TECHNICAL PAPER

STATE HIGHWAY 79: ROUTE UPGRADE ECONOMIC ANALYSIS

Author and Presenter: Chris Morahan, BE(hons)(civil), GIPENZ
Graduate Transport Engineer/Modeller
Opus International Consultants Ltd
chris.morahan@opus.co.nz

ABSTRACT

Using traditional techniques, conducting economic analysis to justify and prioritise improvement works on a road with deficient width for large portions over a long route can be difficult and time consuming. The process is made easier and faster by utilising Geographic Information Systems (GIS) to map and analyse road characteristics, conduct bulk economic calculations and display them spatially over the route.

State Highway 79 is a 61km length of road located in Canterbury between Geraldine and Fairlie. It has a poor safety record with a large number of crashes which might have been prevented by a wider carriageway, sealed shoulder and/or guardrail.

Economic analysis was carried out along this route for seal widening and guardrail installation. Characteristics of the road were measured and mapped out using GIS including seal width, location of guardrail, locations of accidents, traffic flow, speed limit and terrain type.

Economic analysis was undertaken in accordance with the NZTA's *Economic Evaluation Manual*, using two of the specified methods for calculating safety benefits; the *Accident History Method* and the *Accident Typical Rate Method.*

The analysis revealed benefit cost ratios ranging from 0 to 3.6 for various sections along the route, and first year rate of returns ranging from 0% to 25%. Generally the economic returns were higher using the *Accident Typical Rate Method*. The analysis clearly showed the client which sections of the State Highway should be prioritised for improvement works, and the GIS mapping highlighted the relationship between the locations of reported crashes with road characteristics such as seal width and the location of guardrails.

INTRODUCTION

State Highway 79 (SH79) is a 61km length of road located in Canterbury between Geraldine and Fairlie. It is used by a number of tourists and holidaymakers, being an important link in the route between Christchurch and Queenstown.

The road has safety deficiencies, highlighted by a crash in 2007 in which four people died. This crash involved a campervan driven by a European tourist which lost control after drifting onto the unsealed shoulder, then crossed the centreline and collided with 2 oncoming motorcycles, both with pillion passengers. At the time, an on-going seal widening programme was in progress, commencing at the Rangitata end of SH79, completing on average 3km of seal widening per year out of “Strategic Plan Initiative” funding, as the highway had been identified as being under its strategic seal width. The coroner’s inquest findings into this crash event made reference to the on-going seal widening programme in place at the time by the New Zealand Transport Agency (NZTA), and factored this into the rulings. However, since that time, the Strategic Plan Initiative funding has become unavailable, and a structured seal widening programme has ceased, with the exception of widening to target seal width in association with pavement renewals. This study was commissioned to investigate the feasibility of securing alternative capital funding for the completion of the widening programme.

Economic analysis of minor road safety improvements is undertaken in New Zealand according to the NZTA’s *Economic Evaluation Manual*[1]. This manual lends itself to being used to assess individual projects, but an innovative approach was required to assess the entire length of SH79 as multiple potential improvement projects. A methodology involving mapping characteristics of the route, such as seal widths and crash history, using Geographic Information Systems (GIS) was developed. This quickly identified sections of the route which returned the highest Benefit Cost Ratios (BCRs) and calculated an indicative BCR for 16 sections of the route, as well as an overall BCR for the entire route. Two alternate methodologies for calculating safety benefits were applied, one based on the crash history, and one based on crash prediction models.

Taking this approach required collaboration between several different teams within the NZTA and Opus. The work was commissioned by the NZTA network manager, and required economic analysts within Opus to work closely with GIS experts, while relying on the South Canterbury network maintenance team for local knowledge. The combination of experts from different fields working together resulted in an innovative new process being developed and an effective outcome for the client.

GEOGRAPHIC MAPPING OF THE ROUTE

It was critical to have a detailed knowledge of the current seal width along the route. Seal widths were initially measured from NZTA sourced aerial photographs to identify lengths of the highway which were below the target width of 8.5m. A site visit was then undertaken to physically measure all sections identified as under-width from the aerial photographs. This methodology ensured accurate and up to date seal widths were used in the economic analysis. The seal widths of urban areas where kerbs, footpaths and/or parking lanes were present were not measured. One section of the highway was undergoing seal widening works and was unable to be measured; however it was assumed that it will be widened to a compliant width. The seal widths were then mapped.

Locations of guard rails were obtained from the RAMM database and mapped. Traffic volumes were obtained from NZTA count sites and mapped.

Figure 1 below shows the mapped seal widths and guardrail locations.

[1] NZTA(2010). Economic Evaluation Manual, http://www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/

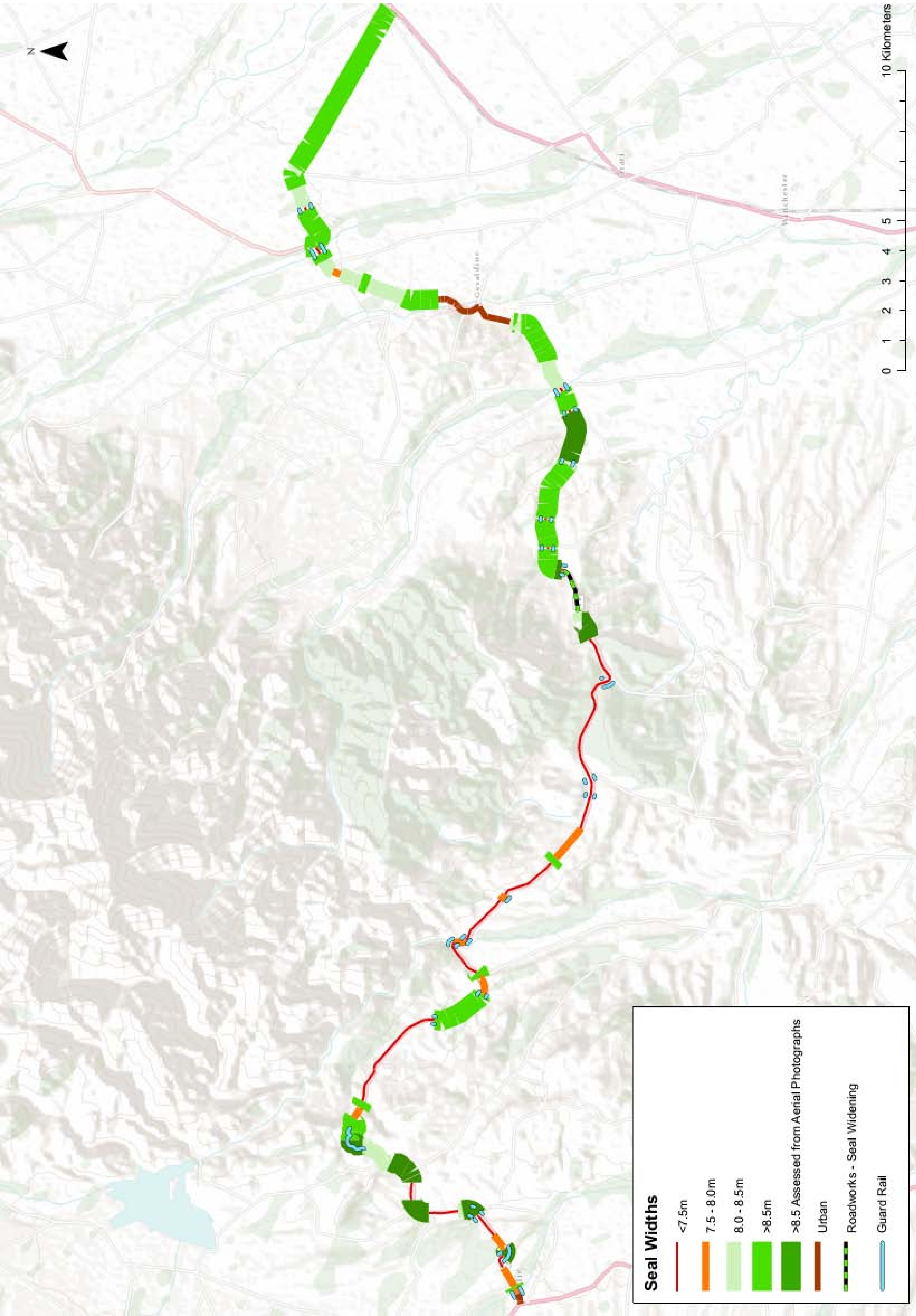

Figure 1 Geographic mapping of seal widths and guardrail locations

GEOGRAPHIC MAPPING OF ACCIDENT HISTORY

Accidents reported in the previous five year period were obtained from the NZTA Crash Analysis System (CAS) and mapped according to their year, enabling easy update of the analysis in subsequent years. This returned a total of 119 accidents.

The Economic Evaluation Manual identifies specific types of accidents which can be reduced by increasing the seal width. These are:

- Loss of control accidents;
- Overtaking accidents; and
- Head-on accidents occurring on bends.

These types of accidents made up 71% (85 accidents) of the total number of reported accidents from 2007 to 2011. These accidents relating to seal width are shown as circles in Figure 2, with all other accidents shown as diamonds.

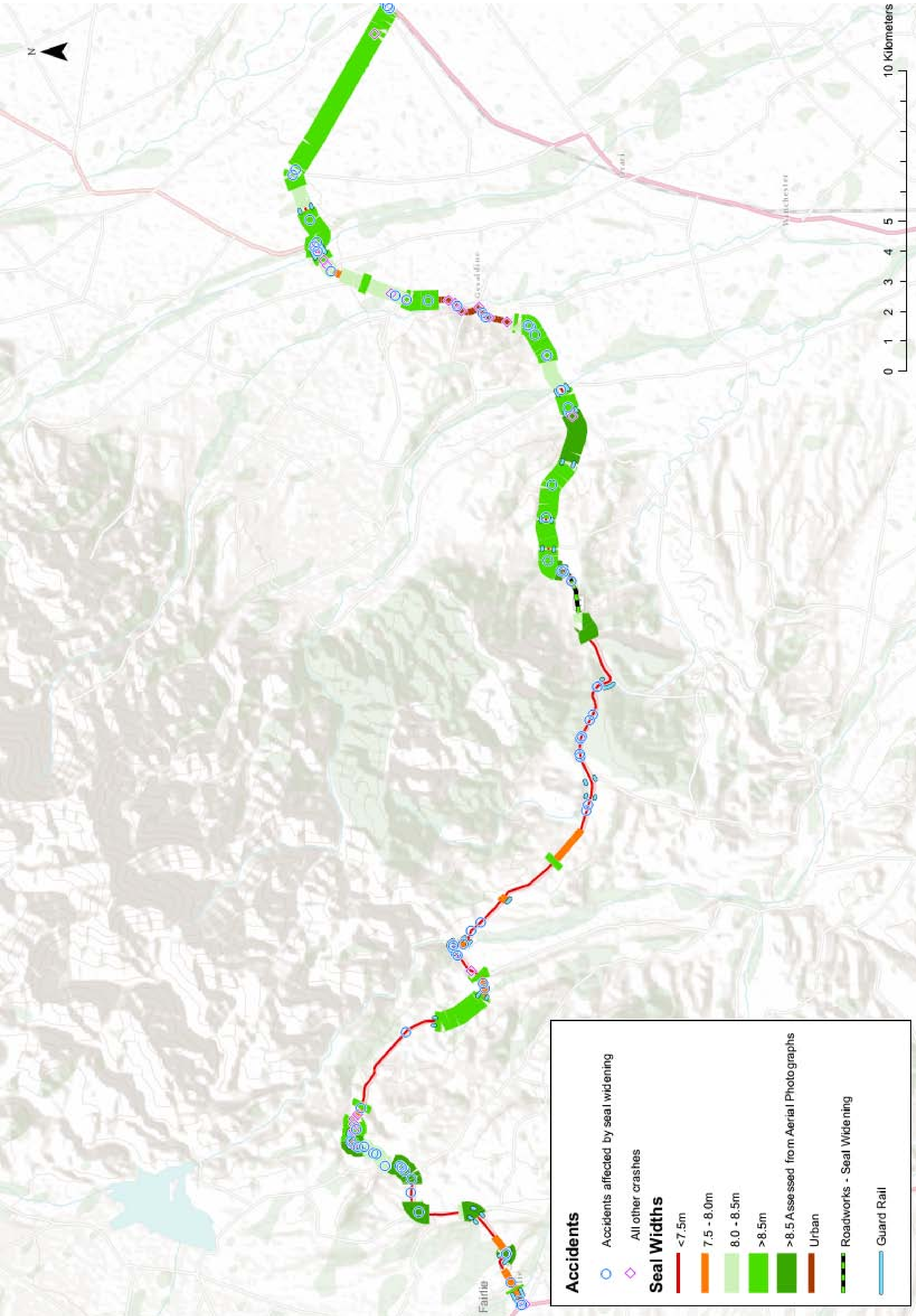

Figure 2 Geographic mapping of accidents, seal widths and guardrail locations

ECONOMIC ANALYSIS METHODOLOGY

The route was analysed to identify all sections of the highway which could potentially benefit from seal widening to 8.5m. This included all sections narrower than 8.0m, excluding bridges, urban areas and sections already treated with guardrails. This analysis identified a total length of 22.6km of the 61km highway which could potentially benefit from seal widening.

This 22.6km length was initially assessed as one project, involving widening of all the identified sections of the highway. The seal width was averaged across all sections of the 22.6km length. All accidents occurring in this length were included in the analysis. There are three terrain categories identified in the Economic Evaluation Manual:

- Level;
- Rolling; and
- Mountainous.

The "rolling" terrain category was judged to be the most representative of the entire route.

The route was next broken down and analysed as 16 shorter sections of highway, which could be widened as individual projects. These sections ranged in length from 267m to 3899m and were divided up in a way in which seal widening works might be expected to occur in practice, according to:

- Terrain changes;
- Seal width changes; and
- Guardrail installation.

Each section had its average width calculated, relevant accidents identified and a terrain category assigned.

The traffic volume and growth used was the average of the two NZTA count sites south of Geraldine, as 99% of the length assessed lies south of Geraldine. The remaining 1% of the length assessed lies north of Geraldine, and so the traffic volume and growth of the Upper Orari Hall count site were used for this section, hereafter referred to as section A.

For illustrative purposes one specific site with a high accident rate was assessed to determine what BCR could be achieved by optimising section lengths around accident hot spots.

CAPITAL AND MAINTENANCE COSTS

Costs were estimated based on recent examples of seal widening works undertaken on State Highway 79 by Opus. Five separate seal widening projects undertaken between 2007 and 2010, ranging in length from 1800m to 3370m, were investigated. From the actual costs of these (adjusted to 2012 dollars) the following construction cost rates were derived:

Terrain	Construction Cost ($ per metre)
Level	95
Rolling	190

Table 1: Capital costs for terrain type

These rates were used to estimate construction costs in the economic analysis. It is noted that this cost is a preliminary estimate only, and actual costs will depend on many other factors such as shoulder geometry, geotechnical conditions and locations of culverts and poles.

It is noted that the same construction cost rate has been used regardless of the length of section being considered. If construction of a shorter section is undertaken as a stand-alone project the cost may be higher than estimated here.

One section (section L) is located on the side of a slope such that any widening works would likely also require the installation of guardrail. Costs for constructing guardrail were assessed as $420 per metre based on actual costs of the Pusey's Gorge guardrail installed in 2010 / 2011. The cost of installing guardrail over the full length of section L was included in its cost estimate.

Maintenance cost rates were estimated from the actual maintenance costs of the recent seal widening projects undertaken on State Highway 79. Maintenance costs were examined for the ten years before widening and compared to maintenance costs in the years since the widening. The following before and after maintenance costs were derived from these actual costs:

Terrain	Maintenance Cost before widening (c per metre per year)	Maintenance Cost after widening (c per metre per year)	Maintenance Cost saving (c per metre per year)
Level	4	1.5	2.5
Rolling	30	3	27

Table 2: Maintenance costs for terrain type

The maintenance costs can be seen to reduce significantly after seal widening, especially for rolling terrain. This is due partly to a reduction in edge break damage, and partly to a less immediate need for its repair meaning multiple repair works can instead be consolidated into a single job. These rates were used to estimate maintenance costs in the economic analysis.

The 16 sections had their costs calculated based on each section being classified as either "level" or "rolling" terrain. For the entire route analysis, the costs were calculated based on the route being made up of 53% "level" terrain and 47% "rolling" terrain, in accordance with the classifications of the shorter sections comprising the entire route.

BENEFITS

Accident benefits were the only type of benefit included in this assessment. Travel time benefits from increased speed were unable to be reliably quantified, and would be partially offset by an increase in accident risk to the point where they were considered negligible. Accident benefits were calculated using two different methods:

- Accident history; and
- Accident typical rate.

Both methods are detailed in Chapter A6.4 of the Economic Evaluation Manual. The accident history methodology uses the accident history from the last five year period (2007-2011) and applies a percentage reduction, which is expected for certain types of accidents due to seal widening works. This comprises the following reductions:

- 20% reduction to all loss of control and overtaking accidents; and
- 20% reduction to head-on accidents occurring on bends.

The guardrail to be installed on section L also has a percentage reduction based on the severity of accidents:

- 40% reduction in fatal accidents
- 30% reduction in serious injury accidents
- 10% reduction in minor injury accidents

The accident history methodology takes into account the mean speed of vehicles when calculating the cost of accidents. This was estimated for each section based on the road alignment and any speed advisory signs on curves. The speeds used for each section ranged from 70km/h to 100km/h. The speeds for each section were then averaged (weighted according to the length of each section) to give a mean speed for the entire route of 95km/h.

The accident typical rate methodology predicts an expected accident rate based on the length of road, terrain, traffic volume, lane width and a cross-section adjustment factor. This cross-section adjustment factor is taken from Table A6.13 in the Economic Evaluation Manual and is dependent on the lane width and sealed shoulder width.

The typical accident rate was calculated for each section based firstly on the measured seal width, and secondly on an upgraded seal width of 8.5m. The difference in the typical accident rate predicted by the model was taken as the accident benefit.

The guardrail to be installed on section L has the effect of reducing the typical accident rate by 25%.

The parameters used in each section of the economic assessment are shown below.

Section	Length (m)	Terrain Type	Accident history method				Accident typical rate method	
			Total accidents 2007-2011				Average width (m)	Cross-section adjustment factor S_{adj}
			Fatal	Serious	Minor	Non-injury		
Entire route	22,559	Rolling	2	1	8	14	7.3	1.156
A	267	Level					7.6	1.086
B	1,560	Level					7.2	1.174
C	3,533	Rolling			3	5	7.2	1.174
D	555	Level					7.1	1.210
E	2,385	Level	1			1	7.5	1.120
F	1,890	Level					7.2	1.174
G	1,806	Level			2		7.1	1.210
H	406	Level				1	7.8	1.018
I	1,245	Level		1	1	3	7.1	1.210
J	571	Rolling			2		7.9	0.984
K	3,899	Rolling	1				7.0	1.210
L	401	Rolling				2	7.6	1.086
M	553	Rolling				1	7.2	1.174
N	990	Level					7.3	1.156
O	1,349	Level					7.3	1.156
P	1,149	Level				1	7.4	1.138

Table 3: Parameters used for each section

ECONOMIC ANALYSIS RESULTS

Using the accident history method returned generally low BCR’s. The entire route returned a BCR of 0.8 and a first year rate of return (FYRR) of 6%. The individual sections returned BCR’s ranging from 0 to 1.8, and FYRR’s ranging from 0% to 14%. The only sections with a BCR higher than 1 were E and I, which was due largely to their relatively high number and severity of accidents. Several of the sections returned a BCR of zero due to an absence of any loss of control, overtaking or head-on (on bends) accidents. Figure 3 below shows colour-coded BCR’s for each of the sections, together with accident density and seal widths.

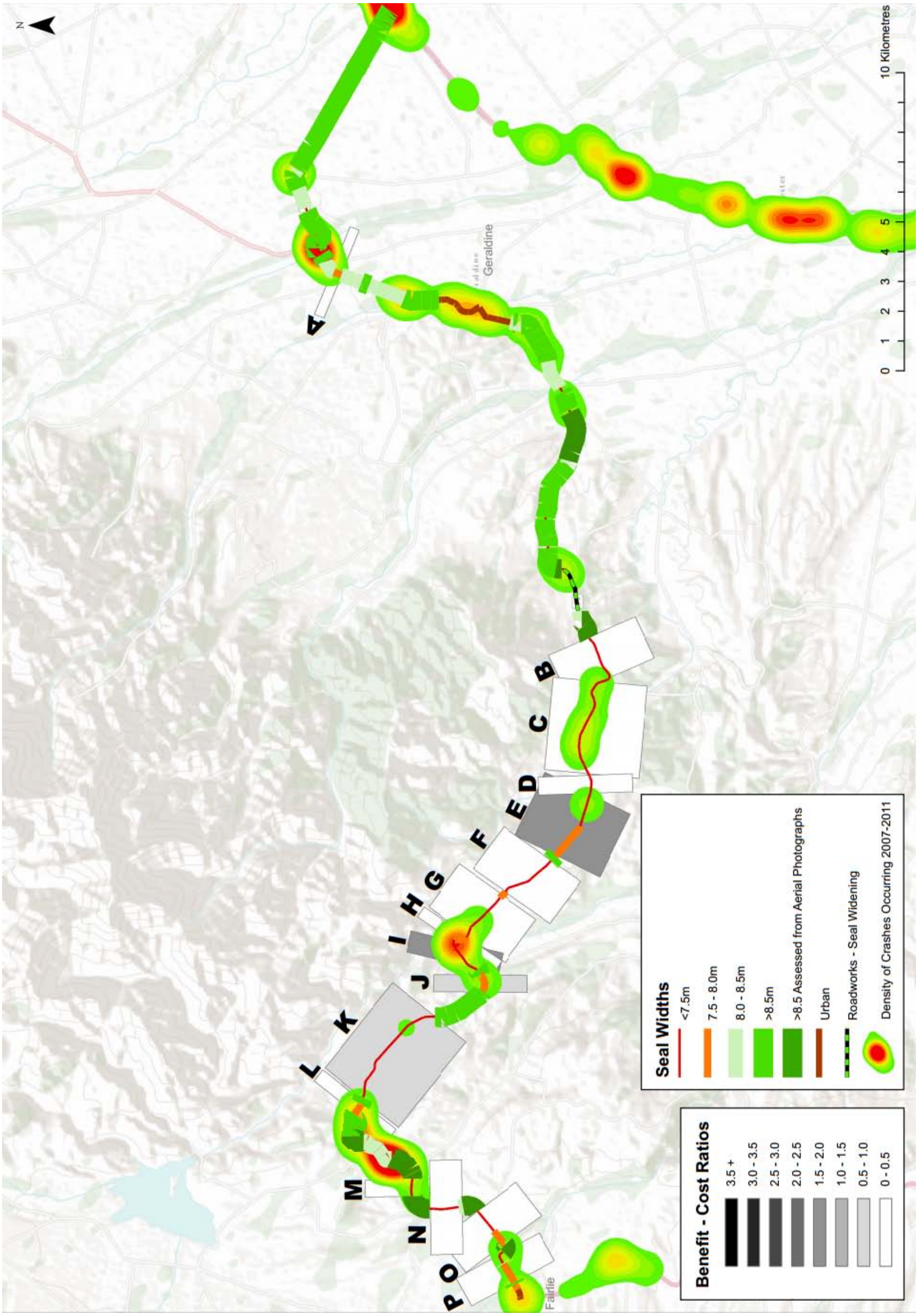

Figure 3 BCRs for each section using the accident history method

The results using the accident typical rate method returned generally higher accident savings than the accident history method. The entire route had a BCR of 1.7 and a FYRR of 12%. The individual sections had BCR's ranging from 0.6 to 3.6 and FYRR's ranging from 5% to 25%. Section A had the highest BCR, due largely to the higher traffic flow on this portion of the highway. Sections B, D, F, N and O also had high BCR's, due to a combination of low construction costs caused by them being situated on level terrain, and narrow existing seal widths. Figure 4 below shows colour-coded BCR's for each of the sections, together with accident density and seal widths.

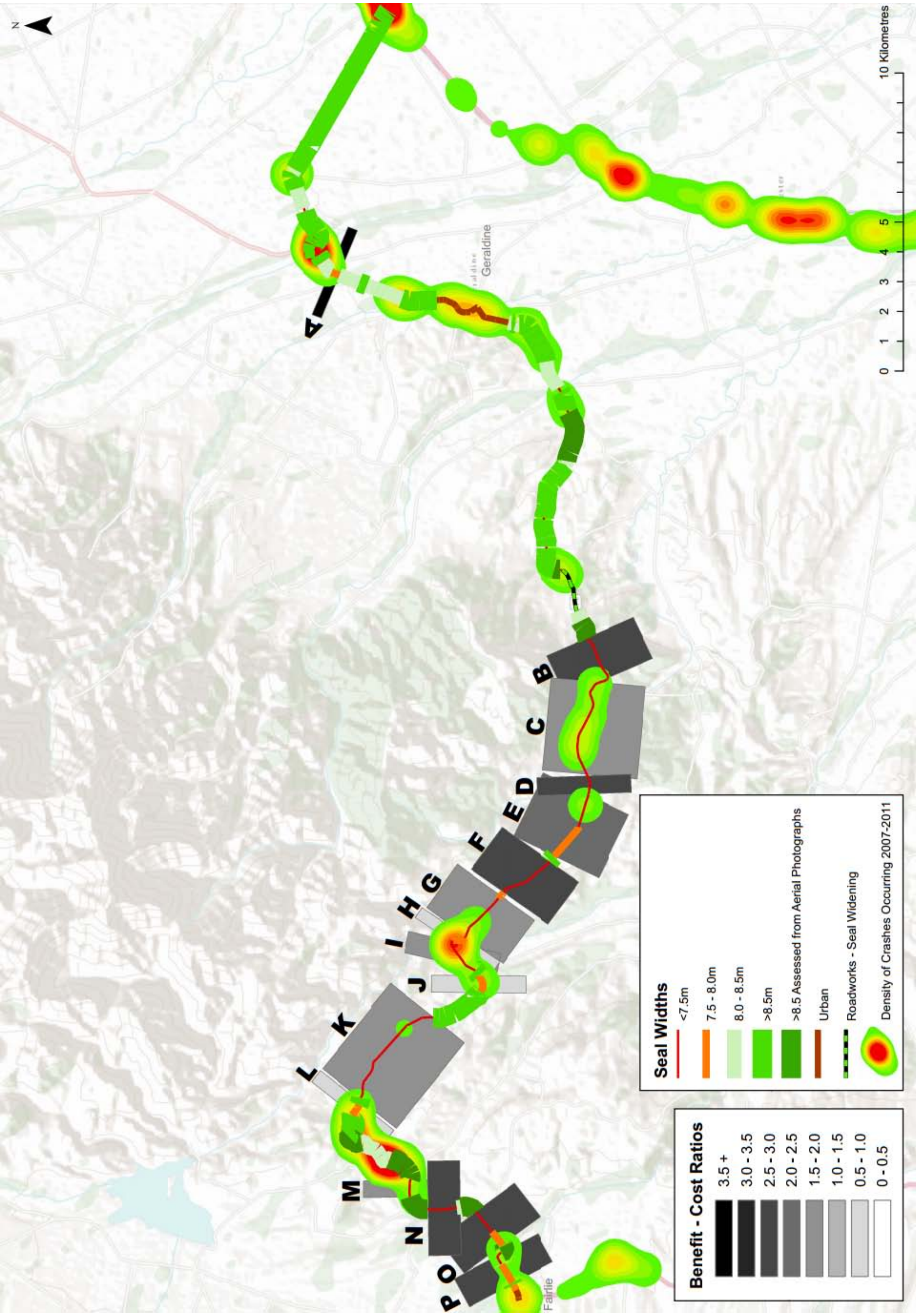

Figure 4 BCRs for each section using the accident typical rate method

The typical annual accident rate for the entire route would reduce from 2.7 reported injury accidents per year to 2.0 reported injury accidents per year if the seal widening was implemented (compared to the actual rate of 2.2 reported injury accidents per year).

SITE SPECIFIC ANALYSIS

One site specific economic analysis was carried out to investigate the impact of optimising the analysis by shortening the length of a section to return the highest BCR. The area around the fatal loss of control accident (within Section E) was chosen, as any seal widening around it results in high accident savings using the accident history method. The economic analysis results of various lengths of road are shown in Table 4: Economic analysis results for different length sections below.

Length (m)	NPV Costs	Accidents	Accident history method		Accident typical rate method	
			NPV Accident savings	BCR	NPV Accident savings	BCR
2385	$217,430	2	$366,321	1.7	$580,429	2.7
500	$45,583	2	$366,321	8.0	$121,683	2.7
100	$9,117	1	$326,374	35.8	$24,337	2.7

Table 4: Economic analysis results for different length sections

The results show that the BCR can be increased by reducing the length of seal widening undertaken if the accident history method is used. This is due to the fact that the construction and maintenance costs reduce with reduced length but the accident savings remain the same provided the analysis is selective in widening the lengths that encompass the specific accidents in question.

It is considered that this form of analysis is flawed as very short sections of seal widening are unlikely to be carried out. There is an element of randomness to the occurrence of accidents of the identified type. If a short section of seal was widened it is possible that accident migration would lead to the accident occurring elsewhere on SH79. If a specific site was identified with a significantly deficient seal width and high accident history this method could be used to return a high BCR to carry out widening, but the treatment may not reduce the overall accident risk for the route.

CONCLUSIONS

The automated GIS-based economic analysis provided a range of preliminary economic results for various combinations of seal widening and guardrailing works along State Highway 79, enabling the client to quickly and clearly see the best way to structure the works so as to have the best chance of securing funding for improvement works. It provides an effective method for quickly assessing a large area with a high number of potential projects, and directing the approach taken when attempting to secure funding.

Treating the route improvements as a single project returned relatively low BCR's of 0.8 using the accident history method and 1.7 using the accident typical rate method.

Using the accident history method BCR's were still relatively low. Sections I and E returned the highest BCR's of 1.8, and were the only two sections with a BCR higher than 1. The sections returning the highest BCR's were those with the worst accident records for the previous five year period.

Using the accident typical rate method the calculated BCR's were much higher, ranging from 0.6 to 3.6. All but two of the sections assessed returned BCR's higher than 1.0, with the sections returning the highest BCR's being those which were situated on level terrain (resulting in a lower cost estimate) and the narrowest existing seal width (resulting in higher accident benefits).

The typical annual accident rate for the entire route would reduce from 2.7 to 2.0 reported injury accidents per year if the seal widening was implemented (actual accident rate is 2.2 reported injury accidents per year).

The site specific method can be used to manipulate the BCR based upon a specific accident; however it is unlikely to solve the overall accident risk.

The results showed that for seal widening works on this route using the accident typical rate method will generally return more favourable economic results than using the accident history method. There were several sections with relatively low costs of widening which returned high BCR's and could be progressed as individual projects. Progressing the entire route as a single project would return a lower BCR, although other factors such as the strategic fit may make this approach worthwhile. At the time of writing, the approach to be taken had not yet been decided by the client. This will be determined when more national seal widening funds become available.

The development of this analysis method relied heavily on collaboration between experts from different fields. Economic analysts were required to work closely with GIS experts to develop the methodology, and involvement of the network maintenance consultant team was crucial in providing realistic construction costs and robust estimates of maintenance cost savings. This was carried out successfully resulting in the development of a better tool for the client.

REFERENCES

NZTA, 2010. *Economic Evaluation Manual*, http://www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/