Losing our Grip?

The Challenge of Maintaining Safer Road Surfaces on Southern New Zealand State Highways

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ABSTRACT

The NZ Transport Agency and it's suppliers are finding it ever more challenging to maintain safe skid resistant road surfaces on NZ State Highways. Increasing Heavy Commercial Vehicles (HCV) carrying heavier loads (now up to 63 tonnes) travelling at higher speeds (speed limit for HCV's has increased from 80KMH to 90KMH in 2004) are putting more and more stress on NZ State Highway's (SH) particularly, rural highways with tight horizontal alignment. This, combined with ever increasing surfacing layers, reducing budgets, changes in climatic conditions and pressure on aggregate sources, continues to challenge traditional thinking and surface maintenance and renewal techniques.

This paper explores the findings of some surface treatment mitigation techniques explored over many years including results of field trials and analysis of 2100 KM of Otago and Southland State highways.

1. INTRODUCTION

The New Zealand Government has set some key priorities for the NZ Transport Agency and roading industry. One of which is reducing the number of deaths and serious injury crashes on our roads (Safer Journeys strategy, Ministry of Transport). The NZ Transport Agency is focussed towards embedding the "safe system" approach into everything they do to help achieve this outcome. Safe speeds, safe vehicles, safe road use and safe roads and roadsides are the cornerstones to this approach.

In this paper we will describe strategies adopted over time to manage safe skid resistance as our contribution to delivering "safer roads" on the Southern State Highway network;

1. Resurfacing treatment methodology

The selection of appropriate chip grade and the methodology to construct the chip surface requires careful consideration. There are many variables to assess, including the expected skid performance overtime. We have found some construction methodologies and chip size selection perform better than others, in a skid context.

2. Aggregate performance

The selection of suitable sealing chip aggregate is one of our most important value for money decisions. Typically the decision has been based on using the nearest chip supply source that meets the specification requirements and has a Polished Stone Value (PSV) value that is deemed suitable to withstand the traffic stress on the site. While the performance history of various local chip sources is reasonably well known, there had previously not been a study (Within Coastal Otago) of how PSV of the chip relates to performance on the road. That is, Infield performance.

3. Aggregate shape

Research to date has suggested that skid resistance increases linearly with percentage crushed faces. Cenek et al 2006, suggested the use of 100% crushed chip has an effect of increasing PSV by 4 to 5 which, if accepted, could result in marginal PSV sources (or poor insitu performing aggregate) becoming more acceptable. Alluvial sourced aggregate (predominant source in the South Island of New Zealand) by its very nature has worn smoothly which creates rounded stone surfaces particularly in larger sized sealing chips. Specifying 100% crushed faces for all sealing chips used for high stress areas will cost more but, from a lifecycle cost perspective is potentially more cost effective if it delays the need to resurface for skid resistance reasons.

4. SOUTHERN SOUTH ISLAND NETWORK CONTEXT

The southern south island State Highway network comprises four Network Management Areas (NMA's) being Coastal Otago, Central Otago, Southland and Milford Sound. The networks have the following statistics;

NMA	Total In.km
Coastal Otago	1524.998
Central Otago	1073.044
Southland	650.488
Milford Sound	196.819

Table 1 NMAs by length

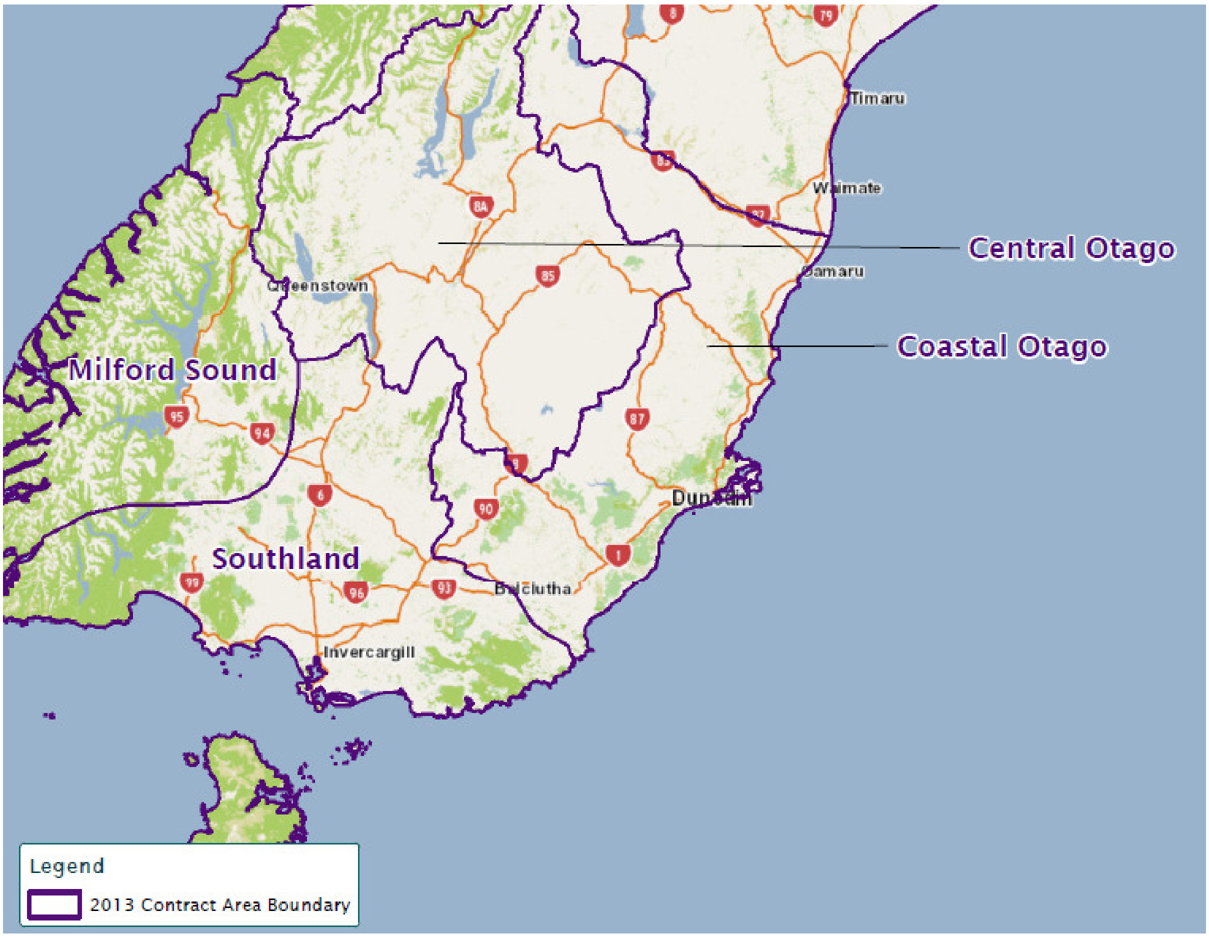


Fig 1 Map of Southern South Island NMA's by State Highway networks

The paper will focus on analysis completed predominantly within the Coastal Otago, Central Otago and Southland NMA's. The networks range from coastal to alpine, flat to mountainous terrain and temperature ranges from sub zero winter conditions to greater than 30 degrees Celsius summer conditions. The Southern South Island NMA's are managed from the Dunedin office of the NZ Transport Agency.

5. NZTA POLICY CHANGE

The skid resistance of the entire state highway network is measured annually using the SCRIM+ truck which produces a skid resistance measure for each wheel path for each 10m section of road network. This skid resistance measure is corrected for speed and temperature and an sfc factor applied to produce a SCRIM coefficient (SC). The average SC for each 10m is then compared against the required Intervestigatory Level (IL) minus 0.1, which is known as the Threshold Level (TL). An exception report is produced detailing locations where the skid resistance is less than the TL.

NZTA's T10 specification outlines the process for implementing the state highway skid resistance policy on the State Highway network. The version introduced in 2010 (later refined in 2012 and 2013) incorporated an important change where the level of skid resistance Investigatory Level (IL), required for out of context curves as determined in the Transport Agency asset database (RAMM) curve table, (Radius < 400 m) was increased from 0.50 to 0.55 SCRIM Co-efficient (SC). This introduced a new category of IL known as 2H. Previously these curves, (those under 250m radius or category 2), were required to meet an IL of 0.50.

Site category	Skid site description	Investigatory level (IL), units ESC					
		0.35	0.40	0.45	0.50	0.55	0.60
1	Approaches to: a) Railway level crossings b) Traffic signals c) Pedestrian crossings d) Stop and Give Way controlled intersections (where state highway traffic is required to stop or give way) e) Roundabouts. One lane bridges: a) Approaches and bridge deck.						
2	a) Urban curves <250m radius						
	b) Rural curves <250m radius			L	M	H	
	c) Rural curves 250-400m radius		L	L	M	H	
	a) Down gradients >10%. b) On ramps with ramp metering.						
3	a) State highway approach to a local road junction. b) Down gradients 5-10% c) Motorway junction area including on/off Ramps d) Roundabouts, circular section only.						
4	Undivided carriageways (event-free).						
5	Divided carriageways (event-free).						

Figure 2 NZTA T/10:2013 table 1

The introduction of a higher level of 0.55 for the category 2H curves resulted in the number of sections now failing to achieve TL increasing dramatically. Upon receipt of the SCRIM exceptions report the investigating engineer is required to promptly investigate priority "A" sites. Priority "A" sites are those that meet one of the following criteria:

- Sites that are below the TL or the TLM and have had at least two wet skid crashes in the previous five years (any wet crash within ±250m of the site will be included in the analysis) Where the crash is within 250m of the start or end of a reference station the analysis will not look across adjacent reference stations).
- Sites that are flushed (defined for 2012/13 as having a lane SC value of ≤0.35 combined with a texture value of ≤0.7mm MPD from either wheelpath)
- Sites where the SC is very low (defined for 2012/13 as having an lane SC value more than 0.15 below IL

Where the investigator determines treatment is "necessary" then a range of treatment options are available, although the time of year should be considered as this will affect the success of some treatment options. Where a surfacing renewal (reseal) is considered the best treatment option, then the surfacing designer must consider the future performance of the surfacing with respect to skid performance.

6. HISTORIC PERFORMANCE

Chart 1 below shows the history of the percentage of network below TL for both the Coastal Otago and Southland networks. Here we can see the immediate impact of the introduction of the new NZTA T/10:2010 specification on the amount of network below the threshold level.

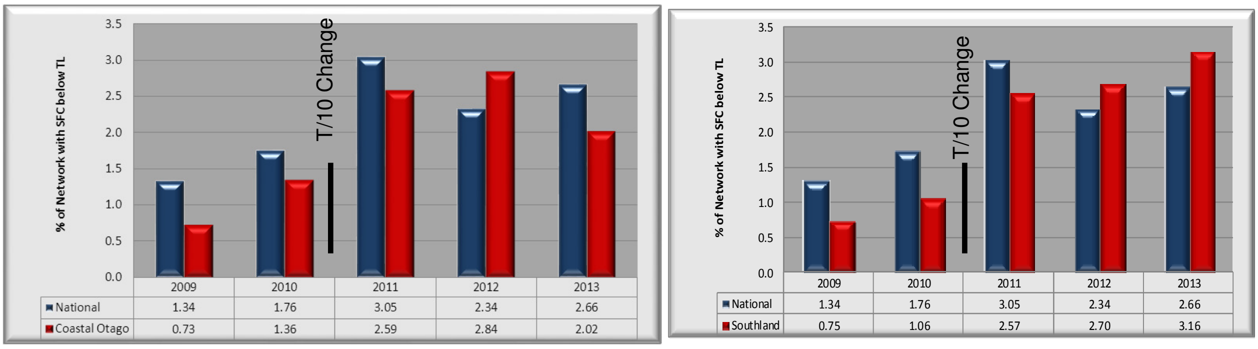


Chart 1: Coastal Otago and Southland NMA Historic Skid resistance performance. (source NZTA NMA annual performance report 2013)

As we can see the Coastal Otago network has increased in the percentage of network below TL in proportion with the National trend through to 2011. In 2012 there was an increase compared with the national trend but decreased in 2013. The Southland network has tended to have less than the national average sections below the TL up until 2012 where it has continued to increase in the percentage of length which is below the TL.

7. DEMAND GROWTH

The skid performance of a road surfacing is directly related to the polishing affect of heavy commercial vehicle (HCV) traffic. The NZ Vehicle Dimension and Mass Rule (VDM), which legislates the size and weight of the NZ HCV fleet, has undergone significant change in the past few years. 1 May 2010 heralded a change to allow High Productivity Motor Vehicles (HPMV) to operate on State Highways and Local Authority networks under permit, with the objective to increase NZ freight productivity. These HPMV's are both length (up to 22m excluding allowable front and rear overhang) and Weight (mass) limited (up to 63 Tonnes). The rule allows HPMV's to operate quad axle sets and limits maximum axle loadings depending on the vehicle configuration. The following charts show the HCV loadings across the Coastal Otago and Southland networks since 2000. We have chosen Vehicle Kilometres Travelled (vkt) as the metric because this best represents the total amount of truck movements within the network. The calculation is based on the percentage of HCV (measured by classifier counter) in each class, multiplied by the average annual daily traffic (aadt) multiplied by the roadway link (section to which the traffic count applies). Therefore any change in HCV loading within a sub network will be represented proportionally.

In New Zealand vehicle counts are taken using classifier counters (usually pneumatic tube) which record the number and spacing of axles and groupings. These counts are then binned according to the scheme described in the NZ Transport Agency manual SM052 Traffic Monitoring for State Highways.

Figure 3 below shows how the vehicle fleet is distributed into the 14 count bins and further amalgamated into the MCV, HCV1 and HCV2 heavy vehicle classes.

Vehicle Classification Scheme (NZTA 2011)

NZTA Axel Class	Vehicle Types in Class	Axles	Groups	Criteria	Maximum axle spacing < 10m			Length Range (WIM data)	NZTA EEM Class	Light or Heavy	NZTA Length Class	Austroads 1994 Class
					AS1- 2	AS2- 3	AS3- 4					
1	oo (very short 2 ax veh = motorbike)	2	1	2 ax, AS 1 criterion	>=0.5, <1.75	-	-	>1.5 - 2.5	(PC)	Light	VS	1
2	o-o (short 2 axle vehicle = car)	2	2	2 ax, AS 1 criterion	>=1.75, < 3.2	-	-	2.5-5.5 (4-6)	PC & LCV	Light	S	1
	o-o--o (car towing 1 axle trailer)	3	3	3 ax, AS 1,2 criteria	>2.1, < 3.2	>2.1	-	7 -11			M	2
3	o-o--oo (car towing tandem trailer)	4	3	4 ax, AS 1,3 criteria	>2.1, < 3.2	>2.1	<=1.0	8 -13	PC & LCV	Light	M	2
	o-o--o-o (car towing car)	4	4	4 ax, AS 1,2,3 criteria	>2.1, < 3.2	>2.1	>2.1	10 -15			M	2
	o----o (truck or bus)	2	2	2ax AS 1criterion	> =3.2m			5 - 12			M	3
4	o--o--o (truck towing light trailer)	3	3	3 ax, AS 1,2 criteria	>=3.2m	>2.1, <=6.8	-	8 -16	Bus & MCV		L	6
	o--o--oo (truck tow light 2 ax trailer)	4	3	4 ax, AS 1,3 criteria	>=3.2m	>2.1	<=1.0	9 -17			L	7
	o--oo (truck or bus/coach)	3	2	3 axles, 2 groups	>=3.2m	<=2.1	-	7 -12			M	4
	o--oo (tractor without semi-trailer)	3	2	3 axles, 2 groups	>2.1, < 3.2	<=2.1	-	6 -8			M	4
	oo--o (twin steer truck)	3	2	3 axles, 2 groups	<=2.1	-	-	7 -12			M	4
5	o--o-----o (artic e.g. bread truck)	3	3	3 ax, AS 1,2 criteria	>=3.2m	>6.8	-	11 -17	Bus & HCV1	Heavy	L	6
	o--oo---o (truck tow light 1 ax trailer)	4	3	4 ax, AS 1,2,3 criteria	>=3.2m	<=2.1	>2.1	10 -17			L	7
	oo--o---o (twin steer tow 1 ax trailer)	4	3	4 ax, AS 1,3 criteria	<=2.1	-	>2.1	10 -17			L	7
	oo--oo (heavy truck)	4	2		<=2.1	-	>1.0, <=2.1	7 - 13			M	5
6	o--ooo (heavy truck)	4	2	4,5 axles, 2 groups	>2.1	<=2.1	>1.0, <=2.1	7 -11	HCV1	Heavy	M	5
	oo--ooo (heavy truck)	5	2		-	-	-	8 -13			M	5
	o--o--oo (artic A112)	4	3	4 ax, AS 1,2,3 criteria	>2.1	>2.1	>1.0, <=2.1	12 -18			L	7
7	o--oo--o (artic A121)	4	3	4 ax, AS 1,2,3 criteria	>2.1,<3.2	<=2.1	>2.1	12 -18	HCV1	Heavy	L	7
	o--o--o--o (truck tow heavy trailer)	4	4	4 axles, 4 groups	>=3.2	>2.1	> 2.1	13 -17			VL	7
	o--oo--oo (truck tow light trailer)	5	3		-	-	-	10-18			VL	8
	o--oo--oo (artic)	5	3	5 axles	-	-	-	12-17			L	8
8	o--o-----ooo (artic)	5	3		-	-	-	12 -17	HCV2	Heavy	L	8
	o--oo--o--o (T+T)	5	4	3,4,5 groups	-	-	-	13 -18			VL	8
	o-o-o-o-o (mobile crane)	5	5		-	-	-	10 -13			L	8
	o--oo--ooo (artic)	6	3			-	>2.2,<12.0	13 -18			L	9
	oo--oo--oo (artic)	6	3		-	-	-	13 -18			L	9
	o--ooo--ooo (artic)	7	3	6-8 axles	-	-	-	> 16			L	9
9	o--oo--oooo (artic)	7	3	3 groups	-	-	-	> 17	HCV2	Heavy	L	9
	oo--oo--ooo (artic)	7	3		-	-	-				L	9
	oo--oo--oooo (artic)	8	3		-	-	-				L	9
	o--ooo--oooo (artic)	8	3		-	-	-				L	9
	o--oo--o-oo (T+T)	6	4		-	-	-				VL	10
	oo--o--o-oo (T+T)	6	4		-	-	-				VL	10
	oo--oo--o--o (T+T)	6	4	6 axles	-	-	-				VL	10
10	o--oo--o-o-o (T+T)	6	5	4,5 groups	-	-	-		HCV2	Heavy	VL	11
	o--o--oo--o-o (A train)	6	5		-	-	-				VL	11
	o--oo--o--o-o (A train)	6	5		-	-	-				VL	11
	o--oo--oo-oo (T+T)	7	4		>2.2m	-	-				VL	10
11	o--oo--oo--oo (B train)	7	4	7 axles, not twin steer	>2.2m	-	-		HCV2	Heavy	VL	10
	o--oo--oo--o-o (A train)	7	5	(AS 1 criterion)	>2.2m	-	-				VL	11
	oo--oo--o-oo (T+T)	7	4		<=2.2m	-	-				VL	10
	oo--o--oo--oo (T+T)	7	4		<=2.2m						VL	10
	oo--oo--oo-oo (T+T)	8	4		<=2.2m	-	-				VL	10
	oo--oo--oo-ooo (T+T)	9	4	7-11 axles	<=2.2m	-	-				VL	10
12	oo--oo--ooo-oo (T+T)	9	4	twin steer	<=2.2m	-	-		HCV2	Heavy	VL	10
	oo--oo--ooo-ooo (T+T)	10	4	(AS 1 criterion)	<=2.2m	-	-				VL	10
	oo--ooo--oo--ooo (T+T)	10	4		<=2.2m						VL	10
	oo--oo--ooo-oooo (T+T)	11	4		<=2.2m	-	-				VL	10
	various (twin steer A train)	7-11	5		<=2.2m	-	-				VL	11
	o--oo--ooo-oo (B train)	8	4		>2.2m	-	-				VL	10
	o--oo--oo--ooo (B train)	8	4		>2.2m	-	-				VL	10
	o--oo--ooo-ooo (B train)	9	4		>2.2m	-	-				VL	10
13	o--oo--ooo-oooo (B train)	10	4	8-11 axles	>2.2m	-	-		HCV2	Heavy	VL	10
	o--oo--oo--o-oo (A train)	8	5	not twin steer	>2.2m	-	-				VL	11
	o--oo--ooo--o-o (A train)	8	5	(AS 1 criterion)	>2.2m	-	-				VL	11
	o--oo--ooo--o-oo (A train)	8	5		>2.2m	-	-				VL	11
14		any	-	Everything else	-	-	-					

NZTA Length Class: VS= 0.5- 2.0m S=2.0- 5.5m M=5.5- 11m L=11- 17m VL> 17m
Axles: Number of axles
Groups: Number of axle groups (an axle group is where axles are less then 2.1m apart.
AS1- 2: Distance between first and second axle
AS2- 3: Distance between second third axle
AS3- 4: Distance between third and fourth axle

Figure 3 NZTA Vehicle scheme (2011), SM052 Traffic Monitoring for State Highways.

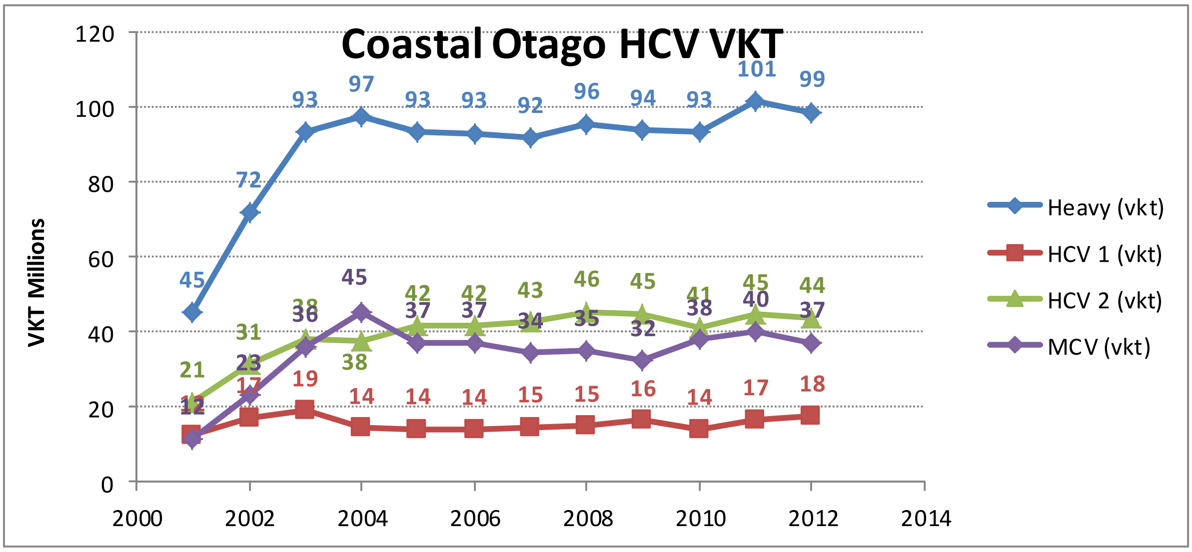


Chart 2. HCV Demand on Coastal Otago Network in VKT

We can see from Chart 2 since 2010 there has been an increase in VKT from 93Million in 2010 to 101 Million in 2011 and 99 Million in 2012.Further there has been a slight increase in HCV1 and HCV2 with little change in MCV. This is suggesting a shift in fleet to larger vehicles. Therefore for Coastal Otago it would seem the change to the VDM rule has not resulted in a reduction in HCV movements.

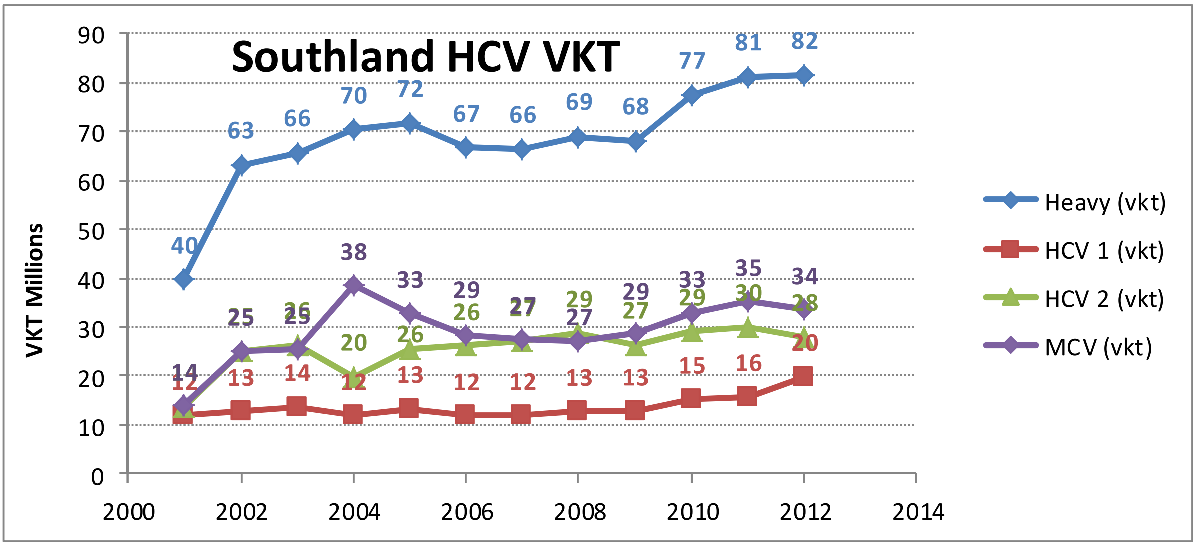


Chart 3. HCV Demand on Southland Network in VKT

In Chart 3 we can see both HCV2 and MCV remain substantially the same with the significant increase occurring within the HCV1 class. This may explain why the Southland network continues to have increasing SCRIM exceptions however although total HCV vkt has been increasing since 2008, there doesn't seem to be a shift to HPMV's (recorded in HCV 2 figures).

8. RESURFACING TREATMENT METHODOLOGY

New Zealand rural State Highways are resurfaced with chip seals (spray seals) (apart from Motorways and high stress areas). This method has proved to be an effective low-cost resurfacing option for New Zealand Roads for over 70 years. The Transport Agency specification that controls the size and quality of sealing aggregate chip is NZTA M6. Chi size is described by “grade”. Below are the dimensions of the respective grades.

Grade of Chip	ALD (mm)	% of Least Dimensions Within 2.5mm of ALD	AGD Ratio ALD	% Passing 4.75mm Sieve	% With at Least Two Broken Faces
2	9.5 – 12.0	65 min	2.25 max	1.1	98 min
3	7.5 – 10.0	70 min	2.25 max	1.1	98 min
4	5.5 – 8.0	75 min	2.25 max	1.1	98 min

Figure 4. Table 2 of NZTA M6, Chip grade and respective size and shape controls

Test Sieve Aperture	% Passing	
	Grade 5	Grade 6
13.2 mm	100	-
9.5 mm	95 – 100	100
6.7 mm	-	95 – 100
4.75 mm	8 max	-
2.36 mm	2 max	15 max
300 µm	0	8 max

Figure 5. Table 3 of NZTA M6, grading limits of smaller aggregate chip.

Within the Costal Otago Network between the period of 2000 – 2005, resurfacing treatments were predominantly constructed using smaller chip grades as past resurfacing cycles were focussed on larger single chip grades typically grade 3 (Average least dimension(ALD) of 7.5 – 10mm). Treatments were generally being applied to correct SCRIM inadequacies or as water proofing. At the previous International Safer Roads conference 2008, Mortimer et al presented the paper “Improved skid resistance through small chip seal design” which published the results of early trials using small chip grades (typically less than 8mm ALD) and using a sealing technique that is aimed at increasing the hysteretic friction and thus an increase in skid resistance. This paper concluded that superior skid performance using these surfacing types was achieved (in early life) and further analysis was needed. These surfaces have been recorded in the NZ Transport Agency’s asset Database (RAMM) as a “Racked in” Seal. This seal type involves the Lager stone being supported insitu by the smaller locking stone.

Figure 6, Racked in Seal schematic (NZ Transport Agency Chip Sealing in New Zealand Practice Note 2)

From the site specific analysis completed in 2008 only 3 of the 5 initial trial sites remain. The other two sites are no longer in service due to road realignment works. Below is an update of the SCRIM performance to that 2008 analysis. The skid values are in Mean Summer SCRIM Coefficient's (MSSC) which is the SC after it has been seasonally corrected for within year variation.

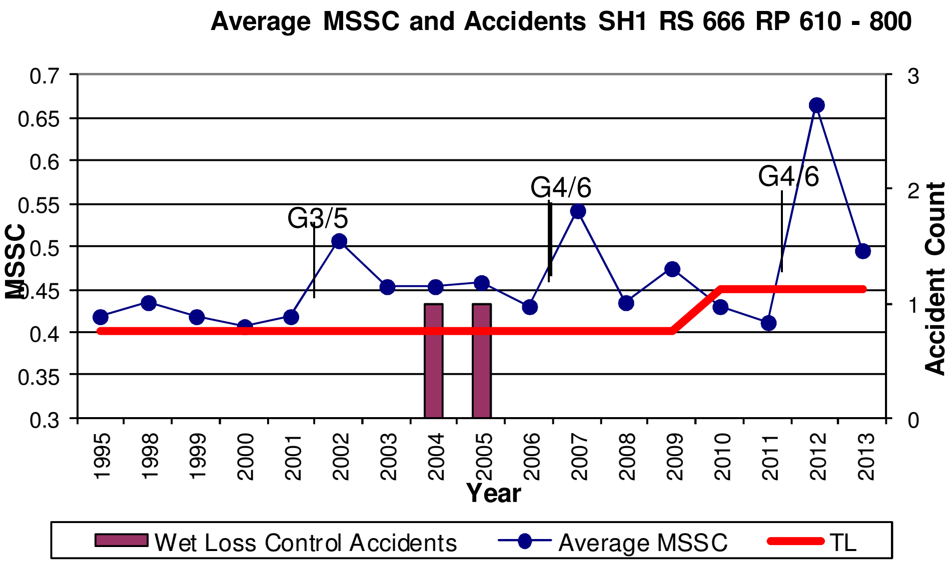


Chart 4. SCRIM performance of SH1 RS666 RP610-800 Waikouaiti Curve

Chart 4 shows the increased SCRIM in the initial year (2007) of the Grade 4/6 racked in seal being much higher than the previous grade 3/5 (2002), however over time the rate of deterioration of SCRIM is greater reaching a terminal condition similar to the previous surfacing after only 4 years (versus 5 years for the Grade 3/5). In early 2012 it was decided another surfacing using an alternative source (Parkburn aggregate, Discussed further herein) would be applied due to the increased SCRIM performance requirements. The average rate of change for the 2006 grade 4/6 racked in seal is 0.026 MSSC per year as compared with 0.015 MSSC per year for the 2001 G3/5 two chip surface.

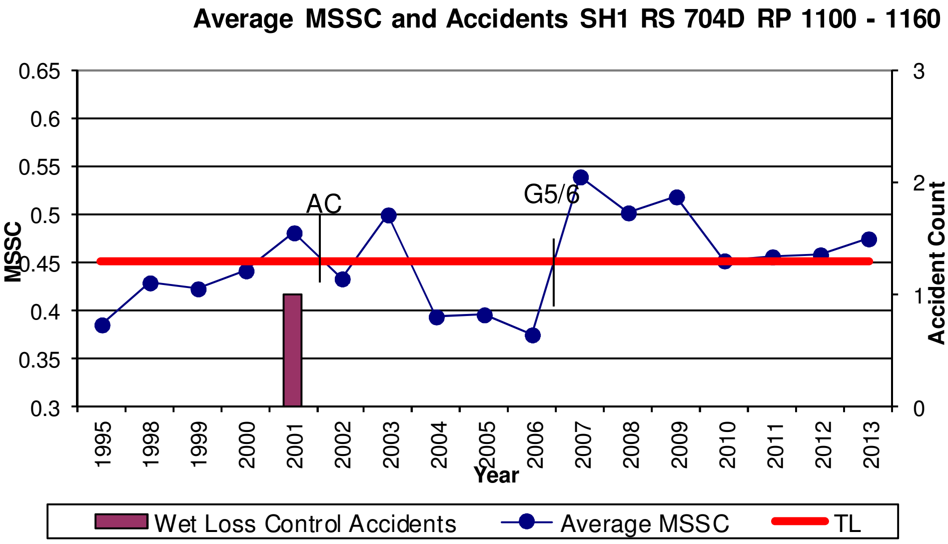


Chart 5. SCRIM performance of SH1 RS 704-D RP1100-1160 Union St Crossing

This site is a category 1 (IL 0.55) approach to a high use pedestrian crossing and is one of the oldest grade 5/6 racked in seals on the network. It initially performed very well with only a small reduction in skid resistance but suffered some rapid loss of skid resistance in 2010 (coincidental with introduction of HPMV's) which is associated with flushing due to chip embedment into the asphalt substrate. Since that time water cutting has been carried out to maintain the skid resistance above the required threshold level (0.45). Given this intervention the calculation of a rate of change for this site is not solely influenced by polishing effect.

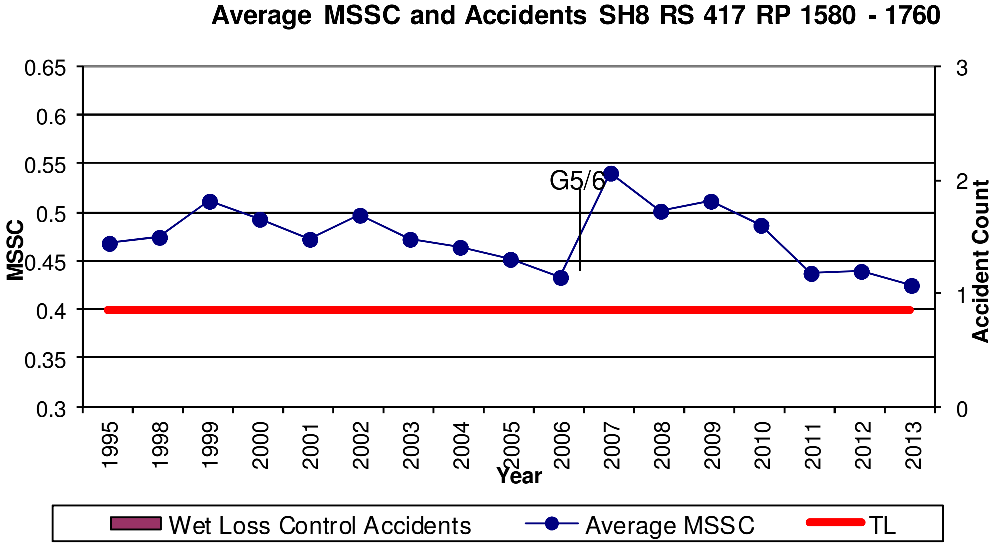
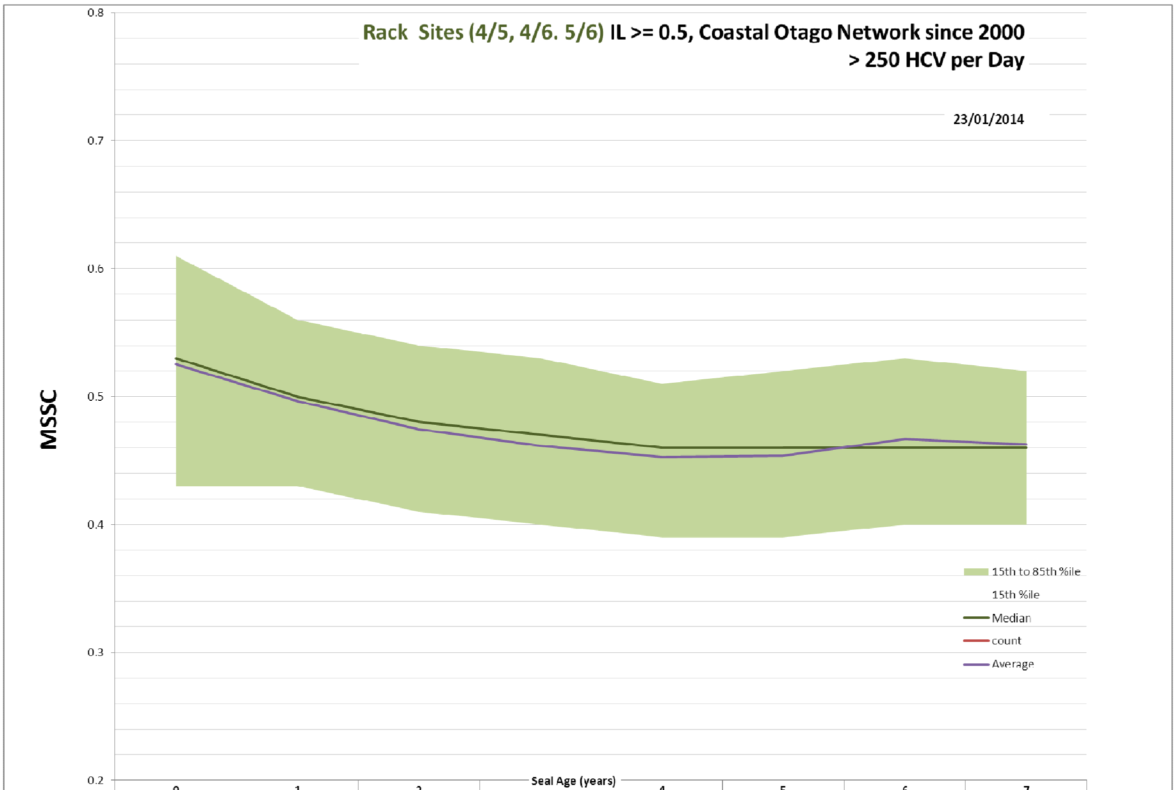


Chart 6. SCRIM performance of SH8 RS417 RP1580-1760 Bowlers Creek curves

According to asset records this site was sealed back in 1988 with a grade 3 chip prior to the 2006 grade 5/6 racked in seal in 2006. However, the SCRIM data shows an increase in 1999 which could indicate a new surfacing was constructed at that time. Since the 2006 surfacing was applied there has been an initial loss of skid resistance as expected with a plateau and another accelerated loss in 2010 followed by another plateau. On the face of it the reason for the deterioration is not obvious. A check of the vehicle counts for this period does not reveal any significant change however the total mass and additional axle sets comprising an HPMV may well be contributing to this step reduction. That rate of change of the grade 5/6 rate is an average 0.0166 MSSC per year.

Many more racked in seals were constructed across the network, not always to improve skid resistance but also because the racked in seal offers other engineering benefits (not part of the scope of this paper). Therefore a much larger pool of sites exists to assess the network wide performance of the surfacing type. By analysing SCRIM data from many years of survey over sites that have a site IL of 0.5 or greater and have greater than 250 HCV's per day we have derived the following chart.



	0	1	2	3	4	5	6	7
15th to 85th %ile	0.18	0.13	0.13	0.13	0.12	0.13	0.13	0.12
15th %ile	0.43	0.43	0.41	0.4	0.39	0.39	0.4	0.4
Median	0.53	0.5	0.48	0.47	0.46	0.46	0.46	0.46
count	4414	6382	5926	5900	5656	4844	3732	1202
Average	0.52	0.50	0.47	0.46	0.45	0.45	0.47	0.46

Chart 7. Skid resistance of Small Chip Racked In seal sites over time.

The SCRIM data has been normalised to the age of each surfacing rather than the year of the survey. Therefore this compares the SCRIM reading of for example a two year old surface constructed in 2005 with a two year old surface constructed in 2008. One data set will be from the 2007 SCRIM survey and the other will be from the 2009 survey. Chart 7 above shows the distribution of values, the range from the 15th percentile to 85th percentile and the median along with the data sample size. This analysis shows that across the network the rate of change of the median SCRIM value to be **0.0087 MSSC per year**. The rate of change of the average is 0.0078 MSSC per year. The distribution of results (representing the consistency or variation) is very narrow (0.12 – 0.13 MSSC). Results older than 7 years have been excluded as the size of the data set is not very large and therefore not statistically significant. Sites where flushing has started to affect performance (as opposed to polishing) were also removed from the analysis so as to better understand the skid resistance (to polishing) performance of small chip racked in seals.

8.1. Resurfacing Methodology Conclusion

From the analysis completed on the performance of chip seal construction aimed at increasing the hysteretic friction, we conclude that 85 percent of small grade chip combinations (5/6 and 4/6) racked in seals perform above the required threshold level on curves with IL 0.50 and with HCV's greater than 250 per day. However if the site IL is 0.55 then only 50% of sites will achieve the threshold level of 0.45

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9. AGGREGATE PERFORMANCE

The previous method for design of new surfacing and selecting suitable aggregate with respect to skid performance is to use the Polished Stone Value method (Section 12.4 of NZTA T10). After the introduction of the new NZTA T10 2010 specification, this calculation was run on all reseal sites proposed within the Coastal Otago network in the 2011/12 Forward Work Programme to determine the minimum PSV required for those treatment lengths. The results of the PSV method calculation reinforced the notion that the current Coastal Otago chip sources would not meet the skid requirements for the new category 2H corners (IL 0.55). 30% of the sites were flagged as having sections within them requiring a PSV of greater than 60.

This posed a significant challenge.

It forced us to seriously consider what aggregate options we had economically to meet this. The most economic option was to find a chip source, currently being used within the Otago / Southland region that performed consistently above the required TL. We were already using high quality chip with compliant PSV's, the best we had available locally. The problem we faced in Coastal Otago was of much lesser significance in the neighbouring Central Otago network. The problem seemed less severe leading us to consider that the chip sources used there perform better, despite the PSV of these being similar to the chip sources in Coastal Otago.

Section 12 of NZTA T10 : 2013 offers an alternative method to the selection of aggregate for new surfacing being the Aggregate Performance method. Section 12.3 of NZTA T10 : 2013 provides limited guidance on the methodology to follow;

This method entails the following steps:

1 Using data on the polishing of aggregate (SC or ESC achieved over the life of the surfacing) from the survey data produce a matrix of aggregate performance in a variety of polishing stress situations normalised for heavy traffic. It may include aggregates from other regions.

2 Produce a list of aggregates commonly used in the region, ordered by their resistance to polishing and use the list to select aggregate(s) that meet the requirements of table 1.

3 For a new alignment, assess the traffic and polishing stress and select appropriate aggregate(s).

It was suggested by senior asset engineering staff within NZ Transport Agency that chip sourced from Parkburn (near Cromwell , NZ) intuitively, was performing better than other sources and may be up to the task so it was decided to compare its performance against that of the current sources in Coastal Otago.

It was agreed that the aggregate performance methodology stated in section 12.3 of NZTA T10 (above) was the best means of comparison. Climate, traffic volumes and the percentage of HCV along with geometry are additional variables all contributing to the insitu performance, and as noted later in this paper **not all of these** have been able to be completely normalised.

We narrowed down our key chip supply sources to one in Central Otago and two in Coastal Otago to compare against each other using the aggregate performance method over time.

The methodology used is reasonably straight forward. Using the information in the NZ Transport Agency asset database, Roads Assessment and Maintenance Management System (RAMM), identify the highest demand sites and the chip that provides the best in service performance for the longest time.

9.1. Chip Source location

The majority of the Coastal Otago Network is serviced mainly from three sources for chip sealing being Oamaru (Hilderthorpe), Balclutha, and Gore. Chip sources exist in Dunedin at Logan Point and Blackhead, however their historic performance and very low PSV means they have not been used since NZTA implemented a Skid Policy.

Figure 7 below shows a map of the current (as at 1 October 2012) surface structure table from RAMM. The treatment lengths have been colour coded to reflect the current top surface chip source. A black section is either asphalt or surfaced from a source which is not from the traditional three sources.

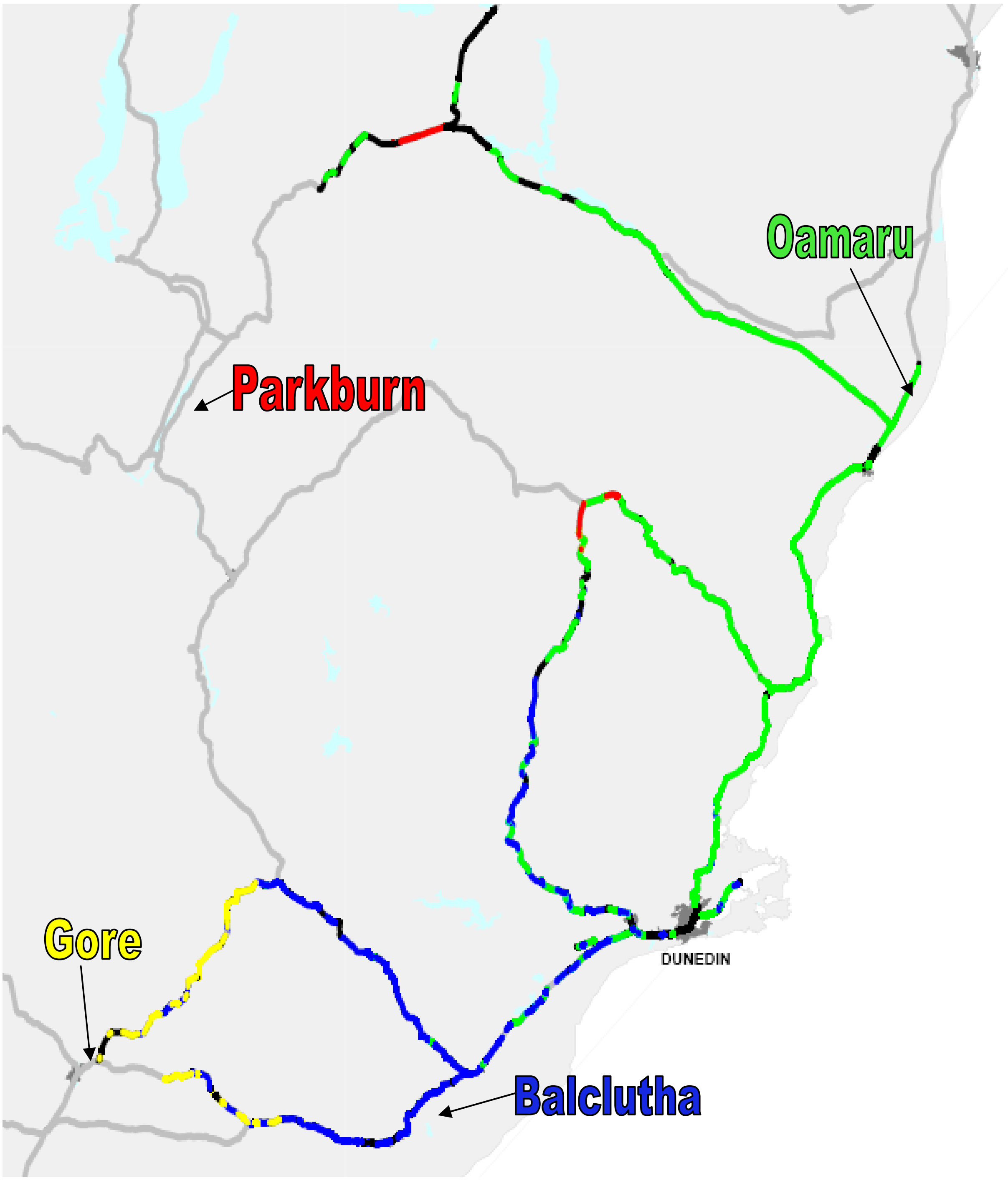


Figure 7. Chip Source coverage

Table 2 below shows the relevant PSV of the historic sources to provide some means of comparison of expected skid performance.

Source	PSV	Description
Oamaru	57	Alluvial, Greywacke
Balclutha	56-57	Hard rock, Greywacke
Balclutha High PSV	60-63	Hard rock, Greywacke
Gore	56-57	Alluvial Greywacke
Parkburn	57	Alluvial, Greywacke

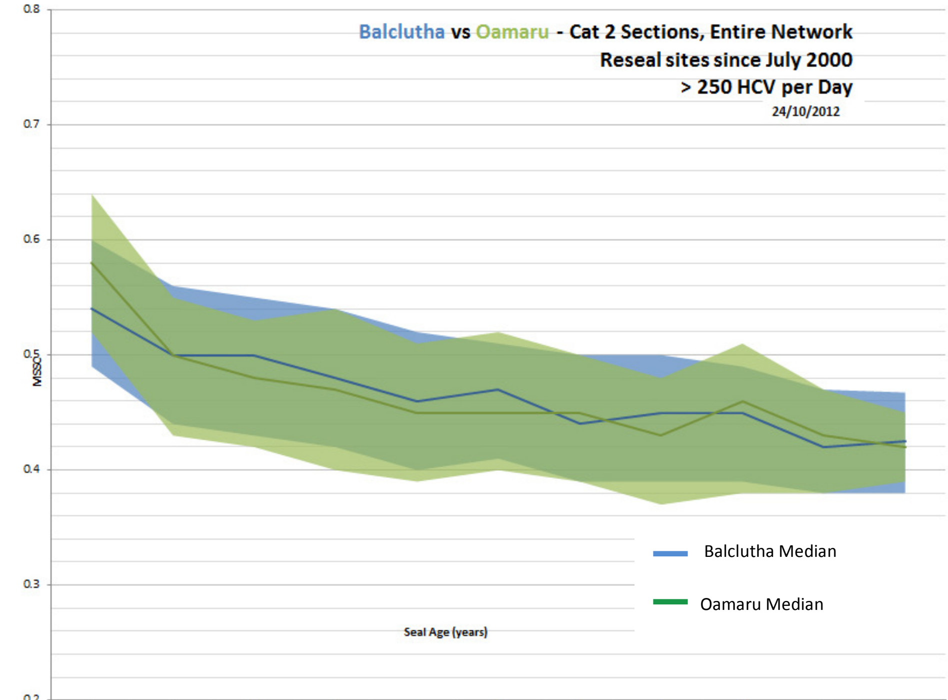
Table 2. Chip Source PSV and geological description.

All sources are broadly defined as mixed Greywacke gravels. The type of Greywacke from each source is different however. The Oamaru (Hilderthorpe) source is mixed Caples and Torlesse Terrane origin, whilst the Balclutha quarry is derived from Caples (volcanistic) type Greywacke. The Parkburn Greywacke is sourced from a much wider variety of Greywacke types that are quite schistose. (Prof Phillipa Black, Auckland University, email October 2012).

9.2. Statistical Analysis

The RAMM database was interrogated using SQL scripts to search all category 2 (IL greater than 0.5) corners on the Coastal Otago and Otago Central Networks. Additional constraints were applied, with only sites sealed since 2000, with HCV's greater than 250 per day (Coastal Otago has a mean of 547 heavies per day, with maximum of 1696). Passed skid resistance analysis of the performance of seals constructed using small chip has shown superior performance. Therefore to eliminate the possible influence of this the analysis data set was further constrained to only large 2 Chip, 1 Chip, Racked in or Sandwich treatment types. Mean Summer SCRIM Coefficient (MSSC) values were used.

The following graphs provide the results of the analysis undertaken. Chart 9 below shows the comparison between Balclutha and Oamaru chip.

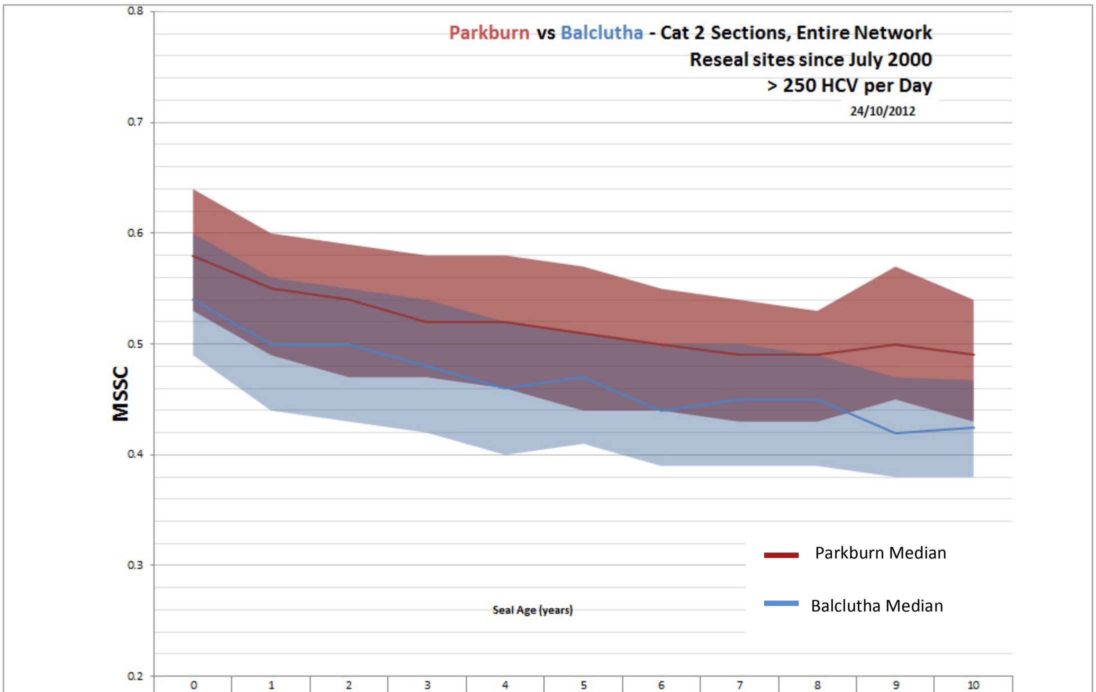


	0	1	2	3	4	5	6	7	8	9	10
Balclutha 15th to 85th %ile	0.11	0.12	0.12	0.12	0.12	0.1	0.11	0.11	0.1	0.09	0.0875
Balclutha 15th	0.49	0.44	0.43	0.42	0.4	0.41	0.39	0.39	0.39	0.38	0.38
Oamaru 15th to 85th %ile	0.12	0.12	0.11	0.14	0.12	0.12	0.11	0.11	0.13	0.09	0.06
Oamaru 15th	0.52	0.43	0.42	0.4	0.39	0.4	0.39	0.37	0.38	0.38	0.39
Balclutha Median	0.54	0.5	0.5	0.48	0.46	0.47	0.44	0.45	0.45	0.42	0.425
Oamaru Count	1916	4401	3300	2548	2110	1176	588	536	370	226	226
Balclutha Count	876	4082	3364	2932	2264	1308	1204	692	584	478	116
Oamaru Median	0.58	0.5	0.48	0.47	0.45	0.45	0.45	0.43	0.46	0.43	0.42

Chart 9. Balclutha V Oamaru MSSC over time.

It is immediately evident that the performance of both products are very similar. Prior to analysis it was anecdotally accepted that Oamaru performed better than Balclutha. This is true for initial results however the Oamaru chip tends to reduce in skid resistance quicker than the Balclutha chip.

Chart 10 below shows the comparison between Parkburn and Balclutha chip.

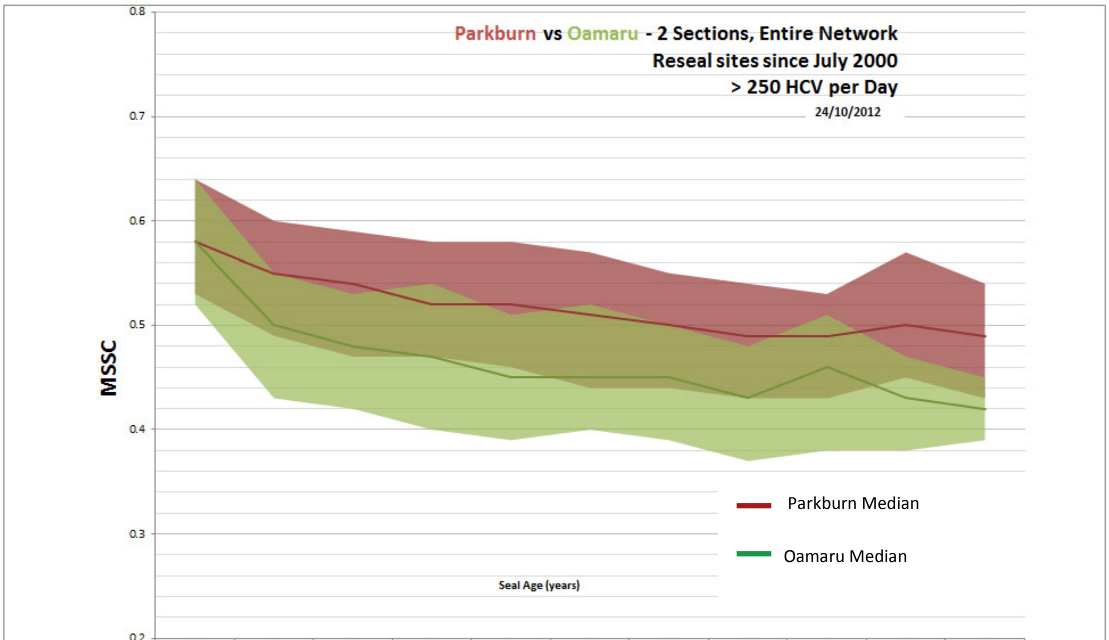


	0	1	2	3	4	5	6	7	8	9	10
Parkburn 15th to 85th %ile	0.11	0.11	0.12	0.11	0.12	0.13	0.11	0.11	0.1	0.12	0.11
Parkburn 15th	0.53	0.49	0.47	0.47	0.46	0.44	0.44	0.43	0.43	0.45	0.43
Balclutha 15th to 85th %ile	0.11	0.12	0.12	0.12	0.12	0.1	0.11	0.11	0.1	0.09	0.0875
Balclutha 15th	0.49	0.44	0.43	0.42	0.4	0.41	0.39	0.39	0.39	0.38	0.38
Parkburn Median	0.58	0.55	0.54	0.52	0.52	0.51	0.5	0.49	0.49	0.5	0.49
Balclutha Count	876	4082	3364	2932	2264	1308	1204	692	584	478	116
Parkburn Count	5946	7918	7178	6460	5316	4776	3860	2888	2276	630	144
Balclutha Median	0.54	0.5	0.5	0.48	0.46	0.47	0.44	0.45	0.45	0.42	0.425

Chart 10. Parkburn V Balclutha MSSC over time.

We can see that Parkburn has a much higher initial skid resistance and deteriorates slightly less than Balclutha. Also over the life of the chip the median skid resistance is maintained well above the Threshold Level (TL) of 0.45 for category 2H curves (IL 0.55). Also worth noting is that that Parkburn chip will start to show some SCRIM exceptions after 5 to 6 years but will not likely require treatment solely to improve skid resistance due to polishing.

Chart 11 below shows the comparison between Parkburn and Oamaru chip.



	0	1	2	3	4	5	6	7	8	9	10
Parkburn 15th to 85th %ile	0.11	0.11	0.12	0.11	0.12	0.13	0.11	0.11	0.1	0.12	0.11
Parkburn 15th	0.53	0.49	0.47	0.47	0.46	0.44	0.44	0.43	0.43	0.45	0.43
Oamaru 15th to 85th %ile	0.12	0.12	0.11	0.14	0.12	0.12	0.11	0.11	0.13	0.09	0.06
Oamaru 15th	0.52	0.43	0.42	0.4	0.39	0.4	0.39	0.37	0.38	0.38	0.39
Parkburn Median	0.58	0.55	0.54	0.52	0.52	0.51	0.5	0.49	0.49	0.5	0.49
Oamaru Count	1916	4401	3300	2548	2110	1176	588	536	370	226	226
Parkburn Count	5946	7918	7178	6460	5316	4776	3860	2888	2276	630	144
Oamaru Median	0.58	0.5	0.48	0.47	0.45	0.45	0.45	0.43	0.46	0.43	0.42

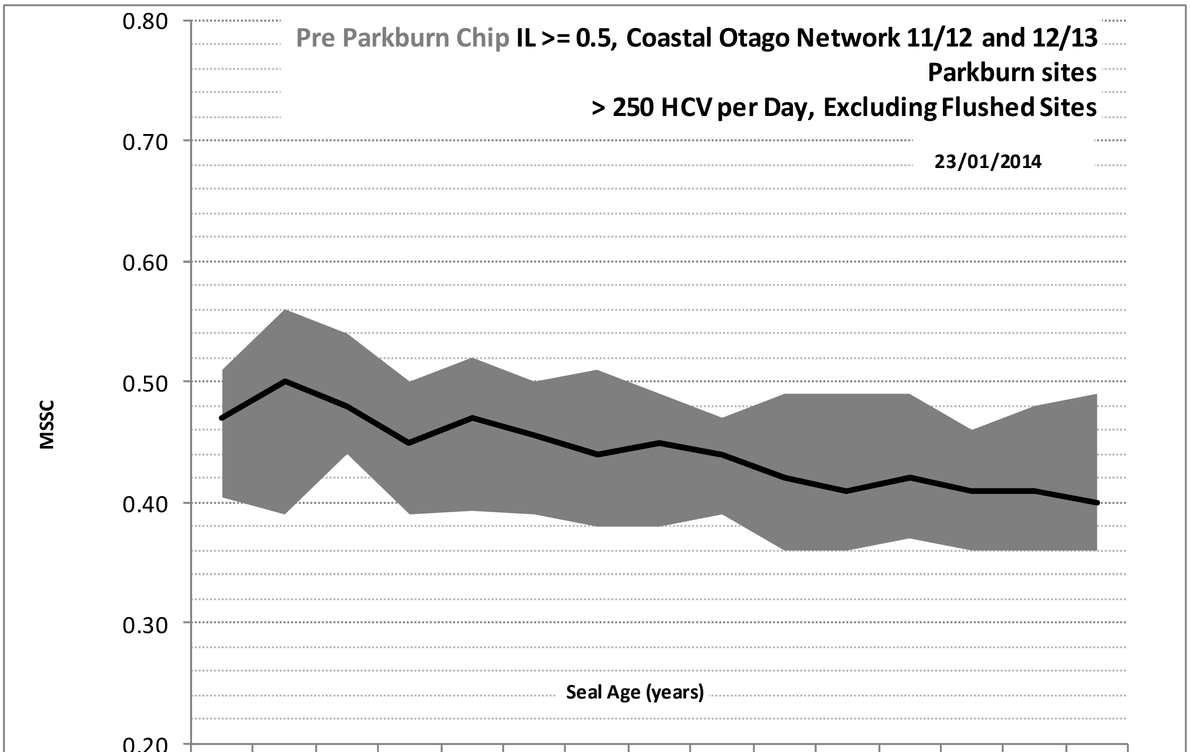
Chart 11. Parkburn V Oamaru MSSC over time.

This graph shows the initial skid resistance for both sources is similar, however because the Oamaru chip deteriorates quicker over the initial two years, it does not perform as well as Parkburn. Further we can see that SCRIM exceptions can be expected on category 2H curves after only one year which is a surprising result. After only 4 to 5 years 50% of a category 2H site surfaced with Oamaru chip will have SCRIM exceptions and likely result in needing to be resurfaced.

All sources show a trend of higher initial deterioration over the first couple years from the initial values, followed by a flattening over time, as the Equilibrium SCRIM Coefficient (ESC) for each site is reached. This is consistent with other published research and has helped to validate the results of analysis.

This analysis shows an the deterioration of the Parkburn aggregate, for large chip grades on sites with SCRIM IL of 0.5 or greater and greater than 250 HCV per day to be **0.011 MSSC per year** for a 7 year analysis period.

Since the decision to use Parkburn chip on high stress sites was made, a number of sites have subsequently been constructed. There has been two years (2011 and 2012) of SCRIM testing on many of these sites. We have analysed the performance of these sites again using the same site selection criteria. Some of the sites have flushed (mainly due to layer instability, with the latest layer tipping the balance) and these have been removed from the analysis set.



	Pre 0	Pre 1	Pre 2	Pre 3	Pre 4	Pre 5	Pre 6	Pre 7	Pre 8	Pre 9	Pre 10	Pre 11	Pre 12	Pre 13	Pre 14
15th to 85th %ile	0.11	0.17	0.10	0.11	0.13	0.11	0.13	0.11	0.08	0.13	0.13	0.12	0.10	0.12	0.13
15th %ile	0.40	0.39	0.44	0.39	0.39	0.39	0.38	0.38	0.39	0.36	0.36	0.37	0.36	0.36	0.36
Median	0.47	0.50	0.48	0.45	0.47	0.46	0.44	0.45	0.44	0.42	0.41	0.42	0.41	0.41	0.40
Count	277	307	307	323	323	294	264	264	192	192	144	80	80	50	50

Chart 12. Pre Parkburn site MSSC performance

Chart 12 above shows the historic performance of sites treated with Parkburn chip. We can see that traditional chip sources have started at a maximum median of say 0.50 MSSC and degraded reasonably constantly to 0.40 MSSC over the analysis period. This equates to **0.0071 MSSC** per year over the 14 years. On the face of it that is a pretty good result, so why change? The problem is that although the rate of deterioration is very low the initial start value is also relatively low in comparison to the initial Parkburn reset value. In fact only the 85th percentile start values are getting close to the predicted Parkburn median start value.

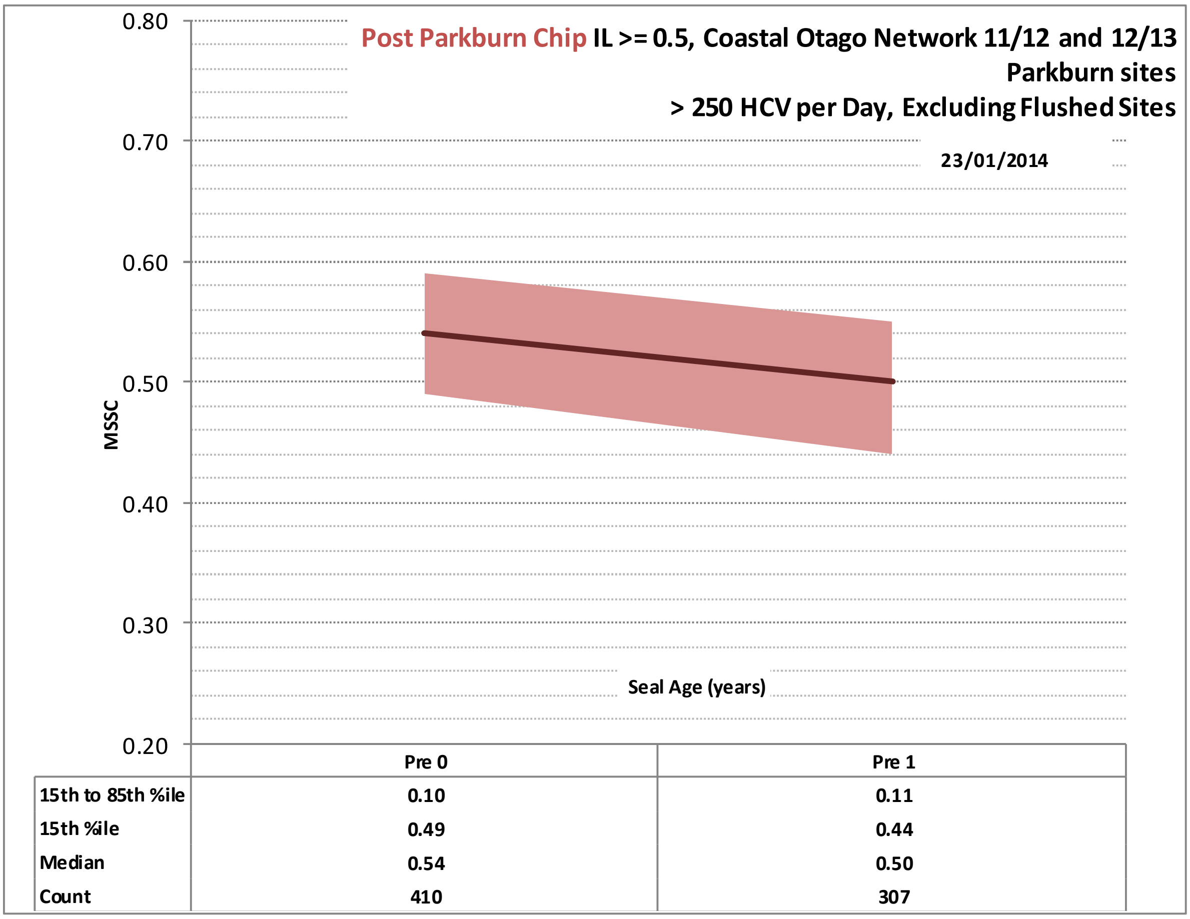


Chart 13. Parkburn trial site performance

Chart 13 above shows the performance of Parkburn trial sites for the first two years of service. Predictably we can see a high initial start value, although it is slightly less than the network analysis showed at 0.54 MSSC as compared with 0.58 MSSC. We also see a reasonably sharp reduction in the second year of life, which again is expected although it is slightly higher than our network model suggests at 0.04 MSSC as compared with 0.03 MSSC. So why the difference? Looking back at the individual site treatments, all were treated with either two coat or combination or sand which seal methodologies. 15th percentile values are still above the SCRIM threshold value therefore there are little no individual SCRIM exceptions within the sites. It is still early days in the analysis period and the third year of testing will be key to identifying whether the rate of deterioration settles into the expected 0.011 MSSC per year.

9.3. Aggregate Characterisation

We believe that the statistical based analysis highlights that the Parkburn aggregate is performing better, at a network level, compared with traditional local sources. However as shown in table two above, the standard PSV test does not reflect this characteristic.

Prof Black et al (2013) states "*Quartz rich fragments, common in aggregate sourced from Schist (so called "pepper and salt" aggregates) notably improve the skid resistance of the aggregate".* Further, "*In New Zealand most specifications for roading aggregates are written* *as if the source material is either quarried rock, or gravels comprising of a single rock type (basalt, andesite or greywacke). When variations are observed, the producer is advised in the notes accompanying TNZ M/4 and Sealing chip specifications to undertake petrographic analysis. But New Zealand's South Island gravels are often complex mixtures of different rocks and there is no guidance as to how to carry out a petrographic analysis of such gravel deposits"*

Therefore there seems to be a need for further guidance on what petrographic testing should be undertaken and indeed further needed to understand the petrographic properties of aggregates that seem to exhibit superior in field performance. Better understanding will also help identify further sources of like performing sources for future use without the risk that infield trials may present.

Figure 8. Photo of Parkburn chip

As we can see in figure 8, the Parkburn chip has a high content of quartz. Upon closer inspection quartz veins are present within the lines of schistose. We have not sought to undertake further petrographic testing of the Parkburn aggregate yet. Downer have been supporting Auckland University PhD student, Adelia Nataadmadja in her research to, among other things, analyse the influence of mineralogy of aggregates on their infield skid resistance performance. This along with work being completed by Professor Phillipa Black of Auckland University, will hopefully provide the industry with better guidance on the types of aggregates and their properties, that are likely to perform the best, to meet the increasingly high compliance requirements and stresses.

10. AGGREGATE CRUSHED FACES

As described in Figure 2 above the NZTA M6 specification requires chip to have a minimum of 98% of the chip having two or more crushed faces for chip grades 2 – 4 (12mm – 5.5mm ALD).

Studies by Opus Central Laboratories (Henderson, R., Cenek P., Patrick J., 2006) resulted in the following conclusions;

1. Skid Resistance increases linearly with percentage crushing. For new and unpolished aggregate the increase in skid resistance in going from 0% crushed to 100% crushed chips is approximately 20%.
2. New and unpolished crushed chips are more ‘angular’ in shape than uncrushed chips.
3. The degree of crushing required to meet a target level of skid resistance depends both on uncrushed and crushed (a) microtexture, and (b) chip shape.
4. Aggregates with a lower level of microtexture need to be crushed more to achieve a given level of skid resistance.
5. Polishing reduces the benefit of crushing on skid resistance by (a) reducing microtexture of crushed faces and (b) ‘smoothing’ sharp chip edges that are initially ‘angular’.
6. The beneficial effect of crushing on microtexture remains after the equilibrium level of polish is achieved. This is equivalent to between 4 and 5 PSV after PSV polishing.

The NZ Transport Agency research report 470 Selection of Aggregates for Skid resistance January 2012 (Cenek, P. Davie, RB. 2012) provided a summary of the best five and worst five performing aggregates with respect to infield skid resistance. Three of the five worst performing aggregates are from sources within the Southland area being Gore gravel, Aparima River and Mataura River.

As a result of the 2012 SCRIM survey, Opus International Consultants recommended to NZ Transport Agency to trial specifying 100% crushed faces for aggregate supply in an attempt to provide a higher performing local product for use on specific high risk SCRIM exception sites with a crash history. These sites were identified as “S12” against the treatment length name for future identification (within the RAMM database) as being treated with the 100% crushed face product. In 2012 the NZ Transport Agency and Opus consulted the aggregate production and sealing industry to gauge ability to provide this 100% crushed face product and what the likely increase in production cost would be in preparation for the 2012/13 sealing season. The additional cost was estimated to be approximately $1 /m³ more expensive and $1 - $2 /m² on site more expensive factoring in cartage. The historic cost of sealing for Southland is low (c.a $3.50 /m²) in comparison to other parts of New Zealand and so this additional cost was not considered excessive if it results in improved performance.

10.1. Site Treatment Selection

The 13 sites treated prior to the 2013 SCRIM survey comprising 100% crushed faces were designed with the following seal types

Treatment Type	Sum of length	% of Length
1CHIP	**1720**	71.67%
3	**70**	2.92%
4	**660**	27.50%
5	**990**	41.25%
2CHIP	**200**	8.33%
3/5	**200**	8.33%
VFILL	**480**	20.00%
5	**480**	
Grand Total	**2400**	

Table 2. Length of Treatment type
Therefore the predominant treatment type for the 100% crushed face SCRIM seal completed prior to the 2013 SCRIM survey is a grade 5 single coat seal.

By comparison 18 sites were sealed with standard sealing chip prior to the 2013 SCRIM survey with the following seal types;

Treatment Type	Sum of length	% of Length
1CHIP	**5400**	35.58%
3	**4250**	28.00%
4	**1150**	7.58%
2CHIP	**5699**	37.55%
3 /5	**4829**	31.81%
4 /5	**870**	2.70%
4 /6	410	3.03%
VFILL	**4080**	
5	**4080**	26.88%
Grand Total	**15179**	

Table 3. Length of standard chip treatment type

Here we see the predominant seal type being a 2 coat chip seal and a significant greater length treated in the traditional manner and of a grade 3 and 5 combination.

10.2. First Year result

Of the proposed sealing programme for the 2012/13 sealing season only 13 treatment lengths were resurfaced prior to the 2013 SCRIM survey (to be updated in presentation post 2014 SCRIM survey results).

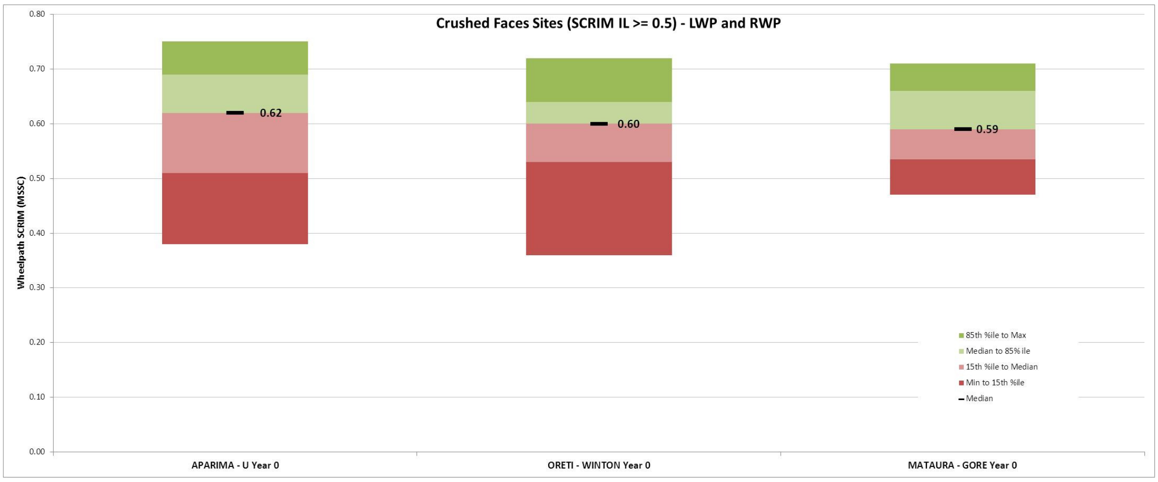


Chart 14. First year 100% crushed face SCRIM performance by source.

Chart 14 shows the performance of the 13 sites treated prior to the 2013 SCRIM survey. The sample data includes all SCRIM readings where SCRIM IL is greater than 0.5. The sites have a range of HCV of 115 to 269 vpd. To eliminate sites with less than 250 HCV leaves very few sites to assess.

As a comparison we also analysed the data on sites sealed in the same season prior to the 2013 SCRIM survey with standard NZTA M6 compliant chip (not 100% crushed face).

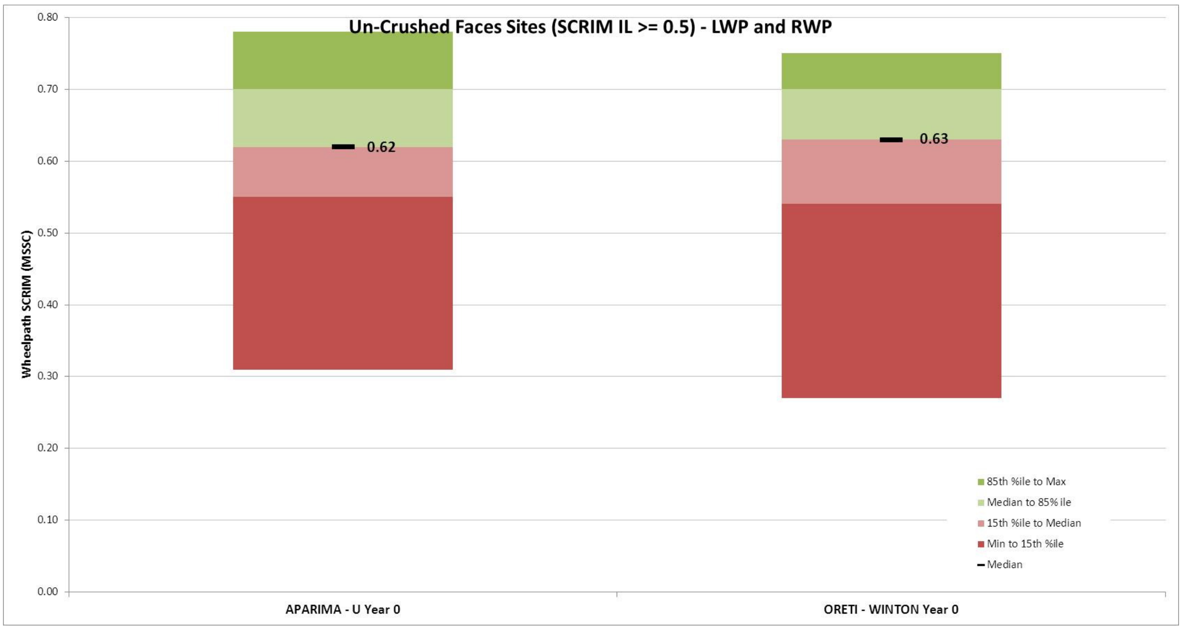


Chart 15. Standard Chip SCRIM performance by source.

The relative performance of 100% crushed face surfacing compared with normal chip surfacing doesn’t highlight any significant difference. At best we could suggest that there is slightly less area performing at the lower end of the distribution within the 100% crushed face data set. However it is early days and another round of HSD in 2014 may provide some further insight into the relative performance.

11. CRASH RATE ANALYSIS

The primary objective for the Safer Journeys strategy is to save lives and reduce serious injuries. When someone dies on our roads it affects us all. Most of all, it changes the lives of those directly connected with the deceased or seriously injured. Further investment in surfacing treatments that are more expensive may not be prudent if there is no impact on crash rates.

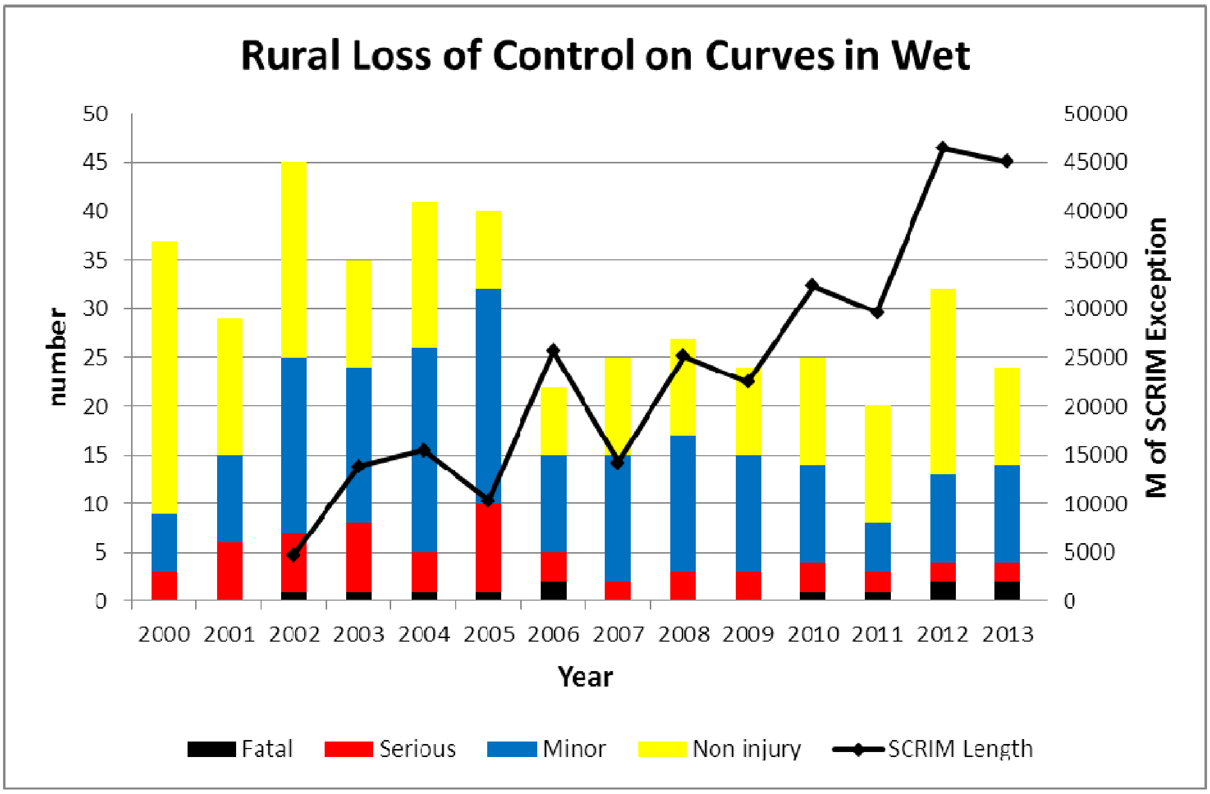


Chart 16. Number and type of wet lost control crashes versus metres of SCRIM exception (uncorrected). Coastal Otago area.

Chart 16 above shows the relationship with wet lost control crashes and the length of SCRIM exception over time. The SCRIM exception length has been normalised to exclude the impact of the NZTA T10 : 2010 specification change for the benefit of comparing trend over time.

We can see a significant step change reduction in the number of crashes from 2006 followed by a slight increase through to 2008 and another steady reduction until 2012 where we see a significant increase especially in non injury crashes. There have also been fatalities in 2010, 2011, 2012 and 2013 related to loss of control on wet road surfaces. Fortunately there does not seem to be a trend in the number of wet loss control crashes with the amount of SCRIM exception.

12. CONCLUSION

So are we (or the Road) “losing our Grip”?

To answer the question we must first understand it.

lose your grip *- idiom*
to lose your ability to control or deal with a situation – (The Free Dictionary, Fairfax, online)

lose (ones) grip
To lose ones control over something – (Dictionary.reference.com, online)

Over the past 14 years we have focussed on various strategies to curb ever increasing SCRIM exceptions across Southern State Highway networks in New Zealand. Have we lost our ability to control or deal with skid resistance? What is the true measure of success? crash statistics or length of SCRIM exception? Are the two related?

The analysis we have completed shows that there are many influences on the skid resistance performance on New Zealand road surfaces. Chip grade, construction methodology and aggregate source all influence in infield performance.

Through analysis of SCRIM data, we have identified that seals constructed using a racked in method using small grade chip meets threshold performance levels for 85% of the length of sites with SCRIM IL greater than 0.5 and greater than 250 HCV per day.

Also our analysis confirms that aggregate source PSV is not a reliable predictor of infield skid resistance performance. We suggest other petrographic properties influence the infield skid resistance and therefore fully support the additional work being done by Auckland University in this area.

The performance of 100% crushed face chip in Southland is showing very little initial promise however it is too early to draw conclusions on the available data at the time of writing this paper.

Our crash statistics keep heading in the right direction however that fact we are still killing or seriously harming people on our roads in not tolerable and nor is it meeting the outcome expected from the Safer Journeys strategy. Our focus must continue to be on critical risk sections of our network. Conditions change fast, especially as our networks become more unstable as maintenance funding is constrained and asset condition is pushed. We must continue to innovate, challenge the norm, and measure performance if we are to meet the objectives of Safer Journeys.

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- Dr David Hutchison – Downer NZ

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Peter Mortimer is Divisional Manager of Technical Services for Downer Otago and Southland area based in Dunedin. In this role he is responsible for a team performing technical service functions for both Road engineering disciplines including asset engineering, asset management, surveying, and geometric and pavement design. He has worked in consultancy, road controlling authority and contracting sectors over the past 22 years with the past 14 years being spent with Downer.

Paul Stewart is Asset Information Manager within the Otago Southland Technical Services group. With a Bachelor of Science degree (Computer Science and Physics) and a strong interest in systems development and implementation. His responsibilities for Downer include business system support, Asset data quality, Asset data collection training (NZTA Level 1), asset data analysis, data mining, and reporting.