Long-term dust suppression using the Otta seal technique

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J. C. Waters
Fulton Hogan Limited
Christchurch, New Zealand

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Private Bag 6995, Wellington 6141, New Zealand
Telephone 64 4 894 5400; facsimile 64 4 894 6100
research@nzta.govt.nz
www.nzta.govt.nz

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Abbreviations and acronyms

AP	All passing the nominated sieve size
GPS	Global positioning system
LCCA	Life cycle cost analysis
NRO	Norwegian road oil
Otta	Otta is taken from the Otta Valley in Norway where the 'Otta seal' process was first trialled
PAH	Polycyclic aromatic hydrocarbons
PTR	Pneumatic-tyred roller
RCA	Road controlling authority
VOC	Volatile organic compounds
vpd	Vehicles per day

Contents

Executive summary

An increasing number of urban people, looking for improved lifestyle, are moving into rural areas serviced with gravel roads, and this has led to a significant increase in complaints to local authorities regarding dust emissions.

A search for treatments to mitigate the dust emissions identified a sealing technique called the 'Otta seal' as a possible treatment to trial. The Otta seal is a low-cost seal option used in developing and 3rd-world countries for seal extension and resurfacing treatments. The technique is called 'Otta seal' because it was first developed and trialled in the Otta Valley in Norway, in 1963, as an inexpensive seal-extension treatment. After its initial success in the Norwegian trial, the use of the treatment spread throughout developing countries in Asia and Africa, and life cycles of up to 25 years are reported from South Africa.

This report describes a trial of the use of a simplified version of the Otta seal as a method for minimising dust emissions from gravel roads in New Zealand. It also compares the performance and cost effectiveness of the Otta seal with traditional dust minimisation techniques.

During the summer of 2005/2006, four trial sections of Otta seal were constructed in East Coast, Otago, Central Otago and Southland alongside waste oil, emulsion and untreated sections. The sites were monitored over two summers, until June 2008, measuring dust emissions, roughness, and maintenance requirements.

The results of the monitoring showed that the Otta seals had performed very well and that the following conclusions could be formed:

- The Otta seal technique was proven to be the lowest-cost solution for dust minimisation.
- The Otta seal technique worked well on the trials in the four different regions with different climatic conditions – this suggests that the technique could be used in New Zealand in all regions with similar climates.
- The Otta seal technique for dust minimisation is more environmentally friendly and sustainable than waste oil.
- The binder applicator is the only additional machinery required, compared to normal gravel road maintenance equipment, for Otta seal construction.
- Apart from the design and application of the binder, the construction of the Otta seal for dust minimisation is a simple technique suitable for most road-construction crews.
- Waste oil should not be used as a dust palliative because of its environmental effects.

Based on the research and the conclusions above the following recommendations can be made:

1. Now that there is a cost-effective, more environmentally friendly treatment, the use of waste oil to minimise dust emissions from unsealed gravel roads should be prohibited.
2. Further research should be carried out to develop a bituminous emulsion product for the construction of Otta seals.

3. If the effects of dust emissions from unsealed gravel roads and the complaints are taken seriously, then there is justification, based on the life cycle cost analysis, to apply an Otta seal to minimise the dust emissions.

A guideline for the design and construction of the simplified Otta seal technique for dust minimisation is also provided.

Abstract

A 2004 trial of the Otta seal technique in various locations in New Zealand showed that it may be a better option for dust minimisation and, based on life cycle costing, could be a lower-cost option when compared with traditional short-term dust palliatives.

A research trial was proposed to, and funded by, Land Transport New Zealand to set up four trial sites around New Zealand, to compare the performance and life cycle costs of the Otta seal with waste oil and other dust minimisation techniques.

In spite of environmental issues, waste oil was used in this research, as it has been widely regarded as the most cost-effective dust minimisation treatment for unsealed roads in New Zealand, and its use is still allowed by a number of territorial local authorities throughout the country.

The research concludes that the Otta seal is the most effective dust minimisation technique available, and the most cost-effective treatment based on life cycle costing. The report also concludes that the use of waste oil as a dust minimisation treatment should be banned.

A guideline for the construction of these seals was developed as part of the research.

1 Introduction

1.1 Background

Increasing numbers of urban people, looking for an improved lifestyle, are moving into rural areas serviced with gravel roads, and this has led to a significant increase in complaints to local authorities regarding dust emissions.

There are numerous publications from both international and New Zealand engineers that discuss the social, safety, asset management and environmental problems caused by the large quantities of dust particles emitted from unsealed gravel roads, and their treatment. The problems include:

1. ratepayer complaints regarding nuisance dust, claiming that it affects their standard of living and causes a loss of value of housing
2. reduced crop yield in horticulture within 200 m of the roadway
3. reduced animal production on farms within 200 m of the roadway
4. loss of fine aggregate, and the effect of that on future maintenance costs
5. the need for regular reshaping and grading
6. safety issues related to visibility, because of dust clouds produced by vehicles, and increasing accident potential
7. increased vehicle operating costs.

A review of New Zealand research (Flockhart 2003) showed that most conventional dust suppressant agents used in this country generally only last 2–3 months and then have to be re-applied. Most of the commercialised materials have not proven to be cost effective, but their use has been necessary to satisfy users and local residents. In some regions, waste oil has been (and still is) applied by residents and local authorities alike, because of its low cost and good performance, compared to the alternatives.

However, the use of waste oil as a dust suppressant is now not considered environmentally acceptable because of the heavy metal and other contaminants contained in the oil, and if the application of oil is not maintained, the dust and waste oil can end up polluting surface-water systems and vegetation. Thus, its use is prohibited by some regional territorial authorities in New Zealand, with more banning its use each year.

1.2 Finding an alternative to the use of waste oil

For some time, local authority engineers, consultant engineers and contractors in New Zealand have been searching for a cost-effective, environmentally friendly, sustainable alternative to the application of waste oil to reduce dust emissions from gravel roads.

1.2.1 Trials in New Zealand

A 2002–3 investigation into an alternative to using waste oil included an international literature search to identify best practice for dust palliatives and dust control techniques, and an evaluation of other techniques previously used in New Zealand (Flockhart 2003). Flockhart and Fulton Hogan, in conjunction with the Gisborne District Council, set up a trial site on Waimoko Road (Gisborne district) comparing the best-performing dust palliatives identified by the literature search.

This trial, conducted between December 2002 and March 2003, compared the performance of *Dust Arrest* (a lignosulphonate compound), *bitumen emulsion* (a special cationic product), *SBO Lignin* (a lignosulphonate and soya bean oil extract blend), and an *untreated* 'control' section. Lignosulphonate is a waste material from the pulp and paper industry and, like the soya bean extract, is drawn from a renewable resource. Thus, systems using these dust palliative products are widely regarded as sustainable treatments.

All of the materials were applied according to the suppliers' instructions. At the same time as the rest of the trial sites were treated with the dust palliatives, the 'control' section was graded to shape but was otherwise untreated.

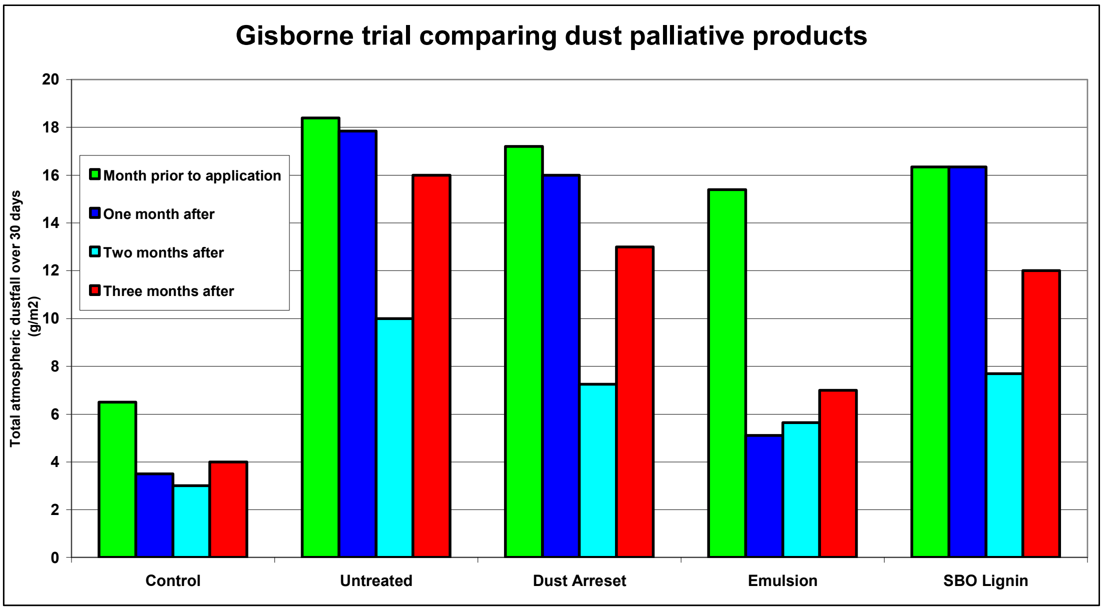

Figure 1.1 Gisborne dust palliative trial

Dust gauges were erected alongside each section in the trial to quantify the difference in performance of the products by the amount of dustfall collected (figure 1.1). The emulsion product out-performed the other two products, which after one month were performing poorly, releasing high levels of dust similar to those from the control section – after three months, the Dust Arrest (lignosulphonate) and SBO Lignin (lignosulphonate soya bean oil blend) sections were performing as if they were untreated.

During the 2002/2003 summer, Dunedin City Council also conducted dust palliative trials (Robinson 2003) comparing a number of products, and found that none performed well after two months.

Following the success of the emulsion as a dust palliative in the Waimoko Road (Gisborne) trial, it was decided to trial various application techniques in mid-Canterbury (Hoattens Road, Ashburton), using the same bitumen emulsion product, to ascertain the best method of application. However, the very dry conditions in mid-Canterbury, during and following construction, prevented the formation of the required 'slurried up' surface, and all of the trial sections failed early.

The results of all of the aforementioned trials, which highlighted the shortcomings (short life cycle, high cost, and so on) of the commercialised dust palliative remedies, were presented at the 2003 Fulton Hogan Roadshow. The consensus was that although none of the remedies had been successful, a replacement for waste oil was still required. A member of the audience suggested that a low-cost sealing technique should be tried, based on life cycle cost analysis.

This comment led to another review by Fulton Hogan of the international literature regarding dust minimisation techniques and alternative seal construction methods. Visser et al (1983) had found that dust palliatives were not an 'economically sound solution', and that light bituminous coatings performed well. Another interesting finding in this new literature search was a paper describing the 'Otta seal' technique; so called because the first 'Otta seal' was constructed in the Otta Valley in Norway.

1.2.1 The Otta seal technique

The Otta seal is a low-cost seal option used in developing and 3rd-world countries for seal extension and resurfacing treatments. The technique is called 'Otta seal' because it was first developed and trialled in the Otta Valley in Norway, in 1963, as an inexpensive seal-extension treatment. After its initial success in the Norwegian trial, the use of the treatment spread throughout developing countries in Asia and Africa, and life cycles of up to 25 years are reported from South Africa.

1.2.2 Trialling an adapted Otta seal in New Zealand

For this technique to be successful as a dust minimisation treatment in New Zealand, it needed to be cost-competitive with the waste oil treatment – but it could only do this on a life cycle cost basis, as the Otta seal is initially a more expensive treatment. An analysis of the whole-of-life-cycle costs over a 5-year period, comparing the Otta seal technique costs with traditional dust palliative costs (as well as the 'do nothing' option), showed that if the Otta seal technique performed well for 5 years or more, it would be the cheapest whole-of-life option.

It was decided to modify the Otta seal technique specifically for dust minimisation treatments and New Zealand conditions, to minimise the cost and improve its competitiveness with other dust minimisation treatments.

Modification of the Otta seal technique was also required to quantify design criteria and develop a binder suitable for application in New Zealand conditions. The available information on design and construction lacked specific detail regarding binder design, binder application rates, and aggregate application rates.

After some investigation overseas, the collected ideas were put into practice in an initial trial of a simplified version of the Otta seal technique. This was constructed on a straight, flat section of Mayes Road (Hurunui District) on 18th November 2004, to minimise the dust on an unsealed section of gravel road that had given rise to many complaints from residents.

It has performed very well. Since it was constructed, the only maintenance required has been to repair 10 m of edgebreak – and most importantly, there have been no dust emissions since the Otta seal was formed.

The success of the Mayes Road trial led to a proposal to Land Transport New Zealand in 2005 for funding to trial the technique more widely, to gain an understanding of the constraints that different climates, aggregates and varying traffic stresses presented to the Otta seal technique. One of the aims, when choosing the new trial sites, was to ensure they were all in areas with different climates, and the aggregate used was locally sourced, to make sure that aggregates with different sources and physical properties were used. As only a limited number of sites were suggested for the trials, it was fortunate that four sites with different climates, and that used different aggregates, were found.

Otta seals and dust palliatives were applied to the four sites during the summer of 2005/2006, and they were monitored until June 2008.

2 Objectives

The objectives of the research project to trial the Otta seal technique for dust minimisation from gravel roads around New Zealand, using local gravels, were to:

1. trial the Otta seal technique, using a suitable binder and locally sourced aggregates, as a dust minimisation technique under varying climatic conditions
2. develop a guideline for the construction of Otta seals as a dust minimisation technique for gravel roads
3. compare the emissions, costs, and performance of the Otta seal technique for dust minimisation with other dust suppressant materials and conventional unsealed road maintenance techniques
4. compare the sustainability of the Otta seal with the traditional methodology, with respect to the reduced use of non-renewable resources such as maintenance aggregate and diesel fuel burnt by machinery on the regular maintenance grading cycle.

To adequately assess the performance and cost effectiveness of the Otta seal as a dust minimisation technique, it was necessary to have a direct comparison between the existing methods and the Otta seal. Thus, the trial sites needed to include at least three test sections with similar geometrics, aspect, weather exposure and traffic, so that the trial could compare an untreated section, an Otta seal technique section, and a waste oil or dust palliative section.

As the main aim of the project was to assess the performance of the Otta seal as a dust minimisation technique, we used dustfall gauges to measure the amount of dustfall in each test section.

The life cycle performance of the treatments is an important aspect of the cost effectiveness of the dust minimisation products, so the sections were regularly monitored, and records kept for the maintenance carried out on each of the sections, to measure how long the treatment continued to perform.

Other testing, such as roughness (using the Optigrade system) and skid resistance (using the Griptester), was carried out on various sections as appropriate.

3 Site selection

Local authorities around New Zealand were asked if they were interested in a trial of the technique, and if so, could provide appropriate sites for the trial where they were having dust complaint issues. The test sites needed to:

- be approximately one kilometre long
- have low traffic
- be reasonably flat and straight, but with consistent geometry throughout
- be causing dust nuisance problems, so that the trial would be of benefit to the local residents and the councils.

The aim was to identify sites located in various climatic regions, and where the trial could use aggregate from different sources.

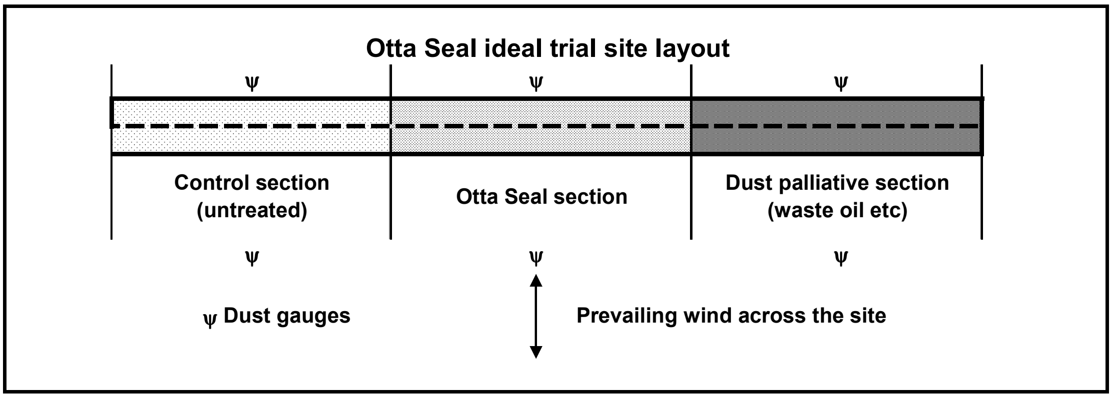

Figure 3.1 Idealised layout of trial sites

The order of the sections in the idealised layout was set to ensure that the untreated and oil sections were separated, so that cross-contamination did not occur. The Otta seal section was placed in the centre, as it was predicted there would be no emissions from the Otta seal six weeks after construction.

Only four territorial local authorities had sites that were suitable for the trial. Other local authorities were reluctant to trial the Otta seal, in case it increased the expectations of other residents who were complaining about dust emissions. Initially, all four sites were within regions that still allowed the use of waste oil as a dust palliative treatment. However, by the time of construction of the Paroa Road trial, the use of waste oil as a dust palliative had been prohibited by the Gisborne District Council, for environmental reasons. Instead, the bitumen emulsion dust suppressant that had performed well in the 2002/2003 trial was used there, and applied as per the previous trial.

The four sites chosen were:

- Paroa Road – Tolaga Bay – Gisborne District Council
- Church Road – Outram – Dunedin City Council

- Keddell Road – Alexandra – Central Otago District Council
- Sinclair Road – Te Anau – Southland District Council.

Each trial site was divided into three sections that had to be at least 300 m long to reduce dust carryover, from one section to another, to the atmospheric dustfall gauges. The gauges were situated at each side of the road, as close to the midway point of each trial section as possible. The sites were all marked out and the GPS location of the start and finish of each section was recorded. While the sites were suitable for comparison with respect to geometrics, roadside vegetation meant that the dustfall gauges could not always be erected in accordance with the testing standard. However, as the sections in each of the sites were affected in a similar manner and the results would still be able to be compared, it was decided to erect the dust gauges and collect the data.

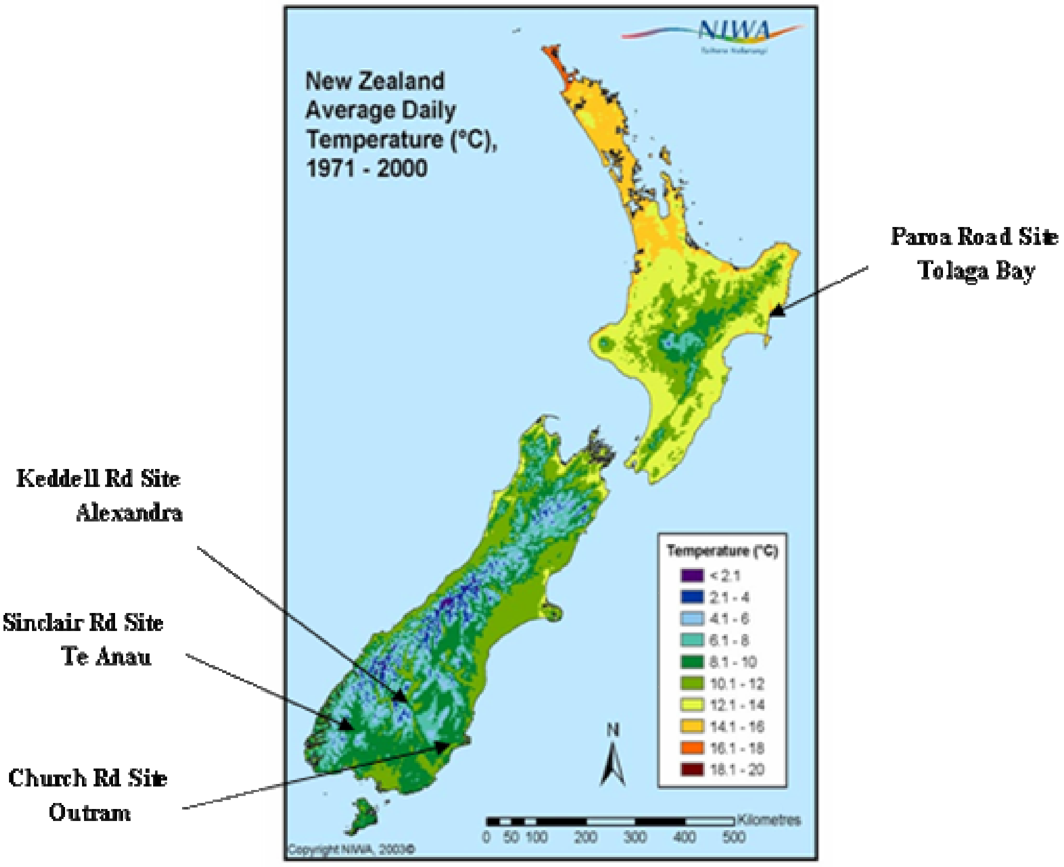

Figure 3.2 Trial site location map

The four sites chosen for the trials were the best sites of those put forward because of their length and consistency of geometry throughout. Their locations are shown on figure 3.2, which also shows the average temperature at each site. Each of the sites is located in a different region of New Zealand, with a different climate, and the aggregates used to construct the seal were sourced locally.

3.1 Site deficiencies

There were some deficiencies with each of the sites.

3.1.1 Paroa Road (Tolaga Bay)

The Otta seal section ran beside a bank with overhanging trees (figure 3.3.), which may have affected the dustfall data on the site.

Part-way through the trial, the Gisborne District Council managed to get funding for a seal extension. This was constructed on the untreated and the emulsion-palliative sections at each end of the Otta seal, at the end of the first summer after construction of the trial.

Figure 3.3 Paroa Road Otta seal

3.1.2 Church Road (Outram)

The waste oil section had a large hedge (see figure 3.4) alongside, which may have affected the dustfall data on site. The Otta seal length included a single-lane culvert, which introduced some stopping and starting stress from the heavy traffic (eg milk tankers).

Figure 3.4 Church Road waste oil section (May 2007)

3.1.3 Keddell Road (Alexandra)

The untreated section and seal sections had large willow trees along one side (figure 3.5), which may have affected the dustfall data on site.

Figure 3.5 Keddell Road – Otta seal section and untreated section

3.1.4 Sinclair Road (Te Anau)

The site was oriented so that the prevailing wind blows along the site, rather than across it, which resulted in dust emissions from the untreated section being blown along the road and over the Otta seal section, creating artificially high dustfall there. The third section of this trial site was already a regular waste oil treatment site (figure 3.6).

Figure 3.6 Sinclair Road, looking towards the lake from the end of the Otta seal

3.2 Effect of trees/hedges and prevailing winds on dustfall results

After comparing each gauge with the average for each section, only 3 sections out of the 12 had biased variation from the average of over 10 percent – the untreated sections on Church Road and Sinclair Road, and the waste oil section on Church Road. Of these 3 sections, only the waste oil section on Church Road had trees. The conclusion drawn from this comparison was that the trees did not cause a bias in the results.

4 Otta seal construction

In the earlier Otta seal technique construction trial on Mayes Road, a simplified construction process, which varied from the one used overseas, had been used. As the aim was to minimise dust, not to construct new sealed pavements, the existing pavement and gravel was used as the base. The pavement geometry was improved by grading the road to shape, with good crossfalls and drainage, to ensure that rainwater was shed by the treated surface.

This significantly reduced the cost of the seal, but it meant that with no pavement improvement, the pavement was not suitable for a normal chipseal binder. A specially developed deferred set soft-residue binder (Norwegian Road Oil, or NRO) was then required to accommodate the expected high deflections of the low-strength pavements. The binder was sprayed on the surface using a normal bitumen sprayer (figure 4.1).

Figure 4.1 Spraying NRO on the Paroa Road site

The soft-residue binder was required to provide an annealing property to the seals, as they were being constructed over low-strength pavements. These generally have higher deflections than normal pavements and hence would cause traditional chipseals to crack and fail early in their life cycle.

The deferred set binder property was required to enable the binder to migrate up through the surfacing aggregate following application. This is a slow process that normally requires 4–6 weeks. If the new surface was over-compacted at construction time, the binder would be forced to the surface and would then adhere to the roller wheels, causing pickup and early failure of the treatment.

The main difficulty in designing the binder was that it needed to be soft enough to migrate through the aggregate and ductile enough to not crack with the pavement deflection when cold – but it also had to retain enough cohesion so that it would not flow, and to retain the aggregate particles in place under traffic stress. However the performance of the seal under stress and high temperatures would also depend on the aggregate particle shape and grading. Using a high proportion of fines (passing the 0.075 mm sieve) would bulk up the binder, reducing the risk of failure under traffic stress, but increasing the risk of cracking during cold periods.

The locally sourced AP 20 or AP 25 'all-in' maintenance aggregate was spread on top of the NRO using fan tails, roller spreaders or chip spreaders (figure 4.2) as appropriate, to ensure an even distribution of the aggregate. There were some difficulties using the local aggregates, as the all-in material contained natural fines that generally did not flow well through the spreader boxes. The problem was exacerbated if the material became too wet.

The fines in the aggregate are an important component in the system, as they bulk up the volume of binder as it migrates to the surface, forming a mastic that binds the aggregate and forms an asphalt-like material.

The aggregate used on the Church Road site had a low fines content – the sealing supervisor chose this because they had had problems spreading the normal gravel on a previous attempt. The low fines content in the aggregate meant that the NRO/fines mixture in the final seal was a bit softer and stickier than desired, so there was some flushing and cohesive failure of the Otta seal because there were less fines to stiffen it (see figure 6.3 in section 6).

Figure 4.2 Spreading aggregate on Sinclair Road, using the chip spreader

4.1 Compaction

A steel-wheeled roller was then used to compact the surface, taking care to not crush the larger aggregate particles (figure 4.3). This initial rolling (3–4 passes maximum) served only to reorient the large aggregate particles and ensure better contact with the sprayed binder.

International literature suggests that the use of a pneumatic-tyred roller (PTR) during construction can accelerate the formation of the seal; however, care should be taken to not draw the soft binder directly to the surface through the aggregate. As part of the simplified methodology to minimise costs, it was decided to not use the PTR, and let the traffic do the compaction and let the seal form slowly.

Figure 4.3 Rolling the Otta seal, Keddell Road

4.2 Maintenance

The site was then opened to traffic and left for 4–6 weeks for the surface to form. During this period, loose material was swept back over the surface to cover any free binder. Loose unbound metal on the surface was then swept off the surface after the seal had formed.

4.3 Waste oil section construction

Waste oil was chosen as the benchmark technique against which to compare the performance of the Otta seal technique, as it is the dust palliative product of choice in most areas (if allowed). Waste oil was considered to be the cheapest and most effective method of dust minimisation. The main negative aspect of using waste oil is environmental pollution through the contaminants in the waste oil.

The waste oil, control and Otta seal sections had all been graded, using normal maintenance practice, at the same time. Additional aggregate had been added as necessary to all sections, to correct the shape and ride.

Waste oil was applied to the Church Road and Keddell Road sections in the normal manner at standard application rates. However, when the waste oil applicator subcontractor became aware of the trial on Sinclair Road, he applied more oil than usual to produce a better result than normal, but in doing so, he over-applied the oil to such an extent that vehicles were sticking to the oiled surface, generating complaints from the local residents.

4.4 Emulsion section construction

The Gisborne District Council decided that waste oil could not be used for the trial, so a more environmentally acceptable product was selected. Dust palliative trials completed in 2003 in the Gisborne region had shown that bitumen emulsion was the alternative product of choice, so this was used in the trial as a comparison. The site was graded to shape, and maintenance aggregate applied as required, with the dust palliative material sprayed on.

5 Life cycle cost comparison

A direct comparison of the tangible costs of applying dust palliatives and the ongoing road maintenance costs, against the cost of an Otta seal and the ongoing road maintenance costs, shows that three years is the break-even point, and any life after that is a gain for the client (figure 5.1).

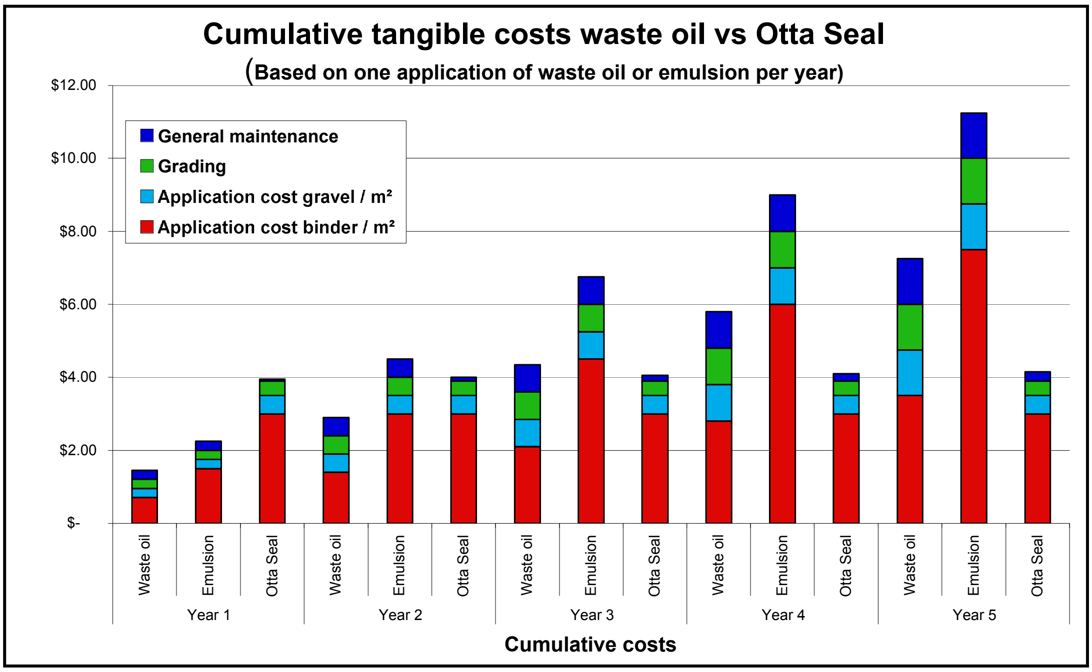

Figure 5.1 Comparing costs of Otta seal vs emulsion or waste oil

The first Otta seal trial on Mayes Road, constructed by Fulton Hogan in November 2004, has lasted well, with only some minor some edgebreak failure (figure 5.2) identified in August 2007, and no other problems recorded since then. This supports the overseas literature that suggests Otta seals normally last 7–10 years, and some up to 25 years. However, the Mayes Road site carries low traffic – <150 vpd (vehicles per day) – in a relatively dry climate, and these conditions may be contributing to the current success of this Otta seal trial.

Figure 5.2 Edgebreak on Mayes Road site (August 2007)

The life cycle cost comparison showed that using emulsion or other water-soluble dust palliatives could not be justified on a cost basis, and neither could the use of waste oil if it had to be paid for.

Some local authorities are unofficially permitting residents to apply oil to the road outside their houses, as it stops complaints. If the Otta seal technique is the most cost-effective treatment for dust minimisation, then the next comparison is with the 'do nothing' treatment, and ignoring the complaints of the residents.

The life cycle cost comparison compared the expected costs over the life of the various treatments (waste oil, emulsion, and the Otta seal technique) for a one-kilometre length of gravel road where dust emissions were affecting the local residents. The costs for each section included the construction costs, the direct maintenance costs, the indirect and intangible costs of normal maintenance, and all other indirect and intangible costs, as shown in table 5.1 overleaf.

The construction costs of each of the sections are self-explanatory, whereas the indirect and intangible costs used in the calculation need to be explained. They were calculated as follows:

- Dust contamination included the costs to the residents caused by the dust emissions, such as extra cleaning, lost produce, etc. The difference between the sections was based on the relative dust emission reductions and the longevity of each of the treatments.
- Dust-complaints costs were based on the estimated time it would take for council staff to talk to the resident, complete the complaint paperwork, find the engineer responsible and discuss the issue, possibly visit the site, and report back to the resident – estimated at $80 per complaint, as a conservative estimate. The total number of complaints could range up to 80 on an unsealed gravel road where the residents have a problem with the dust. This figure was based on 4 complaints per week between December and March, which was a conservative estimate once the dust started affecting the residents.
- Additional Vehicle Operating Costs (VOC) were based solely on Land Transport NZ's 2006 *Project evaluation manual* (passenger car) costs for additional roughness. Relative roughness measurements showed that the Otta seal provided reduced roughness all year round, compared to normal gravel roads and gravel roads treated with dust palliatives; these have cycles of smoothness

similar to that of the Otta seal section immediately after grading, but they degrade into much higher roughness under trafficking.

- Unfortunately, as there were conflicting reports on issues such as reduced numbers of crashes and lower driver stress because of poor visibility, the anecdotal benefits of improved safety were not used in the calculation of the life cycle cost analysis (LCCA).

Table 5.1 Comparison of the relative input costs

	Otta seal	Waste oil	Emulsion	Untreated
Initial construction costs				
Grading	✓✓	✓	✓	✓
Aggregate	✓✓	✓	✓	✓
Waste oil		✓		
Emulsion			✓	
Norwegian Road Oil	✓			
Annual maintenance costs				
Pothole and edgebreak repairs	✓	✓✓	✓✓	✓✓✓
Grading		✓	✓	✓✓
Aggregate		✓	✓	✓
Waste oil		✓		
Emulsion			✓	
Annual intangible costs				
Dust contamination		✓	✓	✓✓
Dust complaints		✓	✓	✓✓
Additional VOC cf Otta seal VOC		✓	✓	✓✓

Numerical LCCA, based on current values over a five-year analysis period, were calculated and these are shown in figure 5.3. Costs were calculated using average rates for each item from the trials. The data for figure 5.3 is provided in appendix 3.

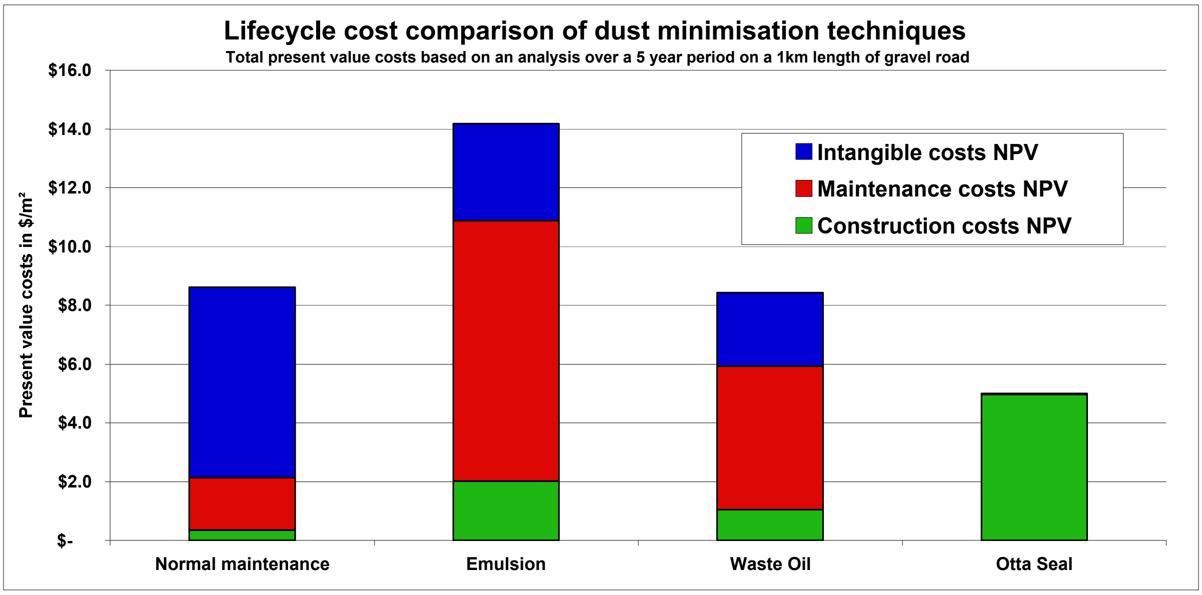

Figure 5.3 Life cycle cost comparison of dust minimisation techniques

The graph shows that over a five-year period, an Otta seal technique is the low-cost option – it is less expensive than doing the normal maintenance treatment (ie do nothing about dust), but only if indirect and intangible costs are considered (see figure 5.4 below). However, the low maintenance and construction costs for normal maintenance activities (doing nothing about dust) make it an attractive short-term option to do the minimum, deal with the complaints, and ignore intangible costs.

The majority of Otta seals around the world are constructed in areas that have extreme variations in climate (with hot, dry summers and cold winters) and low traffic, similar to the conditions where we carried out the first trial. However, there are significant regional variations in climate in New Zealand that may affect the life cycle of the technique. The initial trial (on Mayes Road) was on a low-traffic, low-stress section of gravel road, so the aim of this project was to challenge the technique by constructing trials on roads with higher traffic, more stress and different rainfall.

Current gravel road maintenance methodologies generally require the use of locally sourced aggregates for annual (or more frequent) treatment of roads. The Otta seal would utilise this resource, and reduce the usage from annual to every 7–10 years, or even less frequently.

The low cost of waste oil means that it is less expensive to apply than the emulsified bitumen and the Otta seal, but it only lasts for one season (3 months) on average, and has to be applied at least annually. The emulsified bitumen dust palliative binder is more expensive than waste oil and also only lasts one season (3 months) on average, and has to be applied at least annually.

Figure 5.4 uses the same data as figure 5.3 to show a clearer comparison of the total costs of maintaining a section of gravel road that is generating dust complaints.

The calculation for the cost of dealing with dust complaints assumed that the RCA (road controlling authority) receiving the complaints would have a complaints procedure. The average cost of a complaint used in the calculation ($80) was based on various combinations of Reception + Administration + Complaints officer + Site Visit + Follow-up calls. Even if the cost was reduced to $15 per complaint, the Otta seal was still the lowest-cost treatment if measured over a 5-year period.

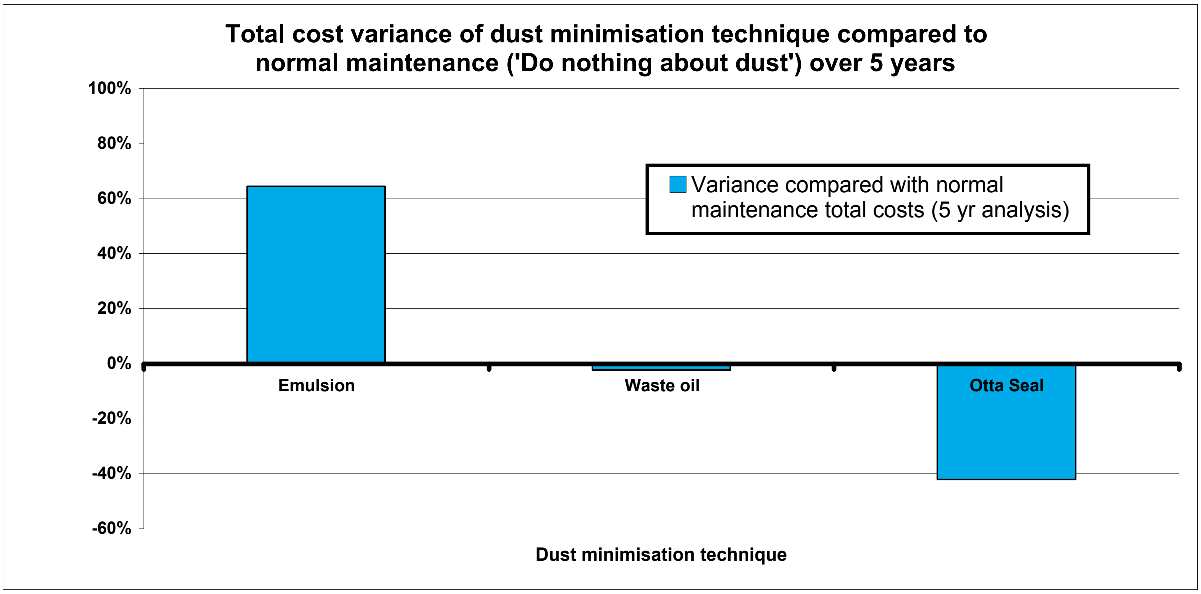

Figure 5.4 Percent variation of total costs compared to normal maintenance costs

When considering all costs over the life of a dust minimisation strategy, if this simplified technique of constructing Otta seals for dust minimisation lasts 5 years or more, then the Otta seal technique would be the most cost-effective treatment. It would also be more environmentally friendly and more sustainable than waste oil. Current performance of the Mayes Road seal suggests that this seal will last at least 10 years, and probably longer.

6 Performance of the Otta seal trial sites

6.1 Atmospheric dustfall data

Monitoring of the trials included monthly measurement of the dustfall for each of the three sections on the four trials sites. The diagrams (not to scale) in appendix 1 show the respective site layouts, and the graphs in appendix 2 compare the average total atmospheric dustfall for each of the sections on the trial sites.

6.2 Sinclair Road (Te Anau) trial site performance

The **Otta seal** had bound in all of the fines, and dustfall levels were similar to the control section, apart from some fugitive dust carried from the untreated section. The Otta seal treatment generally performed very well, but there was a minor pothole repair at one entrance and some edgebreak at another. There were some minor blemishes in the surface, but these were in locations where there had been construction issues.

The **waste oil section** dustfall levels were reasonably low for the first summer, but the surface broke up over winter, and without a reapplication of waste oil, the dust emissions returned to levels similar to the untreated section. The surface formed corrugations and potholes (figure 6.1).

The **untreated section** dustfall levels remained high throughout the monitoring period. The surface formed bad corrugations and potholes.

The Southland District Council reported that the residents were very happy with the Otta seal, including a very vociferous affected resident. They are planning to construct another 600 m of Otta seal on the untreated section of this trial.

Figure 6.1 Sinclair Road waste oil section, looking south (Jan 2008)

6.3 Keddell Road (Alexandra) trial site performance

The **Otta seal section** performed very well, with the dustfall results continuing at levels similar to the recording two months after construction. There was a minor edgebreak at one entranceway.

The **waste oil section** performed well, because one resident applied waste oil on the road outside his residence twice more within 12 months, to keep the dust down.

The **untreated section** (see figure 6.2), which was gravelled with material from a new source chosen specifically for gravel road maintenance, performed reasonably well; the surface stayed intact, with little free material on top.

Figure 6.2 Keddell Road untreated section

6.4 Church Road (Outram) trial site performance

The **Otta seal section** performed very well, with dustfall results continuing at levels similar to those recorded two months after construction. There was some damage done to the Otta seal by a tracked excavator, which broke the seal, and one small section of seal that slid on the loose gravel underneath under braking shear (see figure 6.3).

Figure 6.3 Surface shear failure, Church Road site (Jan 2008)

6.5 Paroa Road (Tolaga Bay) trial site performance

The Paroa Road site **Otta seal section** performed very well in the first year after construction, with dust emissions at levels similar to those of the neighbouring sealed road for most of the monitoring period.

The **emulsion section** (figure 6.4) failed early, without any sign of a reduction in dust emissions from this section, and in June 2007, both the **untreated** and **emulsion sections** were reconstructed and chipsealed as a seal extension.

Monitoring of the dust gauges was discontinued in March 2008, after some gauges were stolen in February; however with all three sections sealed, further collection of data was not considered relevant.

Figure 6.4 Paroa Road seal extension (December 2007)

6.6 Roughness testing

Roughness testing, using the Optigrade testing apparatus, was carried out on the 3 South Island sites just after trial site construction, then 6 months and 14 months after construction. The results (see figure 6.5) showed that the Otta seal roughness was reducing, and was generally lower than the other types of treatment on each of the sites. The roughness of the other sections on the sites was variable, and obviously depended on the time between grading and testing. A comparison of the average roughness for the 3 sections and 3 sites resulted in 50 Optigrade counts/km for the Otta seals, 67 counts for waste oil, and 71 counts for the untreated control sections.

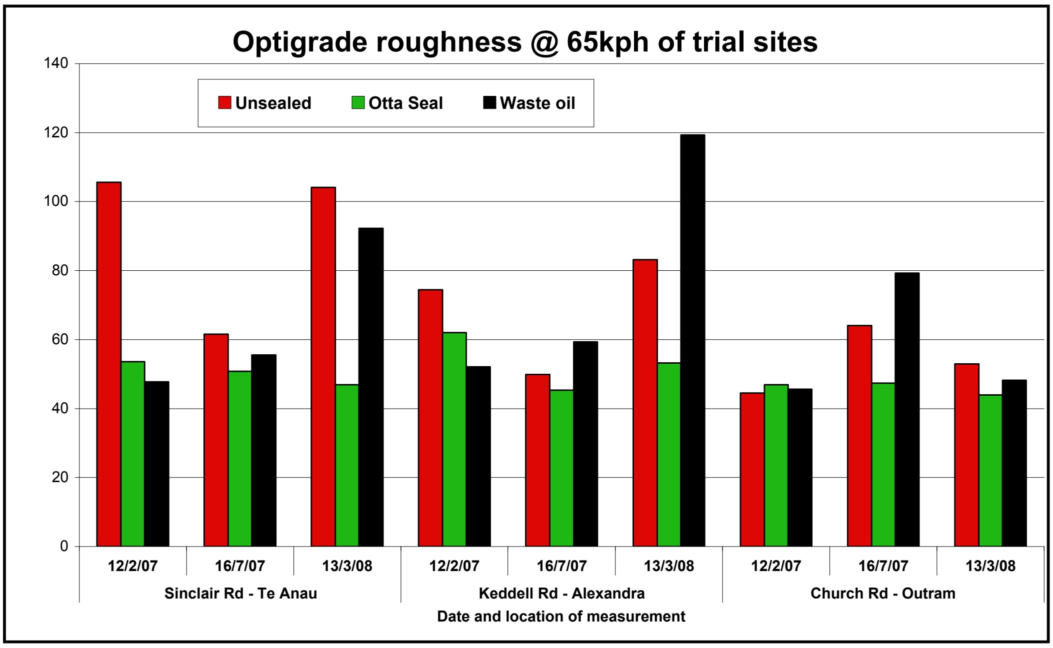

Figure 6.5 Optigrade roughness test results

6.7 Climate comparison

Table 6.1 shows the differences between the sites for wind run, total annual rainfall, mean annual temperature and the average monthly dustfall. Dustfall results could not be predicted from the individual measurements or combinations, as there was no consistency. For example, it would be expected that the sites with the highest rainfall would have the lowest dustfall – but Sinclair Road had the second-highest rainfall and equal-highest dustfall. Also, it would be expected that the site with the highest wind run would have the highest dust emissions – but Paroa Road had the equal-lowest dustfall.

Table 6.1 Climate comparison

Climate summary	Par
Average total annual rainfall/mm	16
Average daily wind run/km	3
Mean annual temperature/°C	1
Average monthly dustfall untreated section/g/m²	1

7 Guidelines for the construction of an Otta seal

One of the objectives of this project was to develop a guideline for the construction of this simple Otta seal technique for dust minimisation, based on the outcomes of the research.

7.1 Site selection

The technique used in this research is suitable for low-stress, low-traffic (<200 vpd) sites. It is expected that the sites will be centred on rural houses and their entrances and exits, with associated shear stress; however, the system used has some annealing properties that enable it to self-repair minor, isolated disruptions of the surface.

7.2 Drainage

Watertables should be cleaned and high shoulders removed, to ensure there is positive drainage away from the edge of the seal, as the construction of an Otta seal will mean an increase in the quantity and velocity of the surface runoff. This could cause problems for the shoulders, and if water is retained in the watertable, it could end up underneath the seal and cause pavement issues and potholes.

7.3 Aggregate selection

An integral part of the Otta seal is the aggregate, and using the locally sourced aggregate normally used for maintaining the gravel road helps to keep the costs down for isolated sites. There are issues with applying these aggregates through a roller spreader, especially when they are wet, as they do not run well. However, the fines (including silts/clays) in these materials seem critical to the success of the seal, as they bulk up the binder forming a mastic that binds the seal together.

The Otta seals constructed with cleaner aggregate chosen for better application properties have not performed as well as the seals constructed using the aggregates containing more fines. Generally, the top size of the stone seems to control the final depth of the Otta seal, so an 'all-in' AP 20 aggregate will form a 20 mm thick seal.

7.4 Binder selection

The selection of the binder has to take into account the deflections in the pavement – if it is too brittle, the seal will crack and fail; if it is too soft, the seal will shove and bleed. Another important property of the binder is that it must be fluid enough during the first 4–6 weeks to wet the fines and form a mastic that is soft enough to migrate upwards, encapsulating the coarse aggregate.

The seal binder must have a soft residue and a deferred set mechanism to enable the seal to form.

7.5 Seal design

The design of the binder application rate depends on the grading and size of the aggregate and the technique used. Most literature regarding Otta seals suggests an application rate of 1.8–2 l/m² of binder for a single-coat seal. The four trial seals used 2.1–2.2 l/m² hot, and this performed well.

8 Why not just seal the site?

One of the frequently asked questions regarding the Otta seal technique is: Why not just chipseal the sites, using normal techniques? The reasoning is that the Otta seal technique used in this project has been developed specifically as a dust minimisation technique where the road is categorised as a gravel road. On this type of site:

- the cost of constructing a pavement and surfacing it with a chipseal cannot be economically justified
- just using a standard chipsealing binder and chip, without constructing a proper base course, would result in cracking in winter due to high pavement deflections
- using a softer binder in a normal chipseal to cope with the pavement deflections would lead to chip rollover and bleeding in summer.

This Otta seal technique uses a soft-residue deferred set binder to bind together a locally sourced aggregate, and hence is more forgiving regarding the low-strength pavements found in gravel roads. The binder is less stiff and brittle, so less likely to crack than normal chipseal binders, and soft enough to heal itself during the warmer temperatures and thus maintain a waterproof surface. The fines in the aggregate prevent the binder becoming too tacky in the heat of the summer.

The Otta seal technique used in these trials was developed specifically for dust minimisation, and is not a suitable seal-extension or traction-seal technique. If the pavement is improved for a seal extension, then a normal chipseal would be a more appropriate surfacing. However, the cost of constructing and sealing small, isolated sections of pavement would be prohibitive – more than 5 times the cost of the Otta seal technique, and also, they would require a second-coat seal within 5 years of construction.

9 Sustainability of Otta seals

The current environmental interest in sustainability means that the sustainability of Otta seals is questioned by both advocates and opponents of the technique. An estimate of the comparative use of non-renewable resources used by the three maintenance techniques is shown below (table 9.1). This comparison is based on the Otta seal lasting 10 years.

Table 9.1 Comparison of non-renewable material usage in alternative dust minimisation techniques

Non-renewable resources	Otta seal	Traditional gravel road maintenance	Dust palliative/ waste oil
Aggregate	1	6X	6X
Binder	1	0	3X
Diesel	1	4.5X	4.8X
Road-user fuel usage – based on roughness and loose gravel	1	1.4X	1.4X

10 Safety of Otta seals

The possibility that the Otta seal provides improved safety, when compared with unsealed gravel roads, has been raised throughout the research project as a possible added benefit. However, research by Minchington and Bradshaw (2007) on the change in accident rate before and after sealing on 393 seal-extension sites around New Zealand concluded that there was no statistically significant benefit or disbenefit of sealing previously unsealed gravel roads.

The Paroa Road trial site provided the opportunity to measure the skid resistance of an Otta seal, and compare the results with the adjacent new seal and older trafficked seal at each end of the Otta seal.

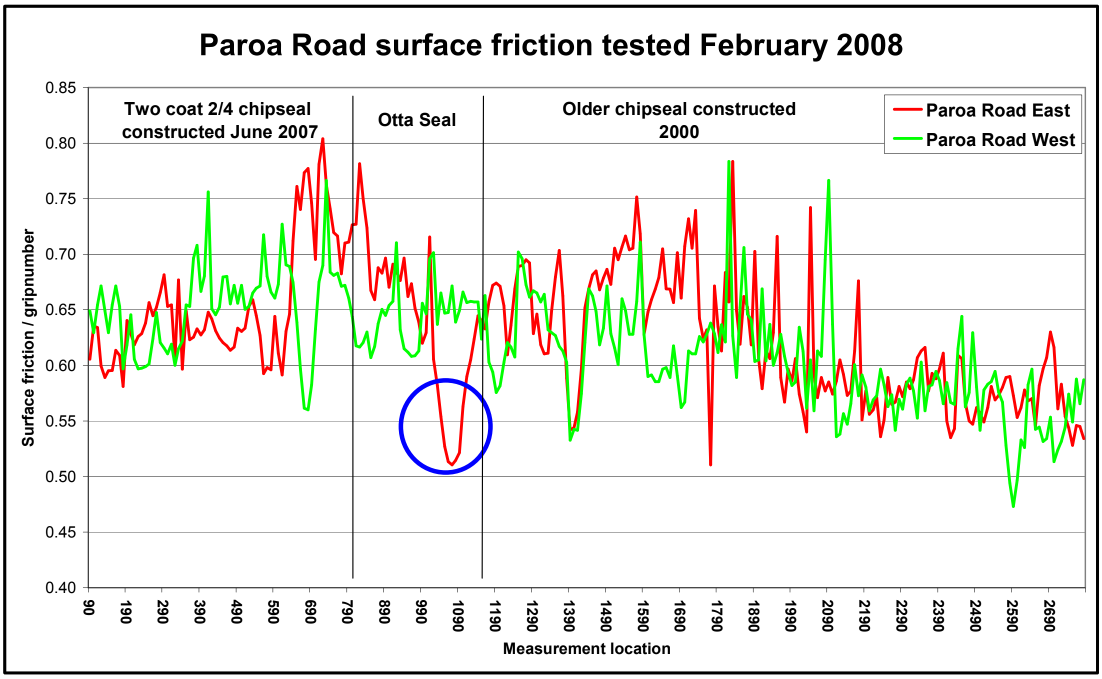

Figure 10.1 Paroa Road surface friction

The surface-friction test results (see figure 10.1) showed that the surface friction of the Otta seal was similar to the adjacent 8-month-old two-coat chipseal, and higher than the older seal at the other end. There was short section (circled) where the surface was contaminated by some loose detritus on the surface of the Otta seal.

11 Environmental effects discussion

One of the largest environmental benefits of the Otta seal is the lack of significant run-off and long-term run-off potential, when compared with waste oil.

Apart from the significant effects of oil on aquatic life, waste oil also contains some serious contaminants, including the by-products of hydrocarbon combustion (eg polycyclic aromatic hydrocarbons – PAH), metals from engine wear, and other related additives. Many of these contaminants are considered to have the potential to cause significant effects and serious harm to the aquatic environment.

Another effect is that of the waste oil-contaminated dust that is released from the treated surface as the effectiveness of the waste oil as a palliative reduces. This dust causes contamination to houses, animals, foliage and pasture around the site.

One of the biggest concerns is the run-off from freshly applied waste oil entering natural waterways via roadside watertables, especially in areas where residents are allowed to apply the oil themselves. The waste oil has a high potential to cause both chronic and acute impacts on life in the receiving environment, as some of the by-products are known to be carcinogenic, teratogenic and mutagenic.

12 Conclusions

- Waste oil should not be used as a dust palliative because of its environmental effects.
- The Otta seal technique was proven to be the lowest-cost solution for dust minimisation.
- The Otta seal technique worked well on the trials in the four different regions with different climatic conditions – this suggests that the technique could be used in New Zealand in all regions with similar climates.
- The Otta seal technique for dust minimisation is more environmentally friendly and sustainable than waste oil.
- The binder applicator is the only additional machinery required, compared to normal gravel road maintenance equipment, for Otta seal construction.
- Apart from the design and application of the binder, the construction of the Otta seal for dust minimisation is a simple technique suitable for most road-construction crews.
- This report provides a guideline for the construction of Otta seals as a dust minimisation technique for gravel roads.

13 Recommendations

1. Now that there is a cost-effective, more environmentally friendly treatment, the use of waste oil to minimise dust emissions from unsealed gravel roads should be prohibited.
2. Further research should be carried out to develop a bituminous emulsion product for the construction of Otta seals.
3. If the effects of dust emissions from unsealed gravel roads and the complaints are taken seriously, then there is justification, based on the life cycle cost analysis, to apply an Otta seal to minimise the dust emissions.

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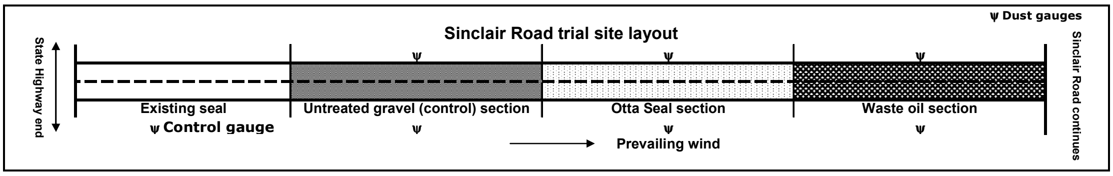
Appendix 1 Trial site layouts and dustfall gauge data

A1.1 Sinclair Road site (Te Anau)



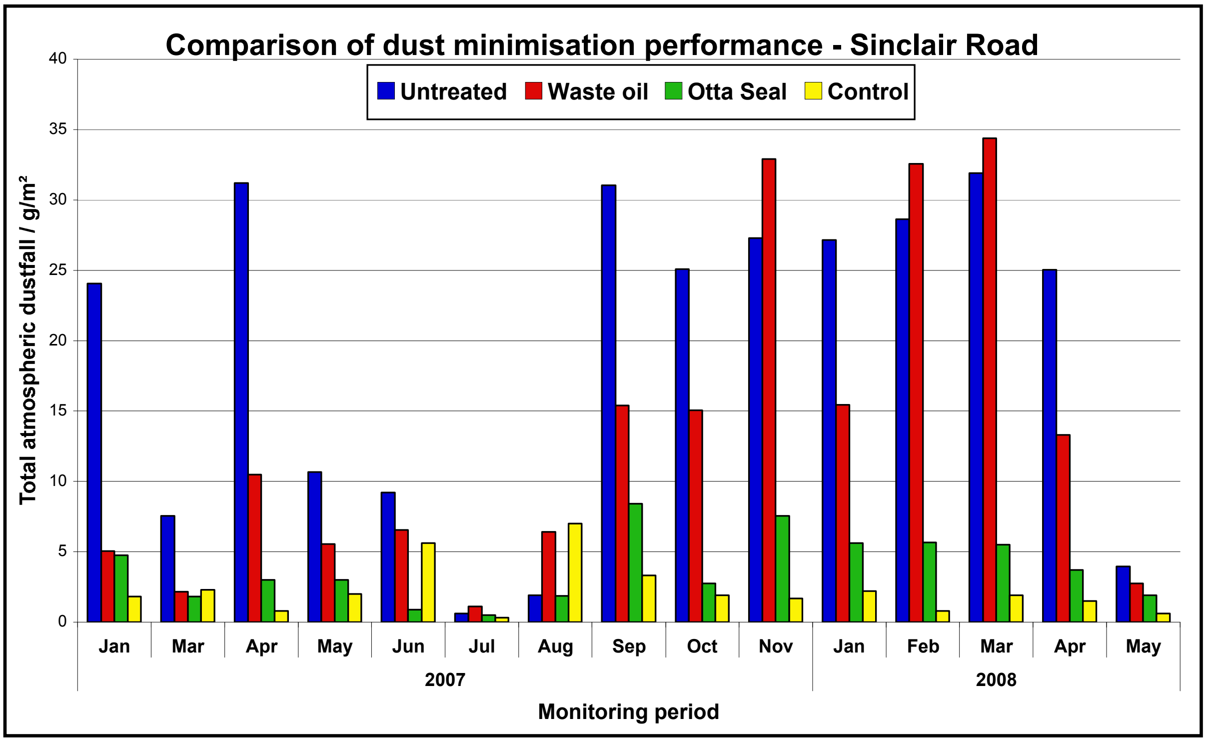
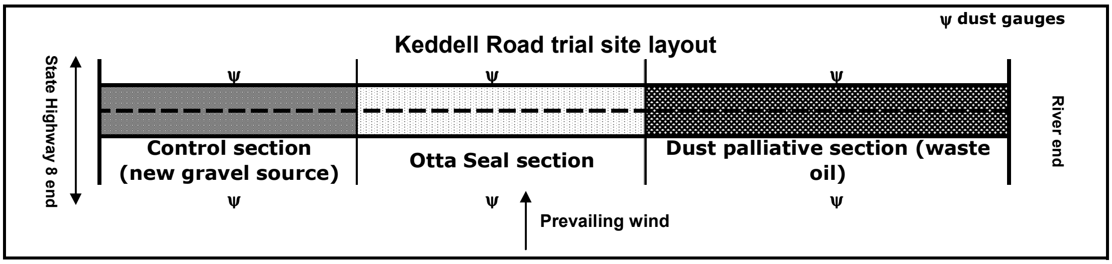


Figure A1.1 Sinclair Road – on Otta seal, looking north to oil section

Figure A1.2 Sinclair Road – on Otta seal, looking south to control section

Figure A1.3 Sinclair Road – looking south from end of Otta seal

A1.2 Keddell Road site (Alexandra)



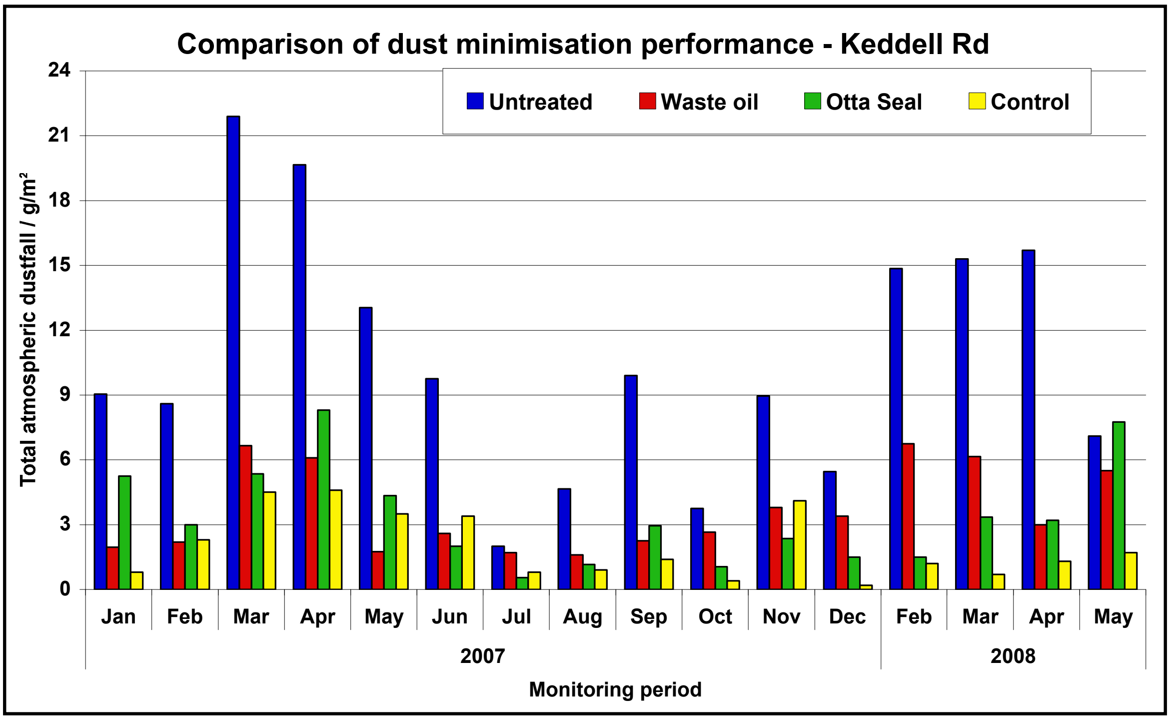


Figure A1.4 Keddell Road – from Otta seal, looking north to control section

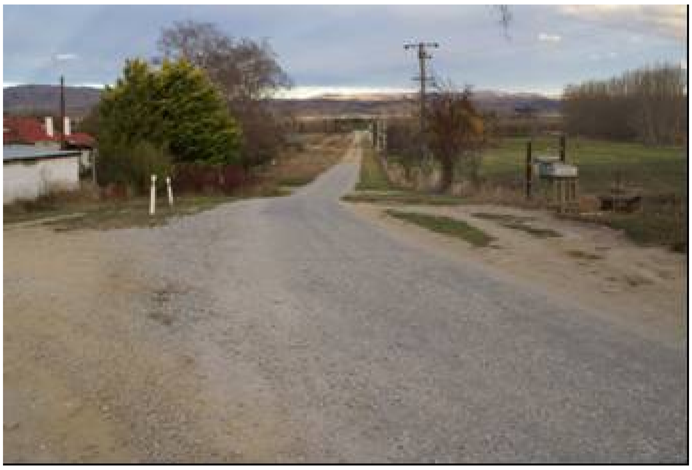
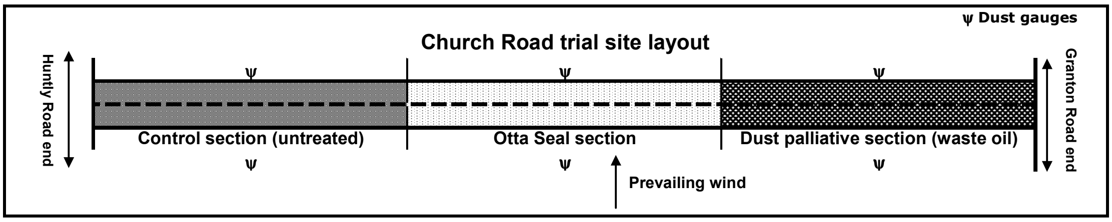


Figure A1.5 Keddell Road – from centre of Otta seal, looking south to oil section

Figure A1.6 Keddell Road – from end of Otta seal, looking south at oil section

A1.3 Church Road site (Outram)



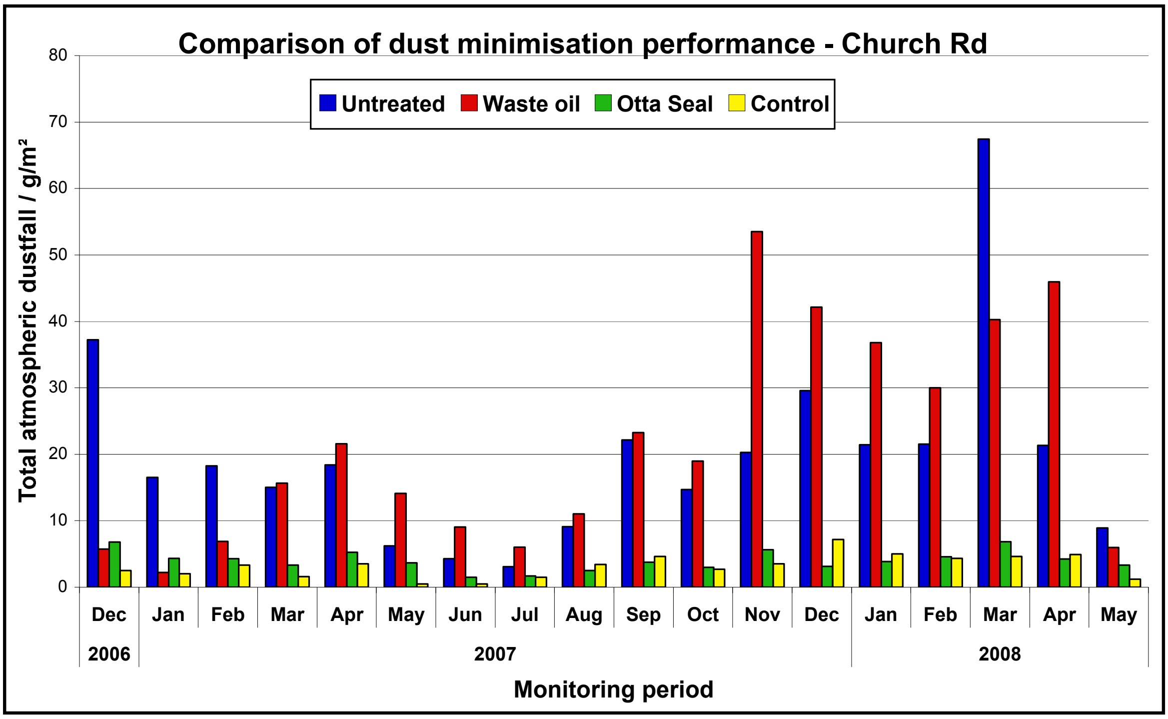
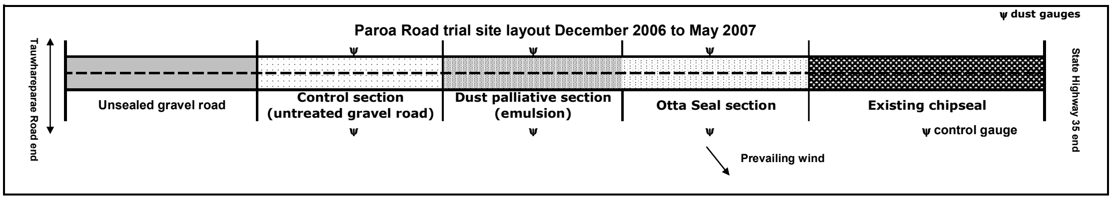


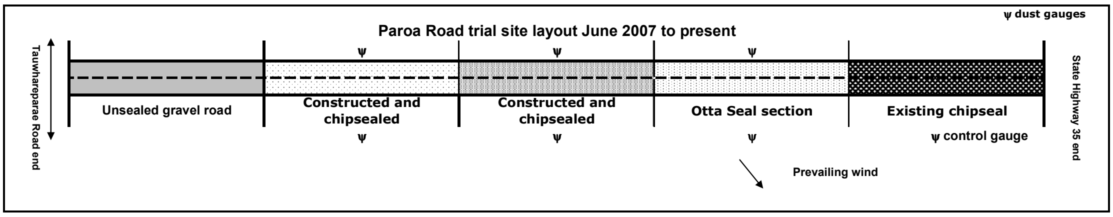
Figure A1.7 Church Road – looking north from oil section, towards Otta seal

Figure A1.8 Church Road – looking north from centre of Otta seal, towards control section

Figure A1.9 Church Road – looking north from end of Otta seal, towards control section

A1.4 Paroa Road site (Tolaga Bay)





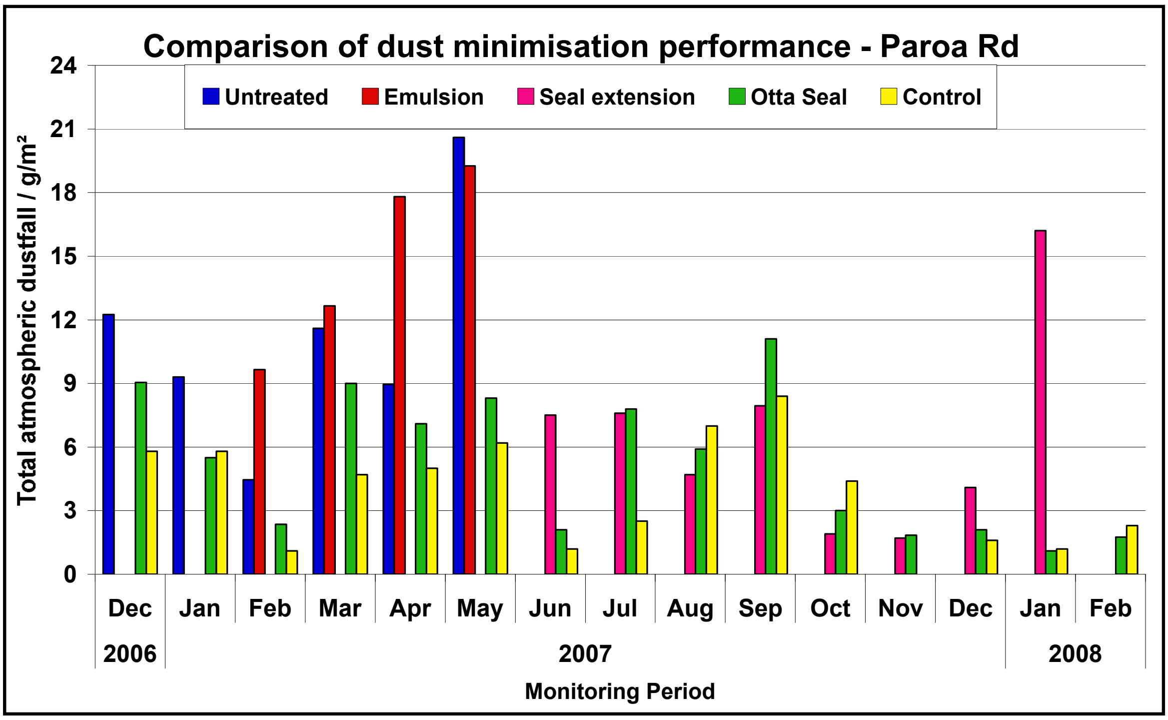


Figure A1.10 Paroa Road – Otta seal, looking north towards start of trial

Figure A1.11 Paroa Road – Otta seal, looking south to start of emulsion section

Figure A1.12 Paroa Road – emulsion section, looking south

Figure A1.13 Paroa Road – a seal extension replaced the emulsion section (photo taken August 2007)

Appendix 2 Material test results

A2.1 Aggregate test results

Test	Sinclair Rd	Keddell Rd	Church Rd	Paroa Rd
Source	Upukeroa River	McPhersons Rd Quarry	Palmers Quarry	Waiapu River
Sieve size (mm)	Percentage passing sieve			
26.5	100	100	100	100
19	96	98	100	97
16.0	90	85	N/T	N/T
13.2	84	76	89	N/T
9.5	71	61	71	67
6.7	61	50	58	N/T
4.75	52	40	44	48
2.36	41	25	24	35
1.18	30	18	13	24
0.6	20	13	7	15
0.3	11	10	4	10
0.15	7	6	2	8
0.075	5	4	1	7
Sand equivalent	67	52	37	47
Broken faces				
26.5-19.0	66	62	N/T	N/T
19.0-16.0	68	76	N/T	N/T
16.0-9.5	66	88	N/T	N/T
9.5-4.75	63	89	N/T	N/T
Test carried out on	Material retained on 16.0 mm sieve	Material retained on 16.0 mm sieve	Material retained on 13.2 mm sieve	
ALD	13.39	12.95	9.32	N/T
Ratio	2.15	2.13	2.87	N/T

N/T = Not tested

A2.2 Binder test results

	Sinclair Rd	Keddell Rd	Church Rd	Paroa Rd
Kinematic viscosity @ 60°C Cst	3150	3100	4970	3570

Average benkleman beam deflections before and after treatment								
	Sinclair Road		Paroa Road		Keddell Road		Church Road	
	Before	After	Before	After	Before	After	Before	After
Untreated section	0.80	1.70		0.81	0.57	0.57	0.86	0.96
Otta Seal section	0.56	1.41	1.42	1.21	0.38	0.62	1.22	1.81
Waste oil/emulsion section	0.38	0.82	1.2	1.05		0.59	1.46	1.55

Appendix 3 Life cycle cost calculation data

	Normal maintenance	Emulsion	Waste oil	Otta seal
Maintenance costs				
Grading	$440	$220	$220	$0
Metalling	$2,000	$2,000	$2,000	$0
Pothole repairs	$250	$150	$100	$50
Emulsion application	$0	$11,000		
Oil application	$0	$0	$5,040	$0
Total maintenance costs	**$2,690**	**$13,370**	**$7,360**	**$50**
Construction costs				
Grading	$110	$110	$110	$220
Metalling	$2,000	$2,000	$2,000	$5,000
Emulsion application	$0	$10,000	$0	$0
Oil application	$0	$0	$4,200	$0
NRO application	$0	$0	$0	$24,570
Initial construction costs	**$2,110**	**$12,110**	**$6,310**	**$29,790**
Intangible costs				
Dust contamination	$2,000	$1,000	$600	$0
Dust complaints	$6,400	$1,600	$800	$0
Additional vehicle operating costs	$1,387	$2,373	$2,373	$0
Total intangible costs	**$9,787**	**$4,973**	**$3,773**	**$0**
Area/m²	6,000	6,000	6,000	6,000
Net present value calculation	**Normal maintenance**	**Emulsion**	**Waste oil**	**Otta seal**
Initial construction costs NPV	$0.35	$2.02	$1.05	$4.97
Total maintenance costs NPV	$1.78	$8.86	$4.88	$0.03
Total intangible costs NPV	$6.49	$3.30	$2.50	$0.00
Total costs NPV	**$8.62**	**$14.18**	**$8.43**	**$5.00**
Maintenance costs annual	$0.45	$2.23	$1.23	$0.01
Intangible costs annual	$1.63	$0.83	$0.63	$0.00