Executive Summary

Potential changes to the cost of stormwater treatment as a result of adopting a standard approach were examined for state highway projects in Northland, Auckland, Waikato, Wellington and Christchurch regions.

Consultants were engaged to complete an evaluation of their original projects which identified environmental factors, design solutions, cost and time to construct storm water treatment systems. Upon completion, they were asked to re-evaluate their projects by applying a draft *Stormwater Treatment Standard for State Highway Infrastructure (Standard.)*

The average cost of stormwater treatment was calculated in two ways:

- cost of vehicle-kilometre-travelled (VKT) and
- cost of attenuation and treatment compared to total cost of stormwater management which includes collection and conveyance, essential to prevent flooding and provide for drainage.

Current Practice Compared to Application of *Standard* to Six State Highway Projects

Average	**$/VKT**	**<u>$ stormwater treatment</u> $ total stormwater management**
current practice	44	21%
application of *Standard*	45	22%
range	21 – 70	6% to 36%

The cost of implementing a *Standard* is considered to be insignificant. Taking into consideration whole life cycle assessment savings are expected in:

- consent application and approval,
- standardised design and
- lower cost of maintenance and operation.

The *Standard* will provide greater clarity and consistency between Highway and Network Operations, consultants and consenting authorities. The *Standard* would ensure all relevant aspects are considered, leading to optimal design and improved environmental outcomes.

Introduction

New Zealand Transport Agency (NZTA) is committed to effective and efficient environmental performance. The agency encourages continuous improvement in environmental outcomes, advancement of environmental management techniques and further integration of environmental and social responsibility.

The *Environmental Plan (2008)* has four objectives relating to water resources:

- ensure run-off from state highways complies with Resource Management Act 1991 (RMA) requirements;
- limit the adverse effects of run-off from state highways on sensitive receiving environments;
- ensure stormwater treatment devices on the network are effective and
- optimise the value of water management through partnerships with others.

One of the roles to further advance achieving the objectives was to develop a Stormwater Treatment Standard for State Highway Infrastructure (*Standard*.)

Background: rationale for a Standard

Ministry of Transport research concluded stormwater chemistry of New Zealand motorways was similar to that of overseas motorways.

The six main sources of contaminants from the roading corridor are fuel, exhaust, lubricating oil, tyres, brake lining and worn road surface. Contaminants accumulate in the closest depositional environment from the carriage way to near by properties and water bodies such as rivers, lakes, and estuaries (MoT, 2003)

A Ministerial Advisory Group (MAG, 2006) determined the need for a balanced and consistent approach to stormwater management which was identified as an emerging cost to roading projects. Currently there are no national guidelines or standards for stormwater management.

Consequently between and within projects a wide variety of solutions are applied resulting in difficulties with compliance, uncertain performance, increased maintenance expenses and inadequate consent applications resulting in project delays and increased costs.

A further call for the adoption of standard approaches was made at a Northern Busway project workshop by representatives from the Auckland Motorway Alliance, nine consultants and Highway and Network Operations (Johnson, M, & Dryburgh, 2008.). One of the recommendations was for standards and specifications to be provided for recurring requirements such as stormwater management. This was highlighted by the difficulty Highway and Network operations have inherited for the maintenance of treatment devices and lack of consideration for whole life cycle costs.

A *Stormwater Treatment Standard for State Highway Infrastructure* has been developed to provide clarity, certainty, efficiency and effectiveness in the design, construction and maintenance of stormwater treatment systems. As such supporting value-for-money considerations.

Adverse environmental effects

Stormwater from roads needs to be treated where high volumes of traffic (generally over 30,000 AADT) drain into sensitive receiving environments. Recent research characterised the most significant contaminants are those which come from tyres (Wik & Dave, 2009.) During a tyre's 40,000 km lifecycle, 30% of the tread is worn off releasing millions of kilograms of waste. The following numbers (table 1) were calculated for several similar countries.

Table 1. Tyre wear emission rates

Country	Kilograms/yr
Sweden	10,000,000
Italy	50,000,000
UK	57,000,000
Germany	60,000,000
USA	500,000,000

Tyre particles are complex micron sized porous particles composed of:

- 40-60% synthetic and natural polymers,
- 20-35% carbon black and silica filling agents,
- 15-20% high PAH oils,
- 1-1.5% vulcanisation agents and activators (sulphur, zinc oxide, stearic acid),
- 1% protective agents (antioxidants and antiozonants) and
- <1% peptisers, plastcisers and softeners.

Tyre particles have been found to cause the following adverse environmental effects:

- exceed toxicity limits in sediments and surface water;
- absorption by filter feeders, benthic organisms and plants;
- acutely toxic leachate;
- growth inhibition of plants;
- evidence of human teratogenic, mutagenic and estrogenic activity;
- suggested links to human latex allergy and asthma from respirable air borne particles (note tyres account for 75% global latex consumption.)

Methodology

A value-for-money assessment calculated a comparative cost-benefit analysis based on the whole life $/vehicle-kilometre-travelled (VKT) between the *Standard* and current practices on a number of recently completed or active stormwater management projects.

Six project sites (table 2) were nominated by regional planners based on recent design or completion, discharge to sensitive receiving environments and availability of project manager and consultants.

Table 2. Nominated projects and consultants

Project	**Consultant**
Christchurch Southern Motorway	Opus
ALPURT Sectors A2 & B1	Transfield
SH20 Mount Roskill	URS
SH2 Dowse to Petone Upgrade	Beca
SH18 Greenhithe Deviation	Opus
Avalon Drive By-pass	Opus

The value-for-money assessment was conducted in two phases. Phase one collected baseline data using a template (table 3) consultatively developed by experts in the field of stormwater management and state highway construction.

Table 3. Baseline data requested from project consultants for selected project sites.

<table>
<tr><td colspan="2">Environmental Factors: catchment description</td></tr>
<tr><td>terrain</td><td>erosion potential</td></tr>
<tr><td>area</td><td>flooding</td></tr>
<tr><td>topography</td><td>design storm event</td></tr>
<tr><td>drainage features</td><td>vehicle kilometres travelled at time of opening</td></tr>
<tr><td>geotechnical</td><td>discharge points</td></tr>
<tr><td>soils</td><td>National State Highway Strategy classification</td></tr>
<tr><td colspan="2">sensitivity of the receiving environment per LTNZ Research Report 315 sec. 3.5</td></tr>
<tr><td colspan="2">Designed Solutions</td></tr>
<tr><td rowspan="3">design philosophy</td><td>objectives (assumptions</td></tr>
<tr><td>criteria (water quality/quantity</td></tr>
<tr><td>references (regional plans, design guides)</td></tr>
<tr><td rowspan="2">stormwater management devices used for</td><td>erosion and sediment control during construction</td></tr>
<tr><td>operational stormwater management (collection/conveyance/attenuation/treatment)</td></tr>
<tr><td colspan="2">Cost</td></tr>
<tr><td colspan="2">resource consents (AEE, council fees, professional services)</td></tr>
<tr><td colspan="2">building and other consents (drawings, council fees and professional services)</td></tr>
<tr><td colspan="2">final design</td></tr>
<tr><td colspan="2">construction (collection, conveyance, attenuation and treatment)</td></tr>
<tr><td colspan="2">Time</td></tr>
<tr><td colspan="2">to acquire resource consents (submission to approval)</td></tr>
<tr><td colspan="2">to acquire building and other consents (submission to approval)</td></tr>
<tr><td colspan="2">required for construction (collection, conveyance and attenuation)</td></tr>
<tr><td colspan="2">of operation and maintenance life expectancy prior to major works or renewal</td></tr>
</table>

Phase two required project consultants to retrospectively apply the *Standard*. This approach allowed an initial "road test" to measure the effectiveness of the *Standard* in a variety of regulatory and receiving environments by a range of consultants.

From the consultants project assessment reports listed in the Reference section of this report, a $/VKT was calculated with and without the *Standard* as well as cost of treatment apart from collection and conveyance.

Retrospective application of *Standard*

The following sections highlight potential differences between project baseline assessment reports and potential changes introduced by use of the *Standard*.

Several reports noted short term design philosophy objectives related to construction are considered alongside planning for erosion and sediment control. However, it should be noted that the *Standard* does not cover erosion and sediment control.

Christchurch Southern Motorway

The Christchurch Southern Motorway project uses dry basins due to Canterbury's relatively well draining soils; however, the Standard contained no design guidance on dry basins. The design storm event requirements of the *Standard* and that of the local authorities varied, with the *Standard* requiring 10mm less than Environment Canterbury's requirements; however, the *Standard* required attenuation for a 1% annual exceedance probability (AEP) compared with a 2% AEP for Environment Canterbury.

The increase in attenuation to a 1%AEP event and to limit flow rates to 80% of pre-developed peak flow rates is predicted to require a 22% increase in runoff requiring attenuation/detention devices to increase proportionally; therefore, requiring additional land. The project consultant determined incremental cost and time for this more stringent requirement as minimal.

ALPURT sectors A2 and B1

Despite changes to some of the design parameters, the use of the *Standard* requires no change in the treatment approach. Swales would have required an increase in the minimum hydraulic residence time and the installation of a level spreader at the start of the swale to reduce channel erosion in the swale. The berm that separates the forebay and the main pond of the wet ponds would have been designed differently.

<u>SH20 Mount Roskill</u>

The water quality of the ponds could have been improved further with a floating wetland designed for the Beachcroft Avenue pond in the Royal Oak Catchment and the use of flocculation treatment to maintain 75% sediment treatment efficiency, which could lead to a small reduction in the pond size.

However, an increase in pond size would be required to limit discharge flow rates to 80% of pre-developed peak flow rates. Due to corridor restraints, additional land purchases would be required to accommodate the larger ponds, the result being an increase in the cost of land purchase. A slight increase in the cost of the final design and construction would also be incurred.

<u>SH2 Dowse to Petone Upgrade</u>

At the time resource consents were obtained for Dowse to Petone, Greater Wellington Regional Council did not require stormwater treatment. However, if consented today, water quality would have received greater prominence by the *Standard* due to the sensitivity of the receiving environments, large catchment size, and visibility.

The *Standard*, and nowadays the regional requirements would require the following from the original design. Dependent upon the availability of land, the capacity of the councils existing hillside attenuation as well as dams that drain into the Western Hills Culvert would have been increased. Property that is currently used for commercial or industrial activity would have been purchased for the construction of an attenuation pond or wetland, within the catchment that drains into Korokoro Stream. Potentially swales, filter strips and rain gardens could have been incorporated into the public car parks, resulting in a reduction in the number of car parks. Several sand filters and other similar treatment devices could have been incorporated, including under the carriageway.

The changes in the design would result in an increase in the cost and time relating to stormwater works on this project. The increases are identified in table 4.

Table 4. Cost and time increases in SH2 Dowse to Petone upgrade stormwater works

Cost	
Final design Costs	$60,000 attenuation quality control design and drawing production.
Construction Cost	$300,000 attenuation $200,000 quality control (excluding land purchase)
Monitoring Cost	$3,000 pond inspections after monthly storms $5,000 filter inspections $2,500 car park swale inspections $20,000 MSQA fee
Operation and maintenance estimated annual costs	$6,000 pond maintenance after monthly storm $2,000 pond sediment fore-bay clean out $5,000 filter cleaning $20,000 car park swale maintenance
Time	
Final design time	An additional 6 weeks due to the additional attenuation and water quality control items
Construction time	It would take 16 weeks to construct attenuation and water quality items, however much of this would have been concurrent with other construction activities

SH18 Greenhithe Deviation

The adoption of the *Standard* would have led to the volume of attenuation/detention devices being increased by 50% to manage a 10% AEP runoff event and allow for the effects of climate change. This would have increased the construction costs of the attenuation devices by approximately $152,000 and would have required a larger designation for the devices. If a larger designation had not been sought, construction costs would have increased due to a more complex engineered solution; for example, requiring the use of retaining walls around the ponds. Current consenting authority requirements normally require attenuation of the 10-year storm, which would reduce the relative difference in costs.

Avalon Drive By-pass

The consultant concluded using the *Standard* would have resulted in minimal changes to the original design. A retention pond could have been reduced from 3,500 to 2,800 m^3.

Cost

During revision of the Economic Evaluation Manual consideration was given to quantify stormwater treatment costs in a manner similar to mitigation of noise and air pollution; however, it was found to be too difficult due to the lack of information.

These costs are now known and most accurately expressed as $/VKT, a surrogate for traffic impacts over a section of highway. The potential cost of adopting the *Standard* per vehicle kilometre travelled (VKT) with the status quo allows different projects to be compared.

Table 5 shows for all six projects the predicted VKT at the time of opening, the actual or the current estimated stormwater system construction costs and the estimated construction costs of the stormwater system had the *Standard* been applied. Table 6 shows the construction costs and the estimated construction costs from using the *Standard* per VKT.

Table 5. VKT and stormwater construction costs

Project	**VKT** (/1,000)	**Cost** (/$1,000,000)
Christchurch Southern Motorway	262	11.3
ALPURT sectors A2 + B1	283	6.1
SH20 Mount Roskill	200	13.4
SH2 Dowse to Petone Upgrade	98	2.3
SH18 Greenhithe Deviation	200	7.7
Avalon Drive Bypass	50	3.5
average	**182**	**7.4**

Table 6. Stormwater construction cost per VKT

Project	**Current**	**Standard**
	$/VKT	
Christchurch Southern Motorway	43	43
ALPURT sectors A2 + B1	21	21
SH20 Mount Roskill	67	67
SH2 Dowse to Petone Upgrade	23*	29
SH18 Greenhithe Deviation	38	39
Avalon Drive Bypass	70	70
average	**44**	**45**
standard deviation	**21**	**20**

(* no attenuation or treatment requirement)

The application of the *Standard* would have had no or limited effect on the construction costs of the Christchurch Southern Motorway, ALPURT, SH20 Mount Roskill and the Avalon Drive Bypass. Applying the *Standard* to the SH18 Greenhithe Deviation project would have lead to an increase of $1/VKT due to the increase in attenuation devices required to comply with the *Standard.*

The SH2 Dowse to Petone Upgrade increased by $6/VKT. The difference is due to the project in its current design not requiring any stormwater treatment, which would now be required by the regional authority, Greater Wellington Regional Council. The Dowse to Petone Upgrade therefore provides a case study of the cost of stormwater treatment measures required by the *Standard*.

Table 7 shows what percentage of the total construction costs that are made-up of attenuation and treatment measures for five of the six projects. The consultant was not able to provide a construction cost breakdown for the Christchurch Southern Motorway because most of the devices were multi-functional. Of the five remaining projects all but the SH2 Dowse to Petone Upgrade required the stormwater runoff to be treated. On average the attenuation and treatment component made-up 21% of the total stormwater system construction cost. When the Standard was applied to the SH2 Dowse to Petone Upgrade, the increase in cost for attenuation and treatment came to be 19% of the total stormwater system construction cost.

Table 7. Percentage of attenuation and treatment cost to total stormwater construction cost (/$1,000,000)

Project	**Attenuation and Treatment Construction Cost**		**Total Stormwater System Construction Cost**		**Attenuation + Treatment/ Total Construction Cost %**	
	Current	**Standard**	**Current**	**Standard**	**Current**	**Standard**
ALPURT sectors A2 + B1	2.2	2.2	6.1	6.1	36	36
SH20 Mount Roskill	0.85	0.85	13.4	13.4	6	6
SH2 Dowse to Petone Upgrade	0.04	0.54	2.3	2.8	*(2)**	19
SH18 Greenhithe Deviation	0.6	1.7	7.7	7.8	20	22
Avalon Drive Bypass	0.76	0.76	3.5	3.5	22	22
				average	**21**	**22**

(* not included in average because no atttenuation or treatment requirement)

ALPURT and SH20 Mount Roskill are respectively 50% higher and lower than the average of 22%, this can be attributed to environmental factors. ALPURT is a greenfield development in an ecologically sensitive receiving environment. SH20 Mount Roskill is within a highly developed existing urban environment. The other three projects closely align with each other.

Conclusion

Given the fact none of these projects were asked to track stormwater costs, representation of a wide variety of receiving environments and regulatory authorities, and were independent compiled by four different consultancies use of the *Standard* should improve environmental performance while saving money on design, obtaining consents, operation and maintenance.

Recommendations

- An *Erosion and Sediment Control Standard for State Highway Construction* should be developed.
- Early design and consenting activities should involved network operations in order to ensure:
    - whole-life-cycle costs are taken into account,
    - consent conditions are clear, and
    - operational costs are considered.
- The *Standard* should be introduced to regional councils and stormwater engineers should be trained. Following a six month 'road test' incorporate suggestions for improvement then finalise and embed within the NZTA "Z/19 Social and Environmental Management Minimum Standard."

References

1. Cassidy, G. (2008.) *SH20 Mount Roskill storm water management system: Project review & summary.* Auckland, New Zealand: URS New Zealand Limited.

2. England, M. (2008.) *Christchurch Southern Motorway: Stormwater management system comparison with proposed NZTA stormwater treatment standard requirements.* Auckland, New Zealand: Opus International Consultants Limited.

3. Gardiner, L., & Armstrong, B. (2007.) Identifying sensitive receiving environments at risk from road runoff. *Land Transport New Zealand Research Report, 315.*

4. Johnson, M, & Dryburgh, T. (2008.) *New Zealand Transport Agency Network Operations & Capital Projects operational requirements workshop report: Northern Bus Way Project.* Auckland, New Zealand: NZ Transport Agency.

5. Kennedy, P. (2003.) *The effects of road transport on freshwater and marine ecosystems.* Wellington, New Zealand: Ministry of Transport.

6. Malaval, C. (2008.) *SH1 Avalon Drive Bypass: Stormwater management system comparison with proposed NZTA stormwater treatment standard requirements.* Hamilton, New Zealand: Opus International Consultants Limited.

7. Ministerial Advisory Group on Roading Costs. (2006.) *Ministerial advisory group on roading costs: Final report August 2006.* Wellington, New Zealand.

8. Moncrieff, I, & Kennedy, P. (2004.) *Road transport impacts on aquatic ecosystems: Issues and context for policy development.* Wellington, New Zealand: Ministry of Transport.

9. NZ Transport Agency. (2008.) *Environmental plan: Improving environmental sustainability and public health in New Zealand, Version 2.* Wellington, New Zealand.

10. NZ Transport Agency. (2008.) *Stormwater treatment standard for road infrastructure: draft July 2008.* Wellington, New Zealand.

11. Smith, I. (2008.) *Stormwater management review: SH2 Dowse to Petone upgrade.* Wellington, New Zealand: Beca Infrastructure Ltd.

12. Transfield Services. (2008.) *ALPURT sectors A2 and B1 stormwater management system review: Application of the NZTA draft stormwater standard.* Auckland, New Zealand.

13. Wik, A., & Dave, G. (2009.) Occurrence and effects of tire wear particles in the environment – A critical review and an initial risk assessment. *Environmental Pollution, 157,* 1-11.

14. Worth, Z. (2008.) *SH18 Greenhithe Deviation: Stormwater management system comparison with proposed NZTA stormwater treatment standard requirements.* Auckland, New Zealand: Opus International Consultants Limited.