Development of a Benefit Evaluation Technique Applicable to Treatment of Road Run-off

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Sioban Hartwell, URS New Zealand Limited
Auckland, New Zealand

Craig Welsh, Resource and Environmental Management Limited
Auckland, New Zealand

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P O Box 2331, Lambton Quay, Wellington, New Zealand
Telephone 64-4-473 0220; Facsimile 64-4-499 0733

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[1] URS New Zealand Limited. Auckland, New Zealand
[2] Resource and Environmental Management Limited, Auckland, New Zealand

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Abbreviations and Acronyms

ADT	Average Daily Traffic volume
ARC	Auckland Regional Council
CDS	Continuous Deflection Separation devices
COD	Chemical Oxygen Demand in road run-off
CRC	Cooperative Research Centre for Catchment Hydrology
Cu	Copper
CVM	Contingent Valuation Method for estimating non-use value
FC	Faecal coliform bacteria in road run-off
g	gramme (weight measurement)
ha	hectare (area measurement)
HINC6	Household income before tax exceeds $80,000 per year
H:V	Horizontal:Vertical
Kg	Kilogramme (weight measurement)
m^2	square metre (area measurement)
m^3	cubic metre (volume measurement)
mm	millimetre
NATUSER	Survey respondent makes use of streams, wetlands, estuaries, beaches , harbours or the sea
NIWA	National Institute of Water and Atmosphere Research
NPV	Net Present Value
NSCC	North Shore City Council
OWNHOME	Household owns their residence
Pb	Lead
PEM	Transfund Project Evaluation Manual
REM	Resource and Environmental Management Limited
RSPS	Roading Stormwater Pollution Strategy for Waitakere City
SS	Suspended Solids in road run-off
TEV	Total Economic Value
TN	Total Nitrogen compounds in road run-off
TP	Total Phosphorus compounds in road run-off
TPH	Total Petroleum Hydrocarbons in road run-off
TSS	Total Suspended Solids in road run-off
UNDER40	Survey respondent less than 40 years old
URS	URS New Zealand Limited
VPD	Vehicle Per Day
Transfund	Transfund New Zealand
WCC	Waitakere City Council
WTP	Willingness To Pay for proposed road run-off treatment
yr	year
Zn	Zinc
$M	Million dollars

Contents

Executive Summary

Introduction

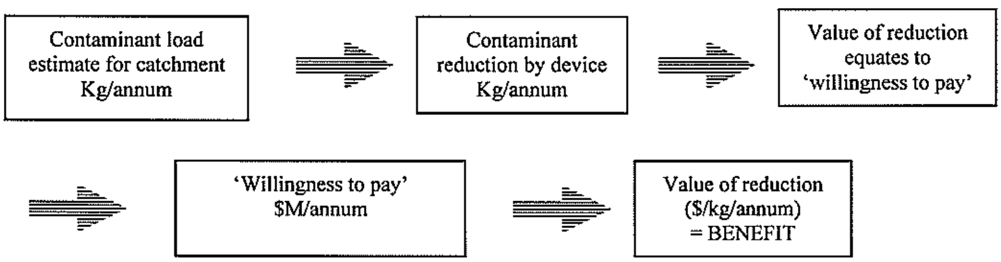
Roads are generally recognised as a key contributor of contaminants to stormwater, with traffic volume being a major factor in the level of contamination present. The installation of stormwater treatment devices is becoming an established part of new road construction projects.

This project investigates the potential to define a cost-benefit based on the reduction of contaminants provided by a stormwater treatment device. The basis for benefit definition is the establishment of a link between stormwater treatment and 'improvement' to the receiving environment. The function of a stormwater treatment device is to remove contaminants that would otherwise enter streams and/or coastal receiving environments. Contaminant contributions from roads can be calculated using estimates of stormwater quality and run-off volumes. By applying assumptions on the removal efficiency of various treatment devices, contaminant reduction can also be calculated.

This project explores the potential for benefit definition based on linking a reduction in contaminants discharged in stormwater to the 'willingness to pay' for environmental improvement.

The approach to benefit definition is represented graphically in Figure 1

Figure 1. Study Approach



Three Auckland Councils, Waitakere City Council, Rodney District Council and North Shore City Council participated in this project.

Economic Valuation Methods

Treating stormwater has potentially significant impacts on a diverse range of values that can be broadly classified into the following categories:

- Direct Use Value - Relates to the influence of receiving water quality on products used by people.
- Indirect Use Value - Relates to the service an ecosystem provides.
- Passive Use Value - Relates to the value people might place on an ecosystem.

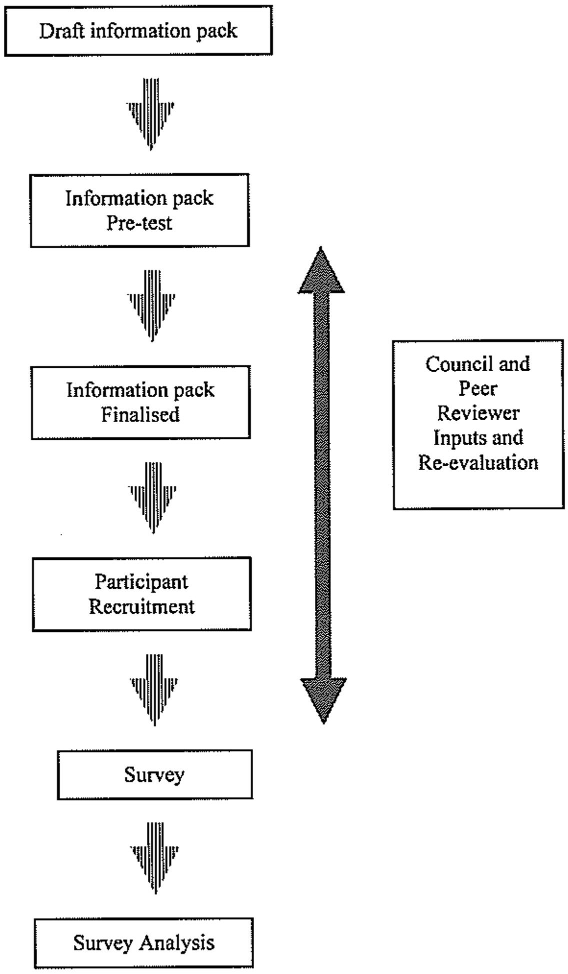
Of the methods available for establishing a monetary basis for these values, the Contingent Valuation Method (CVM) was chosen. CVM involves directly asking people, in a survey, how much they would be willing to pay for specific environmental outcomes.

The Contingent Valuation Method was adopted for this study on the basis that:

- A wide range of international bodies and organisations accept the method as a suitable valuation method; and
- Transfund New Zealand has incorporated monetary measures of non-market values in its Project Evaluation Manual and contingent valuation methods were used to derive some of the benefit parameters adopted.

Contingent Valuation Study

Figure 2 Contingent Valuation Survey Process



Information Pack

The first stage of the project was to develop an information pack for distribution to survey participants, which provided them with enough information to understand and respond to the questions in the survey. It needed to provide enough information for survey participants to understand, and be able to place a value on, stormwater treatment.

The Information Pack focuses on suspended solids, 'oils', copper and zinc.

Questionnaire

The questionnaire asks survey participants to make choices relating to payment for stormwater treatment. Participants are asked how much extra they would be willing to pay in their local authority rates towards stormwater treatment. The cost of the proposal to the

respondent's household was chosen randomly from 10 possible amounts in the set: $5, $10, $20, $50, $100, $200, $400, $800, $1600, $2000.
The questions are presented as choices, i.e. participants are asked to vote for either Option A or Option B.

Participants are also asked to provide an indication as to which contaminants (choosing from oils, zinc, copper and sediments) are of the most concern to them.

Survey Results

Dichotomous choice contingent valuation, which obtains only the respondent's preferred option, has a limited dependent variable.

The dependent variable is WTP (Willing To Pay for the proposed road run-off treatment). The key independent variable is cost. This variable was derived by dividing the total dollar amount proposed in the dichotomous choice question, by the share of rates or rent paid by the individual or family responding to the survey.

The results of the survey are listed in Table 1 as percentage of the population in favour of the run-off treatment proposal at selected costs.

Table 1 Percentage wanting run-off treatment, by cost.

Cost $	Percentage of respondents wanting run-off treatment			
	Rodney %	North Shore %	Waitakere %	Combined %
0	84	86	83	85
250	76	79	75	77
500	67	70	65	68
750	55	59	53	56
1,000	44	47	41	44
1,250	33	35	30	32
1,500	23	25	21	23
1,750	16	17	14	15
2,000	10	11	9	10

The money costs faced by survey participants made a good match with the range of the distribution of values. To further test location differences a single model was fitted to the pooled data from the three councils. This model contained separate constants for the different locations and interaction effects between cost and location. None of these location-dependent coefficients was close to significance.

The money variable is highly significant in all models. This indicates that respondents took account of the money amounts in formulating their responses, with fewer people willing to pay as the money amount increased.

This study has successfully fitted models to the results of the dichotomous choice contingent valuation survey. The models have good fit and the money variable is extremely significant in all models. Economic theory predicts that willingness to pay should increase with income, and this was observed here.

Stormwater Quality

In terms of their impact on water quality, typical stormwater contaminants can be grouped into the following coarse categories:

- Gross pollutants and litter;
- Suspended solids;
- Metals;
- Nutrients (primarily phosphorus and nitrogen compounds);
- Oxygen demanding substances (measured as Biological Oxygen Demand, and Chemical Oxygen Demand);
- Pathogens;
- Oil and grease;
- Trace organic compounds and organic pesticides.

Those which can be attributed directly to the road surface include suspended solids, metals, hydrocarbons, oils and nutrients (primarily phosphorus).

Study Focus

In order to link the 'willingness to pay' values derived from the survey to a benefit cost, calculation of typical contributions needs to be made for these parameters. Two estimates of contaminant loads can be made. The first is for the total load generated on the road surface and the second is for the load in the run-off after it has passed through catchpits.

Table 2 summarises the loadings assumed in contaminant load calculations for road areas based on vehicles per day (vpd).

Table 2 Estimated median contaminant concentrations in stormwater run-off from roads, measured in g/m^3

Number of Vehicles per Day	Contaminant Concentration			
	Total Suspended Solids g/m^3	Total Zinc g/m^3	Total Copper g/m^3	Total Petroleum Hydrocarbons g/m^3
<1,500	13	0.01	0.002	0.02
1,500-5,000	56	0.04	0.007	0.09
5,000-10,000	130	0.09	0.016	0.2
>10,000	307	0.2	0.038	0.5

Contaminant Load Calculations

URS has developed a simplistic contaminant loading model which calculates contaminant mass loading for different land use areas by multiplying the annual run-off volume by 'typical' contaminant concentrations.

Contaminant loads presented in Table 3 are calculated based on the following formula:

$$\textit{Mass Contaminant Loading (kg/yr)} = \text{annual run-off volume (m}^3\text{/yr)} \times \text{contaminant concentration (kg/m}^3\text{)}$$

Table 3 **Contaminant load estimates for varying average daily traffic (ADT) counts (kg/ha/year)**

ADT Counts	Contaminant Concentration			
	Total Suspended Solids kg/ha/year	Total Zinc kg/ha/year	Total Copper kg/ha/year	Total Petroleum Hydrocarbons kg/ha/year
<1500	365	0.06	0.01	0.1
1500-5000	730	0.26	0.05	0.6
5000-10,000	1095	0.58	0.10	1.3
>10,000	1460	0.13	0.24	3.2

Treatment Devices

The cost-benefit approach under review for this study requires input on treatment device costs and treatment efficiencies. There are numerous options available for treatment of road run-off. Device selection is governed by the size of the catchment being treated and the location of the treatment device.

The efficiency values of various treatment devices were estimated and selected to use in the cost-benefit calculation.

Benefit Evaluation

The survey results indicate that 44% of households would be in favour (36% to 52%) of treating run-off from roads at a cost of $ 1,000 per household per year. From this a total benefit value can be calculated for each District/City.

The approach taken was to convert the values obtained into a $/kg/year rate applicable to contaminant removal. This was done by estimating total contaminant generation values per year for roads in each of the study areas. Benefit values were then distributed using the weightings applied by survey participants.

Table 4 **Contaminant benefit reduction values with community weightings.**

Contaminant	Benefit Reduction Value $/kg/year
Total Suspended Solids	44
Total Zinc	37,801
Total Copper	144,818
Total Petroleum Hydrocarbons	106,871

The benefit distribution has a significant impact on the Benefit Reduction Value calculated above for each contaminant. If the same weighting is applied to each contaminant (i.e. 25 %) the contaminant benefit reduction values are quite different as shown in Table 5.

Table 5 **Contaminant benefit reduction values with equal weightings.**

Contaminant	Benefit Reduction Value $/kg/year
Total Suspended Solids	64
Total Zinc	148,503
Total Copper	517,208
Total Petroleum Hydrocarbons	40,481

Using the benefit values given above, a cost-benefit ratio for stormwater projects can be generated through the following key steps:

- Step One. Calculation of existing contaminant loads.
- Step Two. Device selection and calculation of contaminant reduction.
- Step Three. Calculation of contaminant reduction value using $/kg/year values for each contaminant.
- Step Four. Calculation of project NPV (annualised based on capital and maintenance).
- Step Five. Comparison of annual benefit value to annual NPV.

While the process looks simple to apply and use, it is important that the limitations in the base data are well understood. Application of the CVM requires that, in order to provide informed answers to the questionnaire, the public has a quantitative understanding of the benefits associated with stormwater treatment. The relationships between contaminant load reductions and consequential benefits for the environment are very difficult to quantify, even for scientists and engineers working in this field of study. There are many variables to consider; a key one being that it is difficult to isolate the benefits of a single stormwater treatment device on receiving waters from other activities and processes within the wider catchment.

Conclusions

This study investigated the potential to define a benefit cost based on the reduction of contaminants provided by a stormwater treatment device. A contingent valuation approach was used to derive benefit values.

Data from the contingent valuation study was manipulated to generate a benefit value associated with stormwater treatment and this was then converted to a value associated with contaminant reduction ($/kg/year). Contaminant reduction was calculated using estimates of contaminant generation and removal efficiency for stormwater treatment devices.

It was found that a Benefit Cost Ratio can be calculated for stormwater treatment using the elements identified above.

While the process developed through the study does have limitations, a process for calculating Benefit Cost for stormwater treatment has been demonstrated and is amenable to improvement as more accurate data becomes available.

Abstract

This study investigated the potential to define a benefit cost based on the reduction of contaminants provided by a road stormwater run-off treatment device. The basis for benefit definition was the establishment of a link between stormwater treatment and improvement of the receiving environment.

A Contingent Valuation approach was used to derive benefit values.

Data from the contingent valuation study was manipulated to generate a benefit value associated with stormwater treatment and this was then converted to a value associated with contaminant reduction ($/kg/year).

It was found that a Benefit Cost Ratio can be calculated for stormwater treatment.

A process for calculating Benefit Cost for stormwater treatment was demonstrated and was found to be amenable to improvement as more accurate data becomes available.

1. Introduction

1.1 Purpose

Cost-benefit analysis is a technique for comparatively assessing the (monetary) costs and benefits of an activity or project over a relevant time period. In engineering, a cost-benefit approach is most commonly associated with infrastructure projects. Transfund has an established process for cost-benefit evaluation for roading projects, that is outlined in Transfund's Project Evaluation Manual (PEM).

The PEM sets out *"procedures and values to be used for the calculation of benefits such as savings in travel time, increased trip reliability, changes in vehicle operating costs, reduced accident costs, as well as benefits from increased road user comfort, reduced driver frustration and impacts on the environment and non-road users"*.

The benefit parameters covered in the PEM do not relate well to the treatment of run-off generated on road surfaces. The construction of treatment devices is however an established part of new road construction projects. Roads are generally recognised as a key contributor of contaminants to stormwater (CRC 2000, Kennedy and Gadd 2003), with traffic volume being a major factor in the level of contamination present.

Resource consents now commonly require the construction of devices to treat run-off from road surfaces. The increasing awareness of the potential contaminant contribution to stormwater from roads has resulted in some organisations investigating the retrofit of stormwater treatment devices to existing roads, as a means of improving water quality in receiving waters. For example, Waitakere City Council (WCC) issued the Roading Stormwater Pollution Strategy (RSPS) for Waitakere City in October 2001, which focused on treatment of run-off from roads. The RSPS identified fifty-five potential sites for the potential retrofit of stormwater treatment devices adjacent to roads subject to high vehicle usage (greater than 10,000 vehicles per day).

The benefits associated with stormwater treatment are not easily presented in dollar terms, since they tend to be either intangible or require significant research effort to quantify. Treating stormwater benefits the receiving environment through reduced damages (or reduced environmental effects). Equating the reduction in damage to monetized terms requires a methodology to determine the value of the receiving environment. This project investigates the potential to define a cost-benefit based on the reduction of contaminants provided by a stormwater treatment device. The basis for benefit definition is the establishment of a link between stormwater treatment and 'improvement' to the receiving environment

The three Auckland Councils of Waitakere City Council, Rodney District Council and North Shore City Council participated in this project.

1.2 Approach

Improved environmental quality comes about because of reduced damages (or reduced environmental degradation). The economic value of a policy change is the amount of compensation (positive or negative) that an individual would need (by his or her own assessment) in order to be just as well off without the policy. Thus, economic value is a relative value based on the individual's assessment of two (or more) well-defined states of an ecosystem.

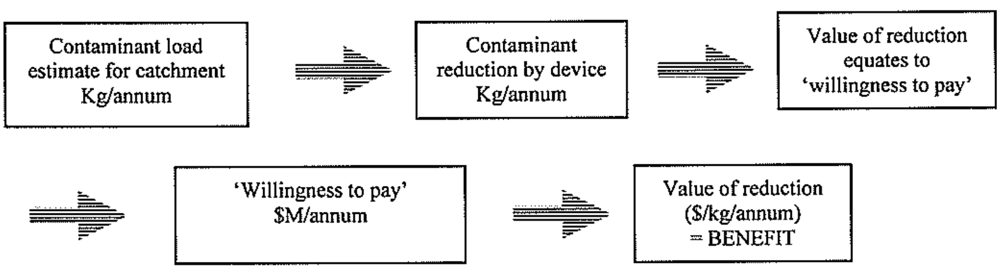
The total sum of individual compensations provides an estimate of the gains and losses for society as a whole. The assumption can thus be made that 'willingness to pay' correlates to accruing environment value.

The function of a stormwater treatment device is to remove contaminants that would otherwise enter streams and/or coastal receiving environments. Contaminant contributions from roads can be calculated using estimates of stormwater quality and run-off volumes (URS, 2001). By applying assumptions on the removal efficiency of various treatment devices, contaminant reduction can also be calculated.

This project explores the potential for benefit definition based on linking a reduction in contaminants discharged in stormwater to the 'willingness to pay' for environmental improvement.

The approach focuses on contaminant discharge and does not cover other effects roads can have on stormwater, in particular flow concentration and temperature effects. The approach to benefit definition is represented graphically in Figure 1-1

Figure 1.1 Study Approach



A contingent valuation approach was adopted in the study to determine 'willingness to pay' The basis for selecting this approach is described in section 2.1. Other key study components included:

- Review of stormwater quality associated with run-off generated on roads;
- Review of stormwater treatment device efficiency; and
- Stormwater treatment device cost (construction and maintenance).

1.3 Process

Table 1.1 summarise the key stages of the research project. Inputs to each of these stages are described in more detail through the report.

Table 1.1 Summary of Key Project Stages.

Stage	Description	Relevant section
One	Definition of target outcomes for benefit evaluation in workshop and through literature review. Stage included workshop to discuss links between the reduction in stormwater pollutants and the environmental outcomes of this reduction with peer reviewers	3.0
Two	Information Pack and questionnaire design based on Task One. Participant recruitment, information delivery, telephone survey	3.0
Three	Survey data analysis	3.0
Four	Literature review on contaminant loads in stormwater run-off, treatment efficiencies of various devices and treatment device costs (operational and maintenance)	4.0 and 5.0
Five	Workshop to present CVM and contaminant load outputs to peer reviewers and initiate methodology development	6.0
Six	Development of benefit transfer methodology based on outputs of task four and five.	6.0

2. Economic Valuation Methods

2.1 Background

Treating stormwater has potentially significant impacts on a diverse range of values that can be broadly classified into the following categories:

- Direct Use Value - Relates to the influence of receiving water quality on products used by people, such as food harvested from streams and coastal receiving environments, in particular shellfish and fish. These 'products' can be given a market value;
- Indirect Use Value - Relates to the service an ecosystem provides; for example the water treatment provided by a wetland would be classed as an indirect value. It is difficult to derive market value for indirect uses.
- Passive Use Value - Relates to the value people might place on an ecosystem, even though they do not actively use it. For example many people value the preservation of certain areas like World Heritage Areas, although they may never visit such areas themselves.

Ecosystem Valuation (www.ecosystemvaluation.org) lists the methods available for establishing a monetary value for these values as follows:

- Market Price Method - Estimates values for ecosystem products or services bought or sold in commercial markets. Applied to stormwater treatment devices this might, for example, cover evaluation of the potential for an increase in shellfish harvesting downstream of a discharge.
- Productivity Method - Estimates the value of ecosystem products that contribute to the production of commercially marketed goods. Applied to stormwater this requires evaluation of the influence an improved quality of the stormwater discharge might have on a product like fish.
- Hedonic Pricing Method - Evaluates the influence of an environmental improvement on the market price of a product, for example, improvements in the water quality of a water body may influence the value of adjacent properties. The method compares two areas having similar characteristics, with the only difference being water quality in an adjacent watercourse. A difference in property price may be explained by this factor.
- Travel Cost Method - Estimates economic values associated with ecosystems or sites that are used for recreation. The method assumes that the value of a site is reflected in how much people are willing to pay to travel to visit it.
- Damage Cost Avoided, Replacement Cost, and Substitute Cost Methods - Estimate economic values based on costs of avoided damages resulting from lost ecosystem services, the costs of replacing ecosystem services, or the costs of providing substitute services.
- Contingent Valuation Method (CVM) - This is one of the most widely used methods for estimating non-use values internationally. It involves directly asking people, in a survey, how much they would be willing to pay for specific environmental outcomes. The method is called 'contingent' valuation, because

people are asked to state their willingness to pay, contingent on a specific hypothetical scenario and description of the environmental outcome. The amount people are asked to pay is varied for different participants, allowing the threshold of social acceptability (i.e. a range of dollar values) to be identified through statistical procedures.

- Choice Modelling - Like the CVM, choice modelling asks people through a survey to make choices based on a hypothetical scenario. The method differs from contingent valuation in that it does not directly ask people to state their values in dollars. Instead, values are inferred from the hypothetical choices or tradeoffs that people make. Choice modelling asks the respondent to state a preference between one group of environmental services or characteristics, at a given price or cost to the individual, and another group of environmental characteristics at a different price or cost. The Auckland Regional Council (Ridley, 2003) used the choice modelling approach for a study on the value of stream habitat loss in that region.
- Benefit Transfer - Entails taking information gained from studies undertaken at various locations and using the data for another similar project at a different location. Benefit transfer has many limitations inherent in the use of data from another location or from a different type of project. It is important to note that a benefit transfer can only be as accurate as the initial study.

2.2 New Zealand Research

An extensive review of local and international literature relating to non market valuation work was undertaken for the Auckland Regional Council (ARC) by Kerr and Sharp (2001). A companion document to assist decision makers/resource users with application of environmental valuation techniques was also produced. This work concluded that the methods best suited for evaluation of mitigation proposals (such as stormwater treatment devices) are:

- dichotomous choice contingent valuation;
- choice modelling; and
- benefit transfer.

With regard to benefit transfer, the report states that '...there are no existing studies that are suitable for transfer to estimate benefits of the waterway impacts of the types of developments occurring in the Auckland Region (particularly land disturbance), or for measuring the benefits of proposed mitigation activities.'

Ward and Srimgeour (1991) attempted to quantify the 'net social worth' of expenditure on stormwater control on the economic value of Auckland Harbours. They estimated:

- The current environmental services of Auckland Harbours (Waitemata, Manukau and Tamaki Estuary) to be worth over $400 million;
- The future benefits of maintaining water quality at current levels over the next twenty years had a present value (in 1991) of $800 million; and

- Taking into account a population growth of 1.7 %, the present value (in 1991) of the Harbours was estimated to be in the order of $1,200 million.

These values were reached by placing value on:

- Amenity;
- Commerce (tourism, fishing)
- Recreation (beach, boating, fishing, shellfish gathering, watersports); and
- Flow-on intangibles (benefits of jobs associated with tourism and fisheries)

Numerous assumptions were made in the process of developing the above costs and the study outcomes are also now outdated.

Paterson and Cole (1999) provided an estimate of New Zealand's biodiversity total economic value (TEV) for the year 1994. TEV consists of the sum of direct use value, indirect use value and passive value, and the authors calculated that for the year 1994 the value of land-based biodiversity was about $44 billion. The study divided ecosystems into type (lakes, wetlands, estuarine etc) and developed estimates of value per hectare. The direct and indirect value of wetlands and estuarine areas were estimated at $34,163 and $39,980 per hectare respectively.

Resource and Environmental Management carried out a literature search of water quality non market valuation examples for Waitakere City Council (REM, 2001). The review concluded that none of the examples reviewed were suitable for benefit transfer.

2.3 Study Methodology

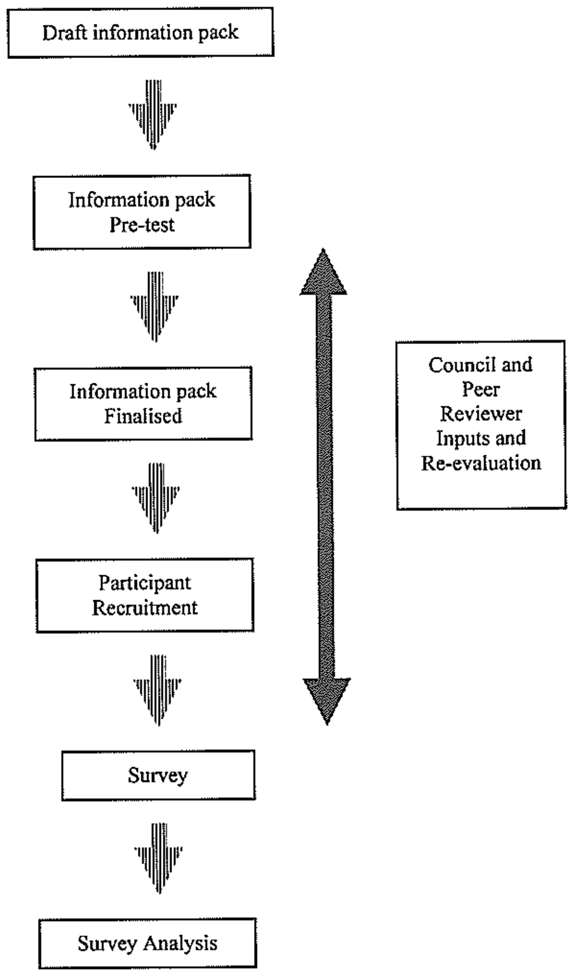
The contingent valuation approach was adopted for this study on the basis that:

- A wide range of international bodies and organisations accept the method as a suitable valuation method; and
- Transfund New Zealand has incorporated monetary measures of non-market values in its PEM and contingent valuation methods were used to derive some of the benefit parameters adopted.

3. Contingent Valuation Study

3.1 Survey Process

Figure 3.1 Contingent Valuation Method Survey Process



The first stage of the project was to develop an information pack for distribution to survey participants. The purpose of the Information Pack was to provide participants with enough information to understand and respond to the questions in the survey. The draft Pack was pre-tested in each of the areas where the telephone survey was to be undertaken (Rodney District, Waitakere City and North Shore City).

Participants in the survey were then recruited randomly (by telephone) and issued with the finalised Information Pack. The survey was undertaken after participants had been allowed sufficient time to review the Information Pack.

3.2 Information Pack

The Information Pack went through several iterations in its development. This was primarily a reflection of the difficulty associated with presenting the linkages between stormwater treatment and environmental improvement.

The interaction of transport on stormwater contaminant generation, and its influence on receiving water quality is complex; in addition the information available on the various components of this process is relatively limited. Contaminants entering streams will also behave differently to, and have potentially different effects from, contaminants entering estuaries and harbours.

The Information Pack needed to provide enough information for survey participants to understand, and be able to place a value on, stormwater treatment. This requires a broad understanding of:

- What the contaminants are in stormwater and which particular contaminants are associated with run-off from roads;
- Why treatment of run-off from roads might have a higher priority than other land uses;
- The potential effects of contaminant release on water bodies;
- How contaminant discharge might affect an individual's activities; and
- How the provision of stormwater treatment devices might reduce contaminant discharge and in what way this is beneficial.

A copy of one of the resulting Information Packs is provided in Appendix A. Apart from area map attachments, the information provided for each of the three participating areas was the same to allow for comparison of the survey results.

The information included is general and simplified for public understanding. This applies in particular to the information provided on the possible contaminants. The Information Pack focuses on suspended solids, 'oils', copper and zinc. These contaminants were selected on the basis that:

- Their concentrations in road run-off tend to be higher than for many other land uses (refer section 4.1);
- These contaminants are easily attributed to roads by members of the public;
- Contaminant loads and potential reduction can be estimated for these parameters; and
- A limited suite of parameters simplifies cost-benefit calculations (refer section 6.0).

Copper and zinc were selected since these are emerging as contaminants of concern for the Upper Waitemata Harbour, which is a common receiving environment for parts of Waitakere City, North Shore City and Rodney District. The Waitakere Roading Stormwater Strategy (URS 2001) identified that levels of zinc in harbour sediments at several locations are predicted to exceed sediment quality guidelines within 10 years, and reach levels where animals may be affected over a 50 year timeframe. Copper levels are also expected to exceed sediment guideline values over time.

The Information Pack does not contain definitive statements relating to potential improvements associated with stormwater treatment. This is due to the difficulty in separating out the effects and management of run-off generated on roads, as well as other activities occurring in a catchment that might influence the condition of a watercourse. Statements along the lines of 'providing stormwater treatment for road run-off will result in an increase in aquatic biota in downstream watercourses' cannot be made due to these other factors. Instead the Information Pack indicates that treatment of road run-off will 'reduce current effects'.

3.3 Questionnaire

The questionnaire asks survey participants to make choices relating to payment for stormwater treatment. Local Authority Rates are used as the payment vehicle. Participants are asked how much extra they would be willing to pay in their rates towards stormwater treatment.

The questions are presented as choices, i.e. participants are asked to vote for either Option A or Option B.

Where the participant might prefer another choice they are asked to consider the situation where votes only apply to Option A (no treatment) or Option B (treatment), and that the option gaining the most votes would be carried out.

Participants are also asked to provide an indication as to which contaminants (choosing from oils, zinc, copper and sediments) are of the most concern to them. The query was included to establish whether the public place higher value on treatment of one type of contaminant over another. The results to this query could be used to develop a weighting for reduction of individual contaminants when deriving benefit costs. Whether this is an appropriate use of the information needs to be considered carefully.

The general public are unlikely to have the technical knowledge to make decisions as to the greater value of treating different contaminants. Also, treatment device design does not generally focus on individual contaminants. This is discussed further in section 6.1.

The questionnaire used is reproduced in Appendix B.

Contingent Valuation Studies always contain invalid responses, because some people react against the valuation process or refuse to accept the valuation parameters they are presented with. Others fail to answer the contingent valuation question. These responses must be removed from the data before analysis can proceed because they come from people who refuse to 'play the contingent valuation game'. The survey was designed to include checks for invalid responses, with the inclusion of open-ended questions seeking the motivation for the response to each contingent valuation question.

The contingent valuation question was:

'Suppose that in order to decide whether the treatment programme should proceed, all residents got to vote tomorrow.'

Responses along the lines of 'road run-off treatment should come out of the rates we pay already', 'the council would just waste the money', 'you only want to increase rates that much now, but you will raise them higher in the future', and similar were removed from the analysis.

Some respondents who were willing to pay were removed from the sample because they made statements along the lines of 'I'm voting for the proposal because I think we should clean up the environment and I don't think it will actually cost this much'.

Many respondents who were not prepared to pay, justified their response by statements like 'I want road run-off treated, but it costs too much'. This type of response was retained for analysis. Many of the supportive responses justified their stand with a statement along the lines of 'this is a small price to pay to prevent the problems from road run-off'.

The cost of the proposal to the respondent's household was chosen randomly from 10 possible amounts in the set: $5, $10, $20, $50, $100, $200, $400, $800, $1600, $2000.

These amounts are distributed approximately logarithmically to account for uncertainty about the distribution of willingness to pay in the target populations, which could not be resolved by the information collected during pre-testing. The most efficient strategy when the distribution is roughly known, is to place money cost amounts close to the median. However, that information was unavailable. A few costs at very high amounts were included to cover the possibility of some high bids and anchor the tail of the distribution. With very little information available on the distribution, a risk-averse strategy of including some very low bids was adopted to ensure that the distribution could be identified.

3.4 Survey Coverage

A total of 752 surveys were undertaken with the distribution being as follows:

- Waitakere City - 297 cases;
- Rodney District - 213 cases; and
- North Shore City - 242 cases.

An initial validity check of the data was undertaken by inspection of descriptive statistics for each of the variables. No out of range responses were observed.

After deletion of invalid responses the sample was reduced to 597 cases (190 North Shore City, 244 Waitakere City, 163 Rodney District).

3.5 Survey Analysis

Dichotomous choice contingent valuation, which obtains only the respondent's preferred option, has a limited dependent variable.

Models were fitted to the data, using maximum likelihood estimation routines developed by Dr Basil Sharp and applied using Limdep (Greene, 1998), a software package designed expressly for analysis of data with limited dependent variables. Goodness-of-fit was measured using McFadden's R^2. Care must be taken in interpreting this measure because, while it falls in the [0,1] range, it cannot be interpreted as the percent of variance explained, as in normal linear regression. McFadden's R^2 greater than 0.2 indicates a good fit, while a score of 0.4 or better indicates an excellent fit to the data.

In dichotomous choice contingent valuation studies the mean can be highly sensitive to functional form, and it is not always possible to choose between functional forms on statistical criteria. Medians are not generally sensitive to functional form (Kerr, 2000).

Two different functional forms (logit and log-logistic) have been utilised to test for sensitivity to functional form. However, the log-logistic models have extremely fat tails, which result in infinite mean willingness to pay. This outcome contradicts economic theory and warns against use of the log-logistic model for policy purposes. Consequently, log-logistic models are not reported. Confidence intervals have been derived using 1000 Monte Carlo replications using a procedure first described by Krinsky & Robb (1986).

3.6 Results

The dependent variable is WTP (Willing To Pay for the proposed road run-off treatment). The key independent variable is COST. This variable was derived by dividing the total dollar amount proposed in the dichotomous choice question, by the share of rates or rent paid by the individual or family responding to the survey. This process was necessary to ensure respondents with different accommodation arrangements (such as individuals flatting together, people living alone, and people living in family homes) were treated in a uniform manner. Only 20 of 597 (3.4%) cases required this adjustment.

Fitted models are reported in Table 3.1. All independent variables were tested for significance. The individual council models contain different independent variables, with age (UNDER40) having a significant effect for North Shore City, but not for the other two council areas. High household income (HINC6) was significant only for Waitakere City.

Table 3.1 Fitted models.

	LOGIT MODELS			
	Rodney	**North Shore**	**Waitakere**	**Combined**
CONSTANT	0.1886	0.4923	0.4661	1.5814***
COST	-0.001895***	-0.001945***	-0.001946***	-0.001956***
UNDER40		1.1541**		
OWNHOME				-1.1318***
NATUSER	1.556**	1.1922**	1.013***	1.059***
HINC6			1.266***	0.5804**
Number of cases	163	189	222	543
McFadden's R^2	.224	.295	.227	.260
Median	$865	$939	$817	$875
(95% CI)	($645~$1209)	($727~$1260)	($625~$1100)	($741~$1048)
Mean	$959	$1015	$912	$960
(95% CI)	($746~$1333)	($811~$1356)	($717~$1220)	($820~$1153)

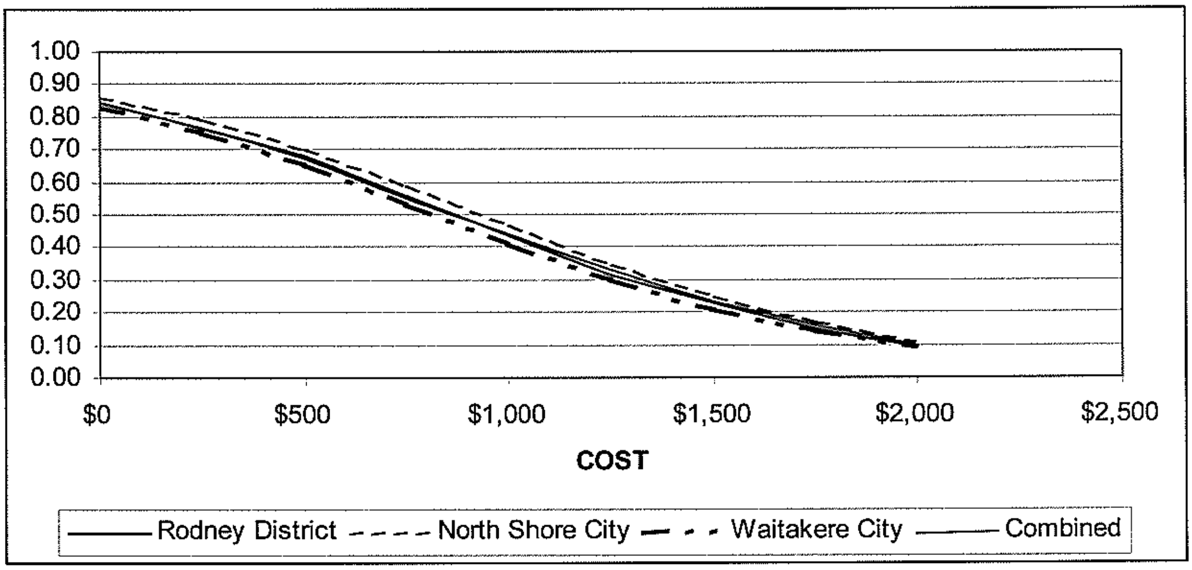
Significance levels * (10%), ** (5%), *** (1%)

UNDER40	Respondent is less than 40 years old
OWNHOME	Household owns their residence
NATUSER	Respondent makes use of streams, wetlands, estuaries, beaches, harbours or the sea
HINC6	Household income before tax exceeds $80,000 per year

Number of cases - Note a reduction in cases (as listed in section 3.4) results from inclusion of variables in the model where people did not answer certain questions.

The independently fitted models are extremely similar, as indicated by Figure 3.2.

Figure 3.2 Probability willingness to pay



This results in measures of central tendency (medians and means) that do not differ between locations. The information contained in Figure 3.2 is reported in Table 3.2 as percentage of the population in favour of the run-off treatment proposal at selected costs.

Table 3.2 Percentage wanting run-off treatment, by cost.

Cost $	Percentage of respondents wanting run-off treatment			
	Rodney %	North Shore %	Waitakere %	Combined %
0	84	86	83	85
250	76	79	75	77
500	67	70	65	68
750	55	59	53	56
1,000	44	47	41	44
1,250	33	35	30	32
1,500	23	25	21	23
1,750	16	17	14	15
2,000	10	11	9	10

The money costs faced by survey participants made a good match with the range of the distribution of values. However, higher than expected mean willingness to pay suggests that efficiency gains could have been obtained by offering fewer money amounts at the low cost end of the distribution. The practical impact of this is a very small increase in confidence intervals compared with an ideal allocation of cost amounts.

To further test location differences a single model was fitted to the pooled data from the three councils. This model contained separate constants for the different locations and interaction effects between cost and location. None of these location-dependent coefficients was close to significance. Consequently, a simple combined model was estimated that assumed similar behaviour at each location. This model is reported in the last column of Table3.1. The combined model has a larger sample size and produces narrower confidence intervals on the median and mean than the independently estimated models.

OWNHOME, NATUSER and HINC6 were found to be significant in the combined model. Those who owned their own home (OWNHOME) are less willing to pay for the proposed scheme than renters are. Natural facilities users (NATUSER) and people with high household incomes (HINC6) are more willing to pay than others. Both these results accord with prior expectations. The money variable has the expected negative sign and is highly significant in all models. This indicates that respondents took account of the money amounts in formulating their responses, with fewer people willing to pay as the money amount increased. The fitted combined model is illustrated in Figure 3.3. The central line shows the expected proportion of the population willing to endorse the project at the stated cost per household. The outer lines show 95% confidence intervals on those probabilities.

Figure 3.3 Probabilities of willingness to pay

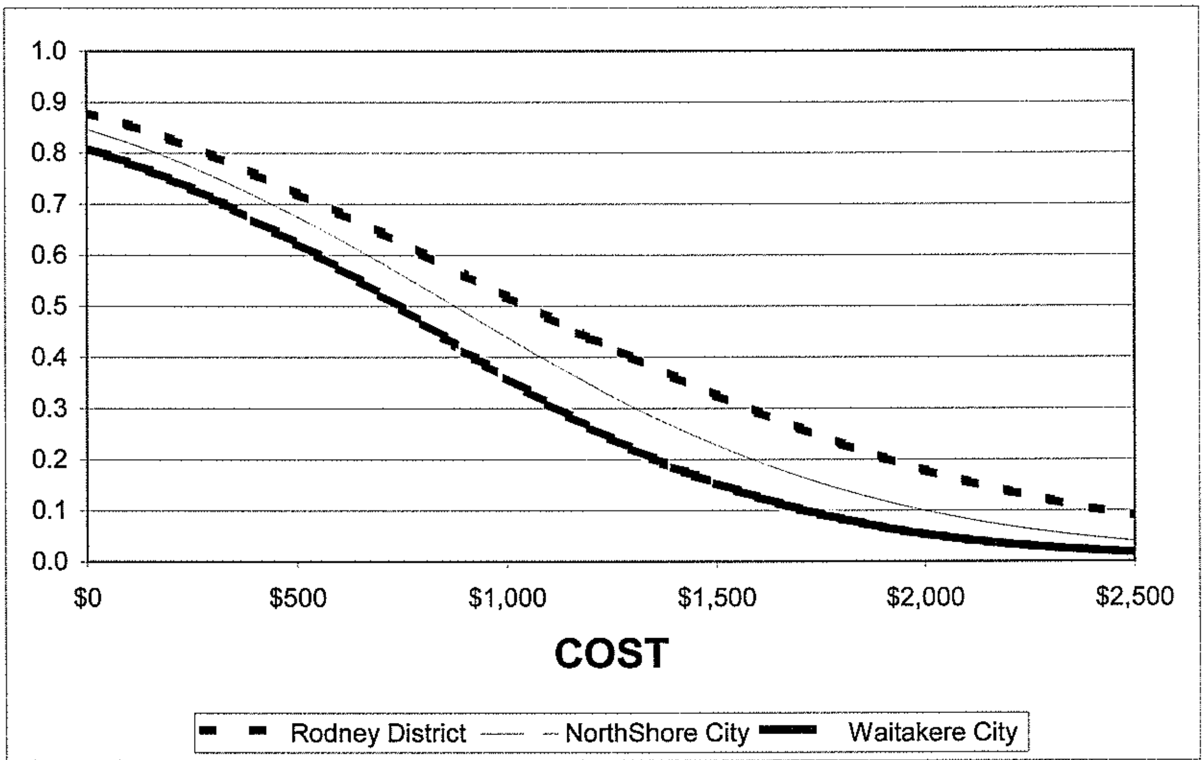


Figure 3.3 shows that 85% of respondents (81% to 88% confidence interval) would support the proposal if it cost them nothing. At a cost of $1000 per household per year 44% of households would be in favour (36% to 52%).

The response to the survey question on which contaminant was of most concern to people in percentage terms were: Oil 66%, Zinc 7%, Copper 10% and Sediment 17%.

3.7 Conclusions

This study has successfully fitted models to the results of the dichotomous choice contingent valuation survey. The models have good fit and the money variable is extremely significant in all models. Economic theory predicts that willingness to pay should increase with income, and this was observed here.

The breadth of confidence intervals on the estimated means and medians mean that the measures of value obtained from this study cannot provide precise indicators of value for policy purposes. However, they do indicate the ranges within which mean and median willingness to pay are likely to fall and can therefore be useful in informing the policy process. They can also be used to predict proportions of the population in agreement with the policy proposal, dependent upon its cost.

4. Stormwater Quality

4.1 Typical Contaminants

Stormwater transports a range of contaminants, originating from a variety of sources such as vehicles, construction activities, atmospheric deposition and spills. The land use in the catchment area is usually a key factor in the type and quantity of contaminants present.

In terms of their impact on water quality, contaminants can be grouped into the following coarse categories (ARC, 2003 and CRC, 2000):

- Gross pollutants and litter;
- Suspended solids;
- Metals;
- Nutrients (primarily phosphorus and nitrogen compounds);
- Oxygen demanding substances (measured as Biological Oxygen Demand, and Chemical Oxygen Demand);
- Pathogens;
- Oil and grease;
- Trace organic compounds and organic pesticides.

Traces of all of the contaminants listed above are often found in road run-off since roads commonly provide drainage for a wider catchment than the road corridor. Those which can be attributed directly to the road surface include suspended solids, metals, hydrocarbons, oils and nutrients (primarily phosphorus). Table 4.1 lists typical contaminant sources associated with road run-off:

Table 4.1 Typical stormwater contaminants found in road run-off

Contaminant	Typical Sources
Gross pollutants and litter	Vegetation, cigarette items, plastics, paper.
Suspended Sediment	Soil (e.g. from construction sites); drain sediments, plant litter and eroding road surface material.
Metals	Copper from vehicle component wear (e.g. brake linings). Lead from exhaust emissions. Zinc from motor vehicle tyre wear, engine additives, industrial processes.
Plant nutrients	Phosphorus compounds from detergents, soil run-off, organic material. Nitrogen compounds (ammonia, nitrate, organic nitrogen species) from plant litter, bird and animal faeces, organic litter, sewage contamination, vehicle emissions, soil run-off.

Table 4.1 Typical stormwater contaminants found in road run-off (continued).

Contaminant	Typical Sources
Oxygen demanding substances	Decaying vegetation, soil matter, faecal matter, bitumen, oil and tyre rubber,
Oil and grease	Lubricating fluids, e.g. engine sump oil.
Microbiological contaminants (*E.coli*, other faecal coliforms, enterococci,)	Faecal wastes of domestic (e.g. dogs, cats) and non-domestic animals (e.g. rats, birds), decaying vegetation.

Table 4-4 from TP10 (ARC 2003) is reproduced below. The table provides an indication of the contaminant loading ranges associated with various land uses. The ranges given indicate roads and commercial including industrial land uses tend to generate higher contaminant loads compared to other land uses.

Table 4-4
Contaminant loading ranges for various land uses
Figures are in kg/ha/yr except for FC (no./ha/yr)

Land use	TSS	TP	TN	Pb (median)	Zn	Cu	FC	COD
Road	281-723	.59-1.5	1.3-3.5	.49-1.1	.18-.45	.03-.09	1.8E+08	112-289
Commercial	242-1369	.69-.91	1.6-8.8	1.6-4.7	1.7-4.9	1.1-3.2	5.6E+09	306-1728
Residential (low)	60-340	.46-.64	3.3-4.7	.03-.09	.07-.20	.09-.27	9.3E+09	NA
Residential (high)	97-547	.54-.76	4.0-5.6	.05-.15	.11-.33	.15-.45	1.5E+10	NA
Terraced	133-755	.59-.81	4.7-6.6	.35-1.05	.17-.51	.17-.34	2.1E+10	100-566
Bush	26-146	.10-.13	1.1-2.8	.01-.03	.01-.03	.02-.03	4.0E+09	NA
Grass	80-588	.01-.25	1.2-7.1	.03-.10	.02-.17	.02-.04	1.6E+10	NA
Pasture	103-583	.01-.25	1.2-7.1	.004-.015	.02-.17	.02-.04	1.6E+10	NA

4.2 Study Focus

The contamination potential associated with a road surface can be attributed to the level of traffic using it; hence a high use motorway generates more contaminants than a smaller residential street. Different sections of a road may also be subject to differing levels of contaminant generation. Areas where traffic is forced to slow down, such as intersections and sections where traffic jams commonly occur, can be expected to receive higher levels of contaminant deposition.

As discussed in section 3.1 the Information Pack developed for this study focussed on sediments, zinc, copper and oils as contaminants associated with road run-off.

In order to link the 'willingness to pay' values derived from the survey to a benefit cost, calculation of typical contributions needs to be made for these parameters.

Two estimates of contaminant loads can be made. The first is for the total load generated on the road surface and the second is for the load in the run-off after it has passed through catchpits. A large proportion of the contaminants (proportion increasing roughly Zn< TPH < Cu) is attached to sediment that is too large to be suspended within the run-off. This fraction moves as bedload and is usually recovered by street sweeping and catchpit cleaning.

For this study, contaminant concentrations are based on the load recovered after passage over the road surface and through catchpits. These contaminants have the potential to reach and effect water bodies. Average contaminant concentrations can be calculated from either estimated or measured contaminant loads in road run-off over a particular period of time, divided by the run-off volume over the same period.

Table 4.2 summarises the loadings assumed in contaminant load calculations for road areas based on vehicles per day (vpd). The ex-catchpit loads in Table 4.2 for roads subject to greater than 10,000 vpd are derived from a NIWA monitoring and modelling project on Richardson Road in Auckland (Timperley et al, 2003). Values in the other columns are pro rata estimates based on the >10,000 vpd values.

Table 4.2 Estimated median contaminant concentrations in stormwater run-off from roads, measured in g/m^3

Number of Vehicles per Day	Contaminant Concentration			
	Total Suspended Solids g/m^3	Total Zinc g/m^3	Total Copper g/m^3	Total Petroleum Hydrocarbons g/m^3
<1,500	13	0.01	0.002	0.02
1,500-5,000	56	0.04	0.007	0.09
5,000-10,000	130	0.09	0.016	0.2
>10,000	[1]307	[2]0.2	[3]0.038	[4]0.5

Table Notes:

1. **Total Suspended Solids**

The Richardson Road study (Timperley et al, 2003) found the total quantity of TSS passing through the catchpits over a 76 day period was 98,918g. This value was obtained from a model fitted to the monitoring data. The total volume of run-off was 322.3 m^3. This gives an average TSS concentration in the run-off ex-catchpit of 307 g/m^3.

2. **Total Zinc**

The Richardson Road study gave an average total zinc concentration ex-catchpit over the 76 day monitoring period of 0.20 g/m^3.

3. **Total Copper**

The ex-catchpit average concentration from the Richardson Road study was 0.038 g/ m^3.

4. **Total Petroleum Hydrocarbons**

The Richardson Road study did not include total petroleum hydrocarbons (TPH). The total TPH load to the road has been estimated to be 0.015 g/vehicle/km. Applying this number to the Richardson Road vehicle and run-off volume data gives an average total run-off concentration of about 31 g/m^3. Most TPH is attached to sediment and if it is assumed that 15% of the sediment remains suspended through the catchpits, this would give an ex-catchpit average concentration in the run-off of about 0.5 g/m^3. The assumed value of 15% is a best estimate based on unpublished data compiled by NIWA.

4.3 Contaminant Load Calculations

URS previously developed a simplistic contaminant loading model for Waitakere City (URS, 2001). This model calculates contaminant mass loading for different land use areas by multiplying the annual run-off volume by 'typical' contaminant concentrations. The basic methodology used in the URS model has been adapted for this study. Contaminant loads presented in Table 4.3 are calculated based on the following formula:

$$\textit{Mass Contaminant Loading (kg/yr)}$$
$$= \textit{annual run-off volume } (m^3/yr) \times \textit{contaminant concentration } (kg/m^3)$$

Annual run-off volume was calculated assuming:

- Mean annual rainfall for the Auckland region of 1200 mm per year (www.metservice.co.nz/learning/data_climate_summaries.asp).
- Run-off coefficient of 1.0 (assumes no infiltration)
- Evaporation of 560 mm per year based on Penman evaporation of 800 mm reduced by a factor of 0.7 to account for rapid run-off (Finklestein, 1973).

Table 4.3 Contaminant load estimates for varying average daily traffic (ADT) counts (kg/ha/year)

ADT Counts	Contaminant Concentration			
	Total Suspended Solids kg/ha/year	Total Zinc kg/ha/year	Total Copper kg/ha/year	Total Petroleum Hydrocarbons kg/ha/year
<1500	365	0.06	0.01	0.1
1500-5000	730	0.26	0.05	0.6
5000-10,000	1095	0.58	0.10	1.3
>10,000	1460	0.13	0.24	3.2

Note - Contaminant load estimates can be adjusted for varying annual rainfall amounts by calculating annual run-off volumes directly (rainfall-evaporation) × run-off coefficient × area.

5. Treatment Devices

5.1 Overview

The cost-benefit approach under review for this study requires input on treatment device costs and treatment efficiencies.

There are numerous options available for treatment of road run-off. Device selection is governed by the size of the catchment being treated and the location of the treatment device. Often space limitation is a key factor that determines what is practicable to install. Table 5.1 below summarises the main categories of stormwater treatment device that might be considered for treatment of road run-off. Design guidelines for most of the non-commercial devices can be sourced from TP10 (ARC, 2003).

Table 5.1 Stormwater treatment device summaries.

Treatment Device Category	Discussion
Wetlands	Constructed wetlands consist of shallow vegetated pond areas which are only practicable where space is available for construction. Wetlands remove contaminants through a combination of mechanisms including sedimentation, aerobic digestion and adhesion of contaminants to vegetation.
Water quality ponds	Water quality ponds are generally categorised as either wet ponds (with a permanent pool) or dry/detention ponds that detain water for a period after rainfall events. The primary mechanism for contaminant removal is sedimentation. As with wetlands the need for land to construct a pond is often a constraint.
Sand Filters	Sand filters are useful where space restrictions apply and they can be designed to take traffic loads. They usually comprise a concrete tank containing sand through which stormwater is filtered and often include a settling chamber for removal of coarse material followed by a tank containing the filter media. Finer materials are trapped or adhere to the filter media. Their limitation is that they can generally only service a small catchment area.
Rain Gardens	Rain gardens are another form of filtration device that use plants and layers of media (e.g. mulch, planting soils, gravel underdrain) for contaminant removal. There may also be treatment through infiltration of stormwater to the base of the rain garden, depending on the underlying soils. The filtration media is placed in layers within a small trench or hollow. Topsoil is placed on the surface and planted. Rain gardens can be incorporated into a landscaping plan. Catchment area served tends to be small (<1,000 m^2).

Table 5.1 Stormwater treatment device summaries (continued).

Treatment Device Category	Discussion
Other Filtration devices	Several types of media including sphagnum moss, carbon slag and leaf litter (Lenhart, 2003) are currently being tested by various research bodies for treatment of stormwater by filtration. Landcare Research has been investigating the use of a range of media placed within treatment walls for stormwater treatment (Pandey, 2003). Various proprietary products such as the StormFilter ® (stormwaterinc.com) are also available. The StormFilter is a filtration system that uses cartridges filled with an array of media, selected to treat the specific pollutant loadings at each site.
Swales	Swales use a combination of slow, shallow water flow and vegetation to remove contaminants from stormwater. They can be used in place of drainage pipes and to convey flood flows. Swales are most effective on gently sloping sites (1% - 5%). In general a width of 3 - 7 m is required to accommodate design requirements (maximum side slope 3H:1V).
Filter strips/riparian planting	Filter strips are used to intercept stormwater before it becomes concentrated. The effect of stormwater travelling through the vegetation is to slow down its rate of passage, allowing some infiltration and removal of contaminants. Riparian planting is a form of filter strip.
Permeable pavement	Permeable pavement designs allow stormwater to infiltrate through the paving surface into the sub-base. Potential benefits are primarily associated with stormwater treatment by filtration through the pavement structure, in particular the sub-base, together with lesser run-off rates and volumes than conventional pavement due to infiltration and storage of stormwater within the sub-base. Permeable paving is best suited to parking areas rather then heavily trafficked roads.
Gross Pollutant Traps and Litter Traps	Devices in this category include floating booms, gratings and mesh inserts (e.g. "Enviropods") installed within culverts and catchpits. There are also several proprietary products available that use a combination of hydraulic motion and sedimentation to remove contaminants. For example, Continuous Deflection Separation (CDS) devices work by using hydraulic motion to separate out and remove contaminants. Stormwater entering a CDS unit is kept in continuous motion as it flows around and through a series of screens. Floating objects are retained and collected on the surface while heavier pollutants settle into a chamber at the base of the unit. Other products include Ecosol Units

Table 5.1 Stormwater treatment device summaries (continued).

Treatment Device Category	Discussion
Oil separation	Several products are available that specifically target oils and greases. Such devices are most applicable to areas where this is the contaminant of concern e.g. garages.

5.2 Treatment Device Efficiency

Removal efficiency data from a literature review on treatment devices is provided in Appendix C. Key points identified in the literature review include:

- Most efficiency data is presented in terms of reduction of totals, and there is limited information on performance in terms of soluble contaminants.
- The majority of references are from overseas.
- Removal efficiency data can be difficult to compare for different reference sources, as the data is reported in different ways e.g. median, event mean.
- Minimal information was found relating to removal efficiencies for hydrocarbons.
- No data or single data points were sourced for several devices.

Information on the treatment efficiency of many of the proprietary devices available on the market is scarce. For many devices no information was found that demonstrates performance in terms of removal of suspended solids, heavy metals and hydrocarbons.

The values presented in Table 5.2 have been selected to use in the cost-benefit calculation. Removal efficiencies relating only to the parameters considered in this study are presented (suspended solids, copper, zinc and TPH). Removal efficiencies used concur with those currently being used by NSCC for catchment planning studies.

Table 5.2 Approximate percentage removal efficiency of various treatment devices.

Treatment Device	Annual Flow Treated %	SS %	Zn %	Cu %	TPH %
Dry Water Quality Pond (24 hr detention of WQV – from TP10)	100	63	27	41	10
Wet Water Quality Pond	100	77	36	51	10
Wet Extended Detention Pond	100	80	41	54	10
Constructed Wetland	100	77	54	69	10
Swale	100	75	47	57	47
Bioretention Device (80% rain garden & 20% Swale)	100	83	59	62	65
Rain Garden	90	84	51	63	48

Table 5.2 Approximate percentage removal efficiency of various treatment devices (Continued).

Treatment Device	Annual Flow Treated %	SS %	Zn %	Cu %	TPH %
Proprietry Device Type 1 – Gross Pollutant Traps	74	30	9	18	10
Proprietry Device Type 2 – Filtrations Systems	90	84	44	59	48
Proprietry Device Type 3 – Catchpit Filter Systems	90	42	13	25	10

Table Notes:

Proprietary Device Type 1 – Gross Pollutant Traps e.g. Downstream Defender, CDS, Ecosol, CleansAll, etc.
Proprietary Device Type 2 – Filtration Systems e.g. Sand filter, Storm filter.
Proprietary Device Type 3 – Catchpit Filter Systems: e.g. Enviropod, Ecosol 100, FloGuard.

The values listed in Table 5.2 should be used as a guide only. Efficiency estimates assume that the device is well maintained and correctly sized for the upstream catchment.

In practice device performance is linked with many factors, including the composition of the influent stormwater and the device size. As an example, particle size is of particular importance where sedimentation is the primary mechanism for contaminant removal. The removal efficiencies listed above may be too high where very fine suspended sediments are a significant component in the run-off.

5.3 Construction and Maintenance Costs

Indicative cost estimates for treatment device construction and maintenance are listed in Appendix D. In practice project costs depend on device location and site specific requirements. Land purchase to facilitate device construction is often the main component of capital cost.

A Net Present Value (NPV) analysis has been applied to estimated capital and maintenance costs listed in Appendix D, as most Councils use NPV cost for planning purposes. NPV calculations are based on a 20 year time period and a discount rate of 10%

6. Benefit Evaluation

6.1 Contaminant Reduction Benefit Calculation

The survey results discussed in section 3.0 indicate that 44% of households would be in favour (36% to 52%) of treating run-off from roads at a cost of $ 1,000 per household per year. If is assumed that a similar willingness to pay (i.e. 44% will pay $1,000) can be attributed to the wider population, then a total benefit value can be calculated for each District/City as shown in Table 6.1.

Table 6.1 Area benefit value calculations.

District/City	Population	[1]Willingness To Pay ($M/year)
Waitakere City	170,000	75
North Shore City	190,000	84
Rodney District	80,000	35
Total	440,000	194

1. Calculated as 0.44 × population × $1,000

The values calculated above need to be broken down further for application to specific projects.

The approach taken was to convert the values given above into a $/kg/year rate applicable to contaminant removal. This was done by estimating total contaminant generation values per year for roads in each of the study areas. Contaminant generation was calculated only for roads with ADT counts of greater than 5,000. This was on the basis that the survey was undertaken in urban areas and treatment, if it occurs, is expected to target high-use rather than rural/low-use roads.

Benefit values were then distributed using the weightings applied by survey participants. Contaminant generation values were calculated using the values given in Table 4.3.

Table 6.2 shows the key inputs to calculation of a $/kg/year value for copper, zinc, TSS and TPH.

Table 6.2 Benefit calculation in terms of contaminant removal – community weightings.

ADT Counts	Road Areas (ha)			
	Rodney District	Waitakere City	North Shore City	
5,000 -10,000	400	66	65	
>10,000	55	52	55	
Total	455	118	120	
Contaminant Loads (kg/ha/yr)-Waitakere, Rodney and North Shore Roads				
ADT Counts	**Total Suspended Solids**	**Total Zinc**	**Total Copper**	**TPH**
5,000 -10,000	441,792	306	54	680
>10,000	311,040	207	39	518
Total	752,832	513	94	198
Benefit Distribution (%)	**17**	**10**	**7**	**66**
Benefit Distribution ($M)	**32.98**	**19.4**	**13.58**	**128.04**
$/kg/year value:	**44**	**37,801**	**144,818**	**106,871**
Total Benefit ($M)	**194**			

Using the above approach the following values are attributed to contaminant reduction:

Table 6.3 Contaminant benefit reduction values with community weightings.

Contaminant	Benefit Reduction Value $/kg/year
Total Suspended Solids	44
Total Zinc	37,801
Total Copper	144,818
Total Petroleum Hydrocarbons	106,871

The benefit distribution has a significant impact on the Benefit Reduction Value calculated above for each contaminant. In the community survey the highest value was placed on treatment of TPH.

The community weighting is different to that which would probably be developed by regulators (e.g. ARC) and the Councils themselves. The treatment devices are designed to treat a range of contaminants associated with stormwater. If the same weighting is applied to each contaminant (i.e. 25 %) the contaminant benefit reduction values are quite different as shown in Table 6.4.

Table 6.4 Contaminant benefit reduction values with equal weightings.

Contaminant	Benefit Reduction Value $/kg/year
Total Suspended Solids	64
Total Zinc	148,503
Total Copper	517,208
Total Petroleum Hydrocarbons	40,481

The weightings used to calculate benefit reduction values have significant impacts on benefit cost outcomes, due to the range in treatment efficiencies for different contaminants, in particular TPH.

TPH removal efficiencies (refer Table 5.2) are low. Therefore, if the majority of the benefit value is attributed to removal of TPH (as per the community weighting), the ultimate benefit calculation will be lower than if an equal weighting was applied. This is discussed further in section 6.2.

6.2 Benefit Calculation

Using the benefit values given above, a cost-benefit ratio for stormwater projects can be generated through the following key steps:

Step One. Calculation of existing contaminant loads (From Table 4.3).
Step Two. Device selection and calculation of contaminant reduction (from Table 5.2).
Step Three. Calculation of contaminant reduction value using $/kg/year values for each contaminant.
Step Four. Calculation of project NPV (annualised based on capital and maintenance).
Step Five. Comparison of annual benefit value to annual NPV.

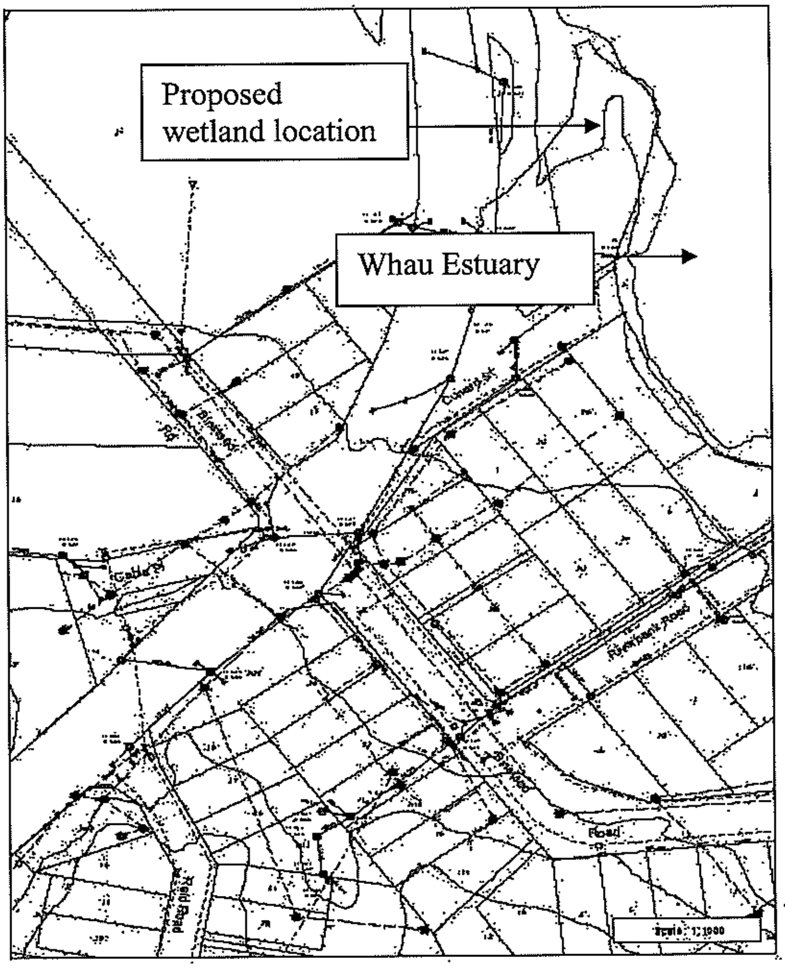
This process is best illustrated by example. In the following examples the contaminant benefit reduction values from Table 6.3 (community weightings) have been used.

6.2.1 Example Calculation 1

Waitakere City Council is currently investigating the construction of a wetland just off Rata Street to treat stormwater from the intersection of Great North Road and Rata Street. The site is located adjacent to Cunard Road. ADT estimates for both the westbound and eastbound carriageways of Rata Street at this location are in the order of 20,000 vehicles.

The proposed wetland will drain a road area of 13,000 m^2. The wetland will discharge directly to the Whau Estuary. Figure 1 shows the proposed location for the wetland.

Figure 6.1 Proposed wetland at Rata Street



An example of how a cost benefit evaluation for this treatment device could be conducted is outlined below.

Cunard Treatment Device

Road Area 1.3 ha
ADT 1500 – 5000 Range
Proposed Device Wetland

Contaminant	Current (kg/year)	Device Removal Efficiency	Future with treatment	Reduction Kg/year	Benefit Value $/kg/year	Benefit Value $/year
TSS	466	77	107	359	44	15796
Copper	0.33	69	0.10	0.23	37801	8694
Zinc	0.06	54	0.03	0.03	144818	4345
TPH	0.70	10	0.67	0.07	106871	7481

Benefit Value per year	$	36,316
NPV Device Cost (20 years)	$	123,848
NPV Device Cost (average per year)	$	6,192
Benefit Cost Ratio		5.9

The example analysis has been undertaken using Net Present Value (NPV) cost estimates for the wetland calculated for a 20 year period and taking account of both construction and maintenance costs. Note, since this project is on land owned by WCC there are no land purchase costs and the project is relatively cheap.

6.2.2 Example Calculation 2

In this theoretical example a sandfilter is proposed to treat a 700 m stretch of motorway.

The example analysis has been undertaken using Net Present Value (NPV) cost estimates for the sandfilter calculated for a 20 year period and taking account of both construction and maintenance costs.

Motorway Treatment Device

Road Area	0.7 ha
ADT	>10,000 Range
Proposed Device	Sandfilters

Contaminant	Current (kg/year)	Device Removal Efficiency	Future with treatment	Reduction Kg/year	Benefit Value $/kg/year	Benefit Value $/year
TSS	251	84	40	211	44	9277
Copper	0.18	59	0.07	0.11	37801	4158
Zinc	0.03	44	0.02	0.01	144818	1448
TPH	0.40	48	0.21	0.19	106871	20306

Benefit Value per year	$	36,819
NPV Device Cost (20 years)	$	300,000
NPV Device Cost (average per year)	$	15,000
Benefit Cost Ratio		2.3

Both of the outcomes are favourable in terms of the benefit exceeding costs.

Of interest, if the contaminant benefit reduction values from Table 6.4 (equal weightings) are used the Benefit Cost ratios increase to 12.4 and 3.7 for Example 1 and Example 2 respectively. This is primarily due to the low treatment efficiency associated with TPH. For wetlands this is indicated to be around 10%. If most of the benefit value from Table 6.1 is applied to TPH rather than other contaminants (which are reduced at higher levels by treatment) then the benefit cost ratio is affected.

6.3 Limitations

The examples presented above outline a process where a Benefit Cost Ratio can be calculated for stormwater treatment using contingent valuation as the basis for

assigning the benefit. While the process looks simple to apply and use, it is important that the limitations in the base data are well understood.
The relationships between contaminant load reductions and consequential benefits for the environment are very difficult to quantify, even for scientists and engineers working in this field of study. There are many variables to consider; a key one being that it is difficult to isolate the benefits of a single stormwater treatment device on receiving waters from possible benefits due to other activities and processes within the wider catchment.

The information pack (refer Appendix A) used for the contingent valuation study, provides some background information on the benefits associated with stormwater treatment. The lack of detail in the pack is a reflection of the current state of information on the processes of contaminant generation, its transport and its influence on receiving water quality. In the information pack it is not possible to support definitive statements about the benefits of treatment e.g. 'stormwater treatment will result in 'x' more fish in a stream'.

Application of the CVM requires that, in order to provide informed answers to the questionnaire, the public has a quantitative understanding of the benefits associated with stormwater treatment. The limitations discussed above determine that the benefit costs developed from the survey and used to generate Benefit Cost Ratios in previous sections, need to be used with caution.

The lack of knowledge in relation to the effects the different contaminants have on the environment is shown in the weightings applied by the public to the different contaminants. TPH was weighted highly and this may be because oils are very visual and easy for people to connect these to roads. It is harder for the public to make the link between roads and metals such as zinc and copper. These are not contaminants the public can see as a discharge. Also, the public cannot be expected to know of the current focus Councils and ARC have on minimising discharge of metal contaminants to the Waitemata Harbour.

Most local authorities and Regional Councils have active programmes to improve public education about stormwater and its effects on the environment. It can be expected that as public understanding of these stormwater matters improves, the procedure developed here will become more accurate and useful for cost-benefit evaluation.

7. Conclusions

This study investigated the potential to define a benefit cost based on the reduction of contaminants provided by a stormwater treatment device. The basis for benefit definition reviewed was the establishment of a link between stormwater treatment and improvement of the receiving environment.

A contingent valuation approach was used to derive benefit values. This approach was adopted because a wide range of international bodies/organisations accept the method as a suitable valuation method. In addition, Transfund New Zealand has used contingent valuation methods to derive some of the benefit parameters adopted in their PEM.

Data from the contingent valuation study was manipulated to generate a benefit value associated with stormwater treatment and this was then converted to a value associated with contaminant reduction ($/kg/year). Contaminant reduction was calculated using estimates of contaminant generation and removal efficiency for stormwater treatment devices.

It was found that a Benefit Cost Ratio can be calculated for stormwater treatment using the elements identified above.

However, the value of the process developed is limited by the current status of information on some of the key inputs. This applies in particular to contaminant generation potential, treatment device efficiencies and the effects of contaminants on receiving environments (both streams and coastal).

It was very difficult to demonstrate linkages between stormwater treatment and environmental improvement in the Information Pack issued in to the public for the community survey. Ideally the public would have a quantitative understanding of the benefits associated with stormwater treatment, in order to provide informed answers to the questionnaire. The lack of information on these components limits the benefit values derived through the contingent valuation survey.

While the process developed through the study does have limitations, a process for calculating Benefit Cost for stormwater treatment has been demonstrated and is amenable to improvement as more accurate data becomes available.

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Appendices

A – Survey Information Packs

B – Survey Questionnaire

C – Treatment Device References

D – Treatment Device Cost Estimates

Appendix A

Survey Information Packs

Waitakere City Council
Te Taiao o Waitakere

ENVIRONMENTAL CHANGES FROM TREATING ROAD RUNOFF INFORMATION PACK

Have your say...

This information pack has been sent to you because you agreed to participate in a survey about Waitakere City Council. This information pack provides information on the environmental effects of road runoff (stormwater runoff from roads) and its management. To find out what you think, a representative will be contacting you shortly to carry out the telephone survey.

The Council wants to take account of public preferences when deciding how to manage road runoff. Your input will help the Council make its decision. The Council is considering installing road runoff treatment systems on high usage roads to reduce the level of contaminants being discharged into our streams, wetlands, estuaries, beaches, harbours and the sea. The final treatment locations have not been selected yet.

WHAT IS ROAD RUNOFF?

Road runoff is stormwater that runs off the hard surfaces of roads, driveways and car parks. Traditionally road runoff enters pipes and is discharged into streams, wetlands, estuaries, beaches, harbours and the sea. While some road runoff is treated, a lot of it is not currently treated in any way.

The familiar grates on roadsides and the pipes at the local beach are often the only visible signs of the road runoff network in Waitakere City Council.

The Council is concerned with the level of contaminants in road runoff and their effects on our environment. Most of the streams in the City receive road runoff. Roads are a big source of stormwater pollution because vehicles deposit large amounts of copper, zinc, and oils onto our roads, which gets mobilized when it rains. Road runoff also carries large amounts of sediment, which is increasing sediment levels in our waterways. Possible locations for road runoff treatment devices will be identified as part of a strategy for stormwater management which the Council is currently developing. These treatment devices will be connected into existing stormwater pipes. These treatment devices will remove contaminants from road runoff as soon as they go in, but the changes in the environment will take time.

ROAD RUNOFF OVERVIEW

1. Road runoff contains:
   - Copper and zinc from tyres, brake pads and exhausts;
   - Oil from leaking vehicle sumps;
   - Airborne contaminants deposited on roads;
   - Sediments washed onto the roads from near-by earthworks or bank erosion;
   - Other pollutants like bacteria, nitrogen and phosphorous.

2. In large quantities, these pollutants can:
   - Make streams, wetlands, estuaries, beaches, harbours and the sea unsightly;
   - Make fish, shellfish, and watercress unsafe to eat (food gathering occurs in a number of locations around the coast); and
   - Harm aquatic plants and animals and damage the places where they live and breed. In more extreme circumstances this may result in:
     - Loss of native fish species in urban streams and estuaries (whitebait, eels, kokopu native trout, smelt, bullies)
     - Loss of common food-fish from estuaries (flounder, mullet);
     - Build up of pollutants in fish and shellfish;
     - Smothering and poisoning of aquatic plants and insects;
     - Harmful effects on birdlife from eating polluted fish, shellfish and crabs;
     - Harm to many of our sport fishing species by impacting on natural nursery areas.

3. A typical 1 km section of high usage road can generate the following contaminant loads in a single year. Installing a treatment device which passes road runoff through a sand filter could remove the following amounts:

Annual Contaminant Loading Estimate

	Current	Assumed Device Removal Efficiency	Estimated Future
	(kg/yr)	%	(kg/yr)
Total Suspended Solids	2904	85	435.67
Total Copper	1	60	0.20
Total Zinc	5	75	1.27
Total Petroleum Hydrocarbons	255	80	51.02

4. Copper, zinc, sediment and oil that are intercepted by the treatment systems will be disposed of in properly designed landfills.

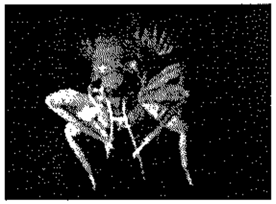
DIFFERENCES THAT TREATMENT DEVICES WILL MAKE

Aquatic Plants

Treating road runoff will reduce the smothering effect of sediment on aquatic plants. Removing sediment will also increase the amounts of sunlight which is needed by plants, by reducing periods of dirty water. Treating road runoff will reduce the impact of oil on the ability of plants to breathe, and reduce contamination of the soil they live in. Treatment will also reduce the uptake of copper and zinc by roots and leaves, which can poison plants. Copper and zinc accumulate in organisms, and as you move further up the food chain they can have greater impact.

Invertebrates (Such as insects/snails/shellfish/lobsters)

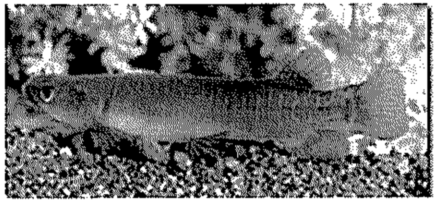
Treating road runoff will reduce the effect of sediment smothering the invertebrates themselves, where they live, and what they eat.

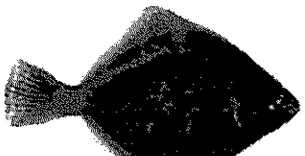


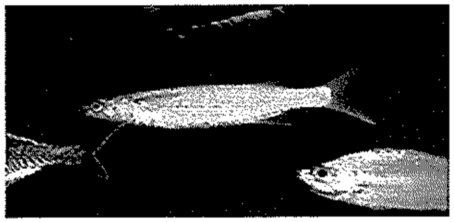
Treating road runoff will reduce the impact of oil on the ability of these animals to breathe, and reduce contamination of the food they eat. Treatment will also reduce the uptake of copper and zinc by these animals, which can poison them and impact on how they breed. Copper and zinc accumulate in organisms, and as you move further up the food chain they can have greater impact. Studies have indicated that the continued build-up of copper and zinc in estuarine sediments may cause toxic effects on estuarine animals in the long term.

Fish (Such as whitebait, Bully, native trout, Eels, Flounder and Mullet)

Treating road runoff will reduce the effect sediment has in smothering fish food and reducing habitat quality. Removing sediment will also increase the ability of fish to see their food which is necessary for feeding. Treatment will also remove fine sediment that can affect fish gills.



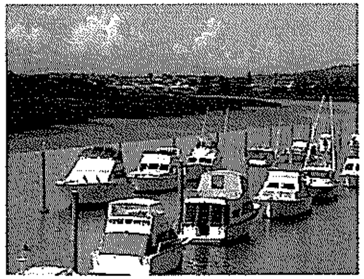




Treating road runoff will reduce the impact of oil on the ability of these animals to breathe through their gills, and reduce contamination of the food they eat. Treatment will also reduce the uptake of copper and zinc by these animals, which can poison them and impact on how they breed. Copper and zinc accumulate in organisms, and as you move further up the food chain they can have greater impact. Studies have indicated that the continued build-up of copper and zinc in estuarine sediments may cause toxic effects on estuarine animals in the long term.

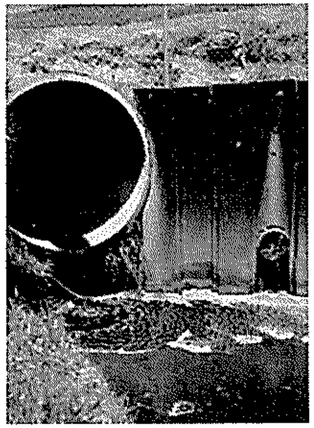
Contact Recreation

There would be less traces of oil on the beaches and estuaries people use for recreation.



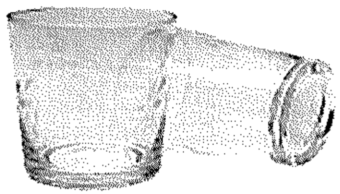
Visual

There may be some visual change in the rivers, estuaries, and harbour immediately downstream from the sites due to less visible oil and sediment. This change will not be noticeable from most streamside areas due to access restrictions in these urban streams.



Drinking water

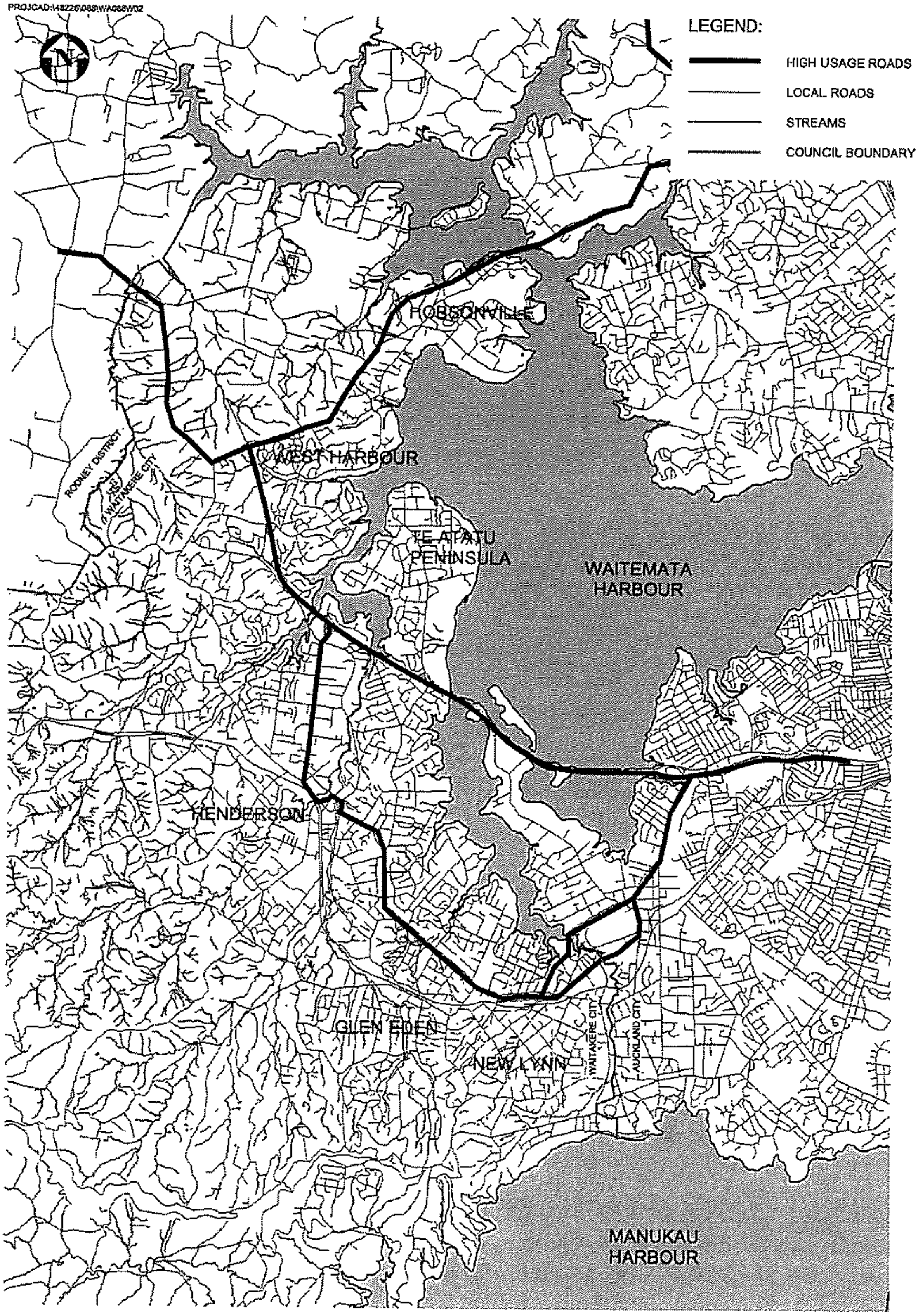
There would be no change in treated water quality. Road runoff does not affect drinking water in Waitakere City Council.



Odour

There is no significant odour associated with road runoff and, therefore there would be no change in odour levels in the City.

Thank you for reading the information pack. We will telephone you shortly to obtain your views about management of road runoff.



WAITAKERE CITY URBAN RECEIVING ENVIRONMENTS

Appendix B

Survey Questionnaire

ROAD RUN-OFF TREATMENT DEVICES QUESTIONNAIRE

[Introduction by interviewer].

"I am ringing to find out if you received your copy of the information pack on environmental changes from road run-off treatment devices?"

[If No arrange a convenient time to call back. Resend the pack if needed.]

If Yes: "Have you had a chance to read the information pack?"

[If "Yes" continue]
[If "No" arrange a convenient time to phone back.]

"The information you provide will be used to clarify our understanding of public reaction to the proposal. Your response is anonymous, all results are merged and nobody is identified."

Council wants to take account of public preferences when deciding how to manage road run-off. The Council is considering installing road run-off treatment systems on high usage roads to reduce the level of pollution in streams, wetlands, estuaries, beaches, harbours and the sea as outlined on the Map Your input will help council make its decision."

"Before we start, I just want to check,

How many adults live in your household?
How many children live in your household?
Please indicate which of the following best represents your household:

- Living alone
- Couple without kids at home
- One adult with kids at home
- Couple with kids at home
- Sharing (e.g. flatting)
- Other, please describe.

Do you live in your own home?"

[If NO:]

"Do you rent the home you live in?"

[If NO go to X, If YES go to Y]

X: Let me clarify. You do not own or pay rent for the place in which you live.
[If that is correct, then finish the interview.]

Y: Do you share rent payments with people other than your family, for example in a flat that you share with other people?

[If YES:]
"What share of the rent for your residence do you pay?" Answer = Z%.

[If No, then Z =100%]

[Record answer]

"You will recall, the Council. is investigating installing road run-off treatment devices on high usage roads. The expected benefits of this treatment are outlined in the information pack."

"The council is considering two options for treating road run-off, these options are:"

[If they pay rates, state:]

Option A: Do nothing. Your rates will not change and the road run-off will not be treated.

Option B: Treat road run-off as outlined in the information pack. Your household rates would increase by $X per year for every year from now on. The money collected would be used for its intended purpose. [Interviewer: choose the next $X off list A. Record $X]

[If they pay rent, state:]

Option A: Do nothing. Your rent will not change and the road run-off will not be treated.

Option B: Treat road run-off as outlined in the information pack. Your household rent would increase by $X per year from now on. This means that you personally would be responsible for paying an extra $X*Z% per year for every year from now on. The money collected would be used for its intended purpose. [Interviewer: choose the next $X off list A. Record $X]

[If they question why their rent would increase, say "rates would go up and landlords will pass this cost onto tenants"]

"Suppose that in order to decide whether the treatment programme should proceed, all [insert relevant Council name] residents got to vote tomorrow. Every adult gets one vote for either Option A or Option B. You may prefer some other options, but suppose that you can only vote for Option A (no treatment) or Option B (treatment). The option gaining the most votes would be carried out. Which option would you vote for? Think about what you are voting for. Imagine that if more than half of people voted for Option B, you would have to pay the extra money every year from now on."

"Would you like to be reminded of any aspect of the two options?"
[If yes, repeat the options] "Which option would you vote for?"

Option A..................0
Option B..................1
Neither/don't know......9

"Please explain briefly why you chose to vote for your preferred option". [Needs to be open-ended, don't probe].

[Interviewer: If they did not chose either option, please ask respondent to state why not?. Needs to be open-ended, do not probe].

[Interviewer: If the respondent did chose an option then ask the following question.

"If it cost your household nothing extra in rent or rates would you be in favour of the treatment devices?"

[Yes/No – record answer]

"Which contaminant was of most concern to you?"

[Oil, zinc, copper, sediment – record answer]

Demographic Information:

Vehicle owner? – Yes/No – type of vehicle
Use of the streams, wetlands, estuaries, beaches, harbours and the sea? – Yes/No
Age (years)
Household income (before tax)? – use typical ranges
Personal income (before tax)?

"This survey was designed to identify what value residents place on the environment. The cost increases you were presented with were made up to help us to identify how residents felt about paying different amounts of money to solve this problem. Costs for these proposals and the methods for funding them have not been worked out in detail. Councils are not committing themselves to treating road run-off, and have no intention to increase rates at the moment."

"Thank you for participating in the survey."

Appendix C

Treatment Device References

Stormwater Treatment Device Efficiency-Summary of published data

Treatment device/option		Data Reference	Reported Data Type	Reported Values TSS	Zinc (Zn)	Copper (Cu)	TPH
Dry pond							
	1	WMI , August 1997	Range	20-60 %	10-50 %	10-40%	
	4	Schueler and Caraco, 2001	Median	47%			
	13	Caraco and Winer, 2000	Median	47%	26%	26%	
Extended detention dry pond							
	1	WMI , August 1997	Range	30-80 %	10-60 %	10-50 %	
	22	Watershed Protection Techniques	Median	70%	26%	26%	
	13	Caraco and Winer, 2000	Median	61%	29%	29%	
Wet pond							
	1	WMI , August 1997	Range	50-90%	30 -90 %	20-80 %	
	20	Blackburn Lake, CRC, 1999	Based on annual pollutant loads	74%			
	2	Pacific Steel (ARC, TP10, May 2003)	Average Event Mean	78%			
	2	Hayman Park (ARC, TP10, May 2003)	Average Event Mean	71%			
	2	Unitech (ARC, TP10, May 2003)	Average Event Mean	83%			
	4	Schueler and Caraco, 2001	Median	80%			
	23	Watershed Protection Techniques-Lakeside Pond	Event Mean	93%	80%		
	23	Watershed Protection Techniques-Runaway Bay	Event Mean	62%	32%		
	13	Caraco and Winer, 2000	Median	79%	65%	58%	
Constructed Wetland							
	3	Strecker, 1996	Median	80%	50%	40%	
	2	Unitech-1994	Average Event Mean	83%	68%	81%	
	2	Unitech-2002	Average Event Mean	45%	86%	79%	
	4	Schueler and Caraco, 2001	Median	76%			
	13	Caraco and Winer, 2000	Median	76%	44%	40%	
Rain garden							
		No Data					
Porous pavement							
	13	Caraco and Winer, 2000	Median	95%	99%		
Infiltration trench							
	13	Caraco and Winer, 2000	Median	100%			
Swales							
Swale	4	Schueler and Caraco, 2001	Median	81%	63%	37%	
dry swale	13	Caraco and Winer, 2000	Median	93%	86%	70%	
dry swale	18	CWP	Reported Average	90%	80-90%	80-90%	
wet swale	13	Caraco and Winer, 2000	Median	74%	33%	11%	
wet swale	18	CWP	Reported Average	80%	40-70 %	40-70%	
Grass channel (Biofilter)	18	CWP	Reported Average	65%	20-50%	20-50%	
Grass Channel	13	Caraco and Winer, 2000	Median	68%	45%	42%	
100m swale	17	ARC, Larcombe, 2003	Mean	36%	82%	60%	
50m swale	17	ARC, Larcombe, 2003	Mean	25%	78%	63%	
Swale	24	Watershed Protection Techniques-Florida Swales	Mean		90%	41%	
Sand filter							
	2	Unitec Site (ARC, TP10, May 2003)	Mean (2 month period)	92%	98%	90%	
	8	Hynds Environmental		75%			
	18	CWP	Reported Average	85%	35-90%	35-90%	
	13	Caraco and Winer, 2000	Median	87%	80%	49%	
	12	Brisbane City Council and Gold Coast City Council					

Reference Number	Author	Title	Data	
1	Watershed Management Institute	Operation, Maintenance and Management of Stormwater Management Systems	Aug-97	
2	Auckland Regional Council	Stormwater Management Devices : Design Guidelines Manual	May-03	Also in paper title: Design for Vegetated Wetlands for the treatment of urban stormwater in the Auckland Region
3	Eric Strecker	The Use of Wetlands for Stormwater Pollution Control Infrastructure Vol 1, No 3, pp 48-66	1996	
4	Thomas Schueler and Deborah Caraco	The prospects for low impact land development at the watershed level Conference Paper :Linking Stormwater BMP Designs and performance to Receiving Water Impacts Mitigation	Aug-01	
5	CRC for Catchment Hydrology	Water Sensitive Road Design-Design Options for improving stormwater quality of road runoff	Aug-00	
6	CRC for Catchment Hydrology	Effectiveness of street sweeping for stormwater pollution control	Dec-99	
7	Ecosol Water Filtration Systems	RSF4000, RSF1000 and RSF100 Gross Pollutant Trap Product Information and Price List	Sep-03	
8	Hynds Environmental	Treatment Device Efficiencies-Letter to NSCC	Sep-03	Note mean of reported data for range of flow rates (NSCC) taken
9	CP Noling	The Road to Environmental Performance: A Small Shipyards Experience	Oct-02	
10	Hynds Environmental	Cleansall Gross Pollutant Trap-supplier brochure		
11	Ingall	Enviropod Filter, Wairau Rd Trial	Apr-01	
12	Brisbane City Council and Gold Coast City Council	Evaluation of Gully Pit Inlet Litter Control Systems	Apr-02	
13	Caraco and Winer	Updated National Pollution Removal Performance database for Stormwater Treatment Practices Center for Watershed Protection	2000	
14	Auckland City Council	Ireland Road, Ecosol,	no date	
15	SQUIDS Monitoring Programme, Stage 2	Kalinga Park CDS	Aug-99	
16	Monash University	From Roads to Rivers, Gross pollutant removal from urban highways	May-98	
17	Auckland Regional Council, Michael Larcombe	Removal of stomrwater contamnants using grass swales	Jan-03	
18	The Center for Watershed Protection	Design of Stormwater Filtering Sytems	Dec-96	Reports metals removal as range
19	Kingett Mitchell Limited for NSCC	Evaluation of catchpit management and street sweeping as methods of removing suspended sediment from stormwater	Jul-03	
20	CRC for Catchment Hydrology	Blackburn Lake Discharge and Water Quality Programme : Data Summary and Interpretation	Nov-99	
21	CRC for Catchment Hydrology	Stormwater Gross Pollutants-Industry Report	Dec-97	
22	Watershed Protection Techniques-Technical Note 62, Vol 2, No1	Performance of a Dry Extended Pond in North Carolina	1995	Data listed is for median of 8 events- paper also gives data for I extreme event where 70% of flow was bypassed
23	Watershed Protection Techniques-Technical Note 63, Vol 2, No2	Performance of Two wet ponds in the Piedmont of North Carolina	1995	Data listed is for mean of 11 events
24	Watershed Protection Techniques-Technical Note 65, Vol 2, No3	Pollutant removal in Florida Swales	1995	Data from Table 65.4 reproduced
25	Urban Water Resources Centre	Rocla Cleansall Monitoring Assessment	Mar-00	
26	Hynds Environmental	Oil-water management systems-product information		No efficiency data

Appendix D

Treatment Device Cost Estimates

Estimated Installation Costs

	Treatment device/option	Site Investigation Work [12]	Device Supply and Construction	Design and Construction Supervision [13]	Contingency [14]	Total	NPV
1	Dry pond[1]	$4,200.00	$42,000.00	$6,300.00	$4,200.00	$56,700.00	$276,136.00
2	Extended detention dry pond[1]	$4,500.00	$45,000.00	$6,750.00	$4,500.00	$60,750.00	$294,545.00
3	Wet pond[1]	$5,790.00	$57,900.00	$8,685.00	$5,790.00	$78,165.00	$312,955.00
4	Constructed Wetland[1]	$6,900.00	$69,000.00	$10,350.00	$6,900.00	$93,150.00	$343,636.00
5	Rain garden [2]	$2,000.00	$20,000.00	$3,000.00	$2,000.00	$27,000.00	$24,545.00
6	Permeable pavement [3]	$1,200.00	$12,000.00	$1,800.00	$1,200.00	$16,200.00	$14,727.00
7	Infiltration trench [4]	$2,360.00	$23,600.00	$3,540.00	$2,360.00	$31,860.00	$28,964.00
8	Rain Tank (Storage/reuse)[5]	Supplier Cost	$6,500.00	$975.00	$650.00	$8,125.00	$7,386.36
9	Detention Tank [6]	$6,000.00	$60,000.00	$9,000.00	$6,000.00	$81,000.00	$73,636.00
10	Bioretention swale [3]	$2,000.00	$20,000.00	$3,000.00	$2,000.00	$27,000.00	$24,545.00
11	Swale [3]	$1,600.00	$16,000.00	$2,400.00	$1,600.00	$21,600.00	$19,636.00
12	Sand filter [7]	$1,800.00	$18,000.00	$2,700.00	$1,800.00	$24,300.00	$22,091.00
13	API Oil & Water Separator	Supplier Cost	$47,500.00	$7,125.00	$4,750.00	$59,375.00	$53,977.00
14	Cleansall (Hynds Environmental)[8]	Supplier Cost	$105,000.00	$15,750.00	$10,500.00	$131,250.00	$119,318.00
15	Downstream Defender (Hynds Environmental) [9]	Supplier Cost	$35,500.00	$5,325.00	$3,550.00	$44,375.00	$40,341.00
16	CDS (Bisleys Environmental Ltd))	Supplier Cost	$140,000.00	$21,000.00	$14,000.00	$175,000.00	$159,051.00
17	Ecosol RSF100 (Ecosol) [12]	Supplier Cost	$650.00	$97.50	$65.00	$812.50	$739.00
18	Ecosol RSF1000 (Ecosol) - To suit 600mm diameter inlet	Supplier Cost	$15,680.00	$2,352.00	$1,568.00	$19,600.00	$17,818.00
19	Ecosol RSF4000 (Ecosol) - To suit 1050mm diameter inlet	Supplier Cost	$68,200.00	$10,230.00	$6,820.00	$85,250.00	$77,500.00
20	Enviropod (Ingal Environmental Services) [12]	Supplier Cost	$1,000.00	$150.00	$100.00	$1,250.00	$1,136.36
21	Stormfilter (Ingal Environmental Services) [10]	Supplier Cost	$43,000.00	$6,450.00	$4,300.00	$53,750.00	$48,864.00
22	Woolspill filter (Filtration International)	$2,300.00	$23,000.00	$3,450.00	$2,300.00	$31,050.00	$0.00
23	Litter traps (per litter trap) [12]	Supplier Cost	$500.00	$75.00	$50.00	$625.00	$568.00
24	Street Sweeping			$0.00	$0.00	$0.00	$0.00
25	Catchpit Cleaning			$0.00	$0.00	$0.00	$0.00

Note:

(1) Based on a stormwater treatment volume of 600 m^3 and not including land purchases
(2) Contributing catchment area of $3000m^2$
(3) Per km
(4) For a Water Quality Storage Volume of 400 m^3
(5) Using a $10m^3$ tank
(6) Concrete tank with $150m^3$ of storage for $4000m^2$ area
(7) Treating a catchment area of $1000m^2$
(8) Cleansall 900 unit
(9) Downstream Defender 300 Unit
(10) For a 14 cartridge unit
(11) Based on a treatment area of $750m^2$
(12) Each catchpit insert serves a catchment of $200m^2$
(13) Estimated as 15% of Supply and Construction
(14) 10%

Estimated Maintenance Costs

	Treatment device/option	Maintenance Cost Per Device	Frequency	Annual Cost	Annual Average NPV
1	Dry pond[1]	$1500 per site	Yearly	$1,500.00	$545.00
2	Extended detention dry pond[1]	$2000 per site	Yearly	$2,000.00	$726.00
3	Wet pond[1]	$2500 per site	Yearly	$2,500.00	$908.00
4	Constructed Wetland[1]	$3500 per site	Yearly	$3,500.00	$1,271.00
5	Rain garden [2]	$1,000 per site	Yearly	$1,000.00	$363.00
6	Permeable pavement [3]	$200 per km	2 Monthly	$1,200.00	$436.00
7	Infiltration trench [4]	$500 each	6 Monthly	$1,000.00	$363.00
8	Rain Tank (Storage/reuse)[5]	$500 per tank	Yearly	$500.00	$182.00
9	Detention Tank [6]	$200 per clean	4 Monthly	$600.00	$218.00
10	Bioretention swale [3]	$600 per km	2 Monthly	$3,600.00	$1,307.00
11	Swale [3]	$400 per km	2 Monthly	$2,400.00	$871.00
12	Sand filter [7]	$500 each	6 Monthly	$1,000.00	$363.00
13	API Oil & Water Separator	$500 per clean	3 Monthly	$2,000.00	$726.00
14	Cleansall (Hynds Environmental)[8]	$1000 per clean	4 Monthly	$3,000.00	$1,089.00
15	Downstream Defender (Hynds Environmental) [9]	$500 per clean	2 Monthly	$3,000.00	$1,089.00
16	CDS (Bisleys Environmental Ltd))	$1500 per clean	4 Monthly	$4,500.00	$1,634.00
17	Ecosol RSF100 (Ecosol)	$30 per clean	2 Monthly	$180.00	$65.00
18	Ecosol RSF1000 (Ecosol) - To suit 600mm diameter inlet	$400 per clean	6 Monthly	$800.00	$290.00
19	Ecosol RSF4000 (Ecosol) - To suit 1050mm diameter inlet	$3000 per clean	10 Monthly	$3,600.00	$1,307.00
20	Enviropod (Ingal Environmental Services)	$30 per clean	3 Monthly	$120.00	$44.00
21	Gullypit Stormfilter (Ingal Environmental Services) [10]	$1000 per clean	6 Monthly	$2,000.00	$726.00
22	Woolspill filter (Filtration International)				
23	Litter traps (per litter trap)	$30 per catchpit	2 Monthly	$180.00	$65.00
24	Street Sweeping				
25	Catchpit Cleaning	$50 per catchpit	2 Monthly	$300.00	$109.00

Note:

(1) Based on a stormwater treatment volume of 600 m^3
(2) Contributing catchment area of $1000m^2$
(3) Per km
(4) For a Water Quality Storage Volume of 400 m^3
(5) Using a $10m^3$ tank
(6) Concrete tank with $150m^3$ of storage for $4000m^2$ area
(7) Treating a catchment area of $600m^2$
(8) Cleansall 900 unit
(9) Downstream Defender 300 Unit
(10) For a unit to treat flows over 8 m^3/s
(11) Estimated as 12% of Supply and Construction
(12) Estimated as 15% of Supply and Construction
(13) 10%