide values for hydrocarbon concentrations in surface waters. Similarly, the Australian and New Zealand Environment and Conservation Council (**ANZECC**) *Water Quality Guidelines* (2000) do not provide criteria for hydrocarbon discharges.

Williamson (1993) noted the paucity of hydrocarbon levels and guidelines for urban runoff and consequently recommended event mean concentrations (**EMCs**) of:

- Total hydrocarbons: 1 – 5 **ppm**; and
- PAHs: 7 **ppb.**

- **Heavy metals**:

Issues relating to the effects of heavy metals concerns two aspects of potential toxicity:

- Water column toxicity (soluble contaminants); and
- Sediment toxicity (adsorbed contaminants).

Metals present within the water column, and therefore in a soluble form, are typically more bioavailable, and therefore toxic, than those bound to sediments (i.e. which have their effect through digestion). Metal toxicity in runoff is not straight forward however, as already overviewed above, and it is expected that soluble metals are quickly converted to less reactive (and less toxic) forms when discharged into the environment. The *Urban Runoff Databook* (Williamson, 1993) notes that:

Polluted watercourse
Source: NOAA

"Undesirable effects, such as high metal concentrations in sediments or biota are limited to small zones near outfalls. Hence, we observe few obvious effects, but neither can we be sure that there are no insidious effects. The lack of proof may only reflect the difficulty in studying chronic effects....This fact, together with the laboratory evidence for toxicity and the high concentrations observed in stormwater runoff, suggests Pb, Zn and Cu in urban runoff are undesirable additions in our aquatic environment."

The concern about the environmental effects of heavy metals in stormwater therefore relates not so much to the build-up of these contaminants per se, but to the possible ecological consequences of this build-up. Studies have shown that this build up does occur in New Zealand. However the demonstration of impacts in the field is generally difficult to ascertain due to spatial and temporal variability, which tends to mask impacts of a more subtle nature, such as those arising from stormwater contamination. This is further exacerbated where there are multiple sources of contaminants, as it is very difficult to separate effects of stormwater from other sources.

The range of effects arising from heavy metals can include:

- Acute (short term) effects:
  - Avoidance;
  - Reduced abundance and biomass;
  - Loss of an age cohort;
  - Sublethal effects (illness or lethargy affecting predator / prey relationships).

Daphnia ('water fleas')
Source: RSNZ

- Chronic (long term) effects:
  - Impaired fecundity / reproductive ability;
  - Modified population diversity, composition, animal abundance;
  - Bioaccumulation of metals in animals / within the food chain;
  - Mortality.

This fundamental difference in form and bioavailability needs to be recognised in any sampling or monitoring programme. When capturing runoff for monitoring or measurement, water samples should be analysed for soluble heavy metals rather than 'total' metal concentrations. Soluble contaminant concentrations should then be able to be compared with appropriate aquatic environmental criteria. Some studies have suggested that because stormwater is an intermittent event, comparison with short term (i.e. acute) water quality criteria is appropriate (NIWA, 2003). The *ANZECC Water Quality Guidelines* provide only long term (chronic) exposure criteria, meaning such comparisons would need to turn to overseas criteria, such as those provided by the USEPA. This approach may not necessarily be appropriate in all circumstances, especially where the receiving waters are impounded (such as a wetland or lake) and where the discharge is a dominant contributor to inflows. Similarly, it can be inappropriate to analyse sediment samples for 'total' contaminant concentrations (unless this is being undertaken as a 'fingerprinting' exercise to provide a general screen or indicator of the presence of contaminants in discharges over time). Rather, leaching under more benign conditions (e.g. a synthetic precipitate leaching procedure or **SPLP**) is more likely to be representative of in situ conditions, and therefore the bioavailability of adsorbed contaminants.

Contaminated urban stream
Source: RCA Forum

- **Dust, sediment, and particulates:**

The effects of **sediment** are outlined within **Section 4.1**, albeit that it is generally expected that the concentrations of **sediment** discharging from roads over the longer term would be significantly less than that arising from the construction of a road (refer to **Figure 4.1.1**).

Other **particulate** discharges can include concrete, or paint, or other materials improperly discharged into the stormwater system. These substances may also mix with water or have a soluble fraction which may exacerbate any effects of the discharge. In addition to sediment related effects, these compounds may also give rise to other effects such as changes in pH, oxygen availability, or toxic effects. The exact nature of these effects will vary by compound and can range from discolouration or visual and aesthetic effects, to sub lethal ecosystem effects including **bioaccumulation** of toxins, through to lethal effects.

- **Faecal matter (nutrients and pathogens):**

Road related sources of wastewater, faecal matter, pathogens, and nutrients can include those sourced from:

- Stock trucks;
- Stock crossings;
- Wastewater overflows (into road drainage systems); and

– Runoff from adjacent farmed areas (stock and the application of fertilisers)

Stock effluent discharge
Source: Living Streams

More generally, the discharge of faecal matter can affect the recreational use of streams, lakes, and harbours, reduce available oxygen to aquatic organisms, give rise to increased plant growth, and cause eutrophic related impacts (reduced oxygen availability, increased temperature, habitat squeeze and partitioning), amongst others. Many of the effects are interrelated; for example the discharge of nutrients can increase **turbidity** which can increase temperature, or increases plant growth, the eventual die-off of which causes oxygen ;depletion, **eutrophication** and fish mortality.

Polluted stream
Source: Waitakere City Council

The monitoring of bathing and recreational waters is routinely undertaken largely as part of the management regime for wastewater processes and discharges. Whilst wastewater can be a major source of these contaminants, stormwater can also contribute significant loads. However, other than discharges of human and other animal wastes, urban stormwater runoff does not typically sustain long term effects of the nature described above (Williamson, 1993). This is due to the pulse like nature of the discharges and as a consequence of the largely particulate nature of the organic material, which limits its availability to plants and the extent of its oxygen demand. That said, stormwater discharges are nonetheless being identified as a major source of such contaminants, as a consequence of factors such as poor wastewater reticulation maintenance or stormwater inflow causing wastewater systems to surcharge or overflow.

In 2004 / 2005, the Otago Regional Council undertook water quality monitoring of four of its streams and found that all of these exceeded the MfE / Ministry of Health (MoH) 'action red mode' for contact recreation for *Escherichia coli* (*E. Coli*) (>550 /100mL) and that many recorded concentrations of greater than 20,000 *E. coli* colony forming units (cfu)/100mL. In addition, nutrient levels were found to generally exceed the *ANZECC Water Quality Guideline* default trigger levels for lowland streams. The study concluded that:

> *"Dunedin stormwater quality ... is similar to that found in Washington and Auckland. When compared to the five year median ... results, the* [stormwater sites] *monitored had such poor water quality that all the receiving watercourses were adversely affected; of particular concern were elevated bacteria counts."*

The discharge of pathogens and nutrients resulting from human wastes has traditionally been the focus of management efforts for this group of contaminants. More recently, farming practices and other sources have been targeted. This has included direct road related sources such as stock truck discharges and discharges arising from stock crossings. Stock wastes can introduce **pathogens**, solids, and **nutrients** (phosphates and nitrogen) into stormwater resulting in effects such as weed growth and oxygen depletion. Discharges can also give rise to pavement degradation and safety issues, and give rise to odour and aesthetic impacts (Thull, 1999). As a consequence, the National Stock Effluent Working Group was one of the first such groups established by the RCA Forum, and was established to tackle this issue.

In 1999, the *Industry Code of Practice for the Minimisation of Stock Effluent Spillage from Trucks on Roads* was released to:

- Provide information on how to reduce the amount of stock effluent falling onto roads to:
    - groups involved in the handling and transportation of livestock - farmers, livestock carriers, meat processing companies, stock and station agents, saleyards operators;
    - those with a resource management role - regional councils and territorial authorities;
    - road controlling authorities - Transit New Zealand[8] and territorial authorities;
- Ensure voluntary and co-operative industry management of the issues.

Further information on the Code may be found at: http://www.rcaforum.org.nz/national-stock-effluent-working-group/.

Although stock effluent was, and is recognised as a significant issue, there is little information available as to the scale of the problem as it relates to road discharges. Thull (1999) did provide some indicative volumes based on limited data (and focussed on assessing stock handling practices), which is reproduced within Figures 4.3.1 and 4.3.6, but did acknowledge that data to quantify the issue was lacking.

The implementation of the Industry Code of Practice, together with use of stock underpasses and stock effluent collection points should have reduced the amount of stock effluent discharges dramatically (again, no data was available to quantify this[9]). The location of stock effluent collection points can be found on many rural council websites and that of the **NZTA**; a link to a map showing known collection points is available on the RCA website at http://www.rcaforum.org.nz/map-of-disposal-facilities/.

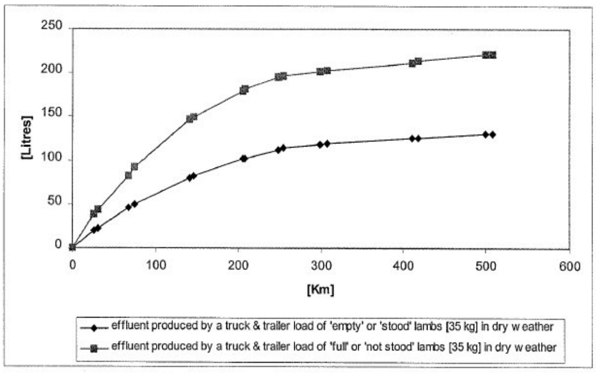


Figure 4.3.1: Lamb Effluent Volumes by Distance Travelled
Source: JP Thull: *Management of Stock Effluent Spillage from Trucks in New Zealand*. PhD Thesis, Lincoln University, 1999.

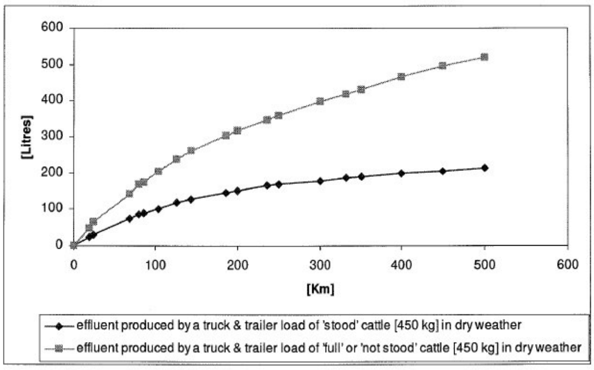


Figure 4.3.2: Cattle Effluent Volumes by Distance Travelled
Source: JP Thull: *Management of Stock Effluent Spillage from Trucks in New Zealand*. PhD Thesis, Lincoln University, 1999.

[8] NZTA.

[9] Notwithstanding any benefit, this may have been offset by the recent growth in dairying.