University of Southern Queensland
Faculty of Engineering and Surveying

Variable Rate Bitumen Spraying in Road Construction and Resurfacing

A dissertation submitted by

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ABSTRACT

Over the last decade, traffic volumes, tyre pressures, wheel loads and the percentage of heavy vehicles using the Australian road network has increased significantly. This has led to increased challenges for road designers to provide economical and durable pavement surfaces with adequate surface texture.

A particular solution for improving surface texture on spray sealed surfaces is transverse variable spray rates (TVSR). In this technique bitumen spray-rates are varied across the lane width to account for the impact of traffic in the wheel-paths. This leads to designs where higher binder application rates are used on the shoulders and between the wheel-paths and lower rates in the wheel-paths.

An extensive literature review has revealed very little quantitative data has been analysed to verify the technique is beneficial in providing roads with improved and more uniform surface texture. Undesirable surface texture issues generally consist of flushing or bleeding of bitumen in the wheel-paths, and stripping of aggregate between the wheel-paths and on the shoulders.

The Queensland Department of Main Roads collects annual survey data of their road network, including surface macro-texture data. This project aims to retrieve and compare survey data over a number of years, and collate it with other relevant data to verify if TVSR technology has provided an improvement in surface texture characteristics.

Carefully selected road sections were studied to identify the effect of the TVSR technology when compared with similar areas sprayed with uniform single spray-rates. The study concluded that transverse variable spray rates were successful in increasing the transverse surface macro-texture uniformity of the analysed sections, and when used in conjunction with polymer modified binders, the surface macro-texture depth in the wheel-paths was increased also. Due to the limited scope of the study, further analysis would be required to verify the results across a wider area.

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ENG4111 Research Project Part 1 &
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Limitations of Use

CERTIFICATION

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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ACRONYMS

AADT	Average Annual Daily Traffic
ALD	Average Least Dimension
ARMIS	A Road Management Information System
ARRB	Australian Road Research Board
BWP	Between the Wheel Paths
DVR	Digital Video Road Viewer
ERCP	Enhanced Road Condition Project
FRS	Fibre Reinforced Seal
GIS	Geographical Information System
GPS	Global Positioning System
GRS	Geotextile reinforced Seal
HSS	High Strength Seal
IWP	Inner Wheel Path
MLP	Multi Laser Profilers
OECD	Organisation of Economic Co-operation and Development
OWP	Outer Wheel Path
PAFV	Polished Aggregate Friction Value
PAVCON	Pavement Condition database
PMB	Polymer Modified Binder
PPE	Personal Protective Equipment
PSV	Polished Stone Value
QDMR	Queensland Department of Main Roads
SAM	Strain Alleviating Membrane
SAMI	Strain Alleviating Membrane Interlayer
SCRIM	Sideways Force Coefficient Routine Investigation Machine
SMTD	Sensor Measured Texture Depth
SPTD	Sand Patch Texture Depth
STD	Standard Deviation
TDIST	Through Distance
TNZ	Transit New Zealand
TVSR	Transverse Variable Spray Rate

Chapter 1 INTRODUCTION

1.1 Case Study Background

Since reliable bitumen spraying technology has been available, Australian road authorities, contractors and the bitumen industry have worked to develop a variety of bitumen surfacing techniques to improve the quality and durability of our road networks. *Road Facts,* published by Austroads in 2000 states there are approximately 800 000 kilometres of roads in Australia of which about 40% are sealed. The surfacing of this 40% is made up of asphalt, sprayed treatments and a small percentage of concrete pavements. A national survey of the Australian road network (ARRB, 2003) revealed 66% of the Queensland network is sealed with sprayed seal surfacing. A breakdown of our Australian road network by Austroads (2000) shows Rural Arterial and Rural Local roads make up over 85% of the total Australian road network but they receive less than 25% of the annual traffic volume.

These rural and lower-volume roads provide essential links between geographically dispersed communities and are a conduit for the transportation of people, goods and services. Due to the high per capita cost of construction and maintenance of roads in sparsely populated rural areas, there is a crucial need for efficient and cost effective surfacing treatments to enable local councils and state road authorities to extend and maintain their road infrastructure networks within limited budgets.

For roads with lower traffic volumes, particularly rural roads, sprayed bituminous surfacings are generally used to provide a durable, low-cost interface between the traffic and the pavement. Over the last couple of decades significant advances in bitumen spraying technology have been made by a number of road authorities and contractors including utilisation of high performance binders and experimentation with transverse variable rate bitumen spraying. Recently a greater focus has been placed on risk management within road corridors. This has led to increased and improved measurement of pavement characteristics which in turn allows any improvements in the engineering properties of the surface layers to be identified.

Many studies have concluded that surface texture is a key parameter in surfacing performance, particularly relating to skid resistance and road safety. Proponents of transverse variable rate bitumen spraying believe that many of the surface texture deficiencies related to traditional sprayed chip-seals can be prevented or remedied by using the transverse variable spray rate technology.

1.2 Significance of the Study

This study focuses on sprayed bituminous surfacings, an area of road construction whose methods has remained largely unchanged since bitumen has found widespread use in road surfacing. Over the last few decades, improved technology has allowed practitioners to trial some innovative new techniques and treatments. One technique in particular, Transverse Variable Spray Rate (TVSR) technology is credited with the ability to compliment and in many cases replace the traditional single spray-rate methods. Single spray-rate sealing methods have provided a relatively effective seal that binds the aggregate into a durable, all-weather surface but as traffic speeds, volumes, loads and tyre pressures have increased, various short comings of single spray-rate bitumen spraying technology have became evident.

A report by John Oliver of the ARRB, titled *Thin bituminous surfacings and desirable road user performance* (Oliver, 1999) highlighted various engineering properties of the surfacing layers that are essential to road user safety and riding comfort. These properties relate to skid resistance, spray generation, road noise, conspicuous road markings, road glare and reflection, smooth ride and the risk of windscreen breakage. Oliver links surface texture deficiencies to most of the identified problems.

Unfortunately, the application of single constant spray-rates for bitumen chip-sealing has in many circumstances contributed to most of the identified problems. The perceived level of risk has caused some road authorities to discount chip-sealing as an acceptable surfacing solution and migrate entirely to alternative treatments like asphalt pavements which have a much higher initial capital cost.

The issue of risk and responsibility in the event of an accident has been recently tested in the 2001 cases of *Singleton Shire Council vs. Brodie* and *Hawkesbury Shire Council vs. Ghantous.* The High Court rulings in these cases have opened the way for road authorities to be held responsible for accidents arising from pavements under their jurisdiction that have fallen into disrepair (Oliver, 2001). The outcome of these cases has caused Australian road authorities to seriously consider all safety related issues, including the surface texture and the skid resistance of their road networks in the light of possible future litigation issues.

The accelerated deterioration of pavements due to increased traffic loadings, combined with the threat of possible litigation resulting from accidents where the pavement condition may have been a contributing factor have led road authorities to look for economical solutions to these issues. Many industry practitioners believe that pavement surface texture can be improved in new construction and corrected on existing pavements by variation of the bitumen spray-rates transversely across the road width.

International Road construction company, Fulton Hogan, have undertaken a research project at Tai Tapu in New Zealand where since 2000 they have been measuring texture depths for a variety of spray-rate reductions in the wheel-paths. Their results, (Fulton Hogan, 2007) show that there is a definite positive trend in wheel path texture depth as spray-rates in the wheel-paths are reduced by up to 30%. In Queensland, various Department of Main Roads districts use transverse variable rate bitumen spraying for chip-sealing. Recent presentations given at industry events from districts including Southern, Central and Border Districts show encouraging results.

A comprehensive literature review of Australian and overseas studies show that apart from Fulton Hogan's New Zealand study, there has been very little quantitative testing done to prove the effectiveness of transverse variable rate spraying. This study aims to provide some quantitative Australian data which can be used to verify the effectiveness of transverse variable spray-rates when compared with single constant spray-rates for sprayed surfacing applications.

1.3 Aims and Objectives

This study will analyse historic and field data to determine any benefits related to utilising transverse variable spray-rate (TVSR) technology in conjunction with chip-sealing as an alternative to other sealing techniques. Key parameters relating the performance of spray-sealed surfacings to important issues such as climate, traffic and cost will be examined. It is also planned to use current available information to identify any areas where the use of TVSRs is beneficial and areas where its use is inappropriate.

During the course of the investigation it is intended to collect published and unpublished knowledge of TVSR technology and present this information in a way that is understandable. By presenting this information in a straightforward way it is more likely to be read and understood by a wider and more diverse audience. An additional aim is to identify the causes of some of the common defects that show up on road surfaces, and some of the available treatments to correct them, and present some solutions that may reduce the incidence of these defects occurring. Available macro-texture data will be used to compare the texture depth on roads treated with single spray-rates and similar roads treated with transverse variable spray-rates to determine if there is a measurable long-term increase in texture depth in the wheel-paths, and an increase in overall surface texture uniformity.

At the conclusion of the study it is anticipated that a model can be derived that presents quantitative evidence to assess the success of transverse variable spray-rate technology in road construction within the study area.

1.4 Study Area

The ARMIS database is a comprehensive repository of information relating to the Queensland state-controlled road network including lane widths, surface texture, skid resistance, rutting, cross-fall, roughness, traffic volume and much more. The surface texture data reveals the macro-texture of the road surface and is captured during an annual survey using Multi Laser Profilers (MLP) mounted on a survey vehicle. This surface texture information related to the Queensland Department of Main Roads (QDMR) network can then be used to analyse the effectiveness of the TVSR technology.

Initially data available from Toowoomba District Office, Darling Downs Region of the Queensland Department of Main Roads was used to develop a model, but then the study could be extended to other areas where relevant surface texture data is available. The Darling Downs Region and Toowoomba District of the Queensland Department of Main Roads are shown in **Figure 1.4.1.**

Figure 1.4.1 Regional Boundaries for Queensland Department of Main Roads (Main Roads, 2008)

The QDMR has established a trial site near Westbrook on the Gore Highway, and Fulton Hogan has established a trial site near Yarraman on the New England Highway. Both sites are being monitored by the respective organisations but historically it is understood that it takes several summers for the actual effectiveness of the application to be judged, as the flushing or bleeding of the bitumen in the wheel-paths generally occurs after warmer weather and significant compaction under traffic. Stripping of the aggregate from the road surface can occur at any time, depending on the circumstances but several years would allow defects to become obvious. Any early data available from these sites would be beneficial in forming a better understanding of the processes that are occurring within the road surface and would hopefully verify the findings of this current study.

Chapter 2 LITERATURE REVIEW

2.1 History of Bitumen in Road Construction

Since ancient times, engineers have been considering better ways to create and maintain transport networks. There is evidence King Nebuchadnezzar of Babylon used natural bitumen as a grout for stone roads in about 600 BC (Shell Bitumen, 2003). The Roman engineer and architect Vitruvius left exact instructions on how a road should be constructed, in five layers finished with a durable pavement of stone (Wright, T., 1861).

The art of road building was neglected during the dark ages and travellers were forced to negotiate muddy and rutted roads constructed through the natural subgrade material (Hindle B, 1990). A major transport revolution began in the late 1700's when Thomas Telford pioneered geometric road design incorporating drainage. John Macadam experimented with various stone sizes to develop a strong bound but unsealed pavement and later incorporated the use of tar as a binder and sealer, to make the surface more durable and hardwearing (Lay, M.,G., 1992).

In Australia during the mid 1800's the techniques of both Telford and Macadam were utilised to improve the rutted and pot-holed road network that was rapidly expanding throughout the more populated coastal sections of the colony. The technique of Macadam using mud as a binder was found to become very dusty in dry weather and the introduction of the pneumatic tyre and the automobile encouraged the creation of dust free and smooth roads. Early in the 20th Century, a tar truck roll-over accident in Adelaide had the unintentional result of demonstrating the usefulness of tar as an independent surfacing material (Lay, M.G., 1984).

Since these pioneers in transport engineering sought to develop improvements in road surfacing, there has been a steady stream of advancements as better materials and technology became available. Since the late 19th Century, the refining of crude oil has provided a number of very useful by-products extracted during the distillation process.

One of the most versatile and valuable by-products is refined bitumen, which due to its excellent binding properties, soon found its way into the manufacture of bituminous surface treatments (Shell Bitumen, 2003). Modern refined bitumen is a sophisticated product available in many forms and grades developed by the bitumen industry for specific uses (Refined Bitumen Association, 2008).

2.2 Available Sprayed Bituminous Surfacing Treatments

The Austroads *Sprayed Seal Design Method* (2006) gives a comprehensive listing of available bituminous sprayed surfacing treatments. It identifies the most common sprayed seal as a single/single seal consisting of one layer of Class 170 bitumen covered with a single layer of aggregate. The designer can choose from a variety of stone sizes from 7mm to 20mm and also has the option of choosing a different class of binder if the situation requires a binder with different performance characteristics.

The ARRB *National Survey* (2003) revealed the most common aggregate sizes used in Australia are 10 & 14mm, closely followed by 7mm. The survey also shows that half the State Road Authorities do not use aggregate larger than 14mm. Austroads *Sprayed Seal Design Method* (2006) explains the reasons for this decision being the increased risk of damage to vehicles from flying loose particles, high tyre / road noise, increased binder application rates and increased costs. The Toowoomba District of QDMR utilises a 12mm crushed aggregate for much of their sprayed seal surfacing and have developed their own Supplementary Specification for this aggregate to accommodate district sealing requirements. The Standard Specification used for aggregates by Main Roads is MRS11.22 Supply of Cover Aggregate.

Double/double seals using 10, 14 and 20mm aggregates on the initial layer were also identified in the *National Survey* as being used around Australia. All states but the Northern Territory made use of the 14mm basecoat with 7mm topcoat. Queensland, New South Wales and Victoria all made occasional use of the 20mm basecoat with 7mm topcoat. Queensland also used a 10mm basecoat with a 7mm topcoat. The publication *Guide to the Selection of Road Surfacing* (Austroads, 2003) explains the theory behind double/double seals by describing how the smaller aggregate particles fit into the interstices between the larger aggregate and locks it into place.

The Austroads *Sprayed Seal Design Method* (2006) also describes the Cape Seal. A sealing method originally used in Cape Province, South Africa. Generally a 20mm stone is used for an initial sprayed seal, and then either a single or double application of slurry surfacing is applied, which can either partially fill the voids between the bitumen and the top of the aggregate or the aggregate can be fully covered.

Even though most design manuals seem to focus primarily on Class 170, Multigrade binders and polymer modified binders (PMB) used for cutback bitumen, the Austroads *Sprayed Seal Design Method* (2006), states that bitumen emulsions can be used for almost any purpose for which cutback bitumen is used and are suited to a number of other applications where the use of cutback bitumen is not appropriate.

Bitumen emulsions consist of a two phase system containing bitumen and water, where the bitumen particles have been emulsified and are held in suspension within the water. After spraying the emulsion, the water evaporates leaving the bitumen behind. The types and grades of bitumen emulsions are given in AS1160 (Standards Australia, 1996). Drawbacks of sealing with bitumen emulsion include the generally higher cost of the product than cutback bitumen and the higher cost of transportation of the residual bitumen due to the water component. Advantages include safety, due to low temperatures and non-flammability, the ability to seal at lower pavement temperatures and the ability to use with damp aggregates. The lower temperature also delays the degradation of polymer modified binders (Austroads, 2006).

There are various other superior quality treatments available including Geotextile Reinforced Seals (GRS) which can be used in conjunction with many of the sprayed surfacing treatments described above. Another superior quality treatment is the Fibre Reinforced Seal (FRS) which consists of a layer of glass-fibre strands sandwiched between two coats of polymer modified bitumen emulsion. These two treatments are used as Strain Alleviating Membranes (SAM) or Strain Alleviating Membrane Interlayers (SAMI) which are used to improve seal performance by working as a waterproofing membrane over cracked or weak pavements.

GeoPave Materials Technology (1998) in their technical note *HSS, SAM and SAMI Sealing Treatments* explains that the membrane eliminates or minimizes the reflection of cracking in a distressed pavement upon the newly laid surface. GeoPave also define a High Strength Seal (HSS) as a sprayed seal surfacing treatment utilizing a polymer modified binder such as crumb rubber and it is used on pavements which are in good condition and will have minimal stress but are subject to high traffic demands. This treatment provides an intermediate solution between a traditional seal using plain cutback bitumen or multigrade bituminous binder, and the premium quality solution of a stress alleviating membrane.

2.3 Factors Influencing Selection of Surfacing Treatments

Guidance is given in this area by the Austroads *Sprayed Seal Design Method* (2006) which gives a comprehensive list of helpful suggestions to assist in the selection process. This literature review has highlighted that many publications are reluctant to give definite threshold values for where a particular treatment is appropriate. It is common to find reference to vague terms like low, medium and high traffic volumes, rather than definite values. Austroads sums this up by stating *'There are no quantitative measures available to define where a seal will perform and where it will quickly exhibit distress, and designers must rely on experience and, if necessary, seek expert advice on the practicalities of using a particular surface treatment.'*

Having given this caveat to designers, Austroads then provide a very useful guide to the selection of sprayed seals in Table 11.1**,** on page 50, of *Sprayed Seal Design Method* (2006). Table 11.1 has been reproduced in this study as **Figure 2.3.1.** It approaches the problem using a decision matrix with traffic volume in vehicles/lane/day (v/l/d) on the vertical axis, and the performance environment on the horizontal axis. This matrix provides solutions ranging from a simple single/single seal on roads with less than 2000 v/l/d and less than 15% heavy vehicles, through to double/double seals using higher grade PMBs for roads with greater than 2000 v/l/d, heavy vehicles greater than 15%, and a grade greater than 5%. The guide goes on to recommend that no sprayed seal is suitable for high stress areas like small-radii roundabouts, intersections and turning lanes.

		Traffic (in v/l/d)			
		> 2000		≤ 2000	
		Heavy vehicles		Heavy vehicles	
Performance environment		> 15%	≤ 15%	> 15%	≤ 15%
High stress areas (e.g. small radii roundabouts, intersections, turning lanes, etc.)		No sprayed seal suitable	S/S + scatter coat or D/D + mod 3	Cape seal or D/D + mod 3	D/D or S/S + mod 3
Grades > 5%		D/D + mod 3	D/D or S/S + mod 3	D/D or S/S + mod 3	S/S or D/D
Pavement strength	Stiff	HSS	S/S	HSS	S/S
	Weak	SAM (D/D only)	HSS	SAM (S/S) + mod 3	HSS
Temperature	Hot	D/D + mod 2	S/S + mod 2	D/D or S/S + multi	S/S + multi
	Temperate	D/D	S/S	D/D or S/S	S/S
	Cold	D/D + mod1	D/D or S/S + mod1	D/D	S/S

Legend

S/S:	Single/single, C170/320 or multigrade binder
D/D:	Double/double, C170 or 320 or multigrade binder
Cape Seal:	Single/single seal filled in with a slurry
HSS:	High Stress Seal is a S/S or D/D, with 7, 10 or 14 mm aggregate, medium/high concentration PMB, multigrade binder C600/170
Scatter coat:	Light application of small aggregate, 7 or 5 mm, to temporarily 'lock in' a larger aggregate. Suitable for intersections, driveways, turning slots
Mod 1:	Lightly modified PMB, S10E, S35E, 10% crumb rubber
Mod 2:	Multigrade or lightly modified PMB, S10E, S35E, 10% crumb rubber
Mod 3:	Higher grade PMB, S20E, S45R Applications also include small radii roundabouts, intersections, cul-de-sacs, turning lanes, etc.
Multi:	Multigrade binder Class 600/170
No sprayed seal suitable:	when applying sprayed seals in highly stressed areas as defined here, that wherever asphalt is available, it should be the first choice of surfacing.

Climate:	Weighted mean annual pavement temperatures (WMAPT)
Hot:	WMAPT > 35˚C e.g. Ayr, Cairns, Townsville, Mt Isa
Temperate:	WMAPT 29˚C < WMAPT ≤ 35˚C e.g. Rockhampton, Roma, Mackay, Gympie, Brisbane
Cold:	WMAPT ≤ 29˚C e.g. Warwick, Kingaroy, Toowoomba

Pavement strength

Stiff:	Rebound deflections	< 0.9 mm
	Deflection ratio	> 0.8 - rigid or bound 0.6 to 0.7 - stiff unbound
	Residual deflections	< 0.15 mm
Weak:	Rebound deflections	> 0.9 mm
	Deflection ratio	< 0.6 - potentially weak pavement
	Residual deflections	> 0.15 mm

Figure 2.3.1 Guide to the Selection of Sprayed Seals
(Source: Austroads Sprayed Seal Design Method, 2006, p. 50)

The Australian Asphalt Pavement Association highlights this issue in their Advisory Note 15, *Bituminous Surfacings for Intersections on Light & Medium Duty Flexible Pavements* (AAPA, 1999) in which they agree that sprayed seals provide an effective and economical solution on lower traffic roads but they recommend that a thin layer of hotmix asphalt should be utilised at intersections, median openings and roundabouts to provide improved smoothness and appearance and reduced maintenance costs. They identify issues related to the braking and turning of heavy vehicles which are likely to cause aggregate to roll out of its bed, leading to loss of aggregate and bleeding of the seal. Concentrations of heavy vehicles at intersections, and particularly increased dynamic loading as heavy vehicles accelerate and decelerate, may cause embedment of the aggregate and lead to flushing of the binder.

The performance of sprayed seals can be enhanced by the use of a multigrade and polymer modified binder (PMB). Further information can be found in Austroads publication, *Guide to the selection of roads surfacings* (Austroads, 2003). The Australian Asphalt Pavement Association in their Advisory Note 7, *Guide to the Selection, Heating and Storage of Binders for Sprayed Sealing and Hot Mixed Asphalt* (AAPA, 2003) provide tables showing situations in which each type of binder is best suited and provide an explanation regarding the properties of multigrade and polymer modified binders. The advisory note also explains that multigrade binders work by blending classes of bitumen binder in such a way that the advantageous properties of each can be harnessed to provide a more satisfactory solution than would be achievable by a single class of binder on its own. This particularly relates to binder performance at high and low temperatures.

PMBs are bitumen binders that have had their properties modified by the addition of elastomeric or plastomeric type polymers or the addition of crumb rubber, usually from old car tyres. These specialized binders are used in areas of high stress where there is a high risk traditional bitumen binders would fail prematurely. Austroads (2004) states PMBs provide superior aggregate retention in addition to a more flexible membrane for improved waterproofing and reduction in crack reflection.

The Queensland Department of Main Roads *Southern District Sealing Guidelines for new construction* (Main Roads, 2004), provide further assistance in seal design by identifying traffic volumes above which transverse variable rate bitumen spraying will be beneficial. Experience in the field in Southern District, now Toowoomba District, has shown that for low traffic volumes, after the application of a well designed seal, excess binder flushing in the wheel paths is not a major issue in new construction. Flushing becomes more prevalent at higher traffic volumes, particularly heavy vehicles, due to the increased compaction in the wheel paths from the higher rate of vehicles using the road.

Experience in this area over many years led Southern District to develop this set of guidelines to assist in seal design. In new construction an initial seal is provided which has the primary purpose of waterproofing the pavement. Regardless of the Annual Average Daily Traffic (AADT), the guidelines recommend the initial seal be set at a single, appropriately designed spray-rate across the pavement width. The subsequent second seal is then applied after a period of time. This timeframe is influenced by a variety of factors including adherence to established timeframe principles, the combination of aggregate sizes selected, the performance of the base and the initial seal, the traffic, the geographical location and the weather.

Table 4 of the *Southern District Sealing Guidelines for new construction* reveals that for subsequent seals on roads with an AADT of less than 200 vehicles, the use of a Class 170 binder and a single, spray-rate across the whole width of the roadway is recommended with a default sealing interval of three years. For AADT between 200 and 1000, the same treatment is recommended but the default sealing interval is reduced to two years. When the AADT reaches 1000 to 3000, Class 170 binder with a transverse variable spray-rate is recommended with a default sealing interval of two years. For AADT above 3000, a polymer modified binder is recommended with transverse variable spray-rates and a default sealing interval of one year. A reproduction of Table 4 is provided in this study as **Figure 2.3.2**.

SOUTHERN DISTRICT SEALING GUIDELINES

Table 4 - Sealing Aggregate and Binder Selection Guide

AADT	First Seal	Second Seal	First Seal	Second Seal	First Seal	Second Seal	First Seal	Second Seal
over 3000	10 C 170* Single	14 PMB TVSR	(Default) 14 C 170* Single	12 PMB TVSR	14 C 170* Single	12 PMB TVSR	N / A	
1000 - 3000	10 C 170 Single	14 C 170 TVSR	10 C 170 Single	14 C 170 TVSR	(Default) 14 C 170 Single	12 C 170 TVSR	14 C 170 Single	12 C 170 TVSR
200 - 1000	10 C 170 Single	10 C 170 Single	10 C 170 Single	14 C 170 Single	(Default) 14 C 170 Single	10 C 170 Single	14 C 170 Single	10 C 170 Single
up to 200	10 C 170 Single	10 C 170 Single	10 C 170 Single	10 C 170 Single	14 C 170 Single	10 C 170 Single	(Default) 14 C 170 Single	10 C 170 Single
	up to 6 months		1 year		2 years		3 years	

ANTICIPATED TIME BETWEEN FIRST AND SECOND SEAL

* Consider the need for binder types other than Class 170 for first seal

Notes:
1. "First Seal" does NOT include Initial Bituminous Treatments (primes and primerseals)
2. Where a seal is not going to be trafficked for some time, a different stone size and binder type may be needed. This should be covered by job specific Supp. Specs.
3. Aggregate sizes larger than 14mm should not be used for the following reasons.
   a. Increased risk of vehicle and property damage
   b. Large texture differences may make subsequent seal designs very difficult
   c. The aggregate size for subsequent reseals is limited to a small size
   d. Increased cost

PMB - Polymer Modified Binder.
C 170 - Class 170 Binder
Single - A single uniform spray rate
TVSR - Transverse Variable Spray Rate

Figure 2.3.2 Sealing Aggregate and Binder Selection Guide
(Source: Southern District Sealing Guidelines, 2004, p. 5)

The NAASRA *Guide to the Selection of Bituminous Surfacing for Pavements* (1985) suggest that for an approximate traffic volume of more than 6000 vehicles/lane/day, asphalt surfacing is generally used but double/double seals have been used satisfactorily with a single application seal used as a retreatment.

2.4 Surface Texture

Surface texture is defined by Viner et al (2006) as the macro-texture of the pavement surface. Macro-texture is inturn defined by Visser (1975) as the average depth of the interstitial surface voids, which can be determined by a sand patch test. The procedure for undertaking a sand patch test will be discussed in **Chapter 3.1**.

Many studies have been undertaken to try and understand the relationship between surface texture and skid resistance and /or stopping distance, including Visser (1975), Vicroads (2002), Viner et al (2006) and Cairney & Germanchev (2006). All studies, except Cairney & Germanchev, emphasise that the relationship that exists is a complex one and skid resistance is related not only to macro-texture but surface micro-texture plays a crucial role as well.

According to Viner (2006), micro-texture is the fine scale texture present on the surface of aggregate chips. Visser (1975) defines micro-texture as the polished stone value (PSV) of the surfacing aggregate. Aggregate polishing occurs as a result of wear over time and results in a loss of friction (Austroads 2004). Vissers' South African study concludes that at high speeds in the range of 100 km/hour, stopping distance is governed by both macro-texture and micro-texture. At these higher speeds a greater value of micro-texture cannot fully compensate for a lack of macro-texture. At low speeds the same study found micro-texture had the greatest effect on stopping distance and macro-texture had little effect at all. This study concluded that in urban, low speed environments the surfacing aggregate should have a high micro-texture (PSV) but macro-texture was relatively unimportant. On high speed roads macro-texture plays a vital role in reducing stopping distances. Austroads *Sprayed Sealing Guide* (Austroads, 2004) warns that the loss of macro-texture including flushing in the wheel paths can result in a reduction in surface friction, leading to loss of control of vehicles in wet weather due to aquaplaning.

One of the aims of the Vicroads (2002) study in Victoria was to determine a surface texture (macro-texture) limit below which there was a marked increase in the risk of crashes. The study was performed on low-volume rural and urban highways and showed that there was an increased risk of crashes when the macro-texture was low. This result helped determined a desirable, long-term, lower limit on macro-texture on high-speed rural roads of 1.2 millimetres. The study suggested that this performance level could be considered for inclusion into future performance-based contracts. A concurrent sub-study of asphalt, mainly urban roads, revealed there was not a significant relationship between crashes and surface texture for those roads, even though their actual macro-texture was generally limited to 0.4 to 1.1mm. These findings support Vissers' earlier South African research. Similar work by Viner et al (2006) in the United Kingdom concludes with a confirmation of the importance of maintaining good levels of texture depth particularly on rural roads and particularly where the skid resistance related to micro-texture is also low.

Cairney & Germanchev (2006) define micro-texture as surface irregularities less than 0.5 mm in depth, and macro-texture as surface irregularities between 0.5 mm and 50 mm in depth. They state micro-texture is thought to affect stopping distance solely by adhesive friction, while macro-texture is believed to exert an effect through the mechanical deformation of the tyre rubber, which absorbs kinetic energy by hysteresis losses. Adequate macro-texture also decreases stopping distance because it enables drainage paths to exist on the road surface, which prevent a film of water forming on the road surface. This thin water film is one of the main causes of aquaplaning which is a major contributing factor for road accidents in wet weather.

Their study aimed to use sensor-measured texture depth data to locate optimum physical testing locations to obtain useful information on the relative contribution of micro-texture and macro-texture to stopping distance at different speeds. During the study a Holden Commodore sedan was used to test stopping distance under a range of speeds and surface conditions. Unfortunately their study was inconclusive as to the relationship between surface texture and stopping distance, but they believe further research and a larger sample of test sites might reveal more conclusive findings.

Cairney & Germanchev also refer to similar testing accomplished overseas but reveal there appears to be no published Australian data relating vehicle stopping distance to macro-texture and micro-texture. All past Australian work has related stopping distance to skid resistance as measured by the Sideways Force Coefficient Routine Investigation Machine (SCRIM). They note that recent technical developments in road survey instrumentation, GPS and GIS have made this type of research feasible, assisted by the trend towards annual collection of surface texture data by most road authorities. This type of data is stored in Queensland in the QDMR ARMIS Database.

As far back as 1976, an international study by the Organisation for Economic Co-operation and Development (OECD, 1976) into hazardous road locations determined that substantial reductions in road traffic accidents could be brought about by improvements to surface texture, thereby improving skidding resistance. The study also commented on the contribution adequate macro-texture has to glare reduction when driving at night, and the associated benefits to safety of improved driver visibility. The OECD study also determined a relationship between macro-texture, micro-texture and skid resistance at a variety of speeds. A copy of page 34 of the study is included on the following page.

Figure 2.4.1 illustrates the terms micro-texture and macro-texture, as they relate to road surface texture and skid resistance. **Figure 2.4.2** graphically depicts the results of the study using a SCRIM type testing machine to determine coefficients of longitudinal friction. It depicts how at lower speeds, adequate micro-texture alone provides excellent skid resistance but at increased speeds the contribution of macro-texture to skid resistance is greatly increased. As a result of this study the OECD went on to recommend that stringent selection of surfacing aggregates should be undertaken and only aggregates which are highly resistant to polishing should be utilised for road surfacing. They also recommended that for satisfactory skid resistance at speeds over 90 kilometres per hour, a minimum texture depth of one millimetre should be maintained for sprayed bituminous surfacings. This finding is supported by Austroads (2004) in relation to skid resistance on spray sealed surfaces.

Figure 4

ILLUSTRATION OF TERMS USED TO DESCRIBE THE ROAD SURFACE TEXTURE

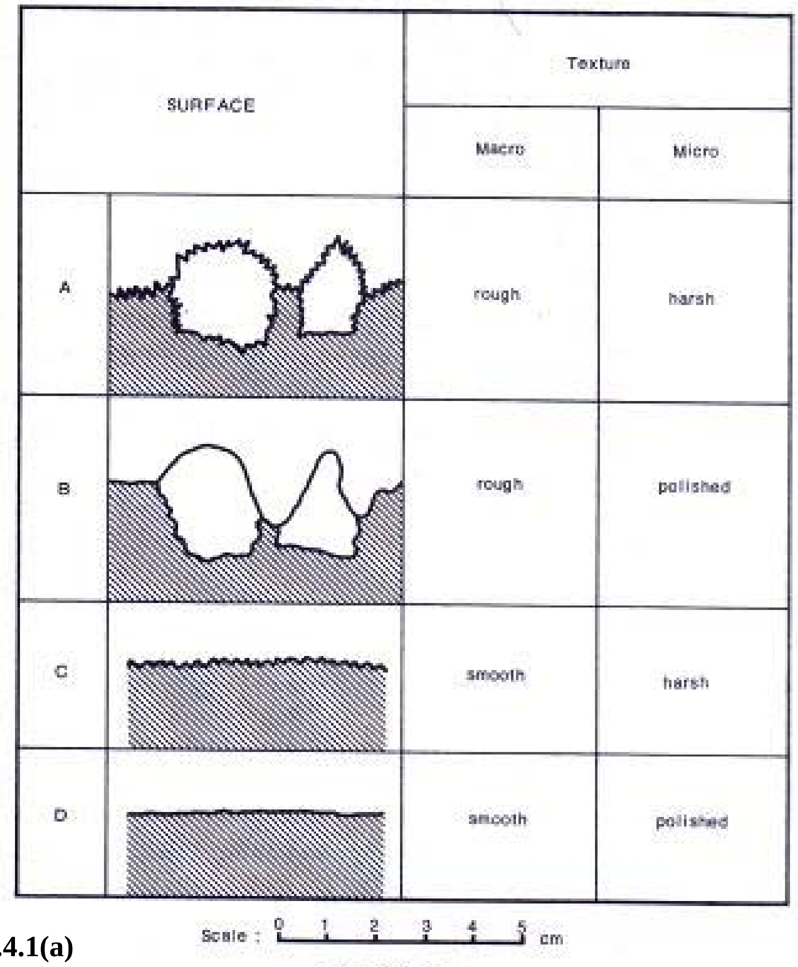


Figure 2.4.1(a)

Figure 5

SKID RESISTANCE WHEN WET ON SURFACINGS GIVEN IN FIGURE 4 (WORN TYRE)

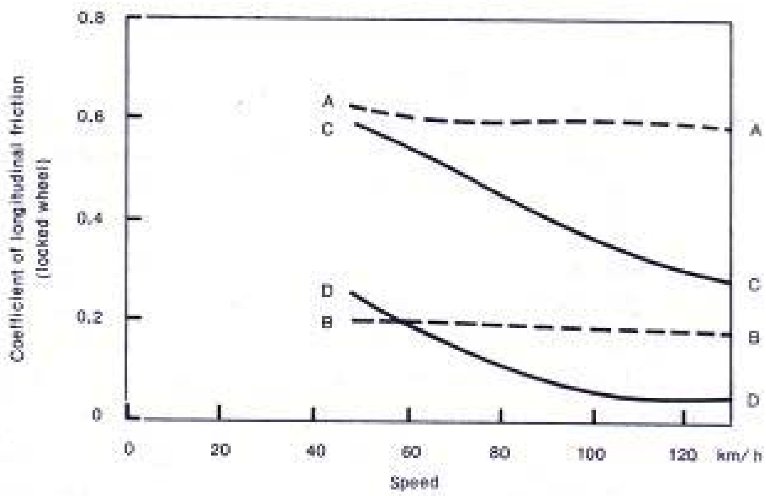


Figure 2.4.1(b) **Relationship between macro-texture, micro-texture, skid resistance and speed. (Source: OECD, 1976, p. 34)**

The OECD study added that roughness and rutting were also associated with the occurrence of road accidents. These irregularities in the surface profile have an effect on user comfort and when closely spaced, at intervals of one meter or less, it is possible for them to cause loss of control at higher speeds. These larger scale surfacing characteristics are referred to by some practitioners as mega-texture. Phillips & Kinsey (2000) offer the definition that mega-texture refers to surface irregularities with wavelengths between 50 and 500 millimetres.

Phillips & Kinsey went on to warn readers that whilst deeper textured (macro-textured) road surfaces generally provided a greater degree of high-speed skidding resistance, they have been associated with higher vehicle noise levels. Elevated tyre noise levels can be a serious issue particularly in residential and urban areas where the noise can be very disturbing. Phillips & Kinsey, (p. 6) suggested that, '*two distinct mechanisms were involved in generating tyre noise. The lower frequency elements of the spectra were attributed to noise resulting from tyre vibration, whereas the higher frequencies were related to the compression of air within the region of the tyre / road contact*.'

A conflict occurs in areas where high values of skid resistance are required but high noise levels will not be tolerated. As a result of this conflict, detailed analyses of the shape of the surface texture are being undertaken in an attempt to separately characterise noise emissions and skidding resistance. Even if the mechanisms of noise generation and skidding resistance are physically attributable to similar features of surface texture, it may still be possible to reduce tyre noise without prejudicing safety. Careful surface treatment selection will be essential in sensitive areas to balance the conflicting requirements. Further research is needed in this area.

Pidwerbesky & Faulkner (2006) comment on the increased traffic loadings that chip sealed roads in New Zealand have been experiencing, and the associated reduction of skid resistance to unacceptable levels in the wheel-paths due to bitumen flushing. Bitumen flushing is defined by Austroads (1992), (p. 37) as '*a surface condition in which the binder is near the uppermost surfaces of the aggregate particles. The uppermost surfaces of the aggregate are still visible, but there is minimal surface texture.'*

Bitumen flushing in the wheel-paths is not a new phenomenon in New Zealand or Australia but increased traffic volumes and particularly the increase in the size and number of heavy vehicles on the Australian rural road network has exacerbated the problem and the Austroads' *Sprayed Seal Design Manual* (2006), (p. 51), states that '*surface texture has an important influence on the amount of binder required to produce an effective sprayed seal. It may be impossible to design a single binder application rate for flushed wheel path areas and for the highly textured non-trafficked areas across a pavement*.'

The inability of a seal designer to select a suitable single spray-rate with the capacity to meet the design requirements of the flushed wheel paths and also the adjacent hungry areas has led to the development of TVSR technology. Oliver (1989) in his presentation, *What is happening to our seals?* recommended the reduction of bitumen spray-rates in the wheel-paths to reduce the risk of flushing and the associated loss of surface texture. Transverse variable spray-rate technology appears to have been developed relatively independently by various road authorities at about the same time, as a counter measure to the increased stress and flushing exhibited by the seals found in most road authorities networks.

Pidwerbesky & Faulkner, 2006, (p.3), quote Tevlin, as far back as 1988, who comments that '*a sprayer with two spray-bars, which allowed control of transverse application rate and spraying width while on the move was developed by the Main Roads Department of Western Australia.*' In Queensland, pioneers of transverse variable spray-rate technology were coming up with their own ideas on how successful variable spray-rates could be achieved. The work of these innovators contributed to the development of the Roadtek twin-bar variable rate bitumen sprayer in Southern District. Subsequent presentations about these developments at Main Roads Regional Symposiums (Seefeld, 2000) and in industry publications (Seefeld, 2003) attempted to broadcast the benefits of the technology to the wider transport engineering community.

In the early 1990's, New Zealand road construction contractor Fulton Hogan became aware of variable spray-rate technology in Europe which was superior to the technology currently available in Australia and New Zealand. By 1996, Fulton

Hogan had developed a local machine inspired by the European technology and began to use it on New Zealand spray-seal jobs. Once successfully trialed in New Zealand, the 'Multisprayer' was brought to Australia in 2007, where Fulton Hogan have been demonstrating its abilities in a variety of situations and seeking bitumen spraying contracts.

2.5 Construction Techniques for Sprayed Surfacings

Regardless of the actual spraying technique employed during the application of a sprayed surfacing, the general plant necessary to successfully complete the job is fairly standard. The sealing operation is a specialised task, and should only be performed by a trained team with a thorough understanding of the process, the requirements and the associated health and safety risks.

The Austroads *Sprayed Sealing Guide* (2004) describes the system of work used for the application of sprayed bitumen for the construction of a chip-sealed surface. The operation revolves around a truck-mounted bitumen sprayer, equipped with a pump and spray-bar capable of delivering a predetermined quantity of hot bitumen onto the road surface. The bitumen sprayer sets the production rate in sprayed sealing, therefore it is critical there is sufficient equipment available to keep pace with the spray truck (Transport Research Board, 2005).

A series of gravel trucks equipped with cockerel spreaders or roller spreaders, or a self-propelled spreader, reverses along following the bitumen sprayer, spreading the aggregate at a predetermined rate. A series of self-propelled, multi-wheeled, pneumatic-tyred rollers then compact the aggregate into the hot bitumen, achieving sufficient embedment and reorientation of the aggregate particles that they will form a lasting and durable chip-seal. A tractor mounted or towed rotary broom is used to prepare the surface before sealing if loose or foreign materials are on the roadway. The rotary broom is then used post-sealing to remove surplus aggregate from the sealed surface. The road is then able to be opened to traffic.

The ability to store sufficient hot bitumen on-site for refilling the bitumen sprayer is essential. The bitumen is normally stored in road tankers equipped with heating elements to maintain the bitumen temperature. The road tankers bring the bitumen on-site from the refinery or from off-site storage tanks as required. For a successful sealing process, it is crucial that the aggregate is in a suitable condition. It must be sound, dry, dust-free, and pre-coated with a suitable bitumen, oil or water-based pre-coating product, depending on the circumstances.

In addition to the careful treatment and selection of aggregates, only sealing when the weather is warm and dry is essential to minimising the risk of aggregate stripping in the new work. Shading of the job site can lead to the surface being too cool for the bitumen to adequately adhere to the aggregate, and the surface temperature should be monitored. The addition of adequate quantities of cutter oil or adhesion agents is required in many circumstances to minimise the risk of aggregate stripping.

The techniques used to apply the bitumen depend on the capability of the spray-truck and the seal design. A single bitumen spray-rate is the simplest design to apply, and once the correct pump speed and ground speed are known for the desired spray-rate, the bitumen is sprayed evenly across the road surface and the aggregate is immediately spread over it.

In the QDMR Central District, a TVSR program has been adopted that consists of consecutive spray-runs by two separate spray-trucks. The first spray-run is applied to the heavy areas (everywhere but the wheel-paths) and the spray-rate is the difference between the heavy and the light spray-rates. The second spray-run delivers a uniform light spray-rate and then the aggregate is applied as usual. This method is only fractionally dearer than single spray-rates, and no special modifications are required (QDMR, 2003).

Toowoomba and Warwick Districts of the QDMR utilise a custom-built Roadtek bitumen sprayer developed by their own sealing experts. It is a twin-bar sprayer, which is extendable to 8 metres and operates three pumps independently, allowing separate spray rates for each bar, bitumen circulation through the bars and separate filling operation (Roadtek, 2003). This sprayer is capable of delivering accurate transverse variable spray-rates and it has been used successfully for a number of years throughout the district (Seefeld, 2003), as well as on contract jobs beyond the boundaries of the district.

These conventional and adapted bitumen sprayers have fixed spray-bars with folding extensions which are quite cumbersome when maneuvering around obstacles and are possibly dangerous to bystanders if unintentionally activated when the extensions are in the folded position due to the orientation of the nozzles (Mott, 2008).

Fulton Hogan developed new technology with telescopic spray-bars that can be extended and retracted as required on the run. See **Figure 2.5.1** for a picture of the extended spray-bars. At the current time this technology appears to be the most advanced in the industry, and Fulton Hogan are looking to increase the capability of the sprayers by integrating electronic surface texture depth capture equipment on the front of the spray-truck, allowing modifications to the spray-rates to be achieved in a real-time environment, to account for existing surface conditions as the sprayer passes over the area of interest (Pidwerbesky & Faulkner, 2006).

Figure 2.5.1 Fulton Hogan Multisprayer with telescopic spray-bars fully extended to five meters width at Gatton Field Day, February, 2008 (Source: Authors Photo, 2008)

The theory involves using digital image processing, incorporating information theory and fast Fourier transform (FFT) analysis to find more accurate methods of measuring surface texture (Pidwerbesky et al, 2006). So far, the research has proved the hypothesis that a physical relationship exists between chip-seal texture and the FFT values of a digital image, but it seems the innovative researchers have quite a way to go before the technique will be available for commercial use.

In the United States, similar problems with bitumen flushing in the wheel paths have been encountered on chip-sealed roads. They have also developed variable application spraying techniques, consisting of a single spray bar equipped with variable nozzles. The variable nozzles are capable of delivering an increased rate of bitumen up to 20% above the design wheel-path rate onto the shoulders and between the wheel paths (Transport Research Board, 2005). This technique was employed by the Queensland Department of Main Roads prior to the development of the twin bar sprayer. It was discontinued due to the difficulties and safety issues involved with adjusting the nozzles to vary the spray rates while hot bitumen is circulating through the bars.

The United States article by the Transport Research Board (2005) goes on to identify industry best practice being achieved by Fulton Hogan of New Zealand, and quotes the results of the variable rate bitumen spraying trials conducted at Tai Tapu in 2000, which show that there is a definite positive trend in wheel path texture depth as spray-rates in the wheel-paths are reduced by up to 30%.

2.6 Types of Surfacing Failures

Deterioration of spray-sealed surfacings occurs in a number of ways and it is a topic that appears to be quite well understood. These issues are addressed in various industry publications but the most comprehensive and easy to understand treatment of the topic is provided in Austroads' *Sprayed Sealing Guide* (2004). The common types of sealing failure that are discussed include;

- gradual hardening of the bitumen binder through oxidisation, resulting in the loss of aggregate (stripping) and the formation of fine cracks – leads to insufficient macro-texture, and the loose stripped aggregate can be dangerous to people and property and often results in windscreen damage and complaints by road users
- aggregate stripping from the seal as a result of aggregate breakdown due to insufficient aggregate strength, or incorrect aggregate application preventing adequate adhesion, including moist aggregate, dusty aggregate, shaded work area or cool or damp pavement
- aggregate embedment from prolonged trafficking and heavy loads
- wear and polishing of aggregates due to heavy traffic volumes – a result of using aggregates with insufficient resistance to polishing for the design application or the use of naturally smooth aggregates, like river gravel – leads to insufficient surface micro-texture
- texture loss through binder flushing or bleeding - often caused by excess binder sprayed in the wheel-paths, but can be caused by sealing too soon after priming or using excess flux/cutter oil – leads to insufficient macro-texture

Wear and polishing of aggregates are dealt with in the Australian Standard AS1141 *Methods for sampling and testing aggregates* under Methods 40, 41 & 42. These tests determine the Polished Aggregate Friction Value (PAFV) or Polished Stone Value (PSV) of a sample. Austroads *Sprayed Sealing Guide* (2004) suggests that generally hard, fine grained aggregates are more susceptible to polishing than softer course grained aggregates, and PAFV/PSV values in the range of 44 and 48 are generally specified on medium to heavily trafficked roads and values up to 55 may be specified approaching traffic lights, pedestrian crossings and roundabouts.

It is emphasised that there is no direct correlation between the PAFV/PSV values and measures of field skid resistance, but the established values allow aggregates to be ranked with regard to susceptibility to polishing. Some road authorities have developed their own specifications with regard to aggregate properties, and Oliver (2001) informs that very-high PAFV aggregates are not available in Australia, and moderately-high PAFV aggregates are in short supply.

The unavailability of highly polish resistant aggregates increases the risk of reduced surface micro-texture, as seals age and become worn under traffic stress. The results obtained from the 1976 OECD study confirm that in the absence of significant micro-texture, the contribution of surface macro-texture becomes critical to maintaining even moderate levels of skid resistance.

Loss of surface macro-texture through flushing and bleeding particularly in the wheel-paths, are common causes of premature failure of spray-sealed surfaces. Flushing has already been defined in **Chapter 2.4**. Bleeding is the next level of failure, which Austroads, 1992 (p. 34) define as '*a surface condition in which an excess of free binder completely covers the aggregate. There is no surface texture*.' Bleeding results from a combination of traffic action, warm temperatures and other factors (Austroads, 2004).

Well designed TVSR seal designs have been shown to have the ability to reduce flushing and bleeding in new surfacing work, and the ability to correct or minimise these defects when resealing in areas exhibiting these pre-existing problems (Fulton Hogan, 2007). Due to the inflexibility of single spray-rates, they cannot deliver an effective spray-rate compromise when hungry areas and flushing occur in the same section of road, which is often the case, as shown in **Figure 2.6.1**.

Figure 2.6.1 Adjacent hungry & flushed areas in a failed chip-sealed pavement A challenge for seal designers (Source: Main Roads)

This inflexibility often leads to the flushing problem actually being exacerbated following the reseal if heavier spray rates are used or it leads to stripping of the cover aggregate in the hungry areas if lighter spray rates are utilised. TVSR technology has the advantage of allowing the seal designer to decrease the spray-rates in the flushed areas but still provide a full or increased spray-rate to treat the hungry or stripped areas.

In addition to deterioration of the seal, often issues related to the underlying pavement can cause seal failures. These topics are addressed in AAPA (2004), Main Roads *Pavement Design Manual* (2005) and again in Austroads (2004). A successful and durable seal must be founded on a stable supportive base. Weak pavement materials, heavy traffic loads and /or the ingress of moisture, either through the seal or from the edges of the road can lead to various forms of pavement failure or deficiency including;

- cracking - including longitudinal, block cracking, slippage cracking or crazing (crocodile cracking)
- deformation - generally associated with heavy traffic, structural inadequacy or independent environment factors
- rutting – vertical deformation of the wheel-paths due to shear failure of one or more pavement layers
- corrugations – leads to pavement disintegration and is thought to be caused by the acceleration or deceleration of slow moving, stop /start traffic.
- shoving – similar causes as for corrugations
- depressions – often caused by settlement or as a result of disturbance due to installation of services etc

2.7 Conclusion

The literature review highlighted that there is very little information available relating to transverse variable rate bitumen spraying and apart from Fulton Hogans' comprehensive New Zealand research at Tai Tapu, there is very little quantitative data to support TVSR technology, even though it appears to be very effective in improving the application and performance of sprayed surfacings and is recommended by various eminent industry groups.

TVSR technology has the possibility to improve macro-texture in the wheel-paths, while assisting seal designers to deliver higher bitumen application rates on the shoulders and between the wheel-paths to prevent aggregate stripping. The literature review revealed that improved macro-texture is not the only factor involved in increasing skid resistance but surface micro-texture plays a critical role, particularly at lower speeds.

This study deals specifically with surface macro-texture but an overall holistic approach to improved skid resistance must also involve research into adequate micro-texture. Modern technology utilising laser sensor measurement has made cheap and efficient collection of surface macro-texture data a reality but widespread surface micro-texture data is more difficult and expensive to collect once the aggregate is in service. Minimum specifications regarding resistance to aggregate polishing are essential to see a widespread improvement in skid resistance. These minimum specifications are already in place in many areas including Queensland where QDMR have their own specifications relating to aggregate quality.

The literature review revealed that while TVSRs appear beneficial in many circumstances, asphalt is still a superior treatment to use at intersections, roundabouts and other high stress areas where the sprayed seal aggregates are easily disturbed or dislodged. There also appears to be a lower AADT limit of approximately 1000, below which TVSRs make little difference to surface texture consistency and an arbitrary upper limit, above which the traffic stress is too great for seals to achieve a reasonable life and designers are advised to select a more robust surface treatment. This upper limit depends greatly on the percentage of heavy vehicles using the road.

Chapter 3 DATA ACQUISITION

3.1 Sand Patch Testing

Initially sand patch testing was utilised to develop an understanding of the practical aspects of surface texture (macro-texture) and how the available data relates to the physical road conditions.

The sand patch test involves spreading a defined volume of graded sand level with the top of the aggregate in a circle by revolving a straight edge and measuring the area covered. In Queensland a volume of 50 ml is commonly used for the calculation. The volume equation can then be solved for the average texture depth by dividing the volume of sand by the area of the sand patch (TNZ, 1981) as shown below:

$$\frac{\pi * \phi^2}{4} = \frac{50ml * 1000}{depth\ (mm)} \qquad \textit{Equation 1}$$

where ϕ is the sand patch circle diameter in millimetres and 50ml is the defined volume of the sand measuring container.

Rearranging *Equation 1* to solve for depth (mm) yields *Equation 2*:

$$Average\ texture\ depth\ (mm) = \frac{50ml * 1000 * 4}{\pi * \phi^2} \qquad \textit{Equation 2}$$

A number of sand patch tests were undertaken along the New England Highway to determine the usefulness of this technique for acquiring data for developing the model. Sand circle tests are shown in Figures 3.1.1(a) & 3.1.1(b), including a 50ml sand measuring cylinder to show the scale. **Figure 3.1.1(a)** shows a 160mm sand circle giving a 2.49mm texture depth in a hungry or bitumen deficient area between the wheel paths. **Figure 3.1.1(b)** shows a 311mm sand circle giving a 0.66mm texture depth in a flushed area in the outer wheel path.

Figure 3.1.1(a) - 160mm Sand circle **Figure 3.1.1(b) - 311mm Sand Circle**

After obtaining samples at several locations, it became obvious that there was such longitudinal variability to the surface texture, particularly along the OWP, that to obtain a true representative average sample value for each road section, a large number of tests would need to be undertaken and this would be a very time consuming process. In addition, as the roads of interest have an AADT of greater than 1000, it would be impractical to undertake so many tests while the roads are open to traffic, as the tester must vacate the roadway when traffic approaches for safety reasons. The author then drew the conclusion that for a project requiring such large quantities of surface macro-texture data to obtain realistic results, sand patch testing was not a feasible method for acquiring the necessary data.

3.2 ARMIS Data

Fortunately the QDMR maintain the ARMIS (A Road Management Information System) database which holds historical and current information relating to the road network including seal type, seal age, binder type, AADT, speed environment, surface texture, rutting, roughness and many other attributes. Unfortunately ARMIS does not record if transverse variable spray rates or single spray rates were used for the seals. This information has to be found manually by researching each relevant reseal at District Office level by its job number. For older jobs this information has to be extracted from archived records. Due to destruction of old records and staff turnover there are occasions where information is not readily available. Another information source is to speak directly to the spraying contractor. In Darling Downs

Region the only two sprayer operators equipped with transverse variable spray rate technology are Roadtek and Fulton Hogan.

The surface texture data in the ARMIS database relates to surface macro-texture, and this data is captured annually by network survey vehicles equipped with Multi Laser Profilers (MLP). The MLP is an array of laser sensors mounted on the modified front bumper bar of the survey vehicle. The lasers take continuous readings along the road surface related to rutting, roughness and surface texture, while the vehicle attempts to maintain constant speed and position in the traffic lane. A typical network survey vehicle is shown in **Figure 3.2.1**.

Figure 3.2.1 Network Survey Vehicle fitted with Multi-Laser Profiler (Source: Courtesy Main Roads)

The laser measurements are taken every 200mm, but to make the data sets more manageable, and to even out localised surface macro-texture inconsistencies, the values are averaged over 100 metre sections. This means that for every 100 metres of road there is one representative surface texture reading at each sensor location, which is the average of the surface texture over that section. The raw data is available from the PAVCON database in Brisbane, but for the purposes of this investigation the averaged data is ideal, as trends can be easily determined.

The configurations and purposes of the lasers of the MLP laser array are shown in **Figure 3.2.2.** The sensors for surface texture measurement are set above the outer wheel path and between the wheel paths.

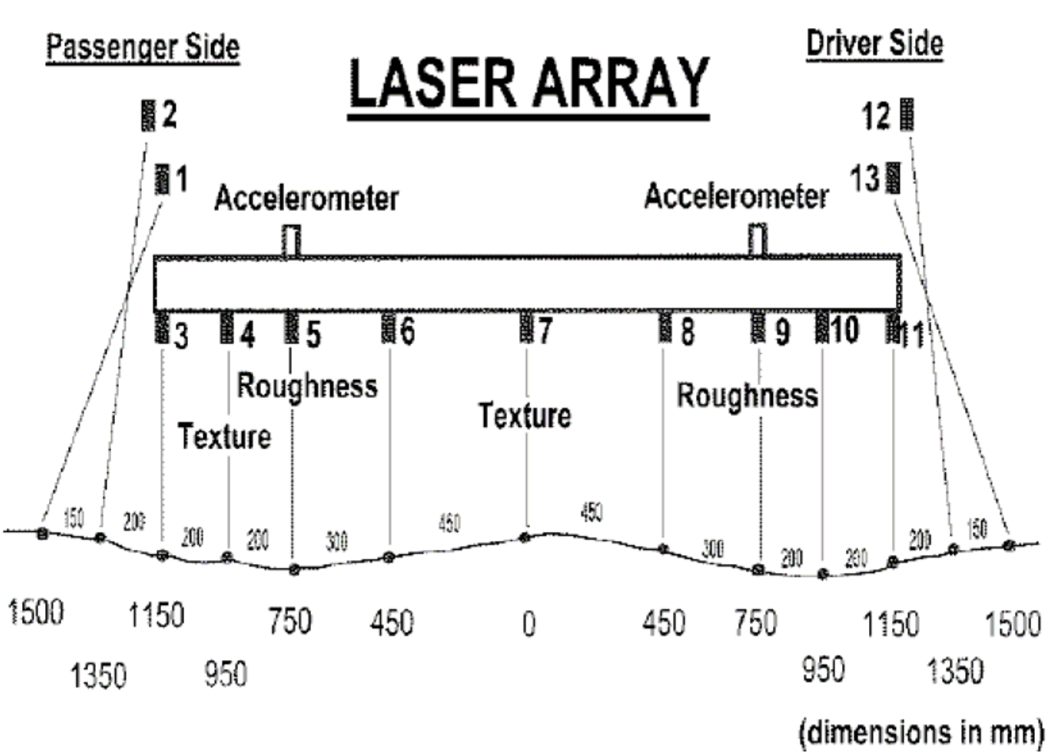


Figure 3.2.2 Network Survey Vehicle MLP Laser Array (Baran, 2007)

3.3 ARMIS Data Retrieval

The relevant surface macro-texture data is stored in the ARMIS database and limited access to the results is available through the Chartview software application, but more in-depth information is available by request from the district ARMIS operators, who have access to all the District's ARMIS Data, and limited access to data from other districts. The ARMIS operators can design data browsers to retrieve the exact information requested by the user.

The MLP laser array measures a value of surface texture depth across the pavement using the laser sensors. These results are known as Sensor Measured Texture Depth (SMTD), but they do not reflect a true value of the actual surface texture, as would be determined by a traditional sand patch test. So as to obtain a set of results which correlate to volumetric sand patch testing, Main Roads has determined that SMTD can be converted to results that are equivalent to sand patch testing by multiplying the SMTD by 2.5 (Clague, 2005). These results are then known as Sand Patch Equivalent Texture Depth (SPTD). The Standard Deviation (STD) of the surface texture data is also available through ARMIS. The STD gives the user a feel for the accuracy of the data.

Sources of error in the ARMIS data include vehicle tracking errors, where the vehicle may drift from the desired optimum position, particularly around curves, and a loss of the laser signal, generally for short sections only, and limitations related to the equipment. Others errors can occur when the actual chainage distance is inconsistent with the recorded data chainage, or data has been corrupted or altered during upgrades to the ARMIS Database system (Clague, 2005).

Chapter 4 METHODOLOGY

4.1 Introduction

Observation of roads shows that the area with the least surface texture is generally found in the outer wheel path as this is the usual location for the most severe bitumen flushing or bleeding. The greatest surface texture is generally found on the shoulders or between the wheel paths. These areas are often deficient of bitumen and appear to be hungry. This is due to a number of issues but one of the most important is lack of compaction by traffic, due to vehicles tracking in the wheel paths. Experience has shown that these hungry areas are likely to show the first signs of bitumen oxidization and potential aggregate stripping.

As the area in the outer wheel path and the area between the wheel paths provide the greatest contrast in surface texture values, it is logical to use these areas for the investigation. For this study the equivalent Sand Patch Texture Depth results from the outer wheel path (SPTD_OWP) and between the wheel paths (SPTD_BWP) were retrieved from the ARMIS database and analysed. The texture depths were compared from roads treated with single spray rates and similar roads treated with TVSR technology to determine if there was a measurable increase in transverse surface macro-texture uniformity and depth across the pavement surface.

A surface texture ratio of the two values was created as shown in *Equation 3*:

Surface Texture Ratio = SPTD_BWP / SPTD_OWP *Equation 3*

On a newly constructed surface the theoretical surface texture ratio should be unity as the texture should be uniform across the lane width. As the pavement becomes trafficked, the wheel-paths receive most of the wear and compaction, particularly the outer wheel-path, so the texture depth in this area usually decreases over time as the seal flushes with bitumen or the aggregate particles are reorientated or embed further into the seal. As this occurs the texture ratio increases to greater than one (1).

Austroads (2006) suggests transverse variable spray-rates are beneficial for preventing or correcting common surface texture defects like flushing and stripping, and many bitumen spraying practitioners agree, but there is very little available quantitative data to support these commonly held industry assumptions. The literature review revealed an industry desire to achieve more consistent long-term surface texture across the pavement width, and the need to improve skid resistance across the road network. The literature review also revealed that at higher speeds, improved surface texture (macro-texture) has a significant role to play in that improvement to skid resistance.

It is not unreasonable to assume that two roads with similar surfacing characteristics and similar traffic history would have similar long-term surface texture ratios when measured at the same seal age. If the only major variable in the analysis was the bitumen spraying technique utilised, it should be possible to compare the surface texture ratios to obtain some quantitative results regarding the performance of transverse variable spray-rates in achieving a more consistent surface texture across the pavement.

Therefore when similar 1000+ AADT roads are identified and where single spray rates have been utilised, the ratios can be compared, to determine if trends show transverse variable spray-rates provide a long-term ratio closer to unity than single spray rates achieve. Theoretically this should be the case, as the variable spray rates mean the seal designer does not need to compromise as much, and can customise the seal design to accommodate existing variability in surface texture or design the spray-rates to limit the extent of future expected difference in surface texture. It must be remembered that the TVSR technique is only as good as the designer applying it, and an incorrectly designed TVSR job is just as likely to flush or strip as a single spray rate job.

The results of this investigation and information gathered from other sources during the literature review were combined to draw conclusions relating to the performance and suitability of transverse variable spray rate technology in a variety of situations. A flow chart showing an overview of the data analysis process is presented as **Figure 4.1.1.**

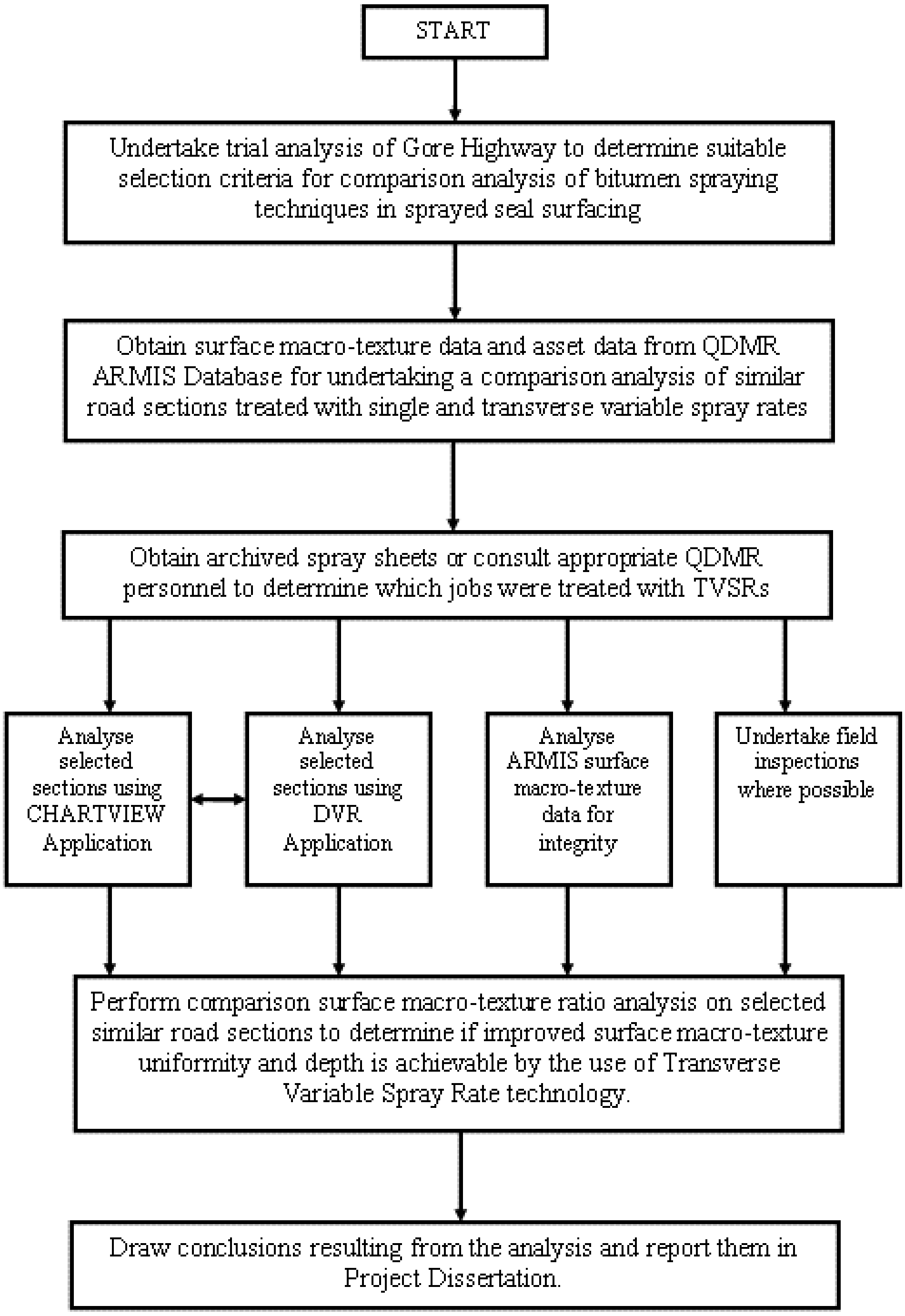


Figure 4.1.1. Overview of the data analysis process flowchart

4.2 Gore Highway Trial Analysis

Before the actual data analysis was undertaken, a trial sample of data was investigated to gain a better understanding of surface macro-texture behaviour and to identify any trends in the data that may be useful for the study. The surface macro-texture data values from the trial section were analysed to assist in identifying optimal test locations, and the parameters or limits to be used in isolating these optimal test locations for the full scale analysis. The trial data was not used to compare bitumen spraying techniques.

The trial sample of data was taken from the Gore Highway (28A) at Westbrook. The road section had an AADT of 4600, with 28% commercial vehicles and the chainage chosen for the trial was between 9.0 and 12.0 kilometres. In the trial section between the chainages of 10.16 and 10.74 kilometres there is a large-radius horizontal, right-hand curve but the rest of the section consisted of straight level sections of road. In 2005, a slurry surface correction was applied to the outer wheel-path to correct rutting issues related to the heavy commercial vehicles using the route. Apart from this treatment, the road had minimal prior works.

This section of road was particularly attractive to study, due to a Main Roads bitumen binder trial held at the same location during the 2007 reseal (Soward, 2007). This bitumen trial meant that information about the site was readily available and QDMR staff were particularly familiar with the section of road, and could be of assistance, if required, during the initial stages of the investigation.

Figure 4.2.1 graphically shows the surface texture history of the outer wheel path (OWP) for this section of the Gore Highway. There is a decreasing trend in the texture depth between 2001 and 2005. The 2005 slurry correction altered the texture depth trend and gave a low, but reasonably consistent surface texture to the whole section. By the time of resealing in 2007, the average texture depth in the OWP had dropped to approximately 0.5 millimetres. Observation of the data behaviour in relation to the slurry surfacing treatment provided a good indication of the sensitivity of the MLP sensors to prior works.

Studies highlighted in the literature review suggest at such a low value of macro-texture, the skid resistance was largely dependent on the micro-texture of the aggregate in the slurry surfacing.

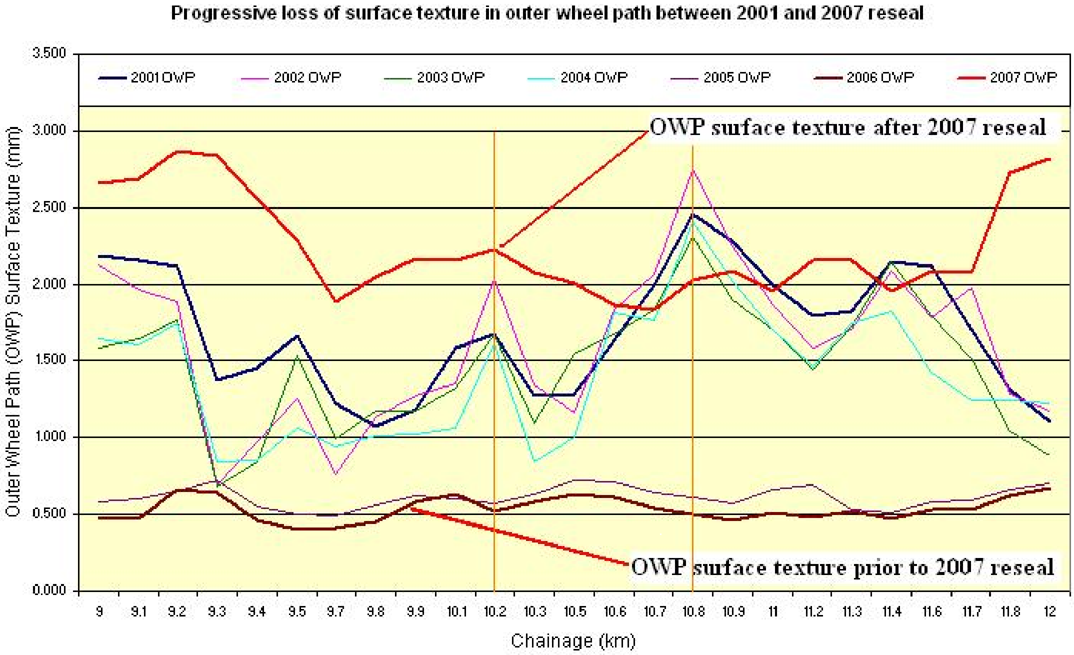


Figure 4.2.1 Progressive loss of surface texture in Outer Wheel Path (OWP) between 2001 and 2007 reseal

Two orange vertical lines are superimposed onto **Figure 4.2.1** at areas where the data shows consistent abnormalities. At the location of these vertical lines on the plot, there is an increase in macro-texture, which is prominent. These two macro-texture data spikes correspond exactly with the entry and exit to the large-radius, horizontal, right-hand curve. It would be reasonable to assume that as the vehicles enter and exit the curve, there is a slight change in alignment of the wheel-paths, due to curve widening of the pavement, and the tendency of vehicles to wander and occupy a greater width than on a straight section of road (Ayers, 2005).

This would spread the traffic stress on the road over a wider area, and thereby allow a courser surface texture to remain in these areas. As this trend is consistent between 2001 and 2005, this is the likely solution.

The analysis has revealed that significant prior works have a major effect on the data values and straight sections of road are more consistent and provide more meaningful data, than sections containing curves, even if the curves are of a large radius.

Figure 4.2.2 graphically shows the difference in surface texture between the OWP and the area between the wheel paths (BWP) prior and following the reseal in 2007. The pre-reseal values are in green and the surface texture between the wheel-paths is shown as a broken line. Prior to the reseal there were large fluctuating differences in surface texture between the two areas. Data collected following the 2007 reseal is shown in red with the same convention as before regarding the broken line representing the BWP texture data. The post-reseal data is much more consistent as expected, with the OWP having an average texture depth of 2.3 millimetres and BWP having an average texture depth of 2.4 millimetres.

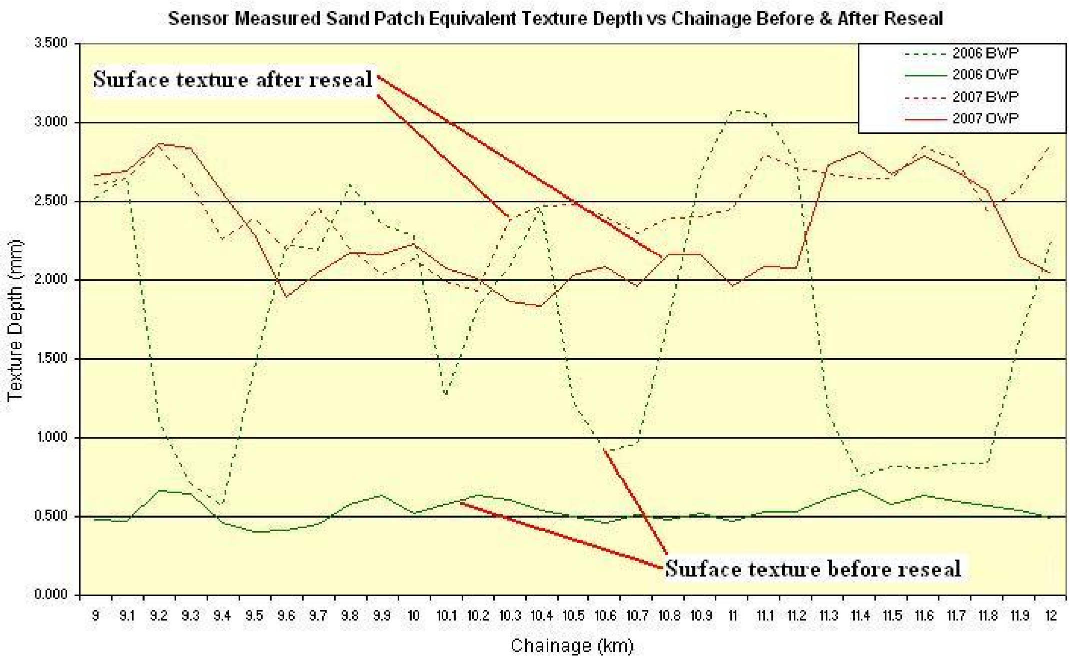


Figure 4.2.2 Surface texture comparison for BWP and OWP before and after resealing

The surface texture data used to develop the graphical representation given in **Figure 4.2.2** is then transformed using the ratio technique given in *Equation 3*, to yield a ratio of BWP texture depth to OWP texture depth. This resulting ratio analysis is presented as **Figure 4.2.3**.

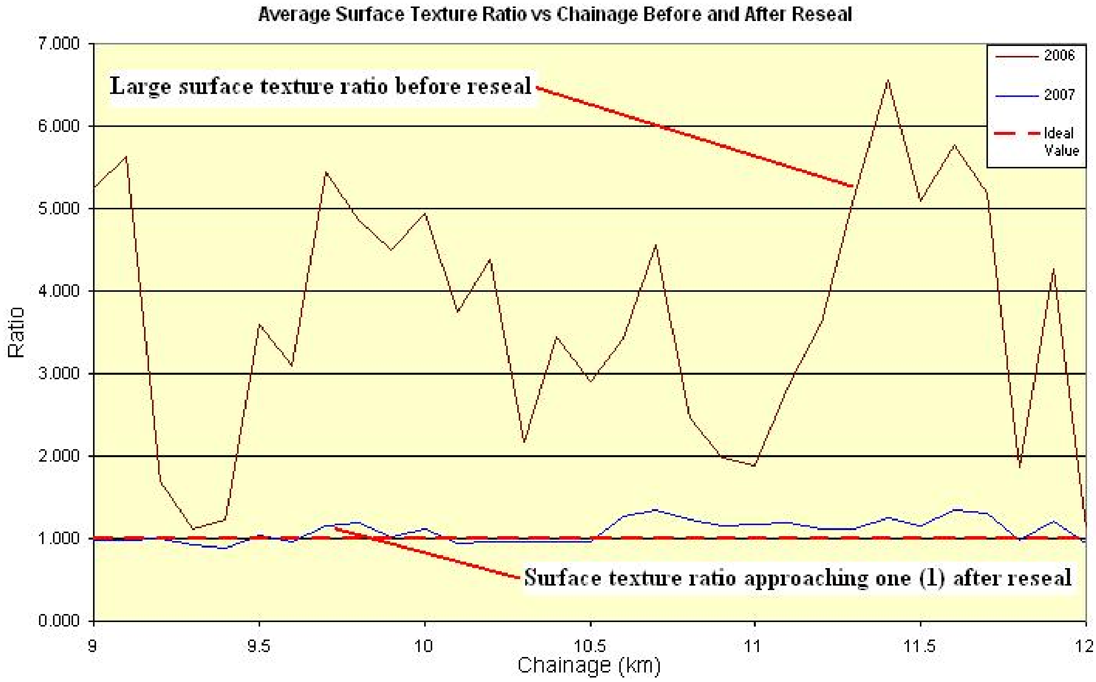


Figure 4.2.3 Average surface texture ratio vs. chainage before and after 2007 reseal

As expected, the surface texture ratio is relatively high prior to the 2007 reseal, but following the reseal, the ratio is close to one, which is the ideal value. These results demonstrate that the surface texture ratio method provides a simple, uncluttered representation of the data, allowing an instant assessment of the uniformity of the transverse surface texture, and a quick method for comparison against a theoretical ideal value. Due to the fact it is a ratio, differences in surface texture longitudinally do not affect the outcome, as long as the transverse values are consistent, the ratio will be unaffected.

4.2.1 Outcomes from the Gore Highway trial analysis

The trial analysis of the Gore Highway at Westbrook has shown that significant prior works have a considerable effect on the data values, and sections of road that have had significant prior works since the previous reseal are unlikely to yield reliable results. The analysis has also revealed that straight sections of road are more consistent and will provide more meaningful data, than sections containing curves, even if the curves are of a large radius.

4.3 Identifying Ideal Analysis Locations

As shown in the *Southern District Sealing Guidelines* (2004), all roads in QDMR Southern District, now Toowoomba District, that have an AADT greater than 1000 and are chip-sealed, receive transverse variable spray rate treatment. Therefore it was essential to obtain sufficient historic information from the ARMIS database regarding AADT, % Commercial Vehicles, binder type, aggregate size and type, speed environment etc to ensure a worthwhile and fair comparison was achieved, with the aim of establishing consistent patterns and trends. The study attempted to restrict its focus area to comparison sections with similar climate and soil types to maximise data consistency for the comparison. The ideal scenario was to use consecutive sections of the same road for the analysis, provided they meet the criteria for a reasonable comparison.

These ideal situations are likely to occur at district boundaries, where one district utilises TVSR technology and the other district still utilises single spray rate. An example of one such situation was the New England Highway (22B) between Toowoomba and Warwick, where the stewardship changes from Toowoomba District to Warwick District. Another situation where suitable comparisons are likely is where a major sealing program has been undertaken using single spray rates and there are areas nearby on the same roads that have been treated with transverse variable spray rates. Such a situation existed in the South Burnett, where the Enhanced Road Condition Project (ERCP) was undertaken between 1998 and 1999. This program was undertaken on major roads in the South Burnett including the Bunya, Burnett and D'Aguilar Highways and the whole program was accomplished with single spray rates. Since the ERCP was undertaken, various sections of other highways in the area have been treated with transverse variable spray rates during routine district resealing operations. These sections allowed suitable comparisons to be made between the two spraying techniques.

4.4 ARMIS Database Limits and Comparison Criteria

Following the Gore Highway trial analysis, certain criteria were identified which must be similar to both sites to maximise the reliability of the comparison data. These criteria include binder type, % heavy vehicles, road geometry, climate, soil types, AADT, aggregate size, binder type, speed environment and seal age.
The analysis was limited to pavement sections one kilometre long or less with the following characteristics:

- traffic speed environment of 100 km per hour
- at least 5 years of macro-texture records available in ARMIS database
- at least two years since the last seal was applied, to allow enough time for surface texture issues to become evident
- straight sections of road without significant changes in grade
- road sections without significant turnouts which may affect surface texture
- Average Annual Daily Traffic (AADT) greater than 1000 (where possible)
- minimal prior works to alter surface texture
- no auxiliary lanes in the section, as these would capture some traffic volume
- consistently decreasing trend in the annual surface macro-texture as the seal ages and becomes worn, with no unexpected data anomalies.
- No bridges or obvious changes in underlying material, unless noted

4.5 Investigation Methodology

As discussed previously in **Chapter 4.3**, The New England Highway (22B) between Toowoomba and Warwick was identified as a suitable section for analysis of the surface macro-texture, to determine if transverse variable spray rates had caused any improvements in surface texture depth and uniformity in the sections under analysis.

For the comparison of surface macro-texture, five suitable sections were identified that have been treated with variable spray rates, and five similar sections were identified that have been treated with the single or uniform spray rates.

The ARMIS Database was queried on my behalf by the district ARMIS Operators using an Oracle data browser customised to extract the records of interest related to the New England Highway (22B). Annual survey data of surface texture was available from September 2001 until December 2006, providing six years of usable records.

The data was extracted from three separate locations within ARMIS and was provided as three separate Microsoft Excel files. For a road of great length with many rows of associated data, careful querying must be used as a maximum of 10000 rows of data can be exported from the ARMIS Database system into an Excel spreadsheet. For roads with more than 10000 rows of data, the system must be queried so as to filter out superfluous records. This is achieved by designing a query to remove attributes that relate to other surface layers like asphalt, so only leaving records relating to spray sealed surfaces. If this still doesn't reduce the file to less than 10000 rows, it can be sectionalised based on the through distance (TDist), and the sections exported separately.

The ARMIS database system has trouble providing all the information as a single file, as the information relates to different units of measurement. The surface texture data is recorded every 200 millimetres, but to reduce the size of the file and make it more manageable, these surface texture values are averages and entered into the database at 100 metre intervals. The layer information is recorded to the nearest metre, and is entered into the database to align with the chainages of the relevant job numbers. The asset data is recorded every kilometre. Therefore the files were extracted and the data was sorted and manually entered by the author in a master file, which married up the relevant information from the separate Layer, Asset and Surface Texture files.

The first file to be extracted from the ARMIS database related to Asset information, and the following attribute headings were used to obtain the necessary data:

1. District ID
2. Road Section ID
3. Carriageway Code

4. TDist* Start
5. TDist* End
6. Seal Width
7. Pavement Width
8. Speed Limit
9. AADT
10. Traffic Percent Heavy Vehicles
11. Traffic Percent Growth
12. Traffic Year (The year the information was gathered)
13. Seal Type
14. Seal Age

* TDist (through distance) refers to the distance with gazettal from a known point at the start of the road, to the point on the section being described. Gazettal refers to the official direction of travel used to describe the road in question.

The file related to Layer information used the following attribute headings to extract the necessary data:

1. District ID
2. Road Section ID
3. TDist Start
4. TDist End
5. Layer Number (ie 1 is the current surface layer)
6. Layer Type# (A code used to identify different road surface types)
7. Layer Type Name (Description of the sealing method ie Bitumen Spray Seal)
8. Layer Depth^ (Refers to the aggregate size in mm for sealed surfaces)
9. Job Number
10. Layer Date (The date the layer was placed)

All spray sealed surface codes begin with the letter K and are shown in **Table 4.5.1**

^ARMIS refers to aggregate size as Layer Depth, as the same attribute heading is used when describing asphalt and concrete pavements.

Table 4.5.1 Layer type information from the ARMIS database

Layer Type Code	**Layer Type Name**
K1	Bitumen Spray Seal
K2	Polymer Modified Binder (PMB) Spray Seal
K3	Surface Enrichment
KU	Spray Seal – Quality Unknown

The final file referred to surface texture information and the following attribute headings were used to extract the data:

1. Road Section ID
2. Carriageway Code
3. TDist Start
4. TDist End
5. Lane Code*
6. SMTD_OWP
7. STD_OWP
8. SPTD_OWP
9. SMTD_BWP
10. STD_BWP
11. SPTD_BWP
12. Rating Date (The date the data was collected by the survey vehicle)

* Generally surface texture is only recorded in Lane 1, which is the lane running with gazettal. This is due to the prohibitive cost of data acquisition across the whole road network.

When the historical surface texture data for 22B, from September 2001 to December 2006 was extracted, it was sorted for Road Section ID, Rating Date and then TDist. The data was sorted using the Data / Sort command in Microsoft Excel, selected from the menu bar.

Following sorting, the information was presented in a useful format, and all the empty or unnecessary columns were deleted. The freeze panes command was chosen from the Window menu and the attribute headings were frozen in place, so when scrolling through the data, the headings were always visible. The data was originally presented vertically, with the start of the 2002 data following on from end of the 2001 data. To minimise scrolling and assist in visual comparison, each annual series was then cut and pasted horizontally across the spreadsheet rather than vertically. This was useful to check each year had the same number of records and the distances matched up for each rating date.

Once the surface texture data was satisfactorily presented in annual columns with 100 metre data intervals, the Asset data is imported. The asset data was presented in 1km sections, so it then had to be distributed manually to each associated 100 metre section of the surface texture data.

Finally the layer data is imported, providing the final pieces of information relating to the pavement. The layer distances were governed by the chainages for the relevant job numbers and were not distributed to the nearest 100 metre interval. As the layer information did not always align with the 100m intervals of the surface texture data, any interface values which didn't comply were removed so as to not corrupt the analysis by taking data that may have been associated with an adjoining job.

The New England Highway (22B) was chosen as it was located conveniently close to Toowoomba and it has about half of its length in District 3 (Toowoomba District) and the other half in District 5 (Warwick District).

The ARMIS database does not store information relating to whether TVSR's or single spray rates were used on the reseal jobs. This information had to be obtained from consultation with the appropriate staff at district office level. The 22B was attractive also as the climate and soil types are fairly consistent along the route and the AADT and %HV remains relatively consistent along many of the areas of interest.

Obtaining information on the spraying technique used in Toowoomba District was very simple, as there were long standing experienced technical staff available, with intimate knowledge of the road and the jobs that had been done over the last decade. The information from Warwick District was not so simple to acquire. This was due to staff attrition and turnover, therefore no-one who was involved in the earlier jobs was available to be questioned. The spray sheets for the relevant jobs had also been archived, but the Warwick staff were kind enough to retrieve the archive boxes from storage and allowed then to be scrutinised. The relevant spray sheets were able to be located and studied to determine which sections had received TVSR treatment.

The 68.5 kilometre length of 22B was then plotted in Excel using the ratio method described in Section 4.1. This gave a snapshot view of the surface texture uniformity across the whole length of the pavement. This graph is presented as **Figure 4.5.1.**

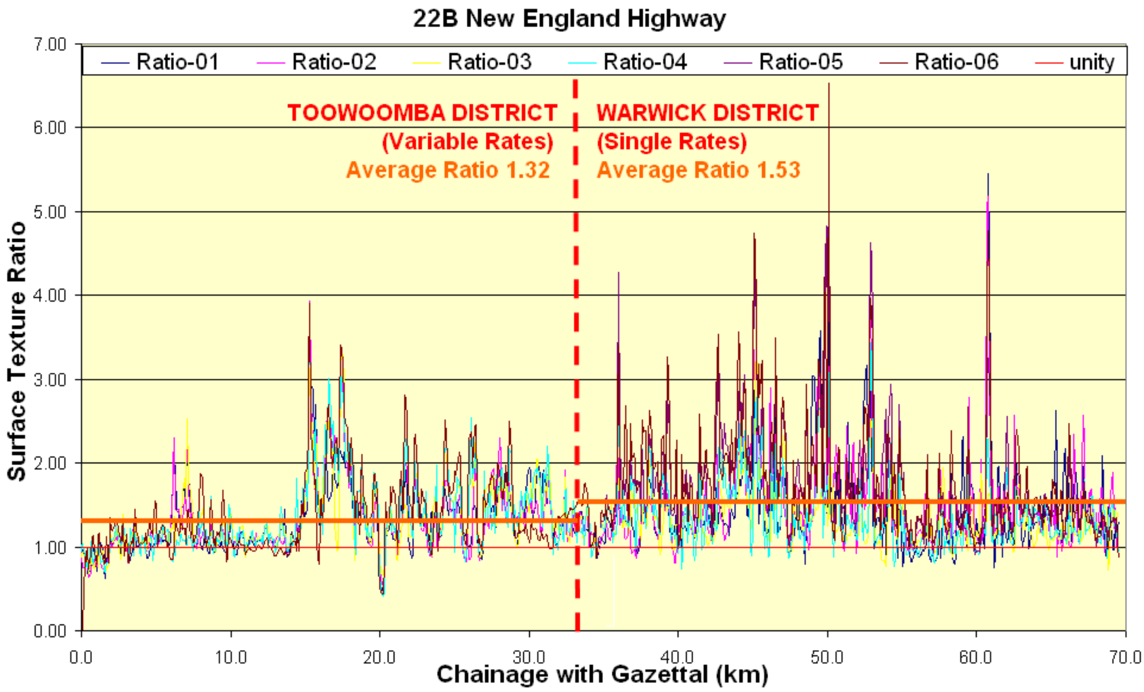


Figure 4.5.1 Surface texture ratio analysis for all New England Highway (22B)

It was instantly recognisable that the surface texture ratio for the analysis period in Warwick District has larger values, meaning less transverse uniformity, than the values for Toowoomba District. This disparity begins near the district boundary, shown by the red dashed line. There is little else that can be established from this plot, as the data is too condensed. The average ratios are also shown on the figure.

The road was then analysed using Digital Video Road (DVR) and the ARMIS Chartview Application. DVR enables the user to undertake a Virtual drive through of the road while remaining in the office. During the annual network survey, digital video images of each road in the QDMR network are captured and uploaded to the Main Roads Server. The files can then be opened through the DVR application and used to assist in managing the road network. DVR and Chartview can be harnessed together to create a drive through, which can also show the location of the different jobs along the route. A mobile red line on the job chart tracks the progress of the DVR during the drive through to provide a powerful, integrated analysis tool. A screen capture of this technology is shown in **Figure 4.5.2**.

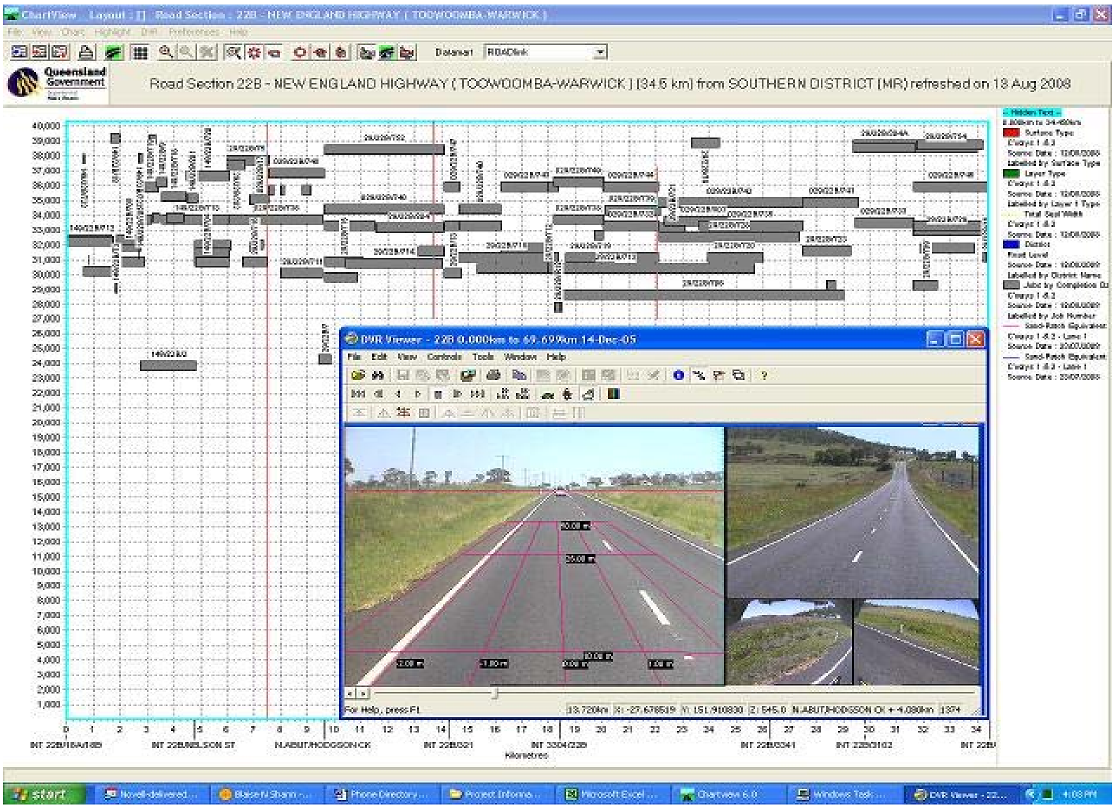


Figure 4.5.2 Chartview and DVR harnessed to create a powerful analysis tool.

In **Figure 4.5.2**, a chart showing the surfacing jobs that have been done along the New England Highway and the corresponding chainages are shown. As DVR performs the Virtual drive through of the road, a red line follows on Chartview to assist in identifying the sections as DVR passes them. DVR shows forward, rear and side views of the road, and a scale grid is able to be turned on to give perspective. This is shown more clearly on **Figure 4.5.3**.

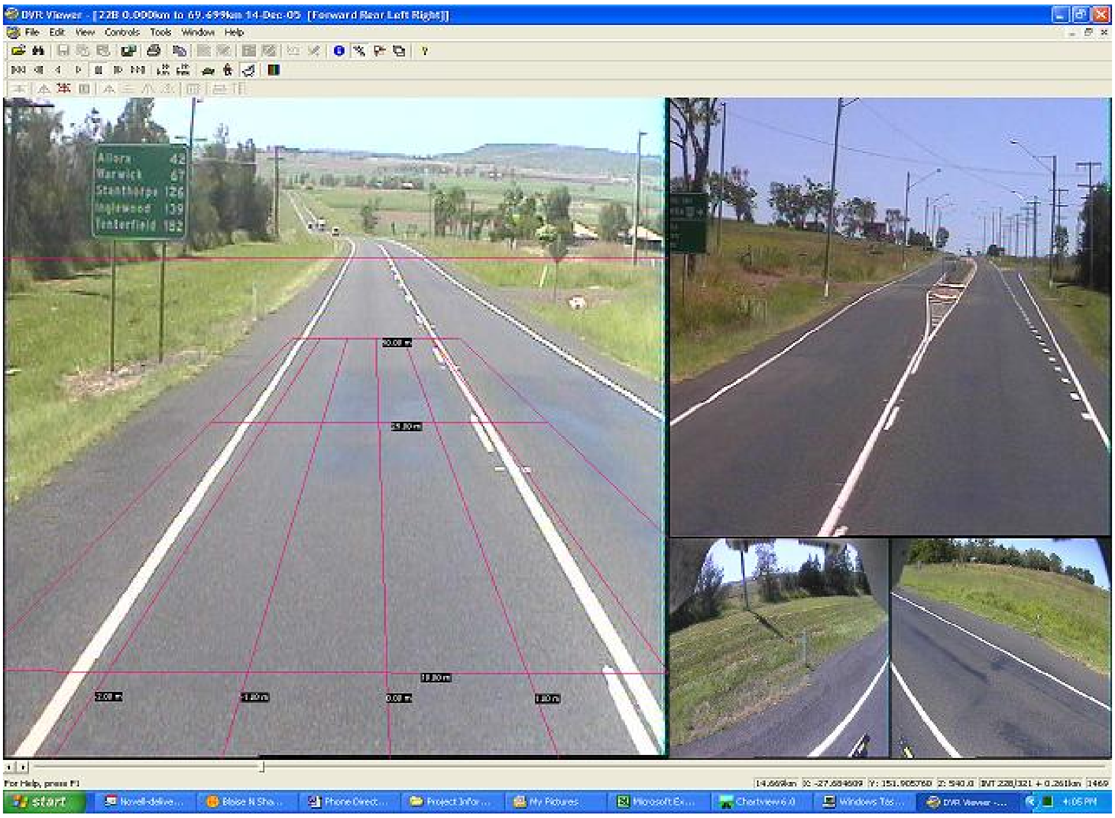
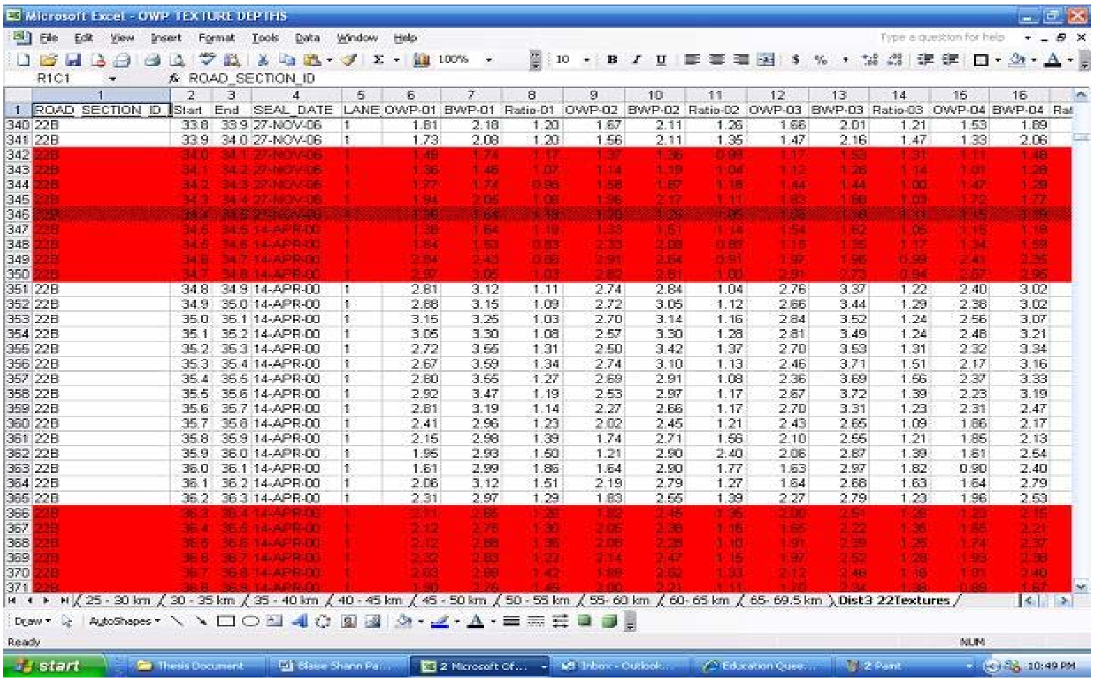


Figure 4.5.3 The DVR application showing the New England Highway (22B) near the junction with the Drayton Connection Road at Hodgsonvale.

Using the DVR/Chartview applications in conjunction with the spreadsheet developed for the analysis, allowed filtering of unsuitable analysis locations and minimised time to be spent on actual field inspections. An example of this efficiency is any lengths of road containing bends, bridges, significant turnouts or obvious prior works can be identified in DVR, and then the corresponding chainages highlighted in the Excel Spreadsheet as unsuitable for analysis using the criteria established in **Chapter 4.4**. A screen capture of the spreadsheet showing some of these highlighted areas is shown as **Figure 4.5.4**.

The sections remaining at the end of this process are ready to be passed to the next stage of analysis, where suitable sub-sections are identified based on the integrity and suitability of the surface macro-texture data.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	ROAD_SECTION_ID	Start	End	SEAL_DATE	LANE	OWP-01	BWP-01	Ratio-01	OWP-02	BWP-02	Ratio-02	OWP-03	BWP-03	Ratio-03	OWP-04	BWP-04
340	22B	33.8	33.9	27-NOV-06	1	1.81	2.18	1.20	1.67	2.11	1.26	1.66	2.01	1.21	1.53	1.89
341	22B	33.9	34.0	27-NOV-06	1	1.73	2.08	1.20	1.56	2.11	1.35	1.47	2.16	1.47	1.33	2.06
342	22B	34.0	34.1	27-NOV-06	1	1.49	1.74	1.17	1.37	1.36	0.99	1.17	1.53	1.31	1.11	1.48
343	22B	34.1	34.2	27-NOV-06	1	1.36	1.46	1.07	1.14	1.19	1.04	1.12	1.26	1.14	1.01	1.28
344	22B	34.2	34.3	27-NOV-06	1	1.77	1.74	0.98	1.58	1.87	1.18	1.44	1.44	1.00	1.47	1.29
345	22B	34.3	34.4	27-NOV-06	1	1.94	2.05	1.06	1.96	2.17	1.11	1.83	1.88	1.03	1.72	1.77
346	[illegible]	34.4	34.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
347	22B	34.5	34.5	14-APR-00	1	1.38	1.64	1.19	1.33	1.51	1.14	1.54	1.62	1.05	1.16	1.18
348	22B	34.5	34.6	14-APR-00	1	1.84	1.53	0.83	2.33	2.08	0.89	1.16	1.35	1.17	1.34	1.59
349	22B	34.6	34.7	14-APR-00	1	2.84	2.43	0.86	2.91	2.64	0.91	1.97	1.96	0.99	2.41	2.35
350	22B	34.7	34.8	14-APR-00	1	2.97	3.05	1.03	2.82	2.81	1.00	2.91	2.73	0.94	2.57	2.96
351	22B	34.8	34.9	14-APR-00	1	2.81	3.12	1.11	2.74	2.84	1.04	2.76	3.37	1.22	2.40	3.02
352	22B	34.9	35.0	14-APR-00	1	2.88	3.15	1.09	2.72	3.05	1.12	2.66	3.44	1.29	2.38	3.02
353	22B	35.0	35.1	14-APR-00	1	3.15	3.25	1.03	2.70	3.14	1.16	2.84	3.52	1.24	2.56	3.07
354	22B	35.1	35.2	14-APR-00	1	3.05	3.30	1.08	2.57	3.30	1.28	2.81	3.49	1.24	2.48	3.21
355	22B	35.2	35.3	14-APR-00	1	2.72	3.55	1.31	2.50	3.42	1.37	2.70	3.53	1.31	2.32	3.34
356	22B	35.3	35.4	14-APR-00	1	2.67	3.59	1.34	2.74	3.10	1.13	2.46	3.71	1.51	2.17	3.16
357	22B	35.4	35.5	14-APR-00	1	2.80	3.55	1.27	2.69	2.91	1.08	2.36	3.69	1.56	2.37	3.33
358	22B	35.5	35.6	14-APR-00	1	2.92	3.47	1.19	2.53	2.97	1.17	2.67	3.72	1.39	2.23	3.19
359	22B	35.6	35.7	14-APR-00	1	2.81	3.19	1.14	2.27	2.66	1.17	2.70	3.31	1.23	2.31	2.47
360	22B	35.7	35.8	14-APR-00	1	2.41	2.96	1.23	2.02	2.45	1.21	2.43	2.65	1.09	1.86	2.17
361	22B	35.8	35.9	14-APR-00	1	2.15	2.98	1.39	1.74	2.71	1.56	2.10	2.55	1.21	1.85	2.13
362	22B	35.9	36.0	14-APR-00	1	1.95	2.93	1.50	1.21	2.90	2.40	2.06	2.87	1.39	1.61	2.64
363	22B	36.0	36.1	14-APR-00	1	1.61	2.99	1.86	1.64	2.90	1.77	1.63	2.97	1.82	0.90	2.40
364	22B	36.1	36.2	14-APR-00	1	2.06	3.12	1.51	2.19	2.79	1.27	1.64	2.68	1.63	1.64	2.79
365	22B	36.2	36.3	14-APR-00	1	2.31	2.97	1.29	1.83	2.55	1.39	2.27	2.79	1.23	1.96	2.53
366	22B	36.3	36.4	14-APR-00	1	2.11	2.85	1.26	1.82	2.46	1.35	2.00	2.51	1.26	1.23	2.15
367	22B	36.4	36.5	14-APR-00	1	2.12	2.75	1.30	2.05	2.38	1.16	1.65	2.22	1.36	1.65	2.21
368	22B	36.5	36.6	14-APR-00	1	2.12	2.88	1.36	2.06	2.28	1.10	1.91	2.39	1.25	1.74	2.37
369	22B	36.6	36.7	14-APR-00	1	2.32	2.83	1.22	2.14	2.47	1.15	1.97	2.52	1.28	1.93	2.38
370	22B	36.7	36.8	14-APR-00	1	2.03	2.89	1.42	1.89	2.62	1.33	2.12	2.48	1.18	1.71	2.40
371	22B	36.8	36.9	14-APR-00	1	1.90	2.76	1.45	2.00	2.21	1.11	1.76	2.34	1.38	0.89	1.67

Figure 4.5.4 Excel Spreadsheet with unsuitable chainages highlighted so as to exclude them from the pool of potential comparison sections.

The road was then broken up into five kilometre sections for graphical analysis, which enabled the remaining annual data values to be more easily studied. During this analysis the surface texture depth in the outer wheel path (OWP) was studied to determine areas where there was minimal disruption from prior works, and the surface macro-texture exhibited a progressive annual decline. This declining trend is characteristic of a stable pavement experiencing significant traffic stress over time.

It was quite difficult to obtain an adequate pool of suitable road sections due to the amount of pavement repairs undertaken on the road since the last reseal. Many sections of the road had a seal age of over 8 years and were coming towards the end of their useful life. The areas that were unsuitable for analysis generally contained wide spread repairs that had significantly altered the surface macro-texture and prevented a meaningful analysis from being undertaken. These repairs in most cases were not related to a loss of surface macro-texture, but were performed due to unacceptable rutting or shoving of the pavement layers, particularly in the outer wheel paths. An example of a section of pavement with an unsuitable surface texture history is shown in **Figure 4.5.5**.

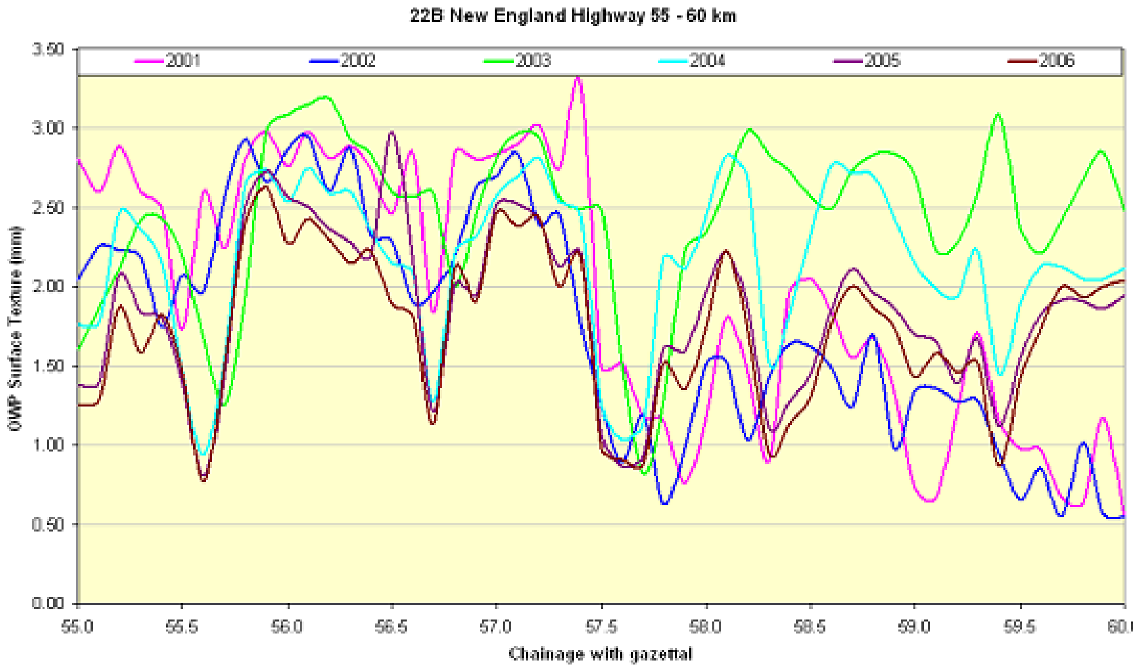


Figure 4.5.5 An unsuitable section of road for data analysis.

The data from the OWP shown in **Figure 4.5.5** is unsuitable for analysis due to the inconsistent nature of the data distribution. There is no progressive annual decline in the surface macro-texture. Instead, the data values fluctuate erratically providing no meaningful data to work with. The OWP surface macro-texture data shown in **Figure 4.5.6** is much more suitable and meets the established criteria.

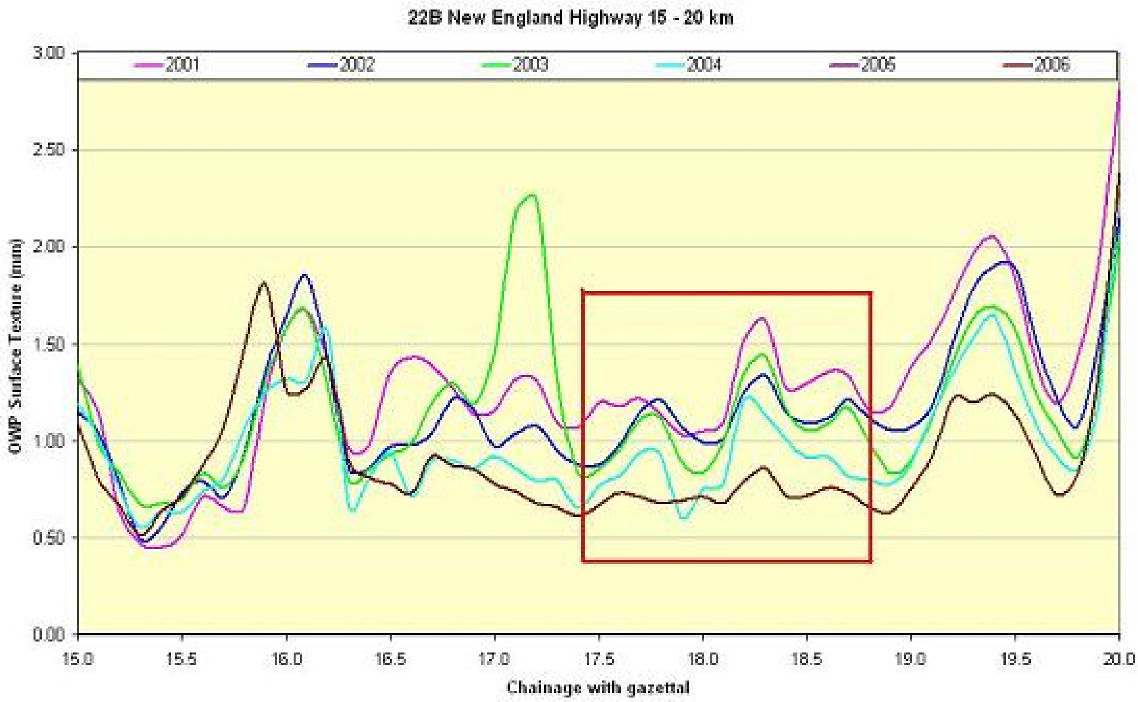


Figure 4.5.6 A section with suitable characteristics is identified by the red box.

Figure 4.5.6 shows a pavement that was resealed in 1999 with the Roadtek TVSR sprayer. The pavement section highlighted by the red box has been chosen for it's progressive reduction in annual surface macro-texture. This consistent reduction in surface macro-texture gives improved confidence that the pavement is not subject to other factors which might distort or influence the results of the analysis.

Once the OWP data has been used to isolate suitable sections, the ratio of the surface macro-texture between the wheel-paths (BWP) and in the OWP are compared using *Equation 3*, as detailed in **Chapter 4.1** of the methodology.

Surface Texture Ratio = SPTD_BWP / SPTD_OWP *Equation 3*

The graphical ratio analysis for each individual section provides a plot showing the surface texture ratio for each year since the data has been collected against the relevant chainage, with one being the ideal value as explained in **Chapter 4.1**. An example of this output is shown in **Figure 4.5.7**.

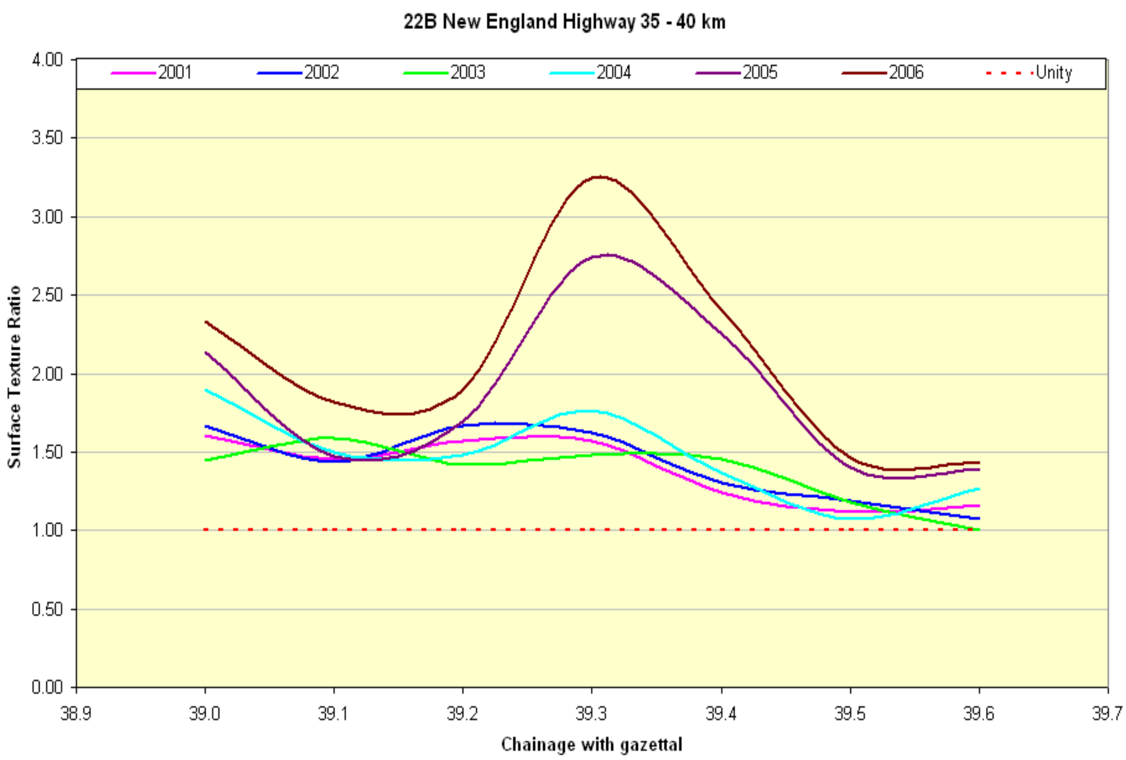


Figure 4.5.7 **Surface Texture Ratio comparison plot 2001 – 2006**
(For chainage 39 – 39.6 km of 22B)

For a single plot this provides a simple and easy to understand format for observing the uniformity of the surface macro-texture across the road surface over time and tracking how the data values increasingly deviate from the ideal value as the seal ages. Unfortunately, it does not lend itself to comparison with similar data from another location while in its present form. If a similar separate data set was overlaid on **Figure 4.5.7**, it would be quite difficult to present the results in an easy to understand format.

To overcome this problem, the data values for each year were then averaged over the chainage of the analysis section to obtain a single representative value for each annual data set. It was then a very simple and straight forward task to present the data for the two carefully chosen locations, so a simple comparison can be made. An example of this presentation technique is shown as **Figure 4.5.8**.

Figure 4.5.8 Average Annual Surface Texture Ratio Comparison

Due to the inherent differences between any two different sections of a road, an exact comparison will be very difficult to achieve, as there are so many factors that contribute to the quality of the road surface. The desire of this study is not to get down to a microscopic level of analysis, but to simply identify trends in the data that indicate whether TVSR technology provides a more uniform surface macro-texture that is achievable using single spray rates. A plot such as **Figure 4.5.8** achieves the goal of identifying the trends in the data and presents them in an easily understood format. This technique can then be repeated with a larger sample to test the outcome.

Chapter 5 COMPARISON SECTIONS & DISCUSSION

5.1 New England Highway (22B) Comparison Sections

Ten suitable sections of the New England Highway (22B) between Toowoomba and Warwick have been carefully identified to meet the established criteria for the comparison analysis. Five of the selected sections have been resealed utilising TVSR treatments and the other five have been resealed utilising single, uniform spray rate treatments.

The 22B section of the New England Highway begins in Toowoomba City at the intersection of the New England and Warrego Highways, and this is where the chainage measurement and through distance (TDist) commence. It terminates at the intersection with the Cunningham Highway at chainage 69.59 kilometres. This is the gazettal direction, or the direction in which measurements related to the longitudinal distance are referenced. New England Highway 22B is shown in **Figure 5.1**.

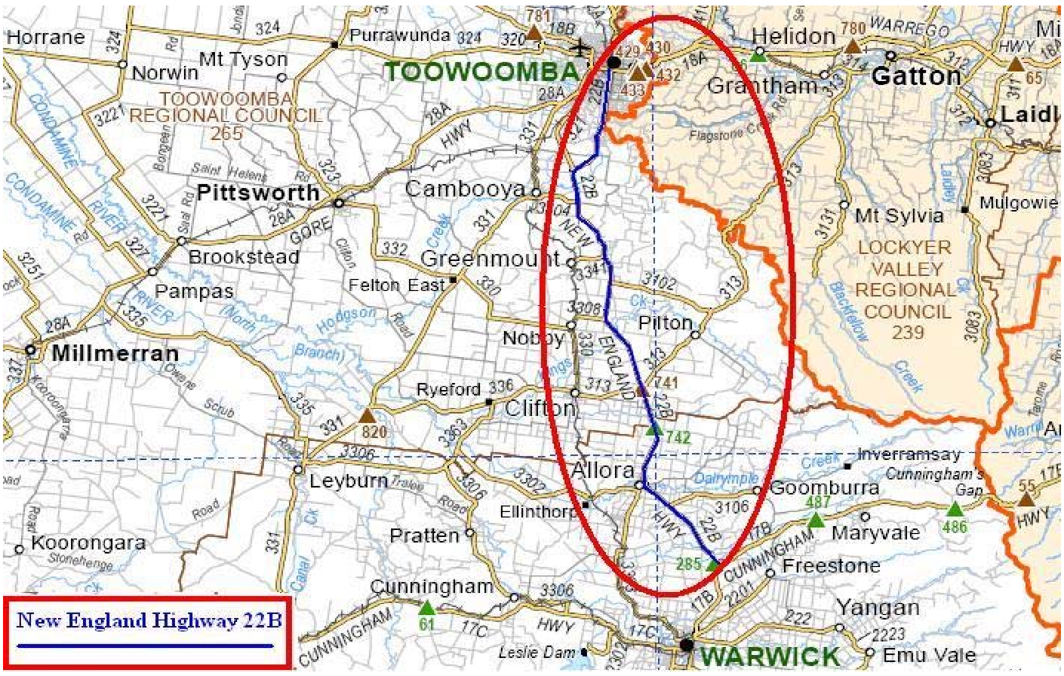


Figure 5.1 **Map of Darling Downs region showing New England Highway 22B (Main Roads, 2008)**

At the commencement of the highway, it is constructed primarily of asphalt until the city limits are reached. By the time the speed environment reaches 100 kilometres an hour, the surfacing has become a sprayed seal and can be scrutinised to determine which sections meet the criteria for analysis.

Selecting sections for comparison in which all parameters were a 100 percent match proved to be impossible due to the many differences in AADT, stone size, seal width, seal type and percentage heavy vehicles along the length of the road, but great care was taken to keep the parameters as close as possible to provide a fair and honest comparison. For convenient comparison between the parameters related to each section, the data for each section is presented in tabular form.

Codes are used to identify the sections during this analysis. For example **Section NE1V** is part of the first comparison section on the New England Highway 22B, and it is the section utilising TVSR (Variable) spray rates. This reference system is shown in **Figure 5.1 (a).**

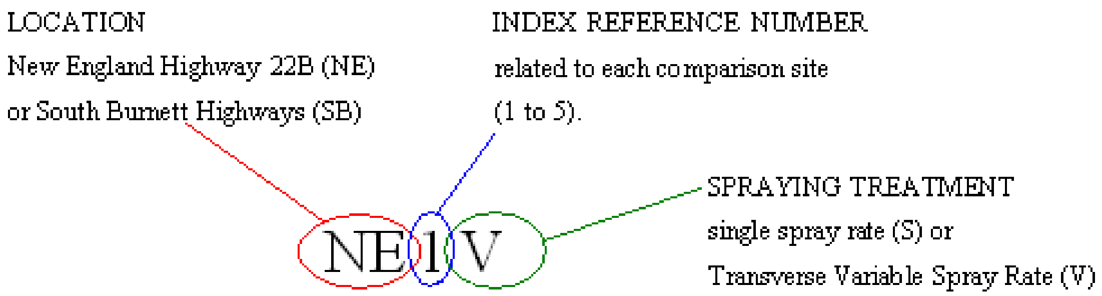


Figure 5.1 (a) Section reference codes for the analysis

For the New England Highway 22B analysis, the Toowoomba District section did not record the surface macro-texture in the 2005 data collection year. Therefore the missing values have been interpolated using the 2004 and 2006 values. The 2007 data has not been released at the time of analysis, so the data values span the years 2001 to 2006 inclusively.

Due to differential maintenance requirements and budgetary and resource constraints, the QDMR rural road network is generally resealed as an ongoing incremental program of work. The nature of this program means that different sections of road are sealed every year in a piecemeal fashion. This system can make it difficult to identify comparable road sections with the same seal age. To overcome this problem, rather than use the calendar year on the x axis of the plots, the seal age is used instead. This allows reseals of different ages to be successfully compared at similar stages of seal life. Unfortunately this can mean that the two data curves do not fully overlap when compared, due to the limited years of data available.

The requirements of the QDMR Standard Specifications related to the supply of cover aggregate, *MRS11.22*, (QDMR, 1999), provide a broad enough Specification that the differences between 10mm & 12mm and 12mm & 14mm cover aggregates can be very small. This is due to the requirements for particle size distribution and the Flakiness Index. Where possible in this analysis, aggregates of the same size have been used for comparison, but where this was not possible the analysis has been limited to aggregates of the next size up or down only.

On a two-lane two-way rural road the seal width identifies the transverse width of sealed pavement between a set of kerbs or between the verge area. The seal width also incorporates any sealed shoulder area. Desirable effective lane widths on these types of road vary between 3.0 and 3.5 metres depending on the situation and the traffic volume (QDMR, 2005). Therefore the seal width is a useful indicator of how much sealed shoulder is provided outside the traffic lanes. On the New England Highway 22B, the road is furnished with edge lines which tend to channelise the traffic to a greater extent than roads of the same width without edge lines, where vehicles are inclined to utilise more of the road and leave less free shoulder.

The AADT is an important measure of traffic volume but for seal fatigue and wear the percentage heavy vehicles (%HV) is the critical component (Ayers, 2005). This behaviour can be modelled using the 4th Power Law, which uses the concept of load equivalence and can be used to determine the equivalent number of cars to create the same pavement damage as is achieved by one heavy vehicle. It can be assumed than it takes approximately 10000 cars to do the same level of damage as one single rear axle Heavy Rigid (HR) truck loaded to about standard maximum allowable axle load (Ayers, 2005).

5.1.1 Comparison Section NE1

The first sections identified for comparison are shown in **Table 5.1.1** and **Figure 5.1.1(a)** and **Figure 5.1.1(b)**.

Table 5.1.1 Comparison Section NE1

Parameters	**Section NE1S**	**Section NE1V**
Road	New England Highway 22B	New England Highway 22B
Spray Technique	Single	Transverse Variable
Chainage (km)	45.2 – 45.8	20.4 – 20.9
AADT (2007)	3411	3239
Heavy Vehicles	127 (3.7%)	391 (12.1%)
Speed (km/h)	100	100
Cover aggregate	14mm	14mm
Seal Width (m)	9	9.1
Seal Age (years)	8.1	9.2
Seal type	K1 - Bitumen spray seal	K2 - PMB spray seal
Seal date	April 2000	April 1999
Job Number	35/22B/802	029/22B/744

Sections NE1S and NE1V share attributes with generally very similar values. Both sections are dressed with 14mm cover aggregate and they share almost identical seal widths and the Annual Average Daily Traffic (AADT) varies by only 5%. The two attributes that differ the most, are the much higher percentage of heavy vehicles experienced on Section NE1V and the use of a polymer modified binder in conjunction with the TVSR on NE1V. NE1V carries over three times the number of heavy vehicles as NE1S.

The sections were resealed within twelve months of each other, providing a good overlap of the data curves in relation to the seal ages.

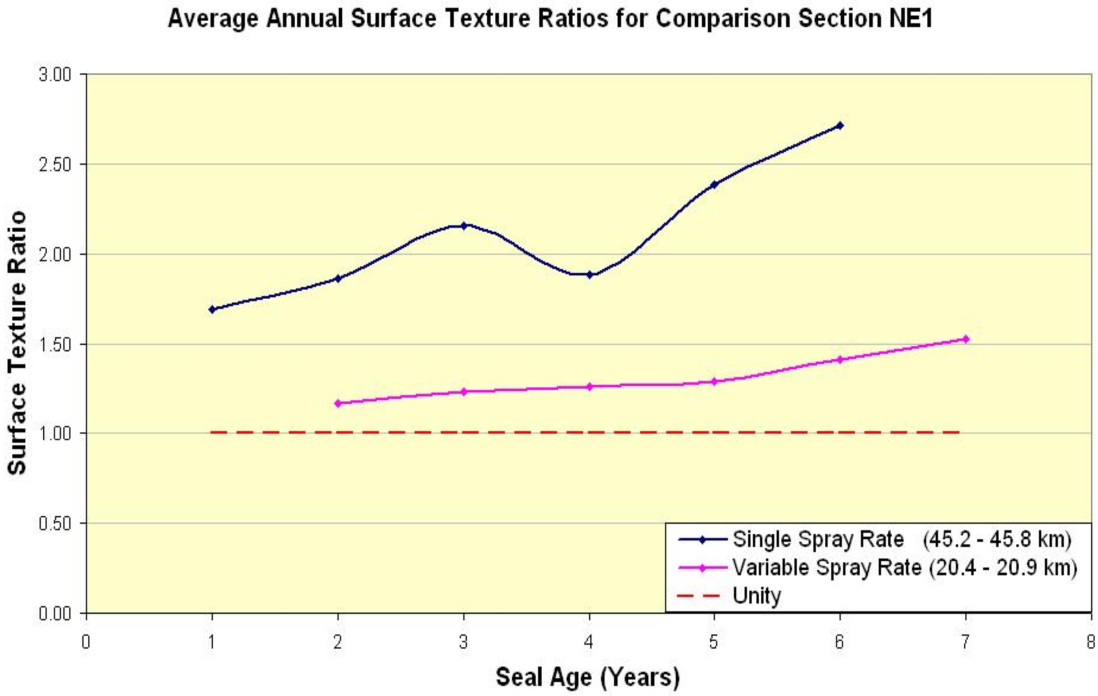


Figure 5.1.1(a) **Average annual surface texture ratio for Comparison Section NE1**

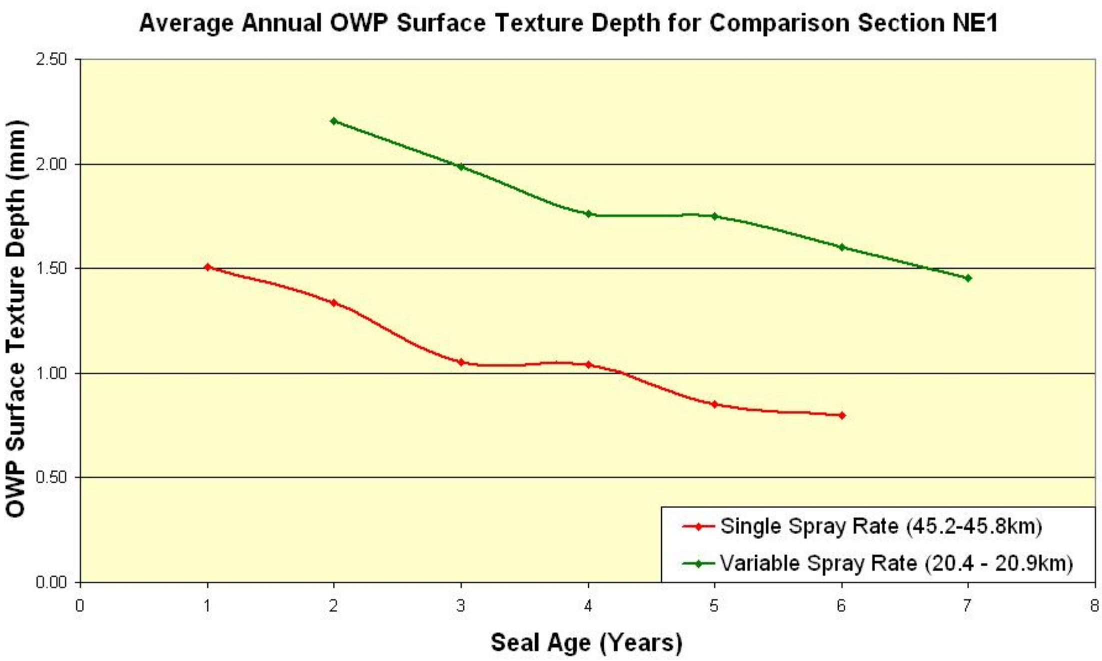


Figure 5.1.1(b) **Average annual surface texture depth (mm) for Comparison Section NE1**

Figure 5.1.1(a) shows that section NE1V exhibits increased transverse surface macro texture uniformity when compared to section NE1S. When both samples are at a seal age of six years, the section treated with transverse variable spray rates, section NE1V, has a surface texture ratio less than 1.5 but at the same age the section treated with single spray rates has a surface texture ratio of greater than 2.7.

Figure 5.1.1(b) shows the actual outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section NE1V has far superior surface macro-texture depth at each comparable seal age. Section NE1V has retained acceptable surface macro-texture depth in the OWP during the complete analysis period. The surface macro-texture depth of Section NE1S has slipped below the recognised minimum acceptable value of one millimetre by the time the seal has reached five years of age.

For the comparison section NE1, it is clear from the data analysis that the section treated with TVSR technology (NE1V) has significantly outperformed the section treated with single spray rates (NE1S) both in regard to surface macro-texture depth and uniformity.

This result has been achieved despite section NE1V carrying over three times the number of heavy vehicles as NE1S.

5.1.2 Comparison Section NE2

The second sections identified for comparison are shown in **Table 5.1.2** and **Figure 5.1.2(a)** and **Figure 5.1.2(b)**.

Table 5.1.2 Comparison Section NE2

Parameters	**Section NE2S**	**Section NE2V**
Road	New England Highway 22B	New England Highway 22B
Spray Technique	Single	Transverse Variable
Chainage (km)	62.8 – 63.4	18.5 – 19.4
AADT (2007)	2871	3239
Heavy Vehicles	422 (14.7%)	392 (12.1%)
Speed (km/h)	100	100
Cover aggregate	14mm	12mm
Seal Width (m)	10.2 – 10.6	11.1
Seal Age (years)	8	9
Seal type	K1 - Bitumen spray seal	K2 – PMB spray seal
Seal date	December 2000	December 1999
Job Number	110/22B/708	029/22B/749

Sections NE2S and NE2V share attributes with generally similar values. Section NE2S is dressed with 14mm cover aggregate and NE2V is dressed with 12mm cover aggregate.

The seal width in section NE2S varies from 10.2 to 10.6 metres during the analysis section and this is slightly narrower than the 11.1m seal width for section NE2V. The AADTs vary by about 11% but the percent heavy vehicles only vary by about 7%, with the larger portion being carried by NE2S. A polymer modified binder has been used in conjunction with the TVSR on NE2V.

The sections were resealed within twelve months of each other, providing a good overlap of the data curves in relation to the seal ages.

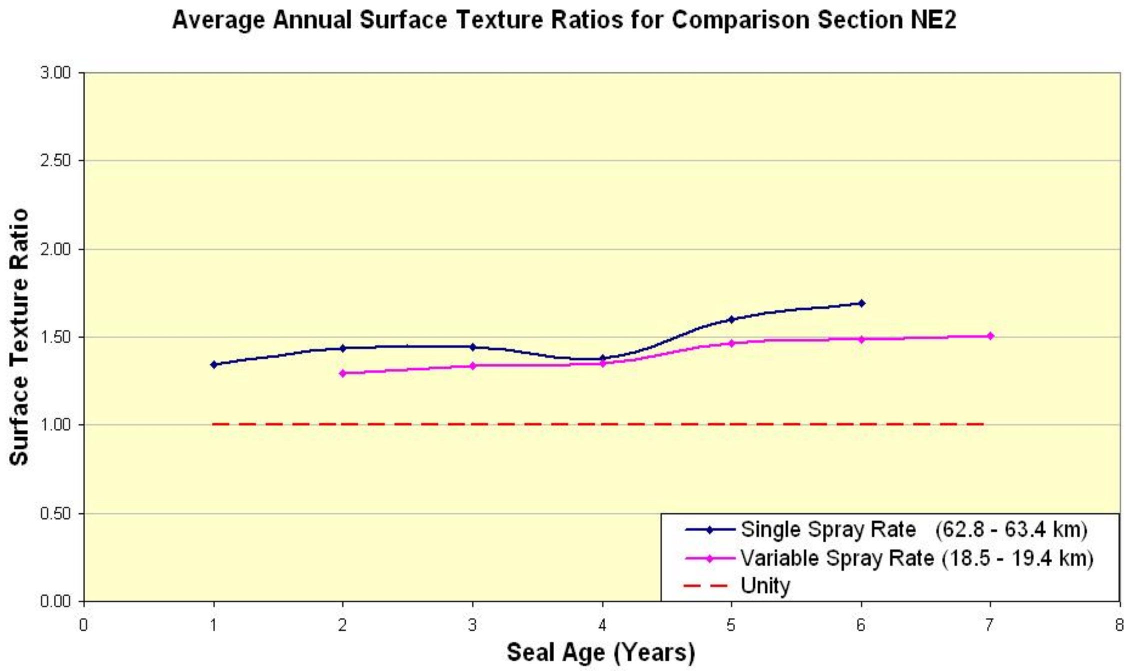


Figure 5.1.2(a) **Average annual surface texture ratio for Comparison Section NE2**

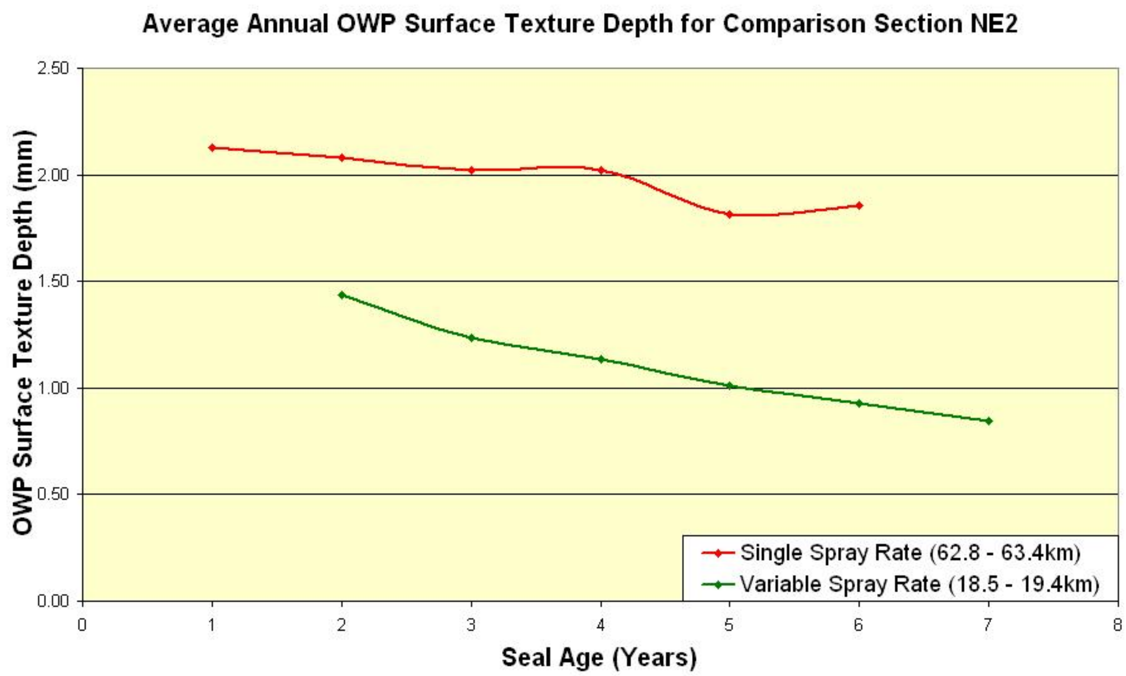


Figure 5.1.2(b) **Average annual surface texture depth (mm) for Comparison Section NE2**

Figure 5.1.2(a) shows that section NE2V exhibits slightly increased transverse surface macro texture uniformity when compared to section NE2S. When both samples are at a seal age of six years, the section treated with transverse variable spray rates (NE2V) has a surface texture ratio of approximately 1.5 but at the same age the section treated with single spray rates (NE2S) has a surface texture ratio of approximately 1.7. These values show that even though NE2V has a slightly increased transverse macro-texture uniformity, there is not a significant difference in uniformity between the sections

Figure 5.1.2(b) shows the actual outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section NE2S has far superior surface macro-texture depth at each comparable seal age. Section NE2S has retained acceptable surface macro-texture depth in the OWP during the complete analysis period. The surface macro-texture depth of Section NE2V has slipped below the recognised minimum acceptable value of one millimetre by the time the seal has reached five years of age.

For the comparison section NE2, the data shows that although section NE2V has superior uniformity, it has a significantly lower OWP surface macro-texture. The increased uniformity but lower OWP texture depth of NE2V means that this section has poor surface macro-texture in both the outer wheel path and between the wheel paths. Discussion with QDMR staff in regard to this particular section indicates that the section is due for full pavement rehabilitation. This may have affected the results for this section.

5.1.3 Comparison Section NE3

The third sections identified for comparison are shown in **Table 5.1.3** and **Figure 5.1.3(a)** and **Figure 5.1.3(b)**.

Table 5.1.3 Comparison Section NE3

Parameters	**Section NE3S**	**Section NE3V**
Road	New England Highway 22B	New England Highway 22B
Spray Technique	Single	Transverse Variable
Chainage (km)	39.0 – 39.6	21.4 – 22.0
AADT (2007)	2811	3239
Heavy Vehicles	416 (14.8%)	392 (12.1%)
Speed (km/h)	100	100
Cover aggregate	14mm	14mm
Seal Width (m)	10.0	9.0
Seal Age (years)	8	9
Seal type	K1 - Bitumen spray seal	K2 – PMB spray seal
Seal date	April 2000	March 1999
Job Number	35/22B/802	029/22B/744

Sections NE3S and NE3V share attributes with generally similar values. Both sections are dressed with 14mm cover aggregate.

The seal widths for the two sections vary by 1m. The AADTs vary by about 13% but the percent heavy vehicles only vary by about 6%, with the larger portion being carried by NE3S. A polymer modified binder has been used in conjunction with the TVSR on NE3V.

The sections were resealed within twelve months of each other, providing a good overlap of the data curves in relation to the seal ages.

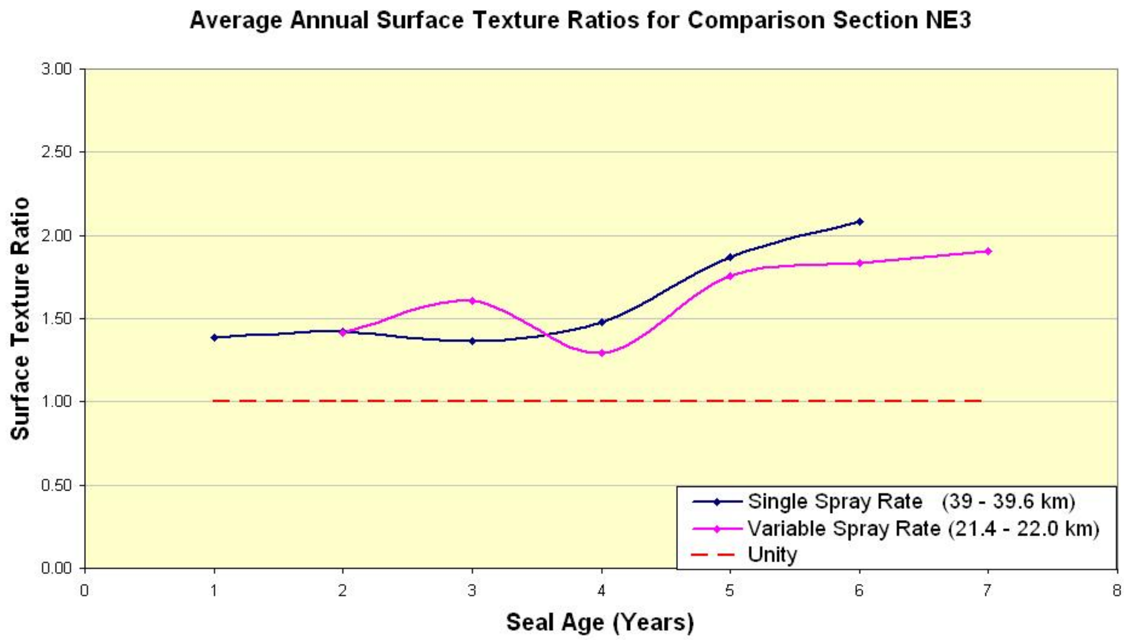


Figure 5.1.3(a) **Average annual surface texture ratio for Comparison Section NE3**

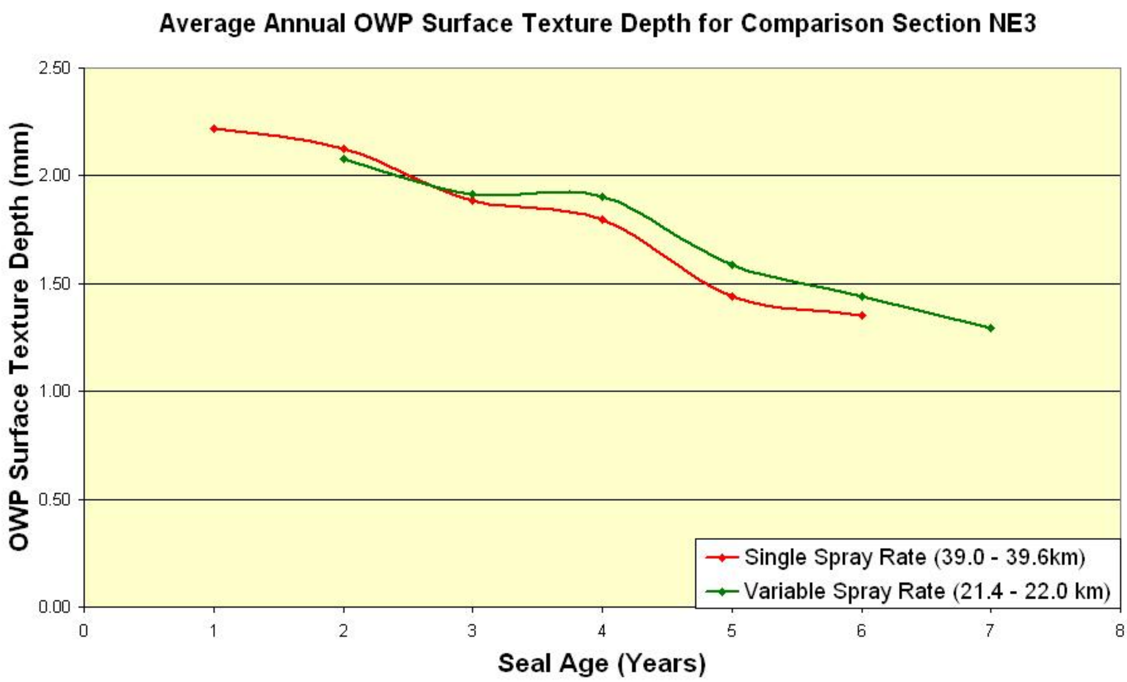


Figure 5.1.3(b) **Average annual surface texture depth (mm) for Comparison Section NE3**

Figure 5.1.3(a) shows that section NE3V exhibits slightly increased transverse surface macro texture uniformity when compared to section NE3S. When both samples are at a seal age of six years, the section treated with transverse variable spray rates (NE3V) has a surface texture ratio of approximately 1.8 but at the same age the section treated with single spray rates has a surface texture ratio of approximately 2.1. It is noted that at three year seal age, section NE3V exhibited inferior surface macro-texture uniformity. This trend does not continue in subsequent years and may be attributable to a data collection error or a localised surface texture defect that was corrected but influenced the results of that years data.

Figure 5.1.3(b) shows the actual outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section NE3V has slightly superior surface macro-texture depth at most comparable seal ages. Both samples have retained acceptable surface macro-texture depth in the OWP during the complete analysis period.

For the comparison section NE3, the data analysis shows that the section treated with TVSR technology (NE3V) has outperformed the section treated with single spray rates (NE3S) both in regard to surface macro-texture depth and uniformity. The differences in values between the samples are not large though, and both sections appear to be performing well above minimum requirements.

5.1.4 Comparison Section NE4

The fourth sections identified for comparison are shown in **Table 5.1.4** and **Figure 5.1.4(a)** and **Figure 5.1.4(b)**.

Table 5.1.4 Comparison Section NE4

Parameters	**Section NE4S**	**Section NE4V**
Road	New England Highway 22B	New England Highway 22B
Spray Technique	Single	Transverse Variable
Chainage (km)	42.6 – 43.1	31.7 – 32.6
AADT (2007)	2811	3239
Heavy Vehicles	416 (14.8%)	392 (12.1%)
Speed (km/h)	100	100
Cover aggregate	14mm	12mm
Seal Width (m)	9.0	9.7
Seal Age (years)	8	9
Seal type	K1 - Bitumen spray seal	K2 – PMB spray seal
Seal date	April 2000	March 1999→ Nov 2006
Job Number	35/22B/802	029/22B/746

Sections NE4S and NE4V share attributes with generally similar values. Section NE4S is dressed with 14mm cover aggregate and NE4V is dressed with 12mm cover aggregate.

The seal widths between the two sections vary by only 70 centimetres and the AADTs vary by about 13% but the percent heavy vehicles only vary by about 6%, with the larger portion being carried by NE4S. A polymer modified binder has been used in conjunction with the TVSR on NE4V.

The sections were resealed within twelve months of each other, providing a good overlap of the data curves in relation to the seal ages.

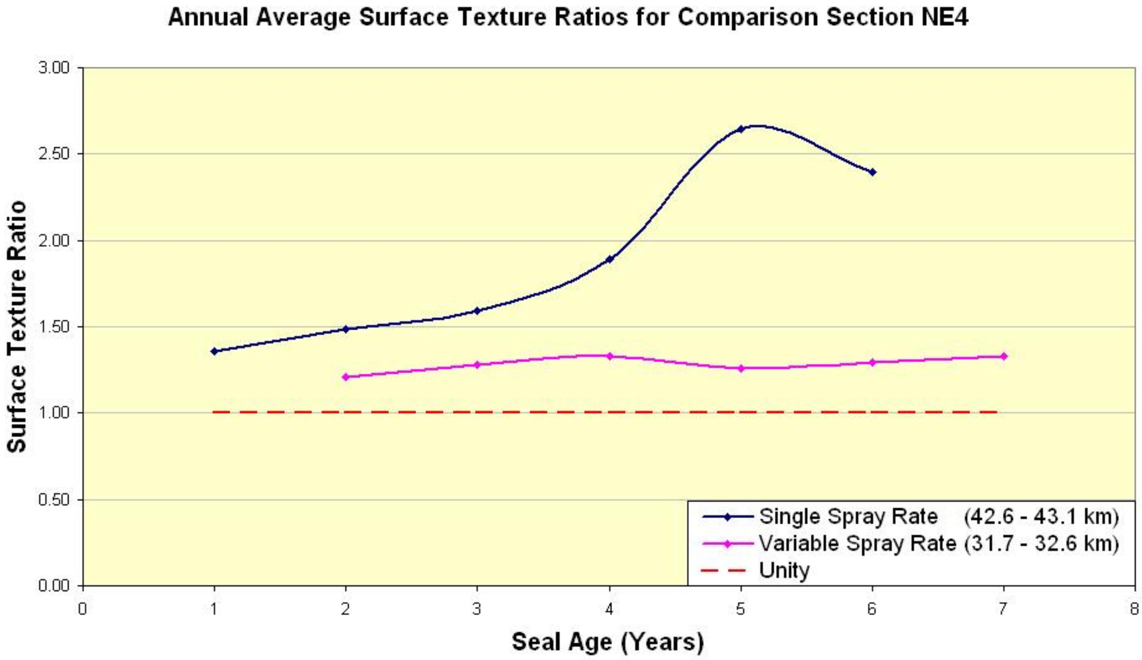


Figure 5.1.4(a) **Average annual surface texture ratio for Comparison Section NE4**

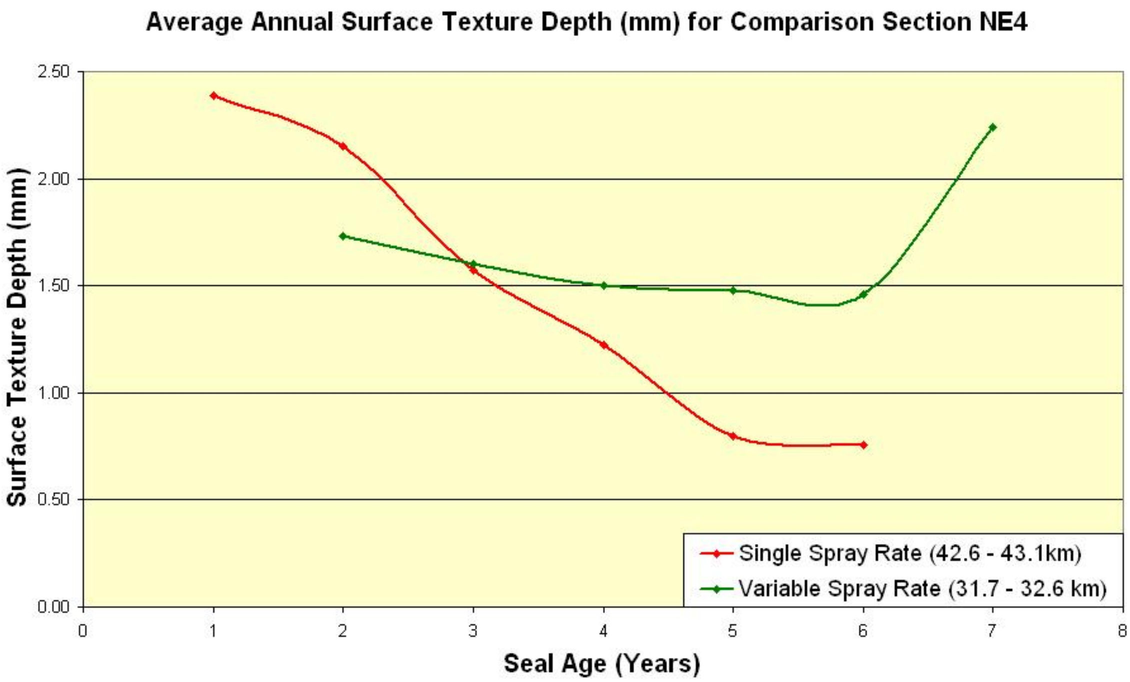


Figure 5.1.4(b) **Average annual surface texture depth (mm) for Comparison Section NE4**

Figure 5.1.4(a) shows that section NE4V exhibits increased transverse surface macro texture uniformity when compared to section NE4S. When both samples are at a seal age of six years, the section treated with transverse variable spray rates (NE4V) has a surface texture ratio of approximately 1.3 but at the same age the section treated with single spray rates has a surface texture ratio of approximately 2.4.

Figure 5.1.4(b) shows the actual outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section NE4V has far superior surface macro-texture depth at most comparable seal ages. Section NE4V has retained acceptable surface macro-texture depth in the OWP during the complete analysis period. The surface macro-texture depth of Section NE4S has slipped below the recognised minimum acceptable value of one millimetre by the time the seal has reached five years of age. Section NE4V was resealed during year six of the seal life and this is evident by the related rise in OWP surface macro-texture. It is also observed that there is not a corresponding alteration to the surface macro-texture ratio shown in **Figure 5.1.4(a)**. Section NE4V exhibits a consistently low surface macro-texture ratio throughout the analysis period.

Figure 5.1.4(b) also shows the surface macro-texture depth in the OWP for section NE4S is deteriorating at a markedly increased rate of change in comparison so section NE4V.

For the comparison section NE4, it is clear from the data analysis that the section treated with TVSR technology (NE4V) has significantly outperformed the section treated with single spray rates (NE4S) both in regard to surface macro-texture depth and uniformity.

5.1.5 Comparison Section NE5

The fifth sections identified for comparison are shown in **Table 5.1.5** and **Figure 5.1.5(a)** and **Figure 5.1.5(b)**.

Table 5.1.5 Comparison Section NE5

Parameters	**Section NE5S**	**Section NE5V**
Road	New England Highway 22B	New England Highway 22B
Spray Technique	Single	Transverse Variable
Chainage (km)	51.1 – 52.0	11.2 – 12.5
AADT (2007)	3411	3558
Heavy Vehicles	126 (3.7%)	221 (6.2%)
Speed (km/h)	100	100
Cover aggregate	14mm	12mm
Seal Width (m)	11.0	9.4
Seal Age (years)	5	13
Seal type	K1 - Bitumen spray seal	K2 – PMB spray seal
Seal date	January 2003	Feb 1995 → Jan 2006
Job Number	110/22B/708	029/22B/740

Sections NE5S and NE5V share attributes with generally similar values. Section NE5S is dressed with 14mm cover aggregate and NE5V is dressed with 12mm cover aggregate. The seal widths between these two sections vary by the greatest amount over the analysis sections with NE5S being 1.6m wider than NE5V. The AADTs vary by only 4% but the percent heavy vehicles vary by about 43%, with the larger portion being carried by NE5V. Both sections are carrying relatively low volumes of heavy vehicle traffic in comparison with other sections of the road. A polymer modified binder has been used in conjunction with the TVSR on NE5V.

This comparison varies from all the previous sections in the seal ages are very different. NE5V was sealed in 1995 and NE5S was only sealed in 2003. Due to the reseal dates and the difference in seal ages, there is limited overlap of the data curves but the trends of the individual data samples can still be clearly observed.

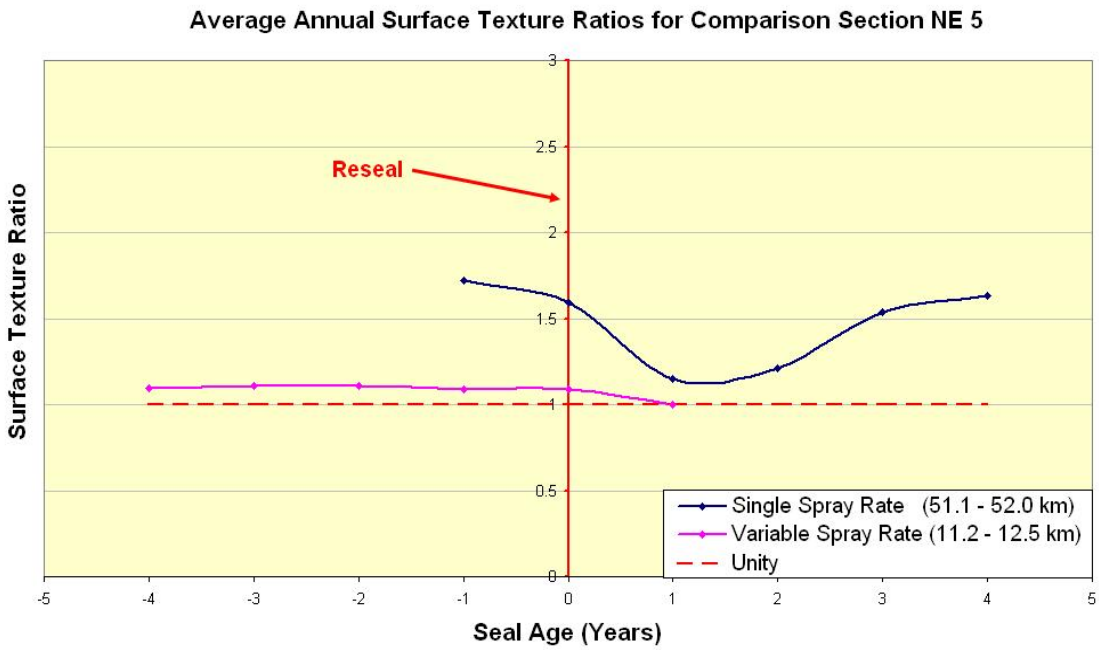


Figure 5.1.5(a) **Average annual surface texture ratio for Comparison ` Section NE5**

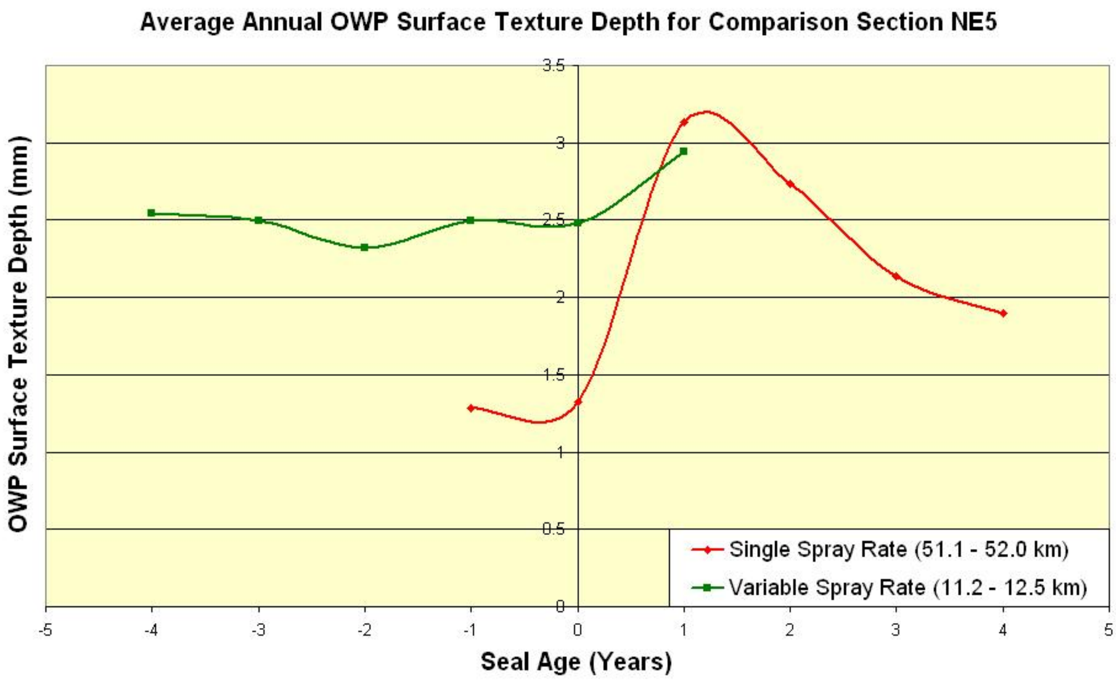


Figure 5.1.5(b) **Average annual surface texture depth (mm) for Comparison ` Section NE5**

Due to a lack of suitable sections meeting the criteria for analysis, Comparison Section NE5 has been displayed in a different layout to the preceding sections with the vertical axis at the point of resealing. This has been necessitated by the vastly different seal ages.

Figure 5.1.5(a) shows that section NE5V exhibits increased transverse surface macro texture uniformity when compared to section NE5S despite the fact the seal was 11 years old at the time of resealing (at the axis). Prior to both sections being resealed, the section treated with transverse variable spray rates (NE5V) had a surface texture ratio of approximately 1.1 but when section NE5S was resealed, it had a surface macro-texture ratio of approximately 1.6. Following resealing NE5S had a recorded surface macro-texture ratio of 1.2 but NE5V had reset to approximately the ideal ratio of unity (one).

Figure 5.1.5(b) shows the actual outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section NE5V has superior surface macro-texture depth at most comparable seal ages. Section NE5V has retained acceptable surface macro-texture depth in the OWP during the complete analysis period, despite the seal age being 11 years at resealing. The surface macro-texture depth of Section NE5S has also retained acceptable surface macro-texture depth in the OWP during the complete analysis period and if the current OWP depth trend continues, surface macro-texture of NE5S is projected to remain above one millimetre by the five year seal age. The rate of change related to loss of surface macro-texture depth for Section NE5S appears to be significant, when compared to the relative stability exhibited by Section NE5V prior to resealing. There is insufficient data available to determine if the consistent behaviour of NE5V will continue following the latest reseal.

For the comparison section NE5, it is clear from the data analysis that the section treated with TVSR technology (NE5V) has significantly outperformed the section treated with single spray rates (NE5S) both in regard to consistent surface macro-texture depth and uniformity.

5.2 Discussion of Results for New England Hwy 22B Analysis.

While attempting to undertake an analysis where the spraying techniques provided the primary difference between samples, the processes described in **Chapter 4.5 Investigation Methodology** were used to eliminate sections unsuitable for analysis. A thorough investigation was undertaken to identify suitable sections to include in the comparison analysis, but due to the stringent criteria very few samples were suitable. The identification of the sections used in this comparison analysis resulted from a long and rigorous selection process in which many samples had to be discarded.

Once the sections containing unsuitable geometry had been removed, sections where there was not a progressive annual reduction in surface macro-texture in the outer wheel path were then discarded. Surprisingly few sections remained that met all the criteria. This lead to the inclusion of NE5, which had to be analysed slightly differently but proved a valuable addition as it gave an insight to the behaviour of a TVSR seal at a greater seal age.

All comparison sections analysed during the New England Highway 22B analysis showed improved transverse surface macro-texture uniformity in the sections where transverse variable spray rates (TVSR) were utilised. These comparisons were made more meaningful by comparing the ratio values at the same seal age. These results are presented graphically as **Figure 5.2.1**.

Four of the five comparison sections also showed consistently greater surface macro-texture depth in the OWP, which when evaluated in conjunction with the ratio analysis results, indicated a generally deeper and more uniform transverse surface macro-texture is achievable by using TVSR treatments. The remaining section was located between the Drayton Connection Road and the Cambooya turn-off. This section is due for a full rehabilitation, which may have influenced the results. The surface macro-texture depth results for New England Highway 22B are presented graphically as **Figure 5.2.2**.

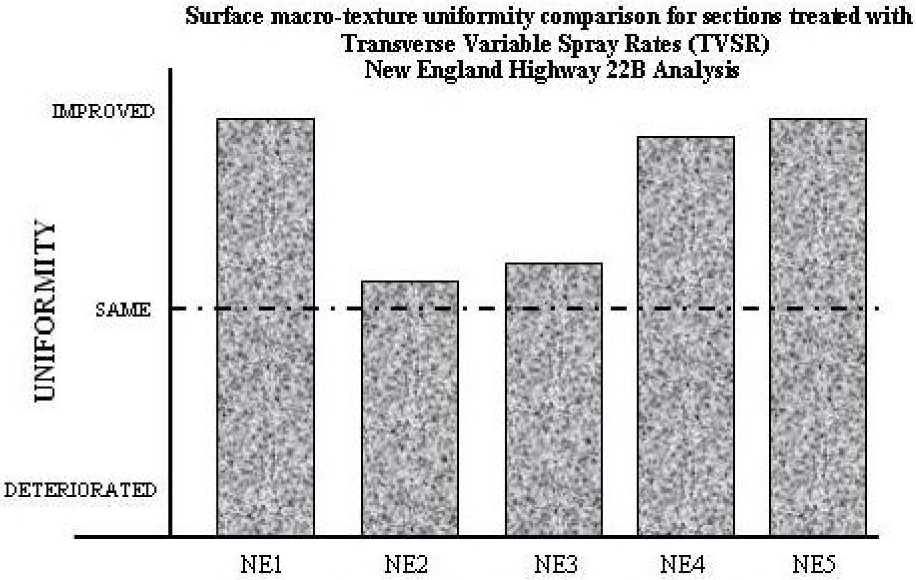


Figure 5.2.1 New England Highway 22B Analysis

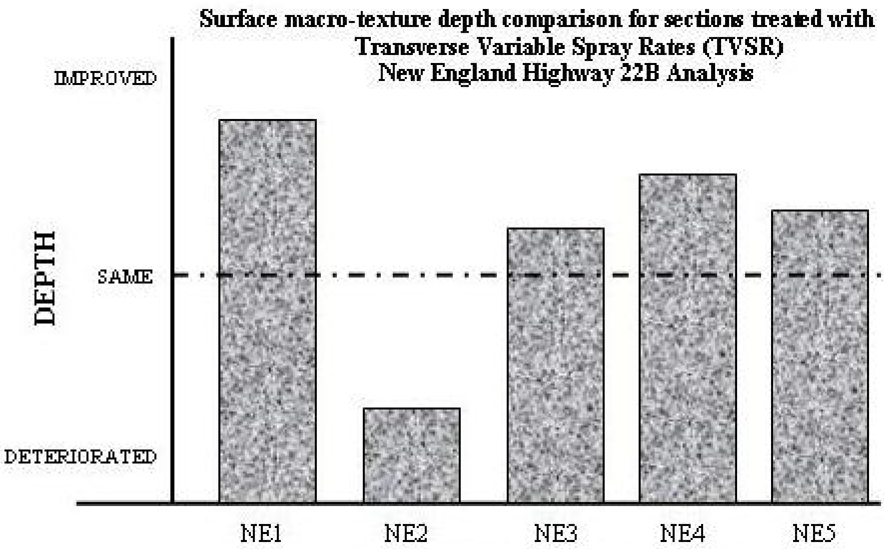


Figure 5.2.2 New England Highway 22B Analysis

The results also do not indicate that the surface texture ratio is influenced significantly by the size of the cover aggregate but the results do indicate that the surface macro-texture depth in the OWP is influenced by the cover aggregate size, but this is a well understood phenomenon. Another influencing factor on the results may be the use of polymer modified binders in conjunction with the transverse variable spray rates. Polymer modified binders (PMB) by design provide a more durable and resilient binder for holding the aggregate chips in position than is achievable using a plain Class 170 bituminous binder. The use of PMBs may have contributed to some extent to the superior results achieved on the TVSR sections.

5.3 South Burnett Highways Comparison Sections

The South Burnett region covers the area from the Blackbutt Range through to the borders of Kilkivan Shire near Gympie. Major towns of the South Burnett are Kingaroy, Murgon, Wondai, Nanango, Yarraman, Blackbutt, Goomeri and Kilkivan. These areas are linked by a network of highways including the Bunya Highway 45A & 45B, D'Aguilar Highway 40B & 40C, Burnett Highway 41A & 41B, Wide Bay Highway 44A and the New England Highway 22A.

In 1998 and 1999 the condition of some of the Highways of the South Burnett was judged to be inadequate and the Enhanced Road Condition Project (ERCP) was undertaken. During this project the majority of highways 40C, 41A, 41B, 44A, 45A and 45B were resealed. The reseal work was undertaken by Boral Limited and single uniform bitumen spray rates were used across the transverse width for the entire project.

The ERCP made this region very attractive to use for the next stage of the analysis due to the large quantity of pavement that had been treated with single spray rates. On the previous New England Highway 22B analysis there had been difficulty locating suitable sections of road that had been sealed with single spray rates but in the South Burnett there were no such difficulties.

The comparison sections for the analysis that have been treated with transverse variable spray rates (TVSR) would be selected from the D'Aguilar Highway 40B and the New England Highway 22A.

After investigating the records and the data sheets for adequate information and researching the roads using the ARMIS Database it was decided to compare D'Aguilar Highway section 40B to D'Aguilar Highway section 40C and Bunya Highway 45A to New England Highway 22A as there were sections of these highways that had comparable AADT and percent heavy vehicles. D'Aguilar Highway 40B and New England Highway 22A had not been included in the ERCP.

The Bunya Highway 45A runs from Dalby to Kingaroy and the New England Highway 22A runs from Yarraman to Toowoomba. The D'Aguilar Highway 40B runs from Kilcoy to Yarraman and the D'Aguilar Highway 40C runs from Yarraman to Kingaroy. To maintain relatively uniform climatic conditions for the comparison, sections of each highway were selected that were all in the same general area. A map of the region with the analysis area shown within the red circle is presented as **Figure 5.3.**

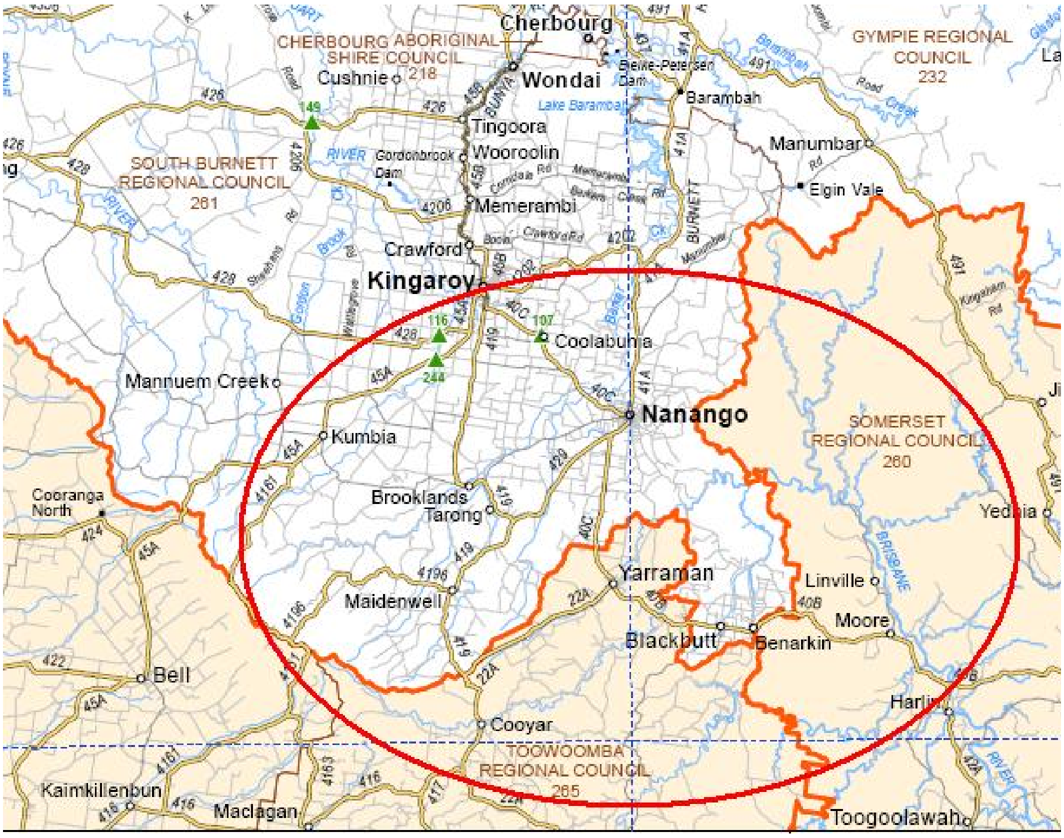


Figure 5.3 Analysis area within the South Burnett region (Main Roads, 2008)

After selecting the analysis area and the highways within the area primarily based on the availability of road sections sealed with single spray rates, the opposite problem to the New England Highway 22B analysis occurred. There were very few suitable jobs sealed with transverse variable spray rates. Due to the Bunya Mountains running through the area, the highways all contained many winding sections and curves. The stringent criteria established at the start of the investigation recognised that curved sections were not suitable for the investigation as tracking around the curves distorted the data values and reduced the integrity of the analysis. This posed a significant problem.

Suitable areas sealed with single spray rates were not an issue, as they were in abundance due to the ERCP, but identifying suitable TVSR areas proved a challenge. Matters were complicated further by the fact that much of the otherwise suitable TVSR data from 40B did not exhibit progressive annual reduction of surface texture in the OWP, which also excluded it from the analysis. Obtaining suitable sections from 40B was crucial, as the AADT was very similar to the subsequent section 40C and would allow comparable analysis.

The other highway in the area which had been treated with transverse variable spray rates was the New England Highway 22A, but the local AADT was too low to provide a comparison to D'Aguilar Highway 40C. To obtain enough suitable data from 40B which fulfilled the other analysis criteria, it was necessary to use data from a reseal completed in May 2004. This provided only three years of data following the reseal. The original criteria required a minimum of five years of data for the analysis but due to the scarcity of suitable data a compromise had to be made in this case.

The New England Highway 22A had a relatively low AADT and the Bunya Highway was chosen as a suitable comparison due to its similar AADT and percentage heavy vehicles.

An important criteria for this analysis was the seal type. As all the TVSR comparison sections used during the comparison of the New England Highway 22B analysis utilised polymer modified binders (PMB), it was crucial to undertake this analysis on samples where the TVSR sections had been sealed using Class 170 bituminous binders for the spray seals. This allowed a comparison of the spraying techniques without the opportunity for any influence from the use of a stronger or more durable type of binder.

During the South Burnett analysis the cover aggregate sizes used during the comparisons consisted of two comparison sections with a 10mm against another 10mm and three comparison sections with a 10mm against a 12mm.

5.3.1 Comparison Section SB1

The first sections identified for comparison are shown in **Table 5.3.1** and **Figure 5.3.1(a)** and **Figure 5.3.1(b)**.

Table 5.3.1 Comparison Section SB1

Parameters	**Section SB1S**	**Section SB1V**
Road	Bunya Highway 45A	New England Highway 22A
Spray Technique	Single	Transverse Variable
Chainage (km)	100.6 – 101.6	14.7 – 16.9
AADT (2007)	894	1181
Heavy Vehicles	169 (18.9%)	168 (14.2%)
Speed (km/h)	100	100
Cover aggregate	10mm	10mm
Seal Width (m)	6.8	7.0
Seal Age (years)	9	5
Seal type	K1 - Bitumen spray seal	K1 - Bitumen spray seal
Seal date	July 1999	October 2003
Job Number	73/45A/721	104/22A/725

Sections SB1S and SB1V share attributes with very similar values. Both sections are dressed with 10mm cover aggregate and the seal widths between the two sections vary by only 20 centimetres.

The AADT varies between the sections by about 24% but the critical percent heavy vehicles only varies by 1 vehicle or half a percent. Both sections utilise Class 170 bituminous binder for the reseals. There is a significant difference between the reseal dates of the two sections with the single spray rate section of Bunya Highway 45A being treated during the ERCP program of 1999 and the TVSR section of New England Highway 22A being treated during the 2003 maintenance season. The difference in seal ages provides a poor overlap of data curves between the two sections.

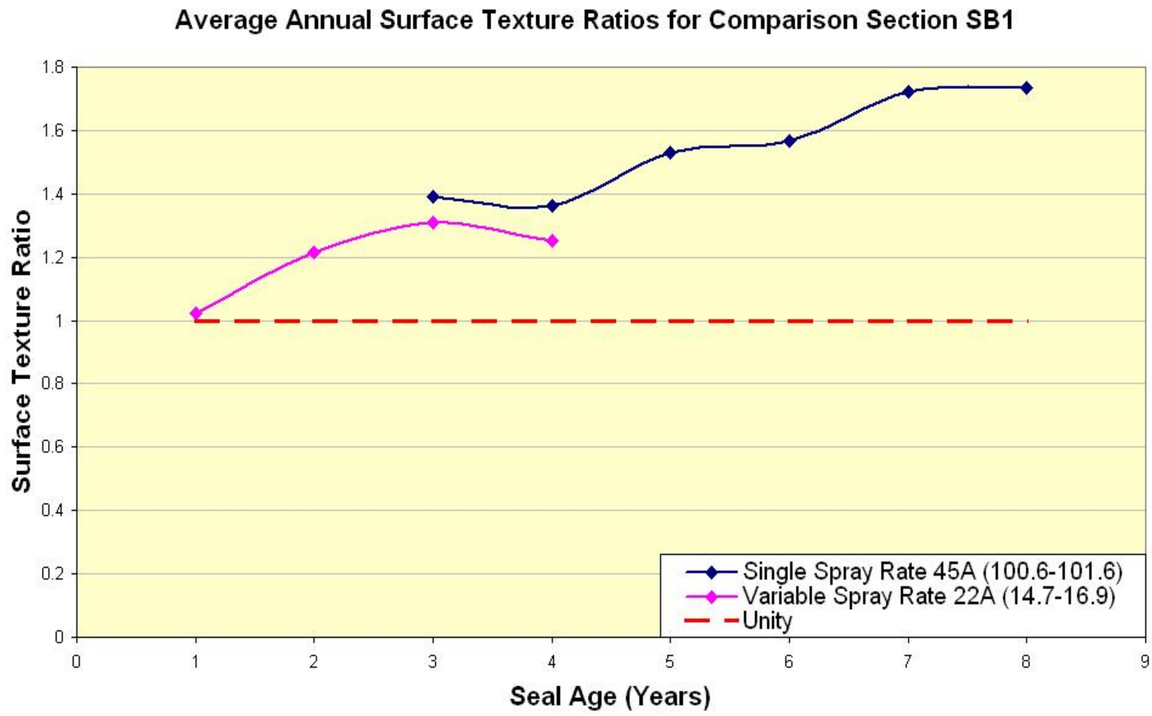


Figure 5.3.1(a) **Average annual surface texture ratio for Comparison Section SB1**

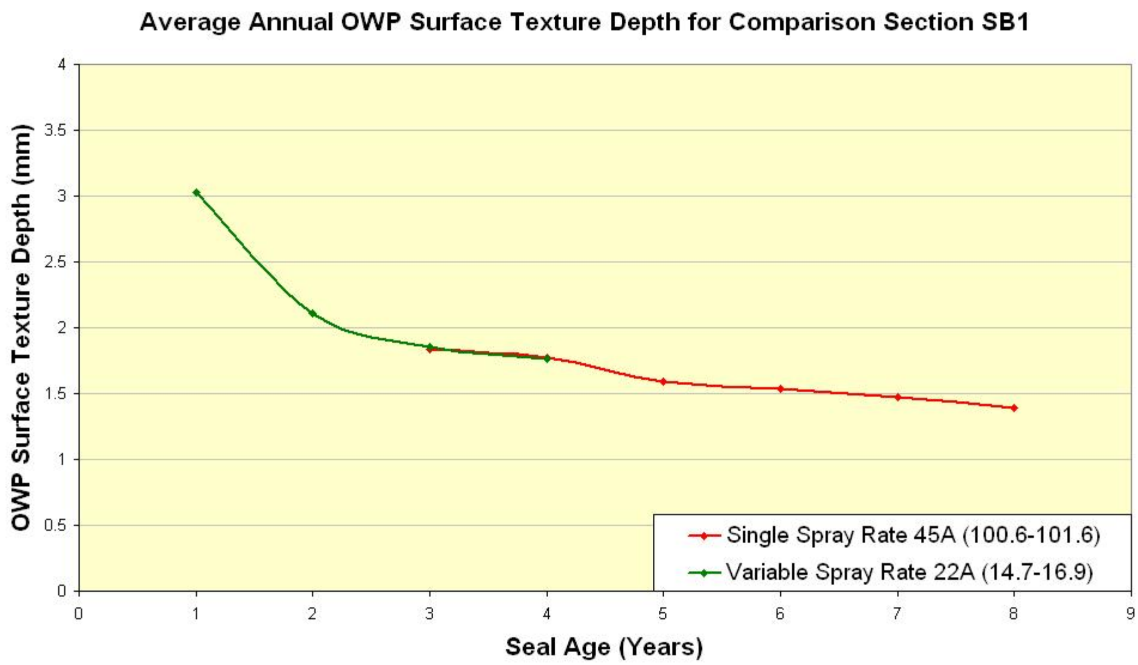


Figure 5.3.1(b) **Average annual surface texture depth (mm) for Comparison Section SB1**

Figure 5.3.1(a) shows that section SB1V exhibits slightly increased transverse surface macro-texture uniformity when compared to section SB1S. Both sections are able to be directly compared between the seal ages of three and four years due to data curve overlap. At these common seal ages, the section treated with transverse variable spray rates (SB1V) has a lower surface texture ratio and therefore a more uniform transverse surface macro-texture.

Figure 5.3.1(b) shows the outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section SB1V appears to directly overlap section SB1S when at the common seal age between three and four years. This means both comparison sections have approximately the same OWP surface macro-texture depth at the common seal age. Both samples have retained acceptable surface macro-texture depth in the OWP during the complete analysis period.

For the comparison section SB1, the data analysis shows that the section treated with TVSR technology (SB1V) has slightly outperformed the section treated with single spray rates (SB1S) in regard to surface macro-texture uniformity and both sections share similar OWP texture depths at comparable seal ages. The differences in data values between the samples are not large, and both sections appear to be performing well above minimum requirements.

5.3.2 Comparison Section SB2

The first sections identified for comparison are shown in **Table 5.3.2** and **Figure 5.3.2(a)** and **Figure 5.3.2(b)**.

Table 5.3.2 Comparison Section SB2

Parameters	Section SB2S	Section SB2V
Road	Bunya Highway 45A	New England Highway 22A
Spray Technique	Single	Transverse Variable
Chainage (km)	100.9 – 103.3	13.2 – 14.6
AADT (2007)	894	1181
Heavy Vehicles	169 (18.9%)	168 (14.2%)
Speed (km/h)	100	100
Cover aggregate	10mm	10mm
Seal Width (m)	6.8	7.0
Seal Age (years)	9	5
Seal type	K1 - Bitumen spray seal	K1 - Bitumen spray seal
Seal date	July 1999	October 2003
Job Number	73/45A/721	104/22A/725

Sections SB2S and SB2V both share attributes with very similar values, and also share the same attributes as the previous SB1 comparison sections. The sections in this SB2 analysis are adjacent to the sections chosen for the SB1 comparison and were part of the same reseal jobs. By analysing these similar adjacent sections it can be shown that the results for SB2 are also similar to the results for SB1. This correlation of results in adjacent sections gives confidence that the data results are not random but are very much the product of the surface texture environment of the sections in question.

Both comparison sections of SB2 utilise Class 170 bituminous binder. There is a significant difference in reseal dates between the two sections with the single spray rate section of 45A being treated during the ERCP program of 1999 and the TVSR section of 22A being treated during the 2003 maintenance season. The difference in seal ages provides a poor overlap of data curves between the two sections.

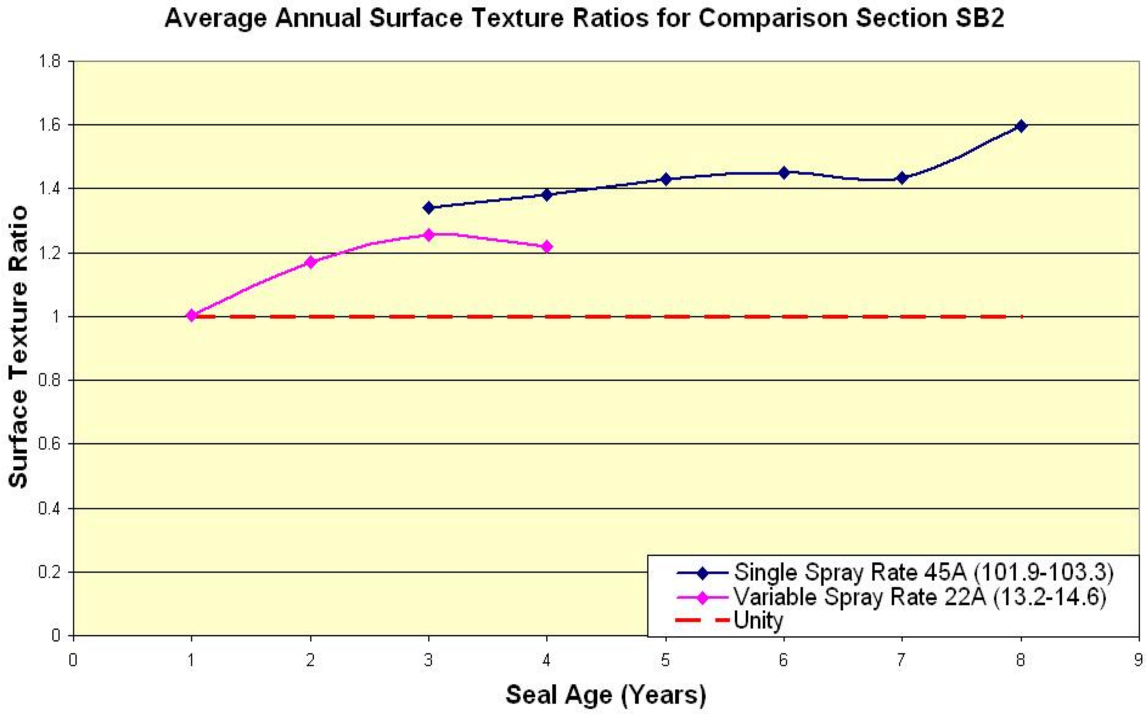


Figure 5.3.2(a) Average annual surface texture ratio for Comparison Section SB2

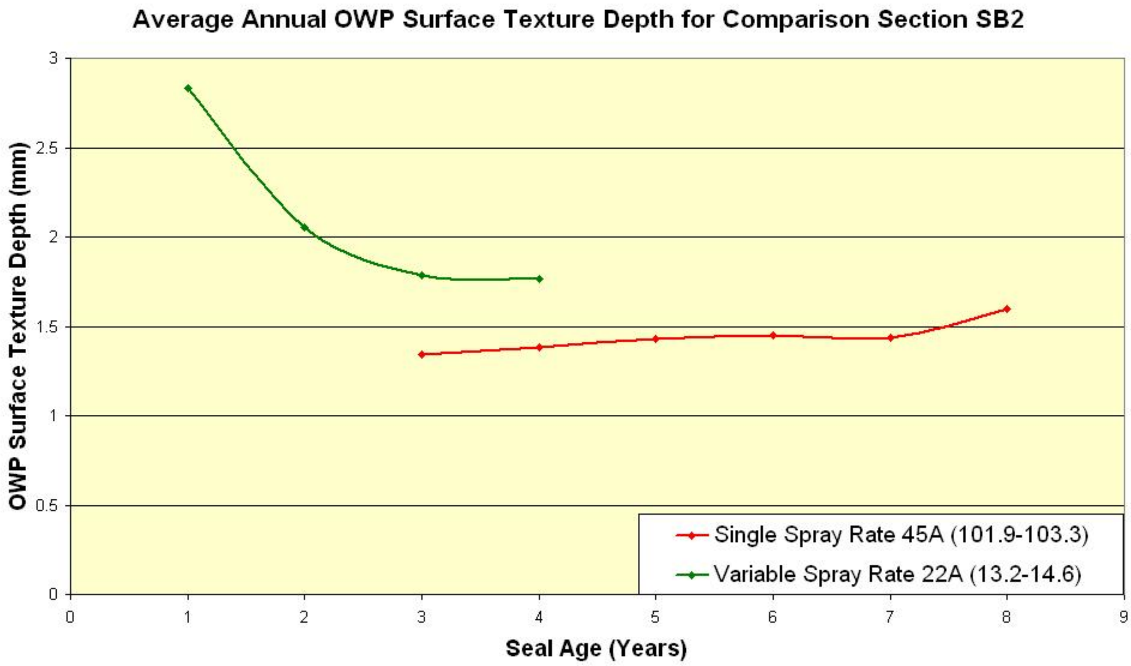


Figure 5.3.2(b) Average annual surface texture depth (mm) for Comparison Section SB2

Figure 5.3.2(a) shows that section SB2V exhibits slightly increased transverse surface macro-texture uniformity when compared to section SB2S. Both sections are able to be directly compared between the seal ages of three and four years due to data curve overlap. At these common seal ages, the section treated with transverse variable spray rates (SB2V) has a lower surface texture ratio and therefore a more uniform transverse surface macro-texture.

Figure 5.3.2(b) shows the outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section SB2Vappears exhibits increased surface macro-texture depth to SB2S when compared at the common seal age between three and four years. Both samples have retained acceptable surface macro-texture depth in the OWP during the complete analysis period.

For the comparison section SB2, the data analysis shows that the section treated with TVSR technology (SB2V) has outperformed the section treated with single spray rates (SB2S) in regard to both surface macro-texture uniformity and OWP texture depths at comparable seal ages. The differences in data values between the samples are not large, and both sections appear to be performing well above minimum requirements.

5.3.3 Comparison Section SB3

The first sections identified for comparison are shown in **Table 5.3.3** and **Figure 5.3.3(a)** and **Figure 5.3.3(b)**.

Table 5.3.3 Comparison Section SB3

Parameters	Section SB3S	Section SB3V
Road	D'Aguilar Highway 40C	D'Aguilar Highway 40B
Spray Technique	Single	Transverse Variable
Chainage (km)	33.1 – 34.1	62.6 – 63.1
AADT (2007)	3421	3267
Heavy Vehicles	267 (7.8%)	500 (15.3%)
Speed (km/h)	100	100
Cover aggregate	10mm	12mm
Seal Width (m)	9	6.8 – 10.4
Seal Age (years)	9	8
Seal type	K1 - Bitumen spray seal	K1 - Bitumen spray seal
Seal date	March 1999	November 2000
Job Number	089/40C/717	104/40B/709

Sections SB3S and SB3V share attributes with generally similar values. Section SB3S is dressed with 10mm cover aggregate and SB3V is dressed with 12mm cover aggregate. The seal width in section SB3V varies from 6.8 to 10.4 metres during the analysis section, while SB3S has a seal width of 9.0metres. The AADT values for the current comparison sections are significantly higher that the AADT encountered in SB1 and SB2. In this case the AADT values vary by only about 5% but the number of heavy vehicles carried on SB3V is almost twice the SB3S values.

Even though the AADT is above 3000 in both cases, a Class 170 bitumen binder has been chosen for the reseal. This goes against the policy given in the Southern District Sealing Guidelines (Main Roads, 2004), but the AADT may have risen significantly since the reseals were undertaken (1999-2000). The sections were resealed within twelve months of each other, providing a good overlap of the data curves in relation to the seal ages.

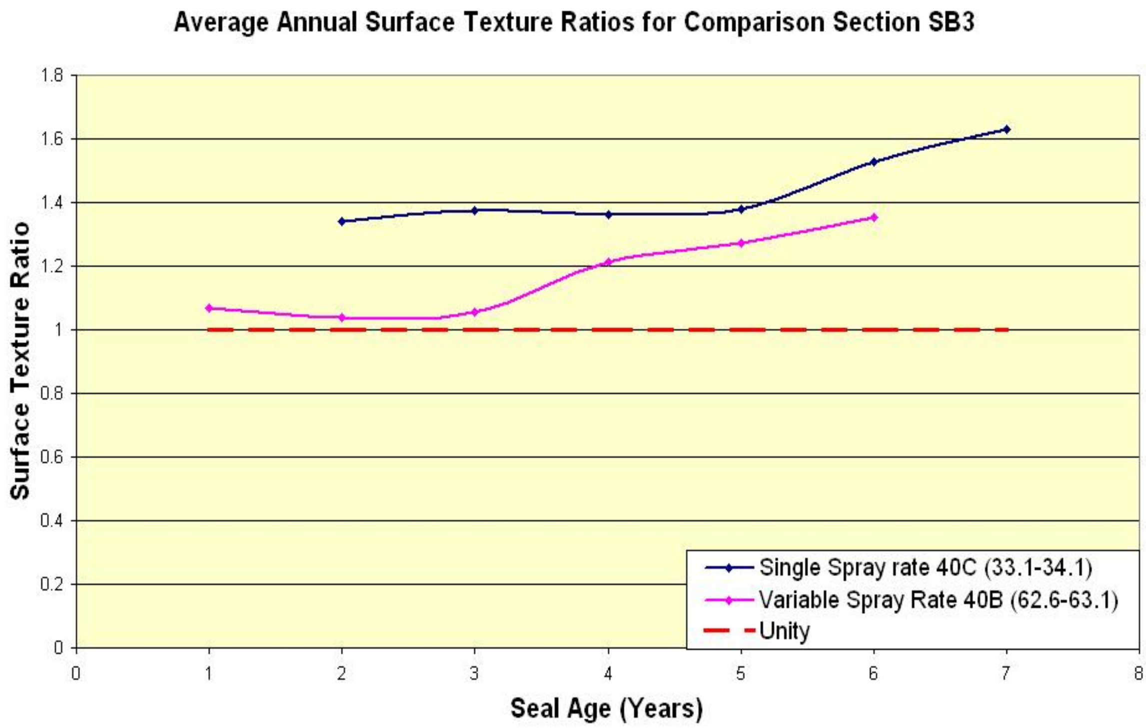


Figure 5.3.3(a) **Average annual surface texture ratio for Comparison Section SB3**

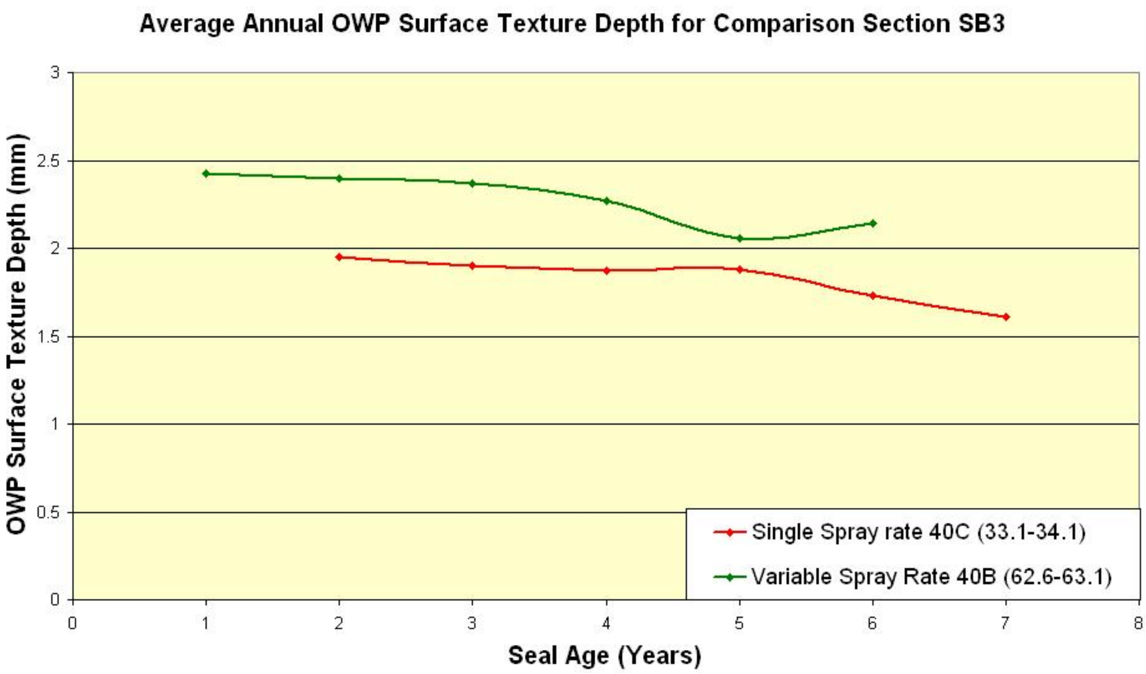


Figure 5.3.3(b) **Average annual surface texture depth (mm) for Comparison Section SB3**

For the South Burnett analysis this was the only comparison section identified where suitable sections had such similar seal ages. Having six years of continuous data for both samples allows trends to be more easily identified than when the data sample only spans three or four years.

Figure 5.3.3(a) shows that section SB3V exhibits increased transverse surface macro-texture uniformity when compared to section SB3S. Both sections are able to be directly compared between the seal ages of two and six years due to improved data curve overlap. At these common seal ages, the section treated with transverse variable spray rates (SB3V) has a lower surface texture ratio and therefore a more uniform transverse surface macro-texture. At a seal age of six years SB3S had a surface texture ratio of approximately 1.53 and SB3V had an approximate surface texture ratio of 1.35.

Figure 5.3.3(b) shows the outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section SB3Vappears exhibits increased surface macro-texture depth to SB3S when compared at the common seal age between two and six years. Both samples have retained acceptable surface macro-texture depth in the OWP during the complete analysis period. At a seal age of six years SB3S had a surface texture depth of approximately 1.73mm and SB3V had an approximate surface texture ratio of 2.14mm.

For the comparison section SB3, the data analysis shows that the section treated with TVSR technology (SB3V) has outperformed the section treated with single spray rates (SB3S) in regard to both surface macro-texture uniformity and OWP texture depths at comparable seal ages despite carrying almost twice the number of heavy vehicles.

5.3.4 Comparison Section SB4

The first sections identified for comparison are shown in **Table 5.3.4** and **Figure 5.3.4(a)** and **Figure 5.3.4(b)**.

Table 5.3.4 Comparison Section SB4

Parameters	**Section SB4S**	**Section SB4V**
Road	D'Aguilar Highway 40C	D'Aguilar Highway 40B
Spray Technique	Single	Transverse Variable
Chainage (km)	29.9 – 30.5	22.0 – 22.5
AADT (2007)	3421	3109
Heavy Vehicles	267 (7.8%)	379 (12.2%)
Speed (km/h)	100	100
Cover aggregate	10mm	12mm
Seal Width (m)	6.8	7.0
Seal Age (years)	9	4
Seal type	K1 - Bitumen spray seal	K1 - Bitumen spray seal
Seal date	March 1999	May 2004
Job Number	089/40C/717	52/40B/723

Sections SB4S and SB4V share attributes with generally similar values. Section SB4S is dressed with 10mm cover aggregate and SB4V is dressed with 12mm cover aggregate. The seal width varies by only 200mm between the two sections and the AADT values vary by only about 9% but there are approximately 30% more heavy vehicles carried on the SB4V section than on SB4S section. Even though the AADT is above 3000 in both cases, a Class 170 bituminous binder has been chosen for the reseal.

This comparison section was chosen for analysis because no other suitable TVSR sections were found in the analysis area that had a greater seal age, and therefore a larger annual series of comparable data values. Section SB4V was resealed in May 2004, therefore only three data points exist for the new reseal. These are the values from 2004 – 2006 inclusively.

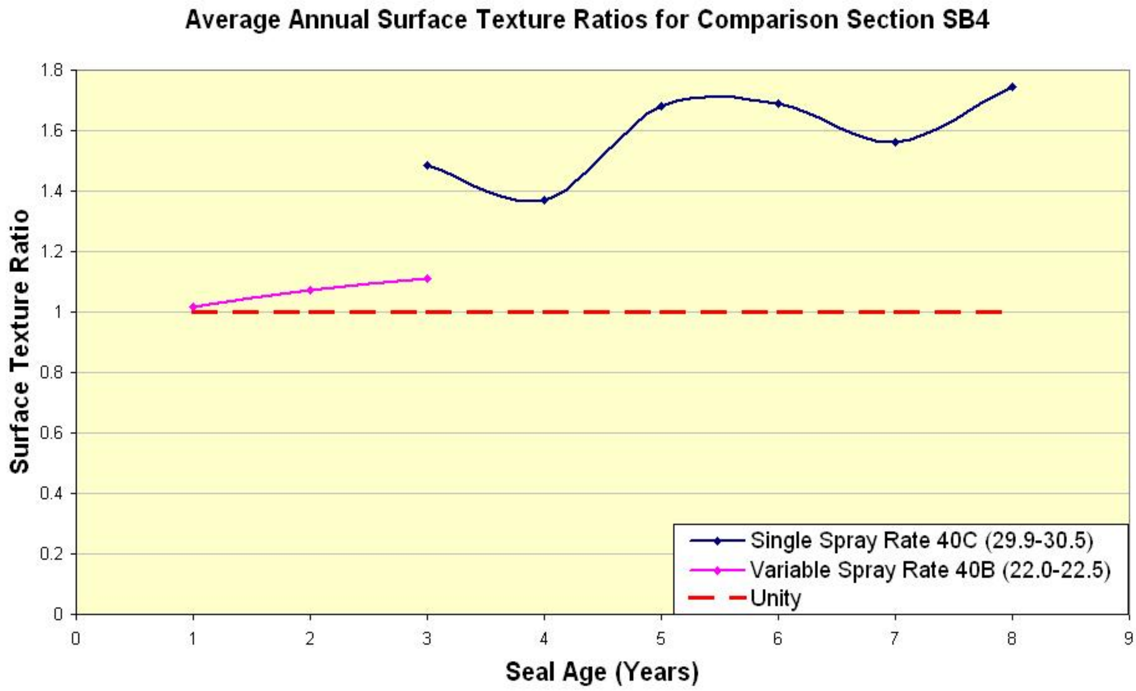


Figure 5.3.4(a) **Average annual surface texture ratio for Comparison Section SB4**

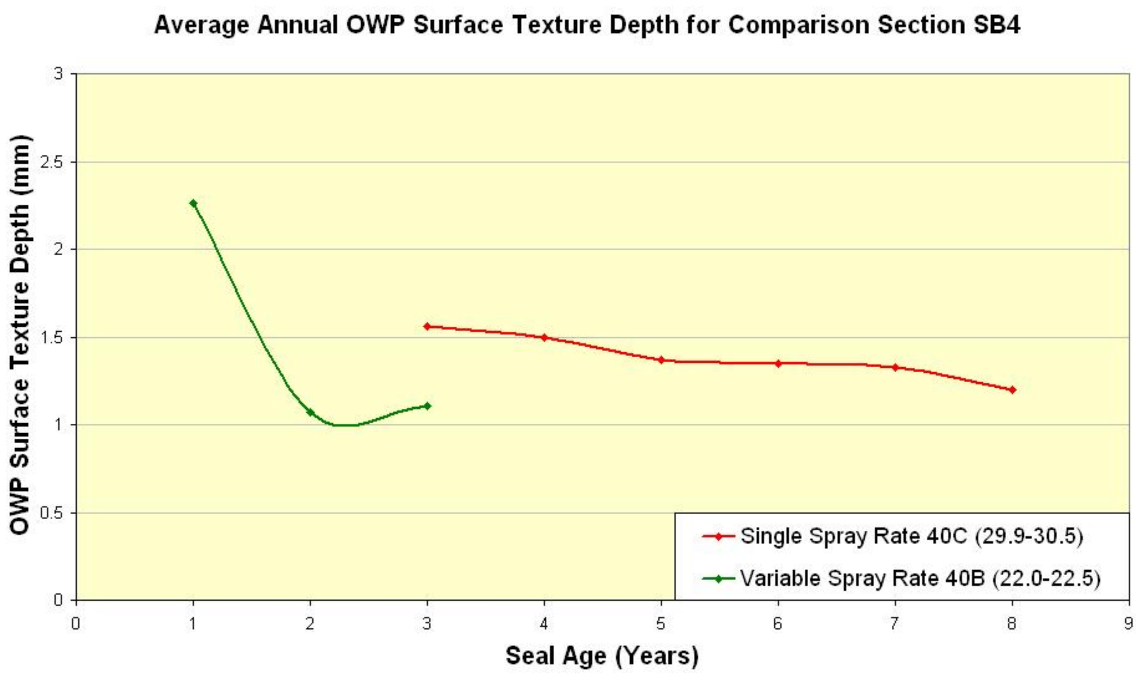


Figure 5.3.4(b) **Average annual surface texture depth (mm) for Comparison Section SB4**

Figure 5.3.4(a) shows that the uniformity of section SB4V begins at close to the ideal theoretical value (one) following the 2004 reseal and in the two subsequent years the uniformity appears to be decreasing at a slow but consistent rate. SB4V exhibits increased transverse surface macro-texture uniformity when compared to section SB4S. Both sections are only able to be directly compared at the seal ages of three years due to the limited data curve overlap. At the common seal age, the section treated with transverse variable spray rates (SB4V) has a significantly lower surface texture ratio and therefore a more uniform transverse surface macro-texture.

Figure 5.3.4(b) shows the outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section SB4Vexhibits a disappointing surface macro-texture depth in the limited available data. The depth is above the minimum acceptable level of one millimetre but is inferior to the surface texture depth recorded by the SB4S section at the same seal age. Both samples have retained acceptable surface macro-texture depth in the OWP during the complete analysis period.

For the comparison section SB4, the data analysis shows that the section treated with TVSR technology (SB4V) has outperformed the section treated with single spray rates (SB4S) in regard to surface macro-texture uniformity but SB4S has out performed SB4V in regard to surface macro-texture depths at comparable seal ages. The significantly higher volume of heavy vehicles on SB4V (approximately 30%) may have been an influencing factor in the comparison. Both sections are performing above the minimum desired values.

5.3.5 Comparison Section SB5

The first sections identified for comparison are shown in **Table 5.3.5** and **Figure 5.3.5(a)** and **Figure 5.3.5(b)**.

Table 5.3.5 Comparison Section SB5

Parameters	**Section SB5S**	**Section SB5V**
Road	D'Aguilar Highway 40C	D'Aguilar Highway 40B
Spray Technique	Single	Transverse Variable
Chainage (km)	37.8 – 38.6	20.0 – 20.5
AADT (2007)	3421	3109
Heavy Vehicles	267 (7.8%)	379 (12.2%)
Speed (km/h)	100	100
Cover aggregate	10mm	12mm
Seal Width (m)	7.4	7.0
Seal Age (years)	9	4
Seal type	K1 - Bitumen spray seal	K1 - Bitumen spray seal
Seal date	March 1999	May 2004
Job Number	073/40C/709	52/40B/723

Sections SB5S and SB5V share attributes with generally similar values. Section SB5S is dressed with 10mm cover aggregate and SB5V is dressed with 12mm cover aggregate.

The seal width varies by only 400mm between the two sections and the AADT values vary by only about 9% but there are approximately 30% more heavy vehicles carried on the SB5V section than on SB5S section. Even though the AADT is above 3000 in both cases, a Class 170 bitumen binder has been chosen for the reseal.
This comparison section was also chosen for analysis because no other suitable TVSR sections were found in the analysis area that had a greater seal age, and therefore a larger annual series of comparable data values. Section SB5V was resealed in May 2004, therefore only three data points exist for the new reseal. These are the values from 2004 – 2006 inclusively.

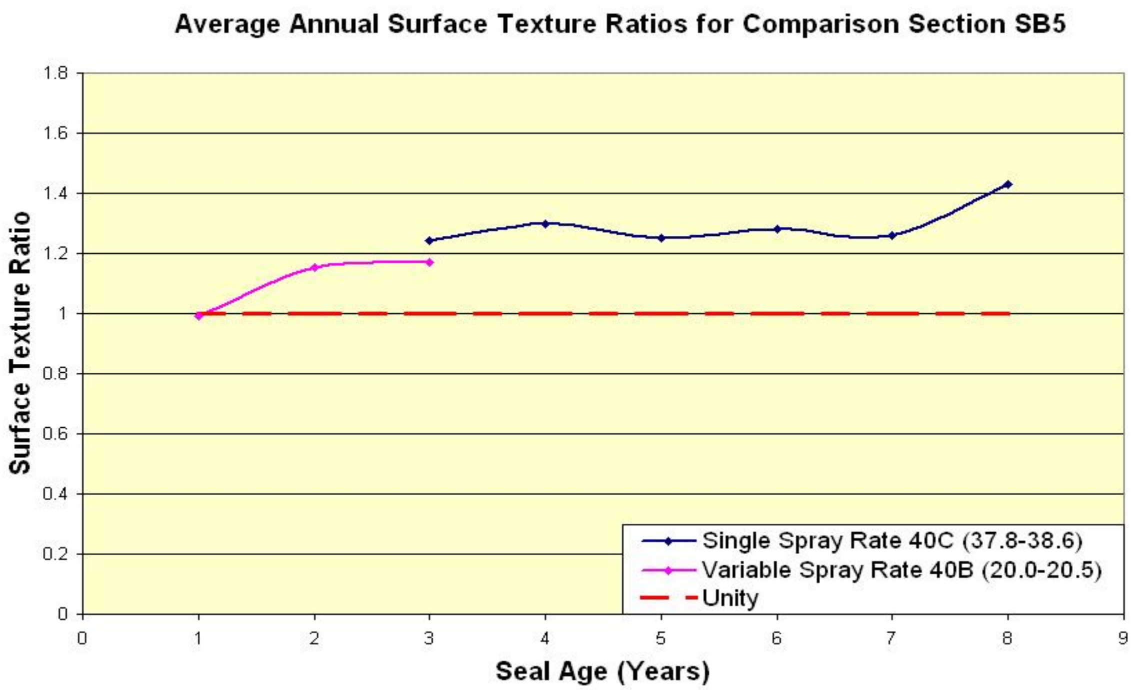


Figure 5.3.5(a) **Average annual surface texture ratio for Comparison Section SB5**

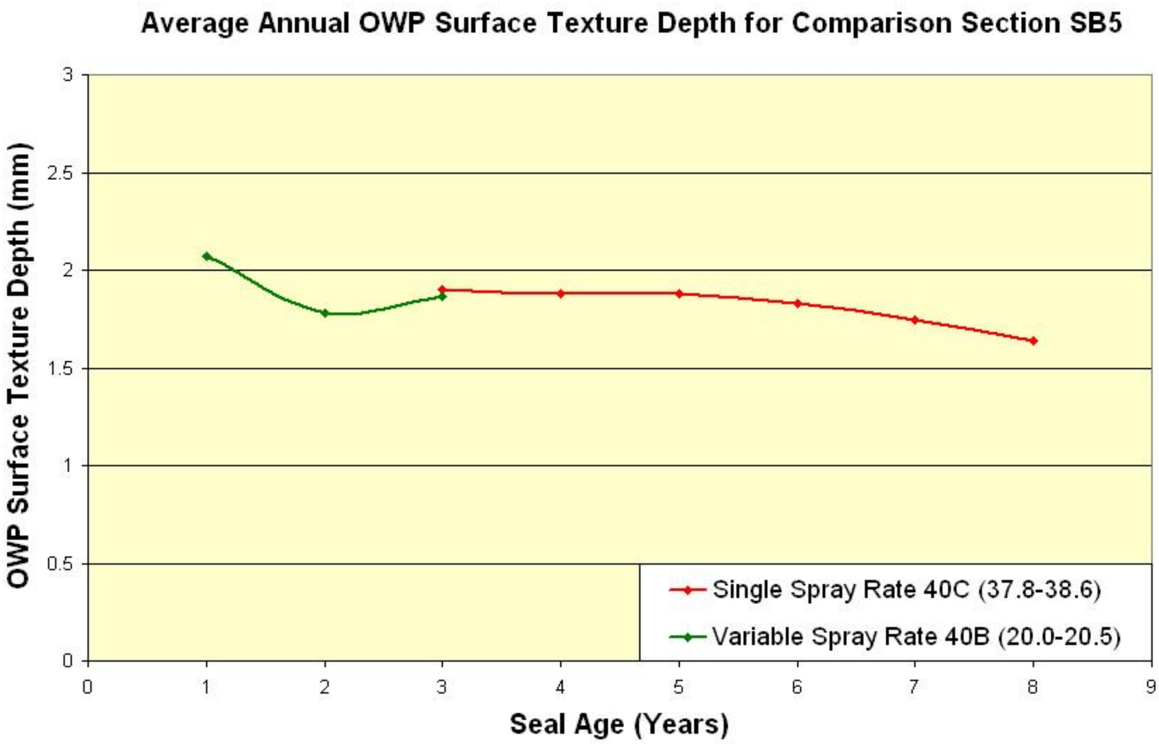


Figure 5.3.5(b) **Average annual surface texture depth (mm) for Comparison Section SB5**

Figure 5.3.5(a) shows that the uniformity of section SB5V begins at close to the ideal theoretical value (one) following the 2004 reseal and in the two subsequent years the uniformity appears to be decreasing at a moderate rate. SB5V exhibits increased transverse surface macro-texture uniformity when compared to section SB5S. Both sections are only able to be directly compared at the seal ages of three years due to the limited data curve overlap. At the common seal age, the section treated with transverse variable spray rates (SB5V) has a lower surface texture ratio and therefore a more uniform transverse surface macro-texture.

Figure 5.3.5(b) shows the outer wheel path (OWP) surface macro-texture depth of the same samples at comparable seal ages. This comparison reveals section SB5Vexhibits very similar surface macro-texture depth to SB5S from the limited data available. Both samples have retained acceptable surface macro-texture depth in the OWP during the complete analysis period.

For the comparison section SB5, the data analysis shows that the section treated with TVSR technology (SB5V) has outperformed the section treated with single spray rates (SB5S) in regard to surface macro-texture uniformity but SB5S and SB5V have very similar OWP surface macro-texture depths at comparable seal ages. The significantly higher volume of heavy vehicles on SB5V (approximately 30%) may have been an influencing factor in the comparison. Both sections are performing above the minimum desired values.

5.4 Discussion of Results for South Burnett Highways Analysis.

All comparison samples analysed during the South Burnett highways analysis showed improved transverse surface macro-texture uniformity for the samples where transverse variable spray rates were utilised. These comparisons were made more meaningful by comparing the ratio values at the same seal ages. These results are presented graphically as **Figure 5.4.1**.

Two of the five South Burnett comparison sections also showed consistently greater surface macro-texture depth in the OWP for sections treated with transverse variable spray rates, one comparison section showed very similar results and the remaining two comparison sections showed poorer surface macro-texture depth for the TVSR sections. These results are presented graphically as **Figure 5.4.2**.

Unlike the New England Highway 22B analysis where polymer modified binders (PMB) were used in conjunction with transverse variable spray rates, the comparison samples in the South Burnett analysis were all treated with Class 170 bituminous binder. The use of Class 170 binder in conjunction with TVSR methods appears to have reduced the effectiveness of the TVSR treatment in maintaining superior surface macro-texture depth in the OWP.

The South Burnett results reveal adequate surface macro-texture depth in all sections that were analysed, but improved surface macro-texture uniformity in the sections where TVSR treatments were utilised. The importance of surface macro-texture uniformity to the long term performance of road sections will be highlighted in the following general discussion of results.

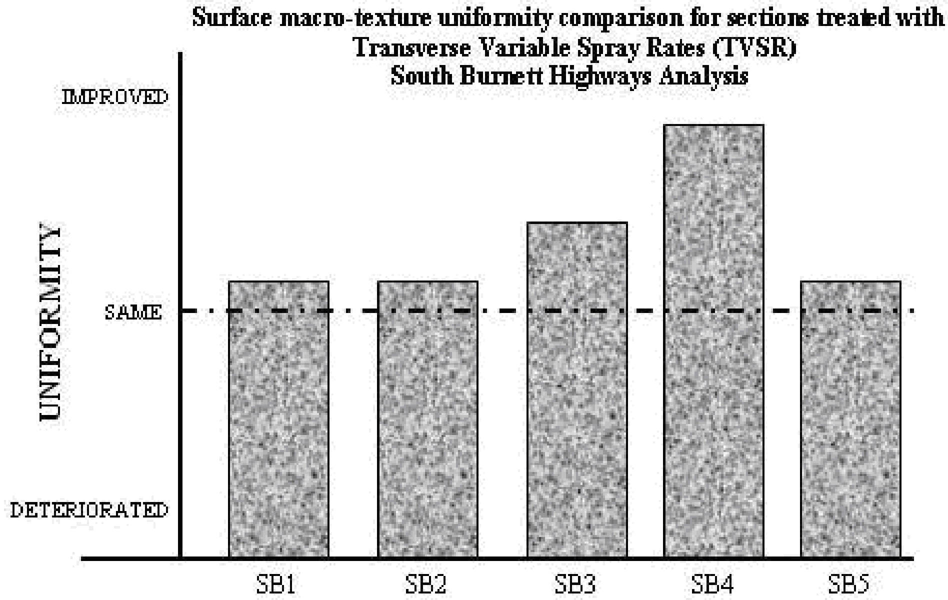


Figure 5.4.1 South Burnett Highways Analysis

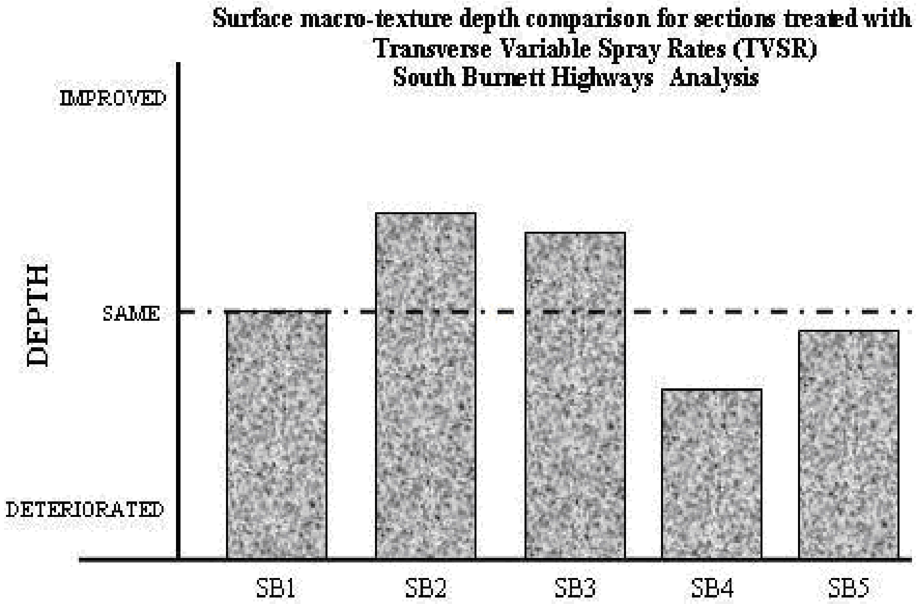


Figure 5.4.2 South Burnett Highways Analysis

5.5 General Discussion of Results

This current assessment of the performance of transverse variable spray rates (TVSR) has concentrated on comparisons of surface macro-texture uniformity and depth. All analysed sections treated with TVSRs exhibited improved surface macro-texture uniformity. The sections treated with both TVSRs and polymer modified binders (PMB) also generally exhibited improved surface macro-texture depth. The sections treated with TVSRs and plain Class 170 binder exhibited improvements in uniformity but generally showed similar performance to the single spray rate sections with regard to surface macro-texture depth. These results are not surprising and correlate well with the logic used to determine the Southern District Sealing Guidelines (Main Roads, 2004) as discussed in **Chapter 2.3 Factors Influencing Selection of Surfacing Treatments.**

A very brief summary of the guidelines for resealing is represented here;

- 0 - 1000 AADT – Single Spray Rates with C170 Binder
- 1000 - 3000 AADT - TVSR with C170 Binder
- > 3000 AADT - TVSR with PMB

There is one simple reason why all Australian roads are not sealed with asphalt, and that is financial constraints. These same constraints stretch all the way down to the selection of binder types for different roads. Ideally from the treatment selection provided in the Southern District Sealing Guidelines, all road sections would receive the premium treatment of polymer modified binders in conjunction with transverse variable spray rates. Unfortunately this is not an economic option, so compromise must be achieved to provide the best possible outcome from the available budget.

There are many Road Authorities and contractors who are still attempting to use single spray rates and Class 170 binder when resealing higher volume roads. The analysis performed during this dissertation has shown that this combination results in generally inferior long-term surface macro-texture uniformity and depth.

The importance of adequate surface macro-texture depth was thoroughly discussed in **Chapter 2.4 Surface Texture** but the other key issue is the transverse uniformity of the pavement macro-texture. The importance of the surface macro-texture uniformity relates to the relationship between the macro-texture in the OWP and the macro-texture between the wheel paths (BWP). The macro-texture between the wheel paths is of critical importance due to the frequency of aggregate stripping experienced in this zone and the other less trafficked areas. The factors that contribute to aggregate stripping were covered in **Chapter 2.6 Types of Surfacing Failures**. Aggregate stripping results not only in a loss of surface texture but also creates dangerous loose aggregate particles capable of causing damage to property, particularly vehicle windscreens, and can also cause personal injury.

The common type of aggregate stripping generally associated with the area between the wheel paths results from oxidisation of the bitumen in this area. The oxidisation of the bitumen leads to bitumen hardening, which in turn can lead to the bitumen losing the ability to retain the aggregate chips. The frequency of this problem is known to increase significantly during the colder winter months, when the bitumen becomes more rigid and the cover aggregate is prone to fracture from the seal matrix. To overcome this problem, a deeper layer of bituminous binder is desirable in this area as it enables the aggregate chips to be held more securely in position.

The issue with this increased binder depth is that unless it is restricted to the less trafficked areas of the road like the shoulders, between the lanes and between the wheel-paths, bitumen flushing in the wheel-paths is likely to occur. Therefore when a seal designer attempts to design the spray-rate for a sealing job and the use of single, uniform spray rates is specified, the designer has to attempt to reach a compromise, in which neither the wheel-paths nor the less trafficked areas finish up receiving their optimal spray-rate. Alternatively expensive pre-treatments may be required. These can involve high pressure water retexturising of the flushed areas, regulation of the entire surface by applying a 5 or 7mm preliminary seal or pre-spraying the coarsely textured areas with additional bituminous binder. These pre-treatments are all designed to create a more uniform and consistent base for the reseal and prevent the underlying issues being reflected in the new work.

As can be seen from this evidence, surface macro-texture uniformity is highly desirable and can be costly to regain once lost. The sections treated with transverse variable spray rates highlighted during this study have been shown unanimously to provide increased surface macro-texture uniformity when compared to the sections treated with single spray rates.

Furthermore, as shown in the New England Highway 22B analysis, when polymer modified binders are used in conjunction with transverse variable spray rates, both the long-term surface macro-texture depth and uniformity are generally improved. By improving both these important surface texture aspects, increased long-term pavement life may be achieved, or at least improved pavement surface macro-texture during its declining years, if reseals are scheduled on more of a time-based cycle rather than on physical pavement condition. These benefits would provide economic and safety related benefits to both the Road Authority and the wider community.

5.6 Austroads Sprayed Seal Design Method

A better understanding of the topic is achieved by having a brief look at the actual design process. The publication used in Australia as the guideline for sprayed seal surfacing (Austroads, 2006) states the Basic Binder Application Rate (Bb) is a function of the Design Voids Factor (VF) and the Average Least Dimension (ALD) of the selected cover aggregate. The Design Voids Factor is in turn the sum of the Basic Voids Factor (Vf), a Traffic Effects Adjustment (Vt) and an Aggregate Shape Adjustment (Va). The Aggregate Shape Adjustment is related to the Flakiness Index (%) of the aggregate.

The Design Binder Application Rate (Bd) is then found by adding Bb to any extra allowances that are warranted for the specific situation. All these factors and allowances can be selected from tables or graphs in Austroads (2006), while the ALD and the Flakiness Index are requirements that must be supplied for the aggregate as stated in the Standard Specification MRS11.22 (QDMR, 1999).

The allowance that is particularly relevant to this analysis is the Surface Texture Allowance (As). Austroads (2006) states that this allowance is determined from performing a sand patch test to measure the existing average surface texture depth. A description of this test is given in **Chapter 3.1 Sand Patch Testing**. These measurements must be performed at least every 400 to 500 metres or wherever there is a visual change in surface texture. Austroads (2006) recommends measurements of the surface macro-texture be taken in the wheel-paths and also the adjacent areas.

If the measurements taken in these different areas amount to a difference of more than 0.3 litres per square metre in the Design Binder Application Rate (Bd), then Austroads suggests pre-treatment with a five or seven millimetre seal to regulate the surface or pre-spraying of the course textured areas may be required to achieve optimal performance across the full width of the seal. Austroads (2006) also suggests that the use of a sprayer capable of applying transverse variable spray rates may be another solution. This option was not included in the earlier Austroads Provisional Sprayed Seal Design Method Revision 2000 (Austroads 2000a), and goes to show that the benefits of this technology are slowly becoming disseminated across the Australian transport engineering community.

5.7 Discussion of Costs related to treatment options

Cost is quite a difficult aspect to quantify as no two jobs are the same and over the course of a year quite a wide range of tender costs will be encountered for similar works. These variations are accounted for by many factors including distance from quarries for aggregate supply, distance from a refinery or storage facility for bitumen supplies, labour factors, local conditions and margin variation between contractors.

These factors make it difficult to compare rates across jobs but so as to provide a rough guide as to some of the costs associated with various treatments the following **Table 5.7.1** has been drawn up after consultation with staff at the Queensland Department of Main Roads. The figures are based on 2007 values and are purely provided to give an indication of the costs and must not be relied upon for any other purpose.

Table 5.7.1 Comparison Costs of Surfacing Treatments (2007)

Surfacing Treatments	**Costs (2007)**	**Rate**
Pre-treatments		
Water texturising	\$8.00 – \$8.50	\$ / m^2
Pre-spraying of course textured areas	\$3.00	\$ / m^2
5 – 7 mm preliminary corrective seal	\$4.00 – \$4.50	\$ / m^2
Sealing treatments		
Single spray rate sealing * (inc cost of cover aggregate)	\$1.50 - \$2.00	\$ / m^2
TVSR sealing * - Fulton Hogan (inc cost of cover aggregate)	\$1.60 - \$2.10	\$ / m^2
Bitumen Costs		
Bitumen cost - Class 170	\$0.65	\$ / litre
Bitumen cost – Polymer Modified Binders	\$0.80 - \$1.10	\$ / litre

* These figures were provided for a 12mm cover aggregate and approximately 1.5 litres per square meter of bitumen binder.

The cost of supply of the bitumen is not included in the sealing treatment costs as the bitumen is supplied to the contractor by the Principal. The rates are given as unit rates, which makes the cost of the pre-treatments seem very dear. The reason these costs seem disproportionately high is the production from the sprayer is much lower during pre-treatments due to the fiddly nature of much of the work, but the standing cost of hiring the spray truck remains the same regardless of the productivity and this increases the unit rate.

From these figures it is obvious that using Class 170 bitumen binder with single spray rates is the cheapest short-term option but if the cost of the recommended pre-treatments is taken into account, the use of transverse variable spray rates and a polymer modified binder appears very good value. It would also be extremely difficult to put a dollar value on the increased transverse surface macro-texture depth and uniformity a seal is likely to exhibit in later life, and the potential for extended seal life resulting from the use of these treatments.

Due to the prohibitive cost of the pre-treatments, some designers in the past have chosen to simply apply the single spray rate reseal over the existing pavement surface without taking into account the differences in surface macro-texture between flushed wheel-paths and the hungry less trafficked areas. Anecdotal evidence suggests these are often the jobs where early surface texture failures become evident due to the previous issues reflecting through the new work. This is particularly so after a hot summer season, where the heat has caused the bituminous binder to become less viscous and any excess bitumen tends to rise to the road surface.

Considering these many factors the use of TVSR technology appears to be an economically attractive option, particularly due to the ability to avoid expensive pre-treatments and also the possibility of extended seal life or at least improved surface texture characteristics in the later life of the seal.

5.8 Critical Appraisal

The comparisons made during this analysis were achieved using existing data recorded using a Multi Laser Profiler (MLP) array during the annual network survey. Due to the variability in pavement conditions, road geometry and history of prior works, many sections were unsuitable for analysis. This meant that to obtain suitable analysis sections, areas had to be compared that were not adjacent to each other. This is not an ideal situation as it allows other subtle variables to possibly influence the results.

As many of these conditions were known and reasonably well understood, great care was taken during the study to maximise the integrity of the analysis by establishing strict criteria each section had to conform to. As a result of the strict criteria established in **Chapter 4.5 Investigation Methodology** various sections were subsequently rejected that would otherwise have provided excellent comparisons. This was a disappointing result as some of these sections would have shown the extreme variations in surface macro-texture that exist on sections of the road network, particularly some of the sections sealed with single spray rate treatments.

The only pre-organised and structured comparison of surface macro-textures in relation to TVSR technology was undertaken by New Zealand contractor Fulton Hogan at their Tai Tapu trial site in the Canterbury region of New Zealand. This trial consisted of a series of treatments being applied to a straight section of state highway with an AADT of 4000 and 5% heavy vehicles. The trial was set up with single spray-rate control sections at either end, and three variable spray-rate intermediate sections. The three variable sections had spray-rate reductions of 10, 20 and 30 percent in the wheel-paths. These sections were then monitored and measured annually between 2000 and 2006.

The results showed superior texture depth was achieved in the variable sections with the best performance from the section with the 30% reduction. A full description of the trial and results is available from Pidwerbesky B. & Waters J., (2006). This was also published as an article in Queensland Roads, Edition No 5 – March 2008. The results of the trial are shown in **Figure 5.8.1**.

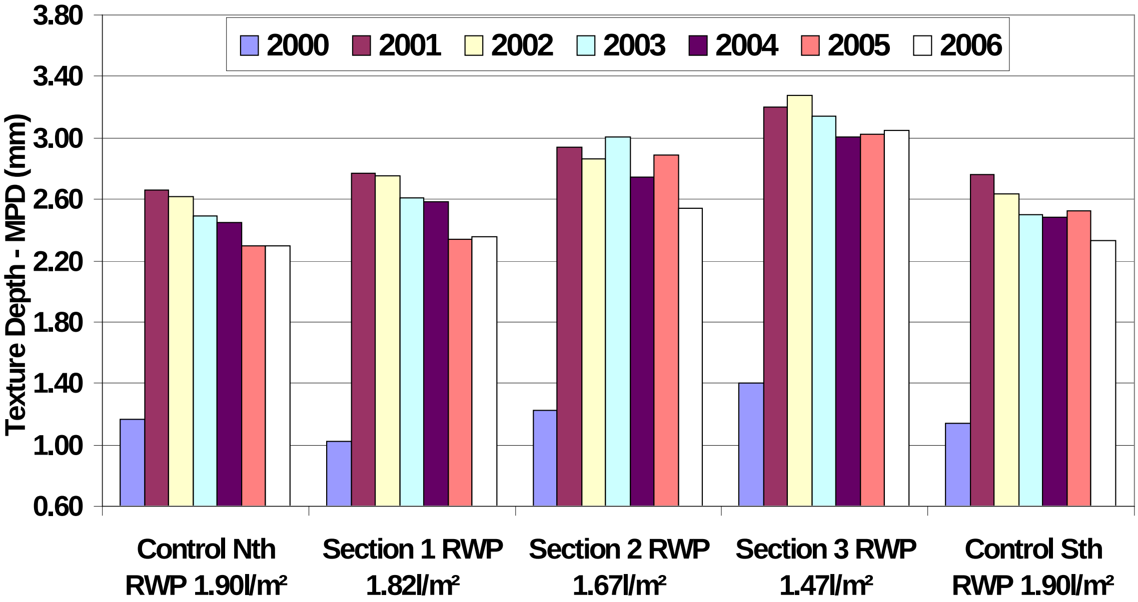


Figure 5.8.1 Fulton Hogan Tai Tapu trial results
(Courtesy Fulton Hogan, 2007)

5.9 Further Work

A formal trial of the type undertaken by Fulton Hogan is far superior to the analysis undertaken in this study due to the level of control that is possible over the many variables. Until trial sites in Australia have been established long enough to yield comparable data, the analysis undertaken for this dissertation can be used as a starting point for further investigation of the topic. Several monitoring trials have been set up at sites in Queensland to investigate and compare spray rates and binder types including two in Toowoomba District. One has been set up by Main Roads on the Gore Highway near Westbrook and the other has been set up by Fulton Hogan on the New England Highway 22A near Yarraman.

Once these formally established sites have been operational long enough to provide meaningful data, a better understanding of long-term surface macro-texture performance under Australian conditions will be available. Until that time analysis using available historical data is the only option. This study has shown the difficulties in achieving meaningful results under these conditions, but despite these complications valuable information regarding data trends has been revealed.

An area of particular interest for further research is the work undertaken on the Warrego Highway at the recently constructed Gatton Bypass. The decision was made by Southern District of QDMR to use a TVSR bituminous seal in conjunction with a PMB for this pavement surfacing even though the total AADT exceeded 13000 (2006) with over 17.8% heavy vehicles and significant anticipated traffic growth. The performance of this economical treatment under these extreme traffic conditions showcases the possible extended capabilities of sprayed sealing in a situation where asphalt was generally regarded as the appropriate treatment.

Due to limited time and resources the present analysis was restricted to ten comparison sections spread between two distinct areas, the New England Highway 22B and the highways of the South Burnett. If additional time and resources were available to undertake further studies in these and other areas, then a clearer picture could be formulated. This study has revealed some quantitative results and identified significant data trends. Due to the limited number of samples it is not possible to draw absolute conclusions from the results at this stage.

Chapter 6 CONCLUSIONS

In Australia sprayed seal surfacings are used on most rural arterial and rural local roads and provide a durable and economical pavement. Over the last few decades significant increases in traffic volume, speed, tyre pressures, loads and percentage of heavy vehicles has been recorded across the Australian road network. This has led to accelerated wear and pavement fatigue. An obvious symptom of this fatigue has been the noticeable loss of surface texture on many roads, particularly in the wheel paths.

Providing adequate surface texture on sprayed seal pavements requires a combination of adequate micro-texture and macro-texture, particularly at higher speeds. A shortage of highly polish resistant aggregates in Australia means maintaining adequate micro-texture is an ongoing challenge for Road Authorities. It also places a greater share of the burden of maintaining adequate surface texture on the contribution of macro-texture.

Sprayed seal surfacings are successfully used on local roads carrying only a few vehicles a day through to major highways carrying many thousands of vehicles. There are a hierarchy of sealing treatments available to satisfactorily accommodate most situations. These treatments range from single spray rate seals with a plain Class 170 bituminous binder through to transverse variable spray rates in conjunction with advanced polymer modified binders (PMB). Specialised treatments are also available utilising Geotextiles, strain alleviating membranes and multiple layer seals.

Sprayed seal surfacings are not recommended for high stress areas like small-radii roundabouts, intersections, turning lanes and median openings. These areas are better served by a layer of hotmix asphalt to provide improved smoothness and appearance and reduced maintenance costs. This is mainly due to issues related to the braking and turning of heavy vehicles which are likely to cause aggregate to roll out of its bed, leading to loss of aggregate and bleeding of the seal.

Sprayed seals are also affected by temperature extremes. Cold weather increases the likelihood of the cover aggregate stripping due to the bituminous binder becoming brittle and the aggregate fracturing from the seal matrix. In hot weather sprayed seals experience flushing of excess bitumen particularly in the wheel paths. Polymer modified and multigrade binders are successfully used to limit the extent of these problems and when used in conjunction with well designed transverse variable spray rates, excellent performance can be achieved.

This study utilises surface macro-texture data collected during the Queensland Department of Main Roads annual network survey to compare the performance of single uniform bitumen spray rates with transverse variable spray rates (TVSR). To achieve an accurate comparison, sections with very similar properties were compared to assess the performance of the spraying technique using the parameters of outer wheel path macro-texture depth and transverse macro-texture uniformity.

The reason for undertaking this study is an extensive literature review revealed that even though TVSR technology has been utilised in Australia to a limited extent for the last 20 years, there has been no quantitative analysis undertaken to investigate the performance of this treatment in comparison to traditional single spray rate treatments under Australian conditions.

A trial analysis was undertaken to formulate a set of assessment criteria to identify suitable sections for comparison. The assessment criteria proved to be so stringent that limited sections were identified as suitable for comparison. The analysis was undertaken at two distinct areas, the first being the New England Highway 22B between Toowoomba and Warwick and the second area being the highways of the South Burnett. Ten sections in each area were compared to identify performance trends related to the choice of binder spraying treatment.

As a result of the comparison analysis it was found that all sections treated with TVSRs exhibited improved surface macro-texture uniformity. The sections treated with both TVSRs and PMBs also generally exhibited improved surface macro-texture depth. The sections treated with TVSRs and plain Class 170 binder exhibited improvements in uniformity but generally showed similar performance to the single spray rate sections with regard to surface macro-texture depth.

The importance of the surface macro-texture uniformity relates to improved road safety but also decreased maintenance costs. If a road has a significant loss of surface macro-texture uniformity, and the designer uses single spray rates for the seal design, costly pre-treatments are recommended. These pre-treatments include high pressure water retexturising of the flushed areas, regulation of the entire surface by applying a 5 or 7mm preliminary seal or pre-spraying the coarsely textured areas with additional bituminous binder. These pre-treatments are all designed to create a more uniform and consistent base for the reseal and theoretically prevent the underlying issues being reflected in the new work.

If these pre-treatments are not undertaken, the seal designer must attempt to reach a compromise between the needs of the flushed and the hungry areas of the pavement. A compromise of spray rates means neither area receives the spray rate it requires and flushing and/or stripping issues are likely to occur, leading to premature failure of the seal.

The simple alternative is to use transverse variable spray rates and select the appropriate rate for each specific location. For the small added cost of using a sprayer equipped for TVSR application, which amounts to only an extra 10 – 15 cents per square metre, costly pre-treatments can be avoided in many cases and a quality, lasting job can be produced in a shorter timeframe and with less disruption to traffic. For these reasons transverse variable spray rate technology is slowly gaining acceptance in Australia as a suitable method for prevention and correction of surface macro-texture related deficiencies in spray sealed surfacings.

The results of this study show that TVSR technology is successful at improving the surface macro-texture uniformity of the pavement and when used in conjunction with polymer modified binders also leads to increased surface macro-texture depth in the wheel paths. Due to the relatively small sample size, further work would need to be undertaken to verify the results.

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Appendix A Project Specification

Appendix A
University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR:	**Blaise Napier SHANN**
TOPIC:	TRANSVERSE VARIABLE RATE BITUMEN SPRAYING IN ROAD CONSTRUCTION AND MAINTENANCE
SUPERVISORS:	A/ Prof. Ron Ayers, USQ Mr David Seefeld, Queensland Department of Main Roads
SPONSORSHIP:	-
PROJECT AIM:	To investigate the performance of sprayed road surfacings constructed with transverse variable rate bitumen spraying, and hence to determine the viability and suitability of this technique for improving the uniformity and depth of the surface macro-texture.

PROGRAMME: (**Issue B, 1st September 2008**)

1. Undertake a literature review of information relating to transverse variable rate bitumen spraying and associated practices, including:
    - The different types of bituminous surfacing treatments used in road engineering;
    - The selection and design of sprayed surfacings;
    - Construction techniques for sprayed surfacings; and
    - Performance, maintenance and rehabilitation of sprayed surfacings.
    - The importance of surface texture to skid resistance and the contribution of micro-texture and macro-texture.

2. Investigate which road authorities and private contractors in Australia and internationally have undertaken variable rate bitumen spraying and seek relevant data from them.

3. In conjunction with Southern District, Department of Main Roads, Queensland, determine the extent of the road network to be investigated to consider the viability and suitability of transverse variable spray rates in bitumen sealing.

4. Develop a suitable investigation methodology which examines key parameters relating the performance of spray sealed surfacings to important issues such as climate, traffic and cost.

5. Analyse historic and field data to determine the benefits related to utilising transverse variable rate bitumen spraying as an alternative to other surfacing techniques.

6. Develop a methodology which will identify areas where the use of variable spray-rates is beneficial and areas where its use is inappropriate.

7. Provide the required written and oral presentations of the project work.

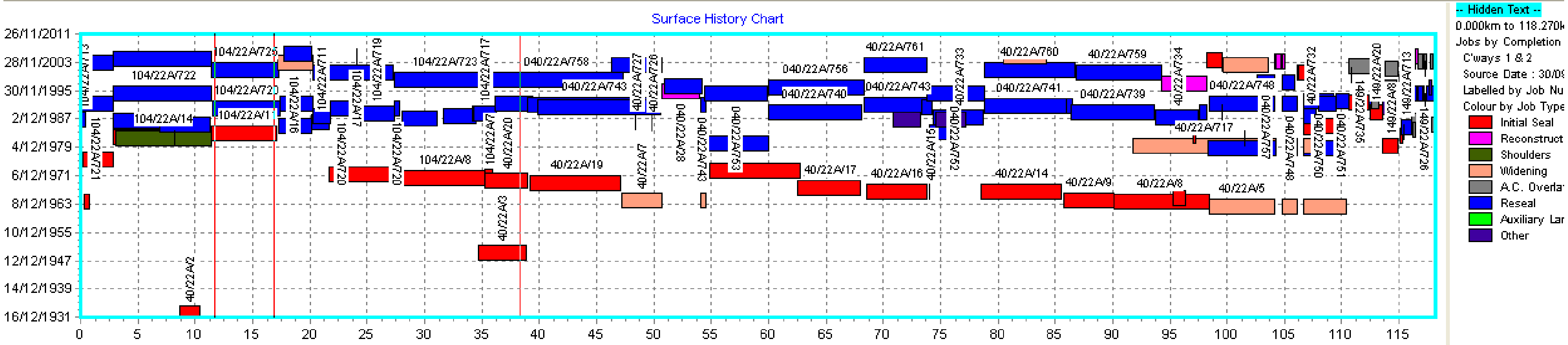
AGREED: ____________ (Student) ____________ , ____________ (Supervisors)
Date: / / 2008 Date: / / 2008 Date: / / 2008

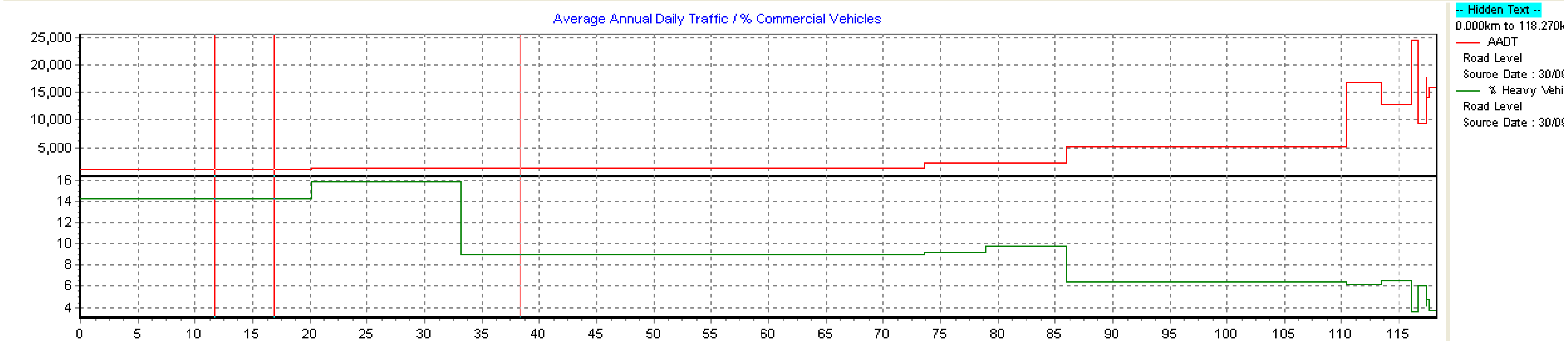
Examiner/ Co-examiner:____

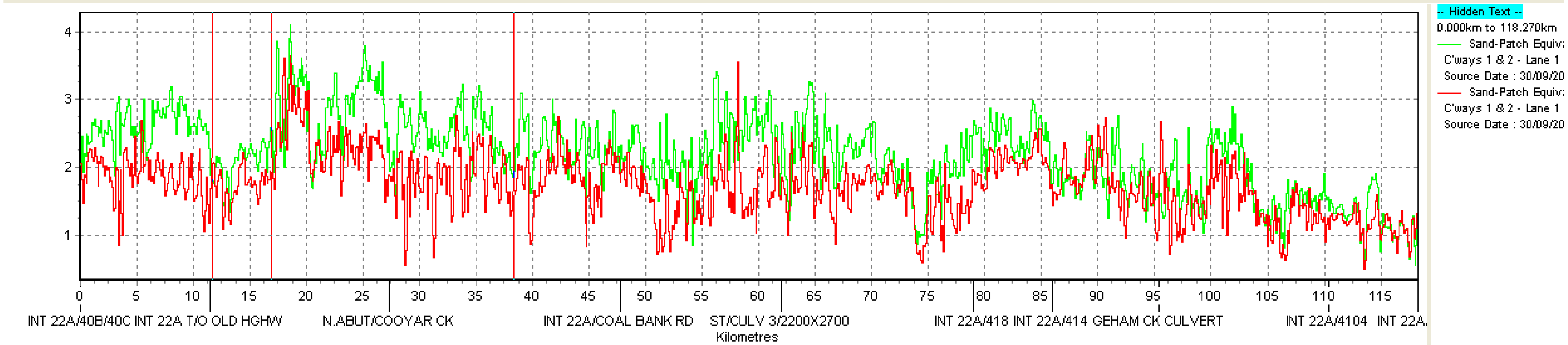
Appendix B ARMIS Chartview Output

Queensland Government
Department of Main Roads

Road Section 22A - NEW ENGLAND HIGHWAY (YARRAMAN-TOOWOOMBA) (118.3 km) from SOUTHERN DISTRICT (MR) refreshed on 01 Oct 2008

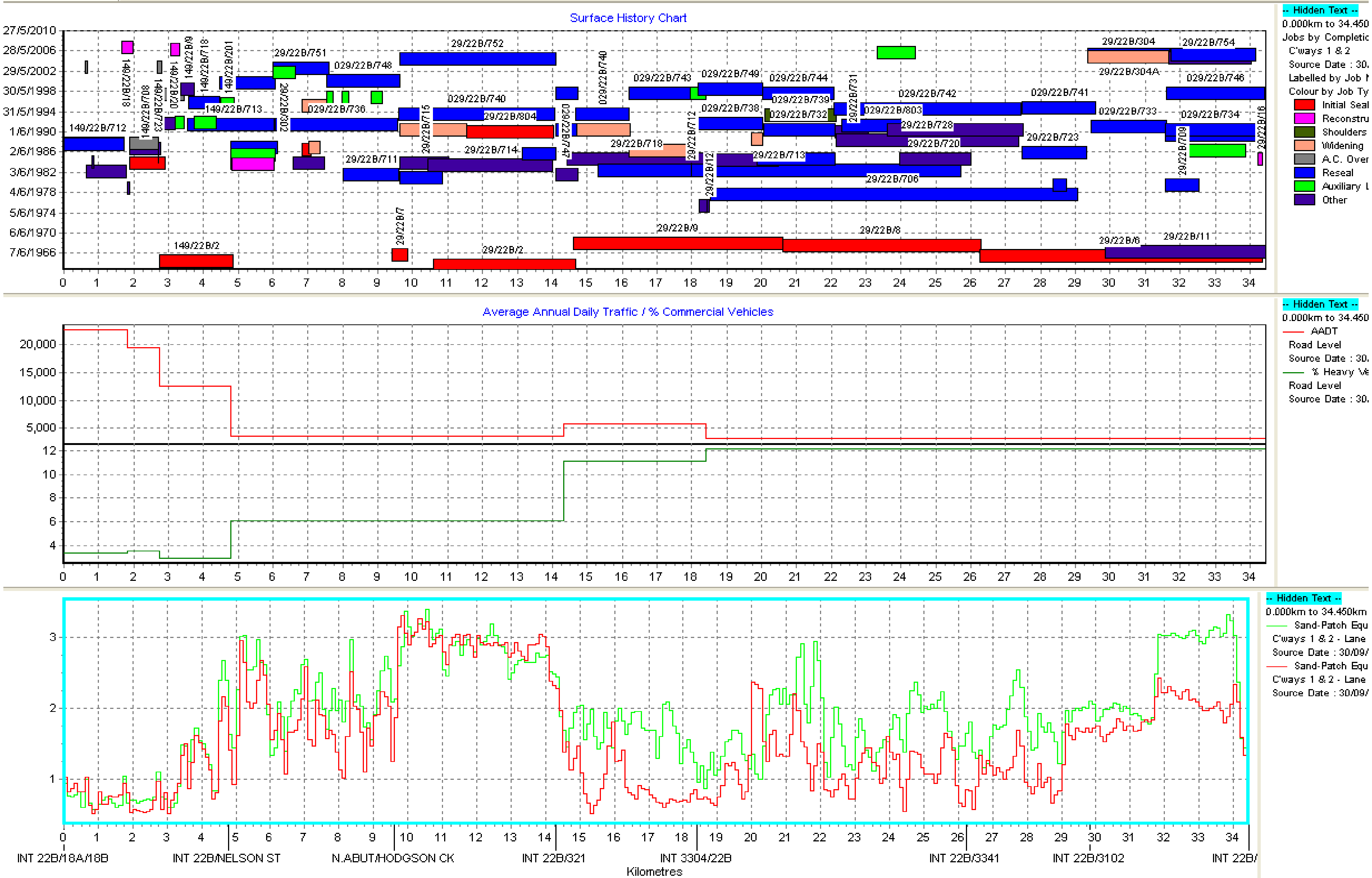




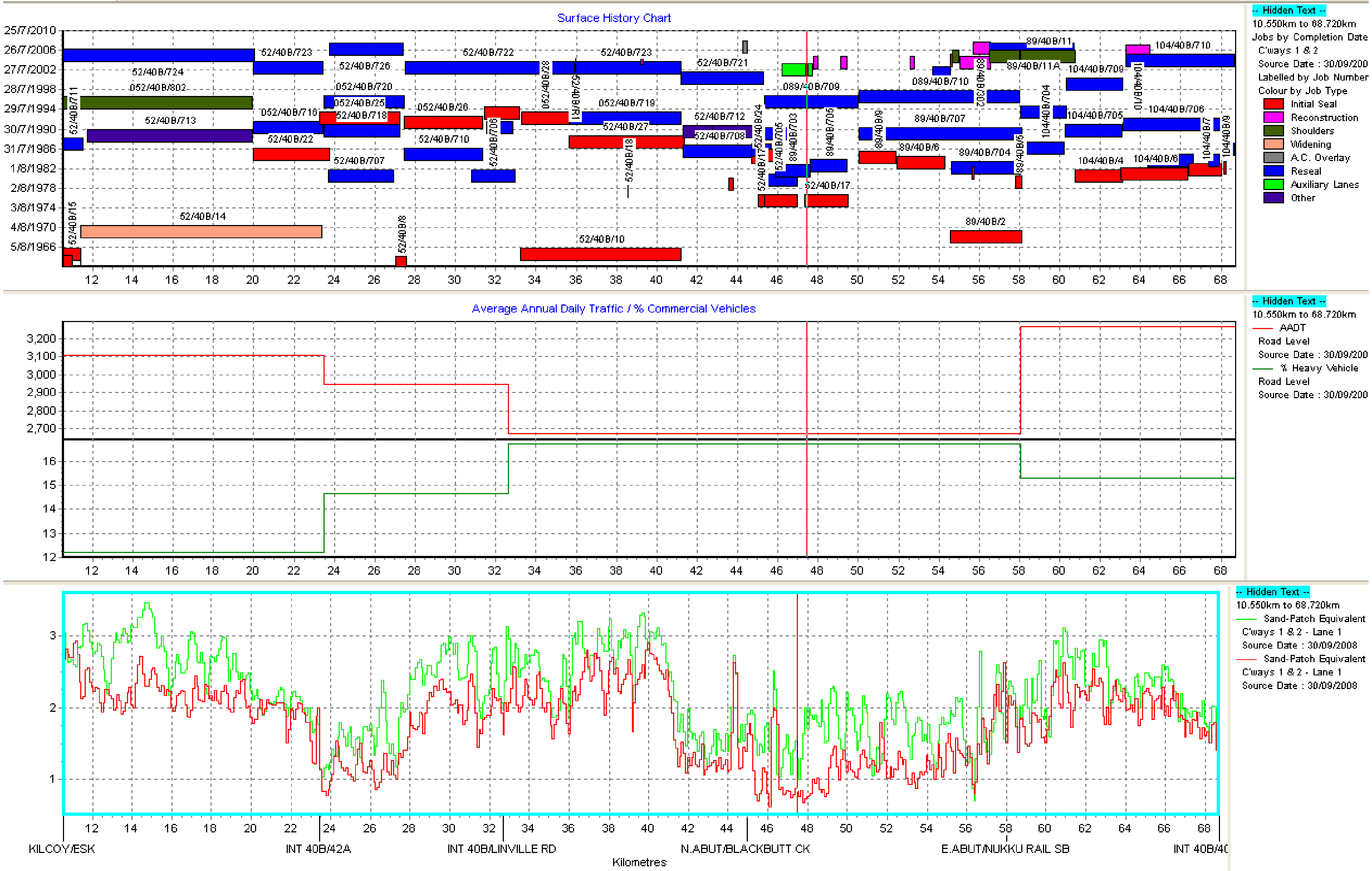


Queensland Government
Department of Main Roads

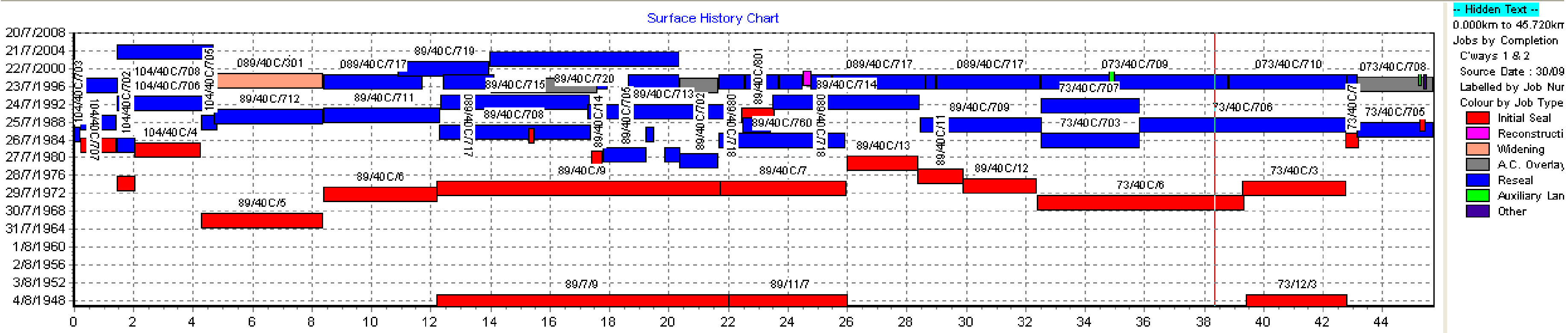
Road Section 22B - NEW ENGLAND HIGHWAY (TOOWOOMBA-WARWICK) (34.5 km) from SOUTHERN DISTRICT (MR) refreshed on 01 Oct 2008

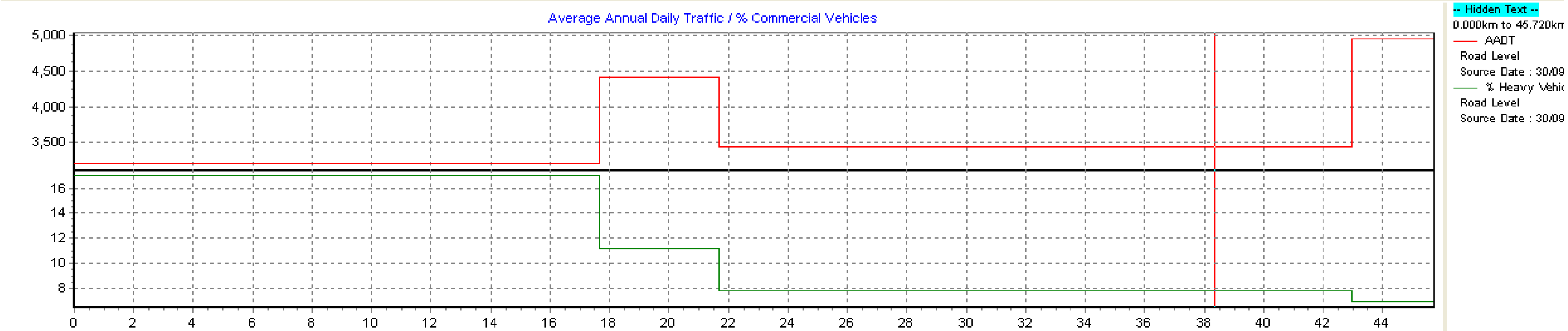


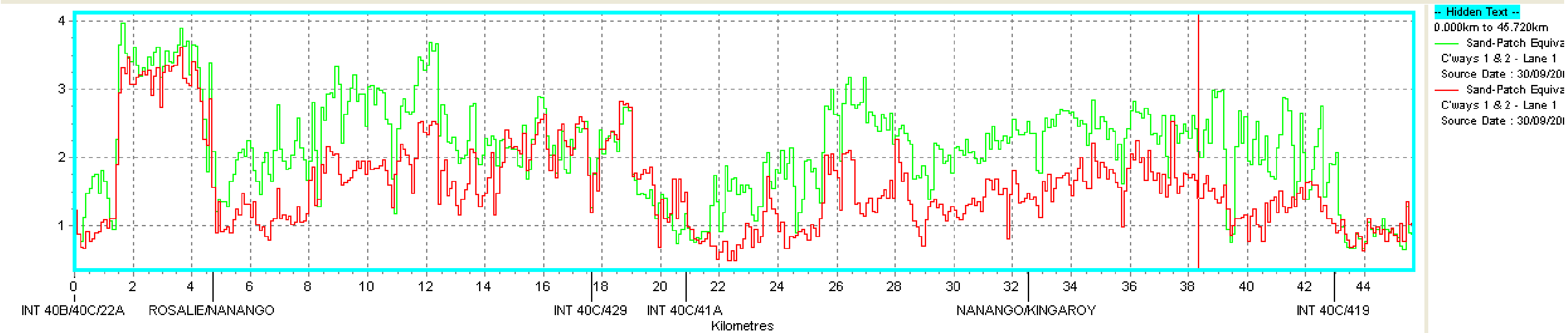
Road Section 40B - D'AGUILAR HIGHWAY (KILCOY - YARRAMAN) (58.2 km) from SOUTHERN DISTRICT (MR) refreshed on 01 Oct 2008



Road Section 40C - D'AGUILAR HIGHWAY (YARRAMAN - KINGAROY) (45.7 km) from SOUTHERN DISTRICT (MR) refreshed on 01 Oct 2008

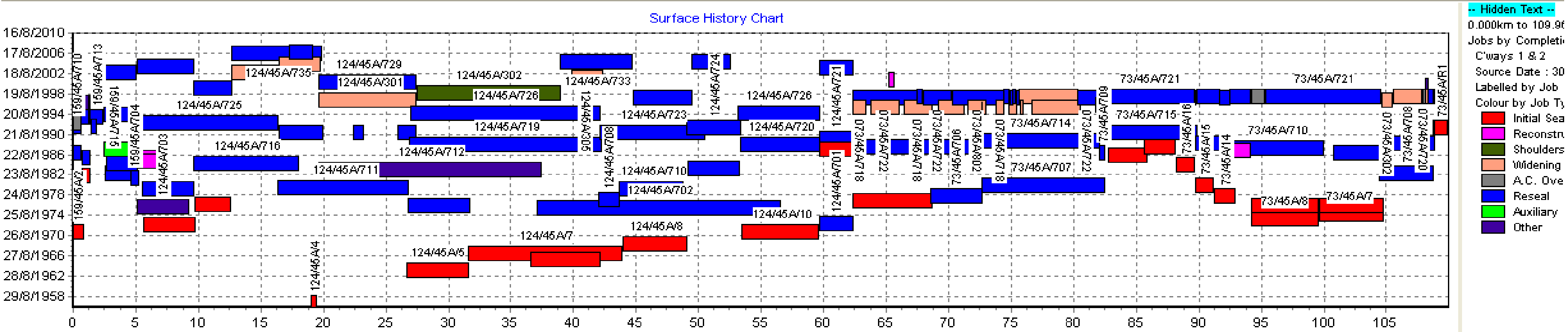


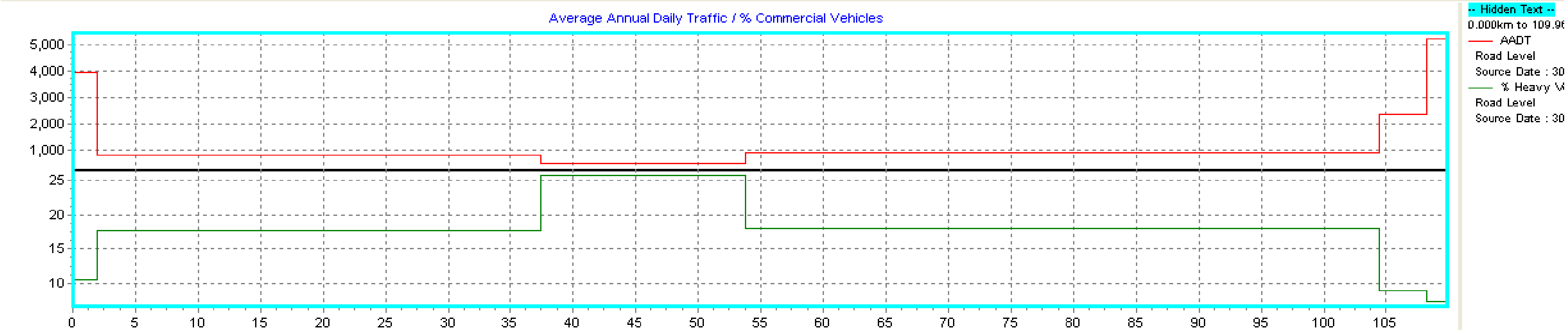


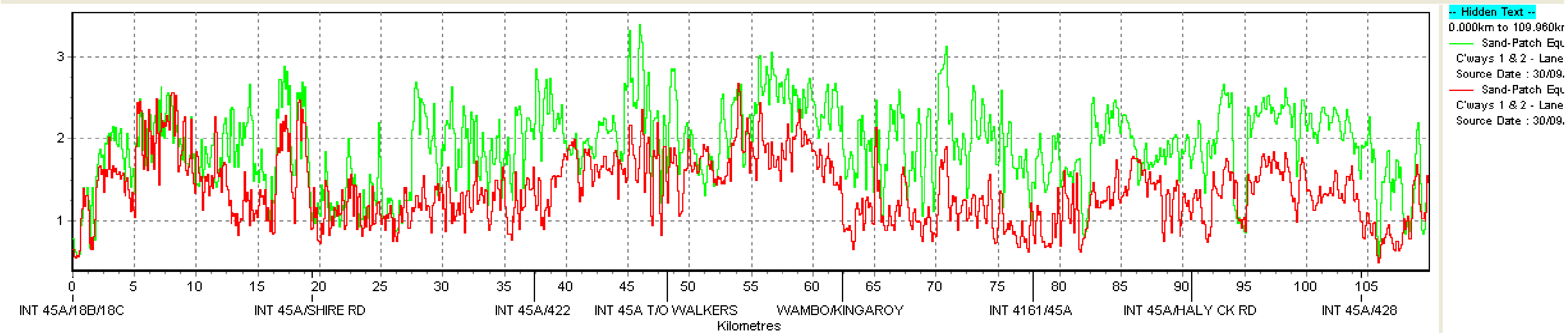


Queensland Government
Department of Main Roads

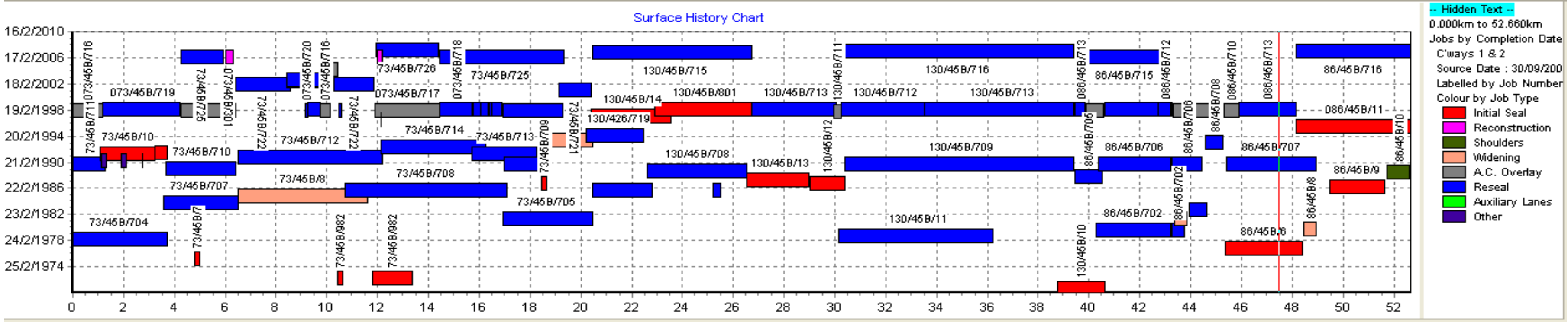
Road Section 45A - BUNYA HIGHWAY (DALBY - KINGAROY) (110.0 km) from SOUTHERN DISTRICT (MR) refreshed on 01 Oct 20

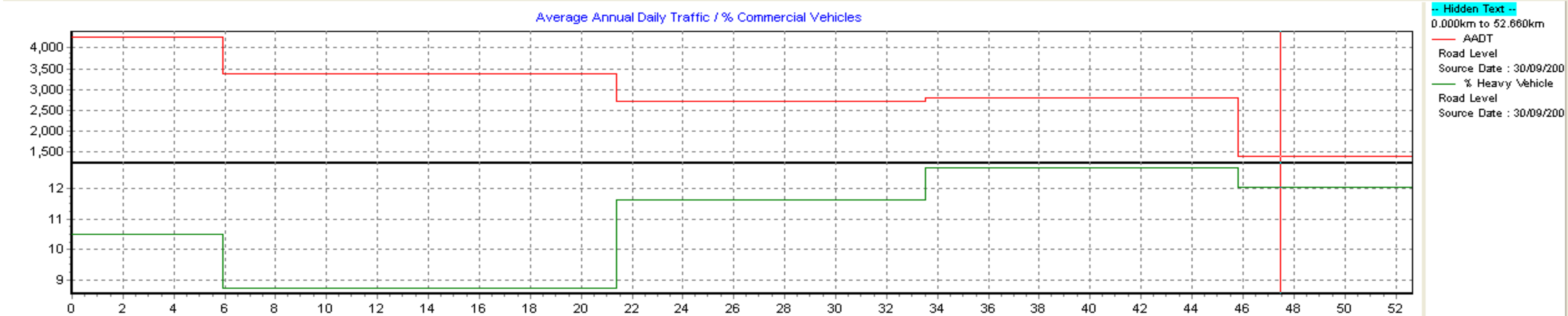


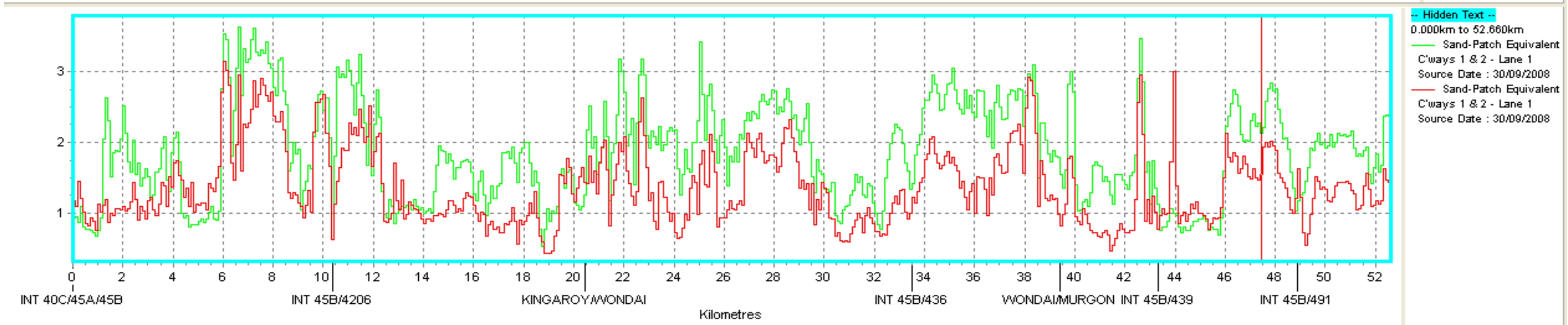




Road Section 45B - BUNYA HIGHWAY (KINGAROY - GOOMERI) (52.7 km) from SOUTHERN DISTRICT (MR) refreshed on 01 Oct 2008







Appendix C Asset & Layer Information master sheets

ROAD_ID	CODE	Start (km)	End (km)	Seal Width (m)	Seal Type	Seal Age (years)	Seal Depth (mm)	Seal Date	Seal (excl. shoulders)	Speed	2007 AADT	%HV
22A		11.4	11.42	9	K1	4	10	14-OCT-03	6	100	1181	14.15
22A		11.4	11.45	9	K1	4	10	14-OCT-03	6	100	1181	14.15
22A		11.5	11.49	9	K1	4	10	14-OCT-03	6	100	1181	14.15
22A	SB2V	11.5	14.6	10	K1	4	10	14-OCT-03	7	100	1181	14.15
22A	SB1V	14.7	17.2	10	K1	4	10	14-OCT-03	7	100	1181	14.15
22A		17.2	17.28	10	K2	2	14	15-NOV-05	7	100	1181	14.15
22A		17.3	17.29	10	K2	2	14	15-NOV-05	7	100	1181	14.15
22A		17.3	17.71	6	K2	2	14	15-NOV-05	6	100	1181	14.15
22A		17.3	17.71	9	K2	2	14	15-NOV-05	6	100	1181	14.15
22A		17.7	18.17	6	K2	0	12	04-APR-08	6	100	1181	14.15
22A		18.2	18.37	6	K2	0	12	04-APR-08	6	100	1181	14.15
22A		18.4	18.99	6	K2	0	12	04-APR-08	6	100	1181	14.15
22A		19	20.13	6	K2	0	12	04-APR-08	6	100	1181	14.15
22A		20.1	20.2	6	K2	0	12	04-APR-08	6	100	1410	15.8
22A		20.2	20.21	6	K2	0	12	04-APR-08	6	100	1410	15.8
22A		20.2	20.26	6	K2	0	12	04-APR-08	6	100	1410	15.8
22A		20.3	21.71	6	K2	5	10	14-FEB-03	6	100	1410	15.8
22A		21.7	21.79	6	K2	5	10	14-FEB-03	6	100	1410	15.8
22A		21.8	21.8	7	K2	5	10	14-FEB-03	7	100	1410	15.8
22A		21.8	22.28	7	K2	5	10	14-FEB-03	7	100	1410	15.8
22A		21.8	22.28	7	K2	5	10	14-FEB-03	7	100	1410	15.8
22A		22.3	22.42	7	K1	5	10	06-MAR-03	7	100	1410	15.8
22A		22.4	22.47	7	K1	5	10	06-MAR-03	7	100	1410	15.8
22A		22.5	23.89	7	K1	5	10	06-MAR-03	7	100	1410	15.8
22A		23.9	24.14	6.5	K1	5	10	06-MAR-03	6.5	100	1410	15.8
22A		24.1	24.19	6.5	K1	0	10	22-OCT-07	6.5	100	1410	15.8
22A		24.2	24.27	6.5	K1	5	10	06-MAR-03	6.5	100	1410	15.8
22A		24.3	27.34	6	K1	5	10	06-MAR-03	6	100	1410	15.8
22A		27.3	27.35	15.6	K1	5	10	06-MAR-03	15.6	100	1410	15.8

ROAD_ID	CODE	Start (km)	End (km)	Seal Width (m)	Seal Type	Seal Age (years)	Seal Depth (mm)	Seal Date	2007 AADT	%HV	Speed
22B	NE5V	11.2	12.5	9.4	PMB Spray Seal	2.4	12	25-JAN-06	3558	6.2	100
22B	NE2V	18.5	19.1	11.1	PMB Spray Seal	8.4	12	30-DEC-99	4294	11.6	100
22B	NE2V	19.1	19.4	9.1	PMB Spray Seal	8.3	12	03-MAR-00	3239	12.1	100
22B	NE1V	20.4	21.0	9.1	PMB Spray Seal	9.2	14	04-APR-99	3239	12.1	100
22B	NE3V	21.4	22.0	9.0	PMB Spray Seal	9.2	14	18-MAR-99	3239	12.1	100
22B	NE4V	31.7	32.6	9.7	PMB Spray Seal	1.5	12	27-NOV-06	3239	12.1	100

34.45km Boundary between Toowoomba and Warwick Districts

22B	NE3S	39.0	39.6	9.0	Bitumen Spray Seal	8.1	14	14-APR-00	2811	14.8	100
22B	NE4S	42.6	43.1	9.0	Bitumen Spray Seal	8.1	14	14-APR-00	2811	14.8	100
22B	NE1S	45.2	45.8	9.0	Bitumen Spray Seal	8.1	14	14-APR-00	3411	3.7	100
22B	NE5S	51.1	52.0	11.0	Bitumen Spray Seal	5.4	14	24-JAN-03	3411	3.7	100
22B	NE2S	62.8	63.1	10.2	Bitumen Spray Seal	7.5	14	06-DEC-00	2871	14.7	100
22B	NE2S	63.1	63.4	10.6	Bitumen Spray Seal	11.5	14	21-DEC-96	2871	14.7	100

ROAD_ID	CODE	Start (km)	End (km)	Seal Width (m)	Seal Type	Seal Age (years)	Seal Depth (mm)	Seal Date	Seal (excl. shoulders)	Speed	2007 AADT	%HV
40B		10.55	10.99	10	K2	1	12	16-NOV-06	6	100	3109	12.22
40B		10.99	11.54	10	K2	1	12	16-NOV-06	6	100	3109	12.22
40B		11.54	11.73	10	K2	1	12	16-NOV-06	6	100	3109	12.22
40B		11.73	19.92	9	K2	1	12	16-NOV-06	6	100	3109	12.22
40B		11.73	19.92	10	K2	1	12	16-NOV-06	6	100	3109	12.22
40B		19.92	19.95	10	K2	1	12	16-NOV-06	6	100	3109	12.22
40B		19.95	19.99	7	K2	1	12	16-NOV-06	7	100	3109	12.22
40B		19.99	20.02	7	K2	1	12	16-NOV-06	7	100	3109	12.22
40B	SB5V	20.02	20.5	7	K1	4	12	13-MAY-04	7	100	3109	12.22
	SB4V	22	22.99	8.5	K1	4	12	13-MAY-04	7	100	3109	12.22
40B		22.99	23.22	8.5	K1	4	12	13-MAY-04	7	100	3109	12.22
40B		23.22	23.23	8.5	K1	4	12	13-MAY-04	7	100	3109	12.22
40B		23.23	23.44	7	K1	4	12	13-MAY-04	7	100	3109	12.22
40B		23.44	23.48	7	G1	14	40	16-FEB-94	7	100	2946	14.65
40B		23.44	23.48	21	G1	14	40	16-FEB-94	18	100	2946	14.65
40B		23.48	23.49	21	K1	11	12	01-JUN-97	18	100	2946	14.65
40B		23.49	23.74	9.7	K1	11	12	01-JUN-97	7	100	2946	14.65
40B		23.49	23.74	21	K1	11	12	01-JUN-97	18	100	2946	14.65
40B		23.74	27.32	9.7	K2	0	12	31-JAN-08	7	100	2946	14.65
40B		60.29	60.31	6.8	K2	0	12	17-DEC-07	6.8	100	3267	15.3
40B		60.31	60.73	6.8	K2	0	12	17-DEC-07	6.8	100	3267	15.3
40B		60.73	60.74	10.4	K2	0	12	17-DEC-07	6.8	100	3267	15.3
40B		60.74	61.3	10.4	K1	7	10	14-NOV-00	6.8	100	3267	15.3
40B		61.3	61.32	10.4	K1	7	10	14-NOV-00	6.8	100	3267	15.3
40B	SB3V	61.32	63.14	10.4	K1	7	10	14-NOV-00	6.8	100	3267	15.3
40B		63.14	63.164	10.6	K1	7	10	14-NOV-00	7	100	3267	15.3
40B		63.16	63.256	7	E1	50	300	01-JAN-58	7	100	3267	15.3
40B		63.16	63.256	10.6	E1	50	300	01-JAN-58	7	100	3267	15.3
40B		63.26	64.37	7	K2	2	10	07-OCT-05	7	100	3267	15.3

ROAD_ID	CODE	Start (km)	End (km)	Seal Width (m)	Seal Type	Seal Age (years)	Seal Depth (mm)	Seal Date	Seal (excl. shoulders)	Speed	2007 AADT	%HV
40C		24.75	25.5	6.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C		25.5	25.78	6.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C		25.78	25.94	6.7	K1	9	10	31-MAR-99	6.7	100	3431	7.78
40C		25.94	26	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		26	27.04	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		27.04	27.08	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		27.08	27.91	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		27.91	27.95	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		27.95	28.38	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		28.38	28.4	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		28.4	28.62	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		28.62	28.94	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		28.94	28.98	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		28.98	29.01	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		29.01	29.9	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C	SB4S	29.9	30.68	6.6	K1	9	10	31-MAR-99	6.6	100	3431	7.78
40C		30.68	31.19	6.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C		31.19	32.39	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		32.39	32.53	7	K1	9	10	31-MAR-99	7	100	3431	7.78
40C		32.53	35.8	7.8	K1	9	10	31-MAR-99	6.8	100	3431	7.78
40C		32.53	35.8	10.3	K1	9	10	31-MAR-99	6.8	100	3431	7.78
40C	SB3S	32.53	35.8	12.8	K1	9	10	31-MAR-99	6.8	100	3431	7.78
40C		35.8	37.5	7.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C	SB5S	37.5	38.8	7.7	K1	9	10	31-MAR-99	6.7	100	3431	7.78
40C		38.8	39	7.7	K1	9	10	31-MAR-99	6.7	100	3431	7.78
40C		39	39.39	7.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C		39.39	42.64	7.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C		42.64	42.68	7.4	G1	9	25	31-MAR-99	6.4	100	3431	7.78
40C		42.68	42.81	7.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78
40C		42.81	42.82	7.4	K1	9	10	31-MAR-99	6.4	100	3431	7.78

ROAD_ID	CODE	Start (km)	End (km)	Seal Width (m)	Seal Type	Seal Age (years)	Seal Depth (mm)	Seal Date	Seal (excl. shoulders)	Speed	2007 AADT	%HV
45A		89.86	91.22	7.4	K1	9	10	01-JUL-99	7	100	894	18.1
45A		91.22	91.25	7	K1	9	10	01-JUL-99	7	100	894	18.1
45A		91.25	91.55	7	K1	9	10	01-JUL-99	7	100	894	18.1
45A		91.55	91.66	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		91.66	92.5	6.8	K1	9	10	01-APR-99	6.8	100	894	18.1
45A		92.5	93.04	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		93.04	93.89	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		93.89	94.26	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		94.26	94.39	6.8	G1	9	40	01-JUL-99	6.8	100	894	18.1
45A		94.39	95.36	6.8	G1	9	40	01-JUL-99	6.8	100	894	18.1
45A		95.36	95.9	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		95.9	99.61	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		99.61	100.01	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A	SB1S	100	101.93	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A	SB2S	101.9	104.46	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		104.5	104.5	6.8	K1	9	10	01-JUL-99	6.8	100	894	18.1
45A		104.5	104.6	6.8	K1	9	10	01-JUL-99	6.8	100	2350	8.89
45A		104.6	104.67	8.6	K1	9	10	01-DEC-98	6.6	100	2350	8.89
45A		104.7	104.71	8.6	K1	9	10	01-DEC-98	6.6	100	2350	8.89
45A		104.7	105.6	8.6	K1	9	10	01-DEC-98	6.6	100	2350	8.89
45A		105.6	106	9	K1	9	10	01-JUL-99	7	100	2350	8.89
45A		106	107.9	8.2	K1	9	10	01-JUL-99	6.2	100	2350	8.89
45A		107.9	108.12	6.2	G1	9	40	01-JUL-99	6.2	100	2350	8.89
45A		108.1	108.16	6.2	G1	7	30	01-SEP-01	6.2	100	2350	8.89
45A		108.2	108.21	9	G1	7	30	01-SEP-01	7	100	2350	8.89
45A		108.2	108.27	9	G1	7	30	01-SEP-01	7	100	2350	8.89

Appendix D Collated Surface Texture Data for analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio	
2	22B	NE5V	11.2	11.3	2.36	2.50	1.06	2.20	2.45	1.11	2.09	2.33	1.11	2.55	2.59	1.02	1.00	0.00	0.00	2.91	2.91	1.00	
3	22B	NE5V	11.3	11.4	2.52	2.82	1.12	2.53	2.74	1.08	2.47	2.62	1.06	2.64	2.76	1.05	1.00	0.00	0.00	3.01	2.89	0.96	
4	22B	NE5V	11.4	11.5	2.50	2.71	1.08	2.47	2.64	1.07	2.37	2.58	1.09	2.27	2.54	1.12	1.00	0.00	0.00	3.05	2.95	0.97	
5	22B	NE5V	11.5	11.6	2.33	2.53	1.09	2.32	2.55	1.10	2.14	2.38	1.11	2.21	2.65	1.20	1.00	0.00	0.00	2.90	2.75	0.95	
6	22B	NE5V	11.6	11.7	2.87	2.84	0.99	2.69	2.91	1.08	2.53	2.62	1.04	2.88	2.95	1.02	1.00	0.00	0.00	3.04	2.90	0.95	
7	22B	NE5V	11.7	11.8	2.92	3.08	1.05	2.73	3.18	1.16	2.74	2.91	1.06	2.95	3.12	1.06	1.00	0.00	0.00	3.05	2.98	0.98	
8	22B	NE5V	11.8	11.9	2.72	2.89	1.06	2.59	2.85	1.10	2.49	2.71	1.09	2.51	2.70	1.08	1.00	0.00	0.00	2.89	2.89	1.00	
9	22B	NE5V	11.9	12.0	2.44	2.62	1.07	2.33	2.62	1.12	2.13	2.39	1.12	2.39	2.57	1.08	1.00	0.00	0.00	2.73	2.80	1.03	
10	22B	NE5V	12.0	12.1	2.64	2.84	1.08	2.63	2.89	1.10	2.33	2.52	1.08	2.64	2.81	1.06	1.00	0.00	0.00	3.04	2.99	0.98	
11	22B	NE5V	12.1	12.2	2.53	2.78	1.10	2.63	2.73	1.04	2.36	2.51	1.06	2.31	2.61	1.13	1.00	0.00	0.00	2.93	2.90	0.99	
12	22B	NE5V	12.2	12.3	2.39	2.66	1.11	2.46	2.59	1.05	2.18	2.40	1.10	2.42	2.46	1.02	1.00	0.00	0.00	2.91	2.95	1.01	
13	22B	NE5V	12.3	12.4	2.39	2.84	1.19	2.37	2.82	1.19	2.16	2.56	1.19	2.32	2.81	1.21	1.00	0.00	0.00	2.92	3.04	1.04	
14	22B	NE5V	12.4	12.5	2.47	3.03	1.23	2.47	3.04	1.23	2.21	2.85	1.29	2.36	2.98	1.26	1.00	0.00	0.00	2.89	3.20	1.11	
15					2.54		1.09	2.49		1.11	2.32		1.11	2.50		1.10	1.00		0.00	2.94		1.00	
16																							
17	22B	NE2V	18.5	18.6	1.30	1.98	1.52	1.09	1.55	1.42	1.05	1.50	1.43	0.91	1.51	1.66	1.00	0.00	0.00	0.72	1.20	1.67	
18	22B	NE2V	18.6	18.7	1.36	1.88	1.38	1.12	1.72	1.54	1.09	1.56	1.43	0.92	1.53	1.66	1.00	0.00	0.00	0.76	0.87	1.14	
19	22B	NE2V	18.7	18.8	1.34	1.84	1.37	1.21	1.78	1.47	1.17	1.68	1.44	0.82	1.39	1.70	1.00	0.00	0.00	0.73	1.13	1.55	
20	22B	NE2V	18.8	18.9	1.16	1.82	1.57	1.12	1.65	1.47	0.99	1.54	1.56	0.80	1.66	2.08	1.00	0.00	0.00	0.66	1.39	2.11	
21	22B	NE2V	18.9	19.0	1.18	1.73	1.47	1.06	1.53	1.44	0.83	1.36	1.64	0.78	1.26	1.62	1.00	0.00	0.00	0.63	1.06	1.68	
22	22B	NE2V	19.0	19.1	1.38	1.74	1.26	1.07	1.45	1.36	0.90	1.26	1.40	0.88	1.12	1.27	1.00	0.00	0.00	0.75	1.14	1.52	
23	22B	NE2V	19.1	19.2	1.52	1.72	1.13	1.18	1.62	1.37	1.12	1.47	1.31	1.13	1.29	1.14	1.00	0.00	0.00	0.92	1.33	1.45	
24	22B	NE2V	19.2	19.3	1.75	1.89	1.08	1.51	1.81	1.20	1.41	1.70	1.21	1.35	1.72	1.27	1.00	0.00	0.00	1.22	1.54	1.26	
25	22B	NE2V	19.3	19.4	1.96	2.02	1.03	1.78	1.87	1.05	1.63	1.75	1.07	1.53	1.71	1.12	1.00	0.00	0.00	1.20	1.57	1.31	
26					1.44		1.31	1.24		1.37	1.13		1.39	1.01		1.50	1.00		0.00	0.84		1.52	
27																							
28	22B	NE1V	20.4	20.5	2.17	2.16	1.00	2.08	2.08	1.00	1.92	1.94	1.01	1.95	1.87	0.96	1.00	0.00	0.00	1.26	1.91	1.52	
29	22B	NE1V	20.5	20.6	2.36	2.75	1.17	2.02	2.51	1.24	1.93	2.28	1.18	1.76	2.33	1.32	1.00	0.00	0.00	1.63	2.19	1.34	
30	22B	NE1V	20.6	20.7	2.34	2.82	1.21	1.93	2.62	1.36	1.71	2.18	1.27	1.91	2.45	1.28	1.00	0.00	0.00	1.70	2.27	1.34	
31	22B	NE1V	20.7	20.8	2.10	2.75	1.31	1.95	2.77	1.42	1.73	2.40	1.39	1.46	2.45	1.68	1.00	0.00	0.00	1.33	2.28	1.71	
32	22B	NE1V	20.8	20.9	2.05	2.54	1.24	1.95	2.38	1.22	1.52	2.18	1.43	1.67	2.00	1.20	1.00	0.00	0.00	1.35	2.07	1.53	
33					2.20		1.18	1.99		1.25	1.76		1.26	1.75		1.29	1.00		0.00	1.45		1.49	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio	
35	22B	NE3V	21.4	21.5	2.49	3.72	1.49	2.77	3.37	1.22	2.66	3.20	1.20	2.10	3.79	1.80	1.00	0.00	0.00	1.54	2.92	1.90	
36	22B	NE3V	21.5	21.6	2.29	2.96	1.29	2.28	3.08	1.35	2.03	2.63	1.30	1.67	2.82	1.69	1.00	0.00	0.00	1.46	2.06	1.41	
37	22B	NE3V	21.6	21.7	1.99	2.57	1.29	1.49	2.72	1.83	1.29	1.72	1.33	1.58	2.22	1.41	1.00	0.00	0.00	1.23	1.80	1.46	
38	22B	NE3V	21.7	21.8	1.42	2.79	1.96	1.40	2.84	2.03	1.39	2.09	1.50	1.20	2.43	2.03	1.00	0.00	0.00	0.84	2.32	2.76	
39	22B	NE3V	21.8	21.9	2.02	3.22	1.59	1.60	3.05	1.91	1.85	2.66	1.44	1.26	2.90	2.30	1.00	0.00	0.00	1.20	2.95	2.46	
40	22B	NE3V	21.9	22.0	2.27	2.82	1.24	1.95	2.91	1.49	2.21	2.48	1.12	1.70	2.71	1.59	1.00	0.00	0.00	1.51	2.69	1.78	
41					2.08		1.48	1.92		1.64	1.91		1.32	1.59		1.80	1.00		0.00	1.30		1.96	
42																							
43	22B	NE4V	31.7	31.8	1.74	1.88	1.08	1.64	1.98	1.21	1.54	1.83	1.19	1.56	1.77	1.13	1.00	0.00	0.00	2.17	2.49	1.15	
44	22B	NE4V	31.8	31.9	1.90	1.93	1.02	1.71	1.98	1.16	1.58	2.08	1.32	1.58	1.73	1.09	1.00	0.00	0.00	2.43	3.05	1.26	
45	22B	NE4V	31.9	32.0	1.95	2.04	1.05	1.92	2.14	1.11	1.62	2.06	1.27	1.73	1.67	0.97	1.00	0.00	0.00	2.23	3.04	1.36	
46	22B	NE4V	32.0	32.1	1.91	2.09	1.09	1.75	2.03	1.16	1.75	1.93	1.10	1.54	1.94	1.26	1.00	0.00	0.00	2.22	3.03	1.36	
47	22B	NE4V	32.1	32.2	1.89	2.19	1.16	1.63	2.05	1.26	1.64	1.95	1.19	1.42	1.85	1.30	1.00	0.00	0.00	2.31	3.04	1.32	
48	22B	NE4V	32.2	32.3	1.85	2.27	1.23	1.73	2.18	1.26	1.63	2.06	1.26	1.51	1.96	1.30	1.00	0.00	0.00	2.25	3.07	1.36	
49	22B	NE4V	32.3	32.4	1.70	2.23	1.31	1.70	2.21	1.30	1.61	2.14	1.33	1.83	1.95	1.07	1.00	0.00	0.00	2.18	3.04	1.39	
50	22B	NE4V	32.4	32.5	1.24	2.01	1.62	0.93	1.78	1.91	0.97	1.78	1.84	1.12	1.80	1.61	1.00	0.00	0.00	2.14	3.01	1.41	
51	22B	NE4V	32.5	32.6	1.42	2.01	1.42	1.43	1.92	1.34	1.16	1.85	1.59	1.01	1.71	1.69	1.00	0.00	0.00	2.24	2.99	1.33	
52					1.73		1.22	1.60		1.30	1.50		1.34	1.48		1.27	1.00		0.00	2.24		1.33	
53																							
54	22B	NE3S	39.0	39.1	1.87	3.01	1.61	1.85	3.08	1.66	1.58	2.28	1.44	1.39	2.64	1.90	1.24	2.65	2.14	1.14	2.66	2.33	
55	22B	NE3S	39.1	39.2	2.21	3.22	1.46	2.11	3.03	1.44	1.62	2.57	1.59	1.76	2.64	1.50	1.60	2.36	1.48	1.50	2.73	1.82	
56	22B	NE3S	39.2	39.3	2.08	3.27	1.57	1.90	3.17	1.67	1.88	2.67	1.42	1.73	2.57	1.49	1.53	2.59	1.69	1.54	2.92	1.90	
57	22B	NE3S	39.3	39.4	2.10	3.29	1.57	2.01	3.26	1.62	1.90	2.81	1.48	1.76	3.10	1.76	1.17	3.21	2.74	1.00	3.25	3.25	
58	22B	NE3S	39.4	39.5	2.43	3.02	1.24	2.39	3.12	1.31	2.02	2.93	1.45	1.97	2.69	1.37	1.31	2.95	2.25	1.20	2.88	2.40	
59	22B	NE3S	39.5	39.6	2.63	2.93	1.11	2.48	2.95	1.19	2.30	2.72	1.18	2.18	2.34	1.07	1.80	2.53	1.41	1.72	2.52	1.47	
60					2.22		1.43	2.12		1.48	1.88		1.43	1.80		1.51	1.44		1.95	1.35		2.19	
61																							
62	22B	NE4S	42.6	42.7	2.20	3.12	1.42	1.62	3.41	2.10	1.83	3.09	1.69	2.02	2.65	1.31	1.04	2.96	2.85	0.90	2.68	2.98	
63	22B	NE4S	42.7	42.8	2.52	3.22	1.28	1.93	3.31	1.72	1.72	3.10	1.80	1.29	2.81	2.18	0.84	2.95	3.51	0.77	2.70	3.51	
64	22B	NE4S	42.8	42.9	2.26	3.38	1.50	2.22	3.20	1.44	1.53	2.74	1.79	0.94	2.06	2.19	0.72	1.92	2.67	0.67	1.41	2.10	
65	22B	NE4S	42.9	43.0	2.33	3.26	1.40	2.39	3.13	1.31	1.37	2.06	1.50	0.90	1.83	2.03	0.69	1.59	2.30	0.71	1.28	1.80	
66	22B	NE4S	43.0	43.1	2.63	3.34	1.27	2.60	3.30	1.27	1.40	1.87	1.34	0.96	1.63	1.70	0.71	1.46	2.06	0.73	1.43	1.96	
67					2.39		1.37	2.15		1.57	1.57		1.62	1.22		1.88	0.80		2.68	0.76		2.47	

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio	
71	22B	NE1S	45.4	45.5	1.97	2.54	1.29	1.48	2.73	1.84	1.25	2.39	1.91	1.33	2.22	1.67	0.96	2.35	2.45	0.80	2.53	3.16	
72	22B	NE1S	45.5	45.6	1.72	2.62	1.52	1.14	2.50	2.19	1.38	2.45	1.78	1.22	2.28	1.87	1.00	2.16	2.16	0.80	2.26	2.83	
73	22B	NE1S	45.6	45.7	1.37	2.59	1.89	1.43	2.53	1.77	1.14	2.19	1.92	0.85	2.13	2.51	0.72	1.98	2.75	0.65	2.08	3.20	
74	22B	NE1S	45.7	45.8	1.77	2.76	1.56	1.65	2.71	1.64	0.99	2.00	2.02	1.25	1.89	1.51	1.08	2.01	1.86	1.15	2.16	1.88	
75					1.51		1.77	1.34		1.92	1.05		2.26	1.04		2.03	0.85		2.53	0.80		2.86	
76	22B	NE5S	51.1	51.2	1.71	2.36	1.38	2.09	2.02	0.97	3.34	3.57	1.07	3.03	3.48	1.15	2.34	3.37	1.44	2.63	2.79	1.06	
77	22B	NE5S	51.2	51.3	1.31	2.23	1.70	1.34	1.96	1.46	3.43	3.56	1.04	3.26	3.44	1.06	2.38	3.50	1.47	2.32	3.18	1.37	
78	22B	NE5S	51.3	51.4	1.10	2.30	2.09	0.95	2.32	2.44	3.29	3.57	1.09	2.51	3.42	1.36	1.99	3.32	1.67	1.46	2.98	2.04	
79	22B	NE5S	51.4	51.5	0.98	2.42	2.47	1.32	2.16	1.64	3.17	3.65	1.15	2.58	3.57	1.38	1.85	3.50	1.89	1.80	3.14	1.74	
80	22B	NE5S	51.5	51.6	1.37	2.10	1.53	1.39	2.10	1.51	3.25	3.70	1.14	2.82	3.43	1.22	2.21	3.45	1.56	2.01	3.10	1.54	
81	22B	NE5S	51.6	51.7	1.14	2.29	2.01	1.52	1.95	1.28	2.94	3.70	1.26	2.62	3.25	1.24	2.02	3.35	1.66	1.54	3.09	2.01	
82	22B	NE5S	51.7	51.8	1.17	1.90	1.62	0.93	1.92	2.06	2.85	3.67	1.29	2.61	3.38	1.30	2.08	3.03	1.46	1.84	2.87	1.56	
83	22B	NE5S	51.8	51.9	1.10	1.92	1.75	0.81	1.81	2.23	2.91	3.54	1.22	2.60	3.18	1.22	2.22	2.85	1.28	1.76	2.71	1.54	
84	22B	NE5S	51.9	52.0	1.67	1.62	0.97	1.59	1.52	0.96	2.99	3.43	1.15	2.57	2.84	1.11	2.11	2.70	1.28	1.74	2.90	1.67	
85					1.28		1.72	1.33		1.62	3.13		1.15	2.73		1.23	2.13		1.52	1.90		1.61	
86																							
87	22B	NE2S	62.8	62.9	2.09	3.02	1.44	1.85	3.15	1.70	2.02	3.58	1.77	2.04	2.55	1.25	1.80	3.29	1.83	1.74	3.55	2.04	
88	22B	NE2S	62.9	63.0	2.06	3.12	1.51	2.15	3.08	1.43	1.95	3.17	1.63	2.08	2.60	1.25	1.87	3.01	1.61	2.00	3.17	1.59	
89	22B	NE2S	63.0	63.1	2.15	2.71	1.26	2.28	2.81	1.23	2.11	3.23	1.53	2.01	2.67	1.33	1.84	2.60	1.41	1.87	2.88	1.54	
90	22B	NE2S	63.1	63.2	2.28	2.31	1.01	2.15	2.79	1.30	2.14	2.65	1.24	2.10	2.70	1.29	1.91	2.66	1.39	1.99	2.71	1.36	
91	22B	NE2S	63.2	63.3	2.02	2.42	1.20	1.94	3.01	1.55	2.09	2.52	1.21	1.87	2.75	1.47	1.68	2.68	1.60	1.73	2.65	1.53	
92	22B	NE2S	63.3	63.4	2.18	2.98	1.37	2.10	3.26	1.55	1.82	2.64	1.45	2.04	3.02	1.48	1.77	3.07	1.73	1.82	3.32	1.82	
93					2.13		1.30	2.08		1.46	2.02		1.47	2.02		1.34	1.81		1.60	1.86		1.65	
94																							

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio
2	22A	SB2V	13.2	13.3	1.43	2.39	1.67	2.04	1.93	0.95	2.39	2.65	1.11	1.59	2.03	1.28	1.26	1.74	1.38	1.15	1.53	1.33
3	22A	SB2V	13.3	13.4	1.38	2.27	1.64	1.7	2.05	1.21	2.6	2.72	1.05	1.93	2.18	1.13	1.61	2.07	1.29	1.48	2	1.35
4	22A	SB2V	13.4	13.5	1.38	2.23	1.62	1.56	2.2	1.41	2.51	2.64	1.05	1.97	2.23	1.13	1.63	2.14	1.31	1.54	2.02	1.31
5	22A	SB2V	13.5	13.6	1.44	2.31	1.60	1.45	2.53	1.74	2.49	2.68	1.08	1.93	2.31	1.20	1.63	2.14	1.31	1.57	2.04	1.30
6	22A	SB2V	13.6	13.7	1.46	2.42	1.66	1.54	2.35	1.53	2.43	2.4	0.99	2.07	2.2	1.06	1.71	2.01	1.18	1.63	2.06	1.26
7	22A	SB2V	13.7	13.8	1.42	2.55	1.80	1.56	2.38	1.53	2.56	2.74	1.07	1.88	2.43	1.29	1.67	2.05	1.23	1.66	2.14	1.29
8	22A	SB2V	13.8	13.9	1.55	2.34	1.51	1.54	2.29	1.49	2.76	2.75	1.00	1.89	2.26	1.20	1.7	2.06	1.21	1.6	2.15	1.34
9	22A	SB2V	13.9	14	1.54	2.27	1.47	1.55	2.25	1.45	2.63	2.76	1.05	1.9	2.27	1.19	1.69	2.2	1.30	1.73	2.11	1.22
10	22A	SB2V	14	14.1	1.76	2.74	1.56	1.88	2.75	1.46	2.88	2.99	1.04	2.2	2.5	1.14	1.95	2.41	1.24	1.99	2.25	1.13
11	22A	SB2V	14.1	14.2	2.05	2.64	1.29	2.16	2.74	1.27	3.17	3.11	0.98	2.31	2.6	1.13	2.07	2.49	1.20	2.03	2.34	1.15
12	22A	SB2V	14.2	14.3	1.98	2.48	1.25	1.99	2.7	1.36	3.18	2.95	0.93	2.23	2.58	1.16	2.05	2.49	1.21	2.05	2.3	1.12
13	22A	SB2V	14.3	14.4	1.72	2.58	1.50	1.76	2.71	1.54	3.77	3.02	0.80	2.34	2.64	1.13	2.04	2.6	1.27	2.21	2.25	1.02
14	22A	SB2V	14.4	14.5	1.77	2.65	1.50	1.81	2.81	1.55	3.24	2.97	0.92	2.28	2.61	1.14	1.99	2.43	1.22	2.12	2.24	1.06
15	22A	SB2V	14.5	14.6	1.98	2.65	1.34	2.09	2.77	1.33	3.08	3.01	0.98	2.24	2.66	1.19	1.98	2.47	1.25	1.94	2.29	1.18
16					1.63		1.53	1.76		1.41	2.84		1.00	2.05		1.17	1.78		1.26	1.76		1.22
17	22A	SB1V	14.7	14.8	1.69	2.48	1.47	1.97	2.32	1.18	2.72	2.86	1.05	2.18	2.53	1.16	1.92	2.22	1.16	1.74	2.14	1.23
18	22A	SB1V	14.8	14.9	1.61	2.63	1.63	1.66	2.72	1.64	2.96	3.04	1.03	1.98	2.63	1.33	1.77	2.45	1.38	1.78	2.2	1.24
19	22A	SB1V	14.9	15	1.96	2.66	1.36	1.82	2.74	1.51	2.78	2.97	1.07	2.07	2.58	1.25	1.85	2.47	1.34	1.82	2.27	1.25
20	22A	SB1V	15	15.1	2.32	2.52	1.09	1.91	2.81	1.47	3.19	3.1	0.97	2.14	2.63	1.23	1.9	2.5	1.32	1.85	2.35	1.27
21	22A	SB1V	15.1	15.2	2.1	2.51	1.20	1.73	2.74	1.58	2.96	3.24	1.09	1.95	2.6	1.33	1.81	2.36	1.30	1.71	2.25	1.32
22	22A	SB1V	15.2	15.3	1.72	2.73	1.59	1.72	2.78	1.62	3.13	3.14	1.00	2.04	2.5	1.23	2	2.27	1.14	1.74	2.2	1.26
23	22A	SB1V	15.3	15.4	1.97	2.68	1.36	1.98	2.81	1.42	2.74	2.79	1.02	2.1	2.42	1.15	2.03	2.28	1.12	1.79	2.16	1.21
24	22A	SB1V	15.4	15.5	1.78	2.74	1.54	1.97	2.66	1.35	2.91	3.07	1.05	2.21	2.57	1.16	2.06	2.34	1.14	1.74	2.2	1.26
25	22A	SB1V	15.5	15.6	1.95	2.84	1.46	2.01	2.83	1.41	3.24	3.03	0.94	2.21	2.68	1.21	2.08	2.44	1.17	1.7	2.25	1.32
26	22A	SB1V	15.6	15.7	1.68	2.5	1.49	1.67	2.58	1.54	2.89	2.89	1.00	2.08	2.39	1.15	1.79	2.22	1.24	1.6	2.04	1.28
27	22A	SB1V	15.7	15.8	1.34	2.26	1.69	1.36	2.31	1.70	2.62	2.94	1.12	1.9	2.26	1.19	1.56	2.05	1.31	1.45	1.95	1.34
28	22A	SB1V	15.8	15.9	1.45	2.4	1.66	1.49	2.18	1.46	2.84	3.02	1.06	2.04	2.35	1.15	1.6	2.25	1.41	1.55	2.07	1.34
29	22A	SB1V	15.9	16	1.59	2.47	1.55	1.65	2.47	1.50	3	2.98	0.99	2.07	2.66	1.29	1.78	2.51	1.41	1.79	2.23	1.25
30	22A	SB1V	16	16.1	1.74	2.59	1.49	2.1	2.42	1.15	3.18	3.07	0.97	2.12	2.72	1.28	1.98	2.58	1.30	1.93	2.39	1.24
31	22A	SB1V	16.1	16.2	1.77	2.63	1.49	1.84	2.74	1.49	3.31	3.19	0.96	2.18	2.7	1.24	1.95	2.61	1.34	1.87	2.42	1.29
32	22A	SB1V	16.2	16.3	1.6	2.65	1.66	1.66	2.68	1.61	3.01	3.11	1.03	2.15	2.62	1.22	1.79	2.81	1.57	1.75	2.37	1.35
33	22A	SB1V	16.3	16.4	1.64	2.46	1.50	1.75	2.61	1.49	3.32	3.26	0.98	2.24	2.63	1.17	1.84	2.8	1.52	1.97	2.3	1.17
34	22A	SB1V	16.4	16.5	1.59	2.36	1.48	1.88	2.64	1.40	3.41	3.18	0.93	2.11	2.37	1.12	1.71	2.43	1.42	1.87	1.98	1.06
35	22A	SB1V	16.5	16.6	1.39	2.4	1.73	1.41	2.6	1.84	3.3	3.34	1.01	2.18	2.67	1.22	1.75	2.34	1.34	1.76	1.92	1.09
36	22A	SB1V	16.6	16.7	1.47	2.7	1.84	1.54	2.85	1.85	2.95	3.48	1.18	2.23	2.68	1.20	1.85	2.28	1.23	1.82	2.29	1.26
37					1.72		1.51	1.76		1.51	3.02		1.02	2.11		1.21	1.85		1.31	1.76		1.25

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio
2	40B	SB5V	20.00	20.10	1.85	2.37	1.28	1.43	2.51	1.76	1.64	2.57	1.57	1.77	1.52	0.86	1.49	1.91	1.28	1.86	2.24	1.20
3	40B	SB5V	20.10	20.20	1.85	2.62	1.42	1.87	2.80	1.50	1.83	2.71	1.48	2.09	2.15	1.03	1.80	1.97	1.09	1.78	2.11	1.19
4	40B	SB5V	20.20	20.30	1.74	2.29	1.32	1.52	2.66	1.75	1.58	2.60	1.65	2.16	2.20	1.02	1.84	2.10	1.14	1.83	2.17	1.19
5	40B	SB5V	20.30	20.40	2.01	2.32	1.15	1.62	2.84	1.75	1.68	2.67	1.59	2.17	2.23	1.03	1.83	2.16	1.18	1.84	2.25	1.22
6	40B	SB5V	20.40	20.50	2.42	2.65	1.10	2.30	2.79	1.21	2.20	2.70	1.23	2.17	2.21	1.02	1.95	2.09	1.07	2.00	2.12	1.06
7					1.97		1.25	1.75		1.59	1.79		1.50	2.07		0.99	1.78		1.15	1.86		1.17
8																						
9	40B	SB4V	22.00	22.10	2.61	3.00	1.15	2.78	3.09	1.11	2.84	3.17	1.12	2.41	2.35	0.98	1.94	2.24	1.15	1.98	2.15	1.09
10	40B	SB4V	22.10	22.20	2.38	2.88	1.21	2.39	3.07	1.28	2.48	3.04	1.23	2.34	2.37	1.01	2.05	2.27	1.11	1.97	2.21	1.12
11	40B	SB4V	22.20	22.30	2.19	2.82	1.29	2.51	2.61	1.04	2.59	3.09	1.19	2.20	2.32	1.05	1.98	2.18	1.10	1.84	2.22	1.21
12	40B	SB4V	22.30	22.40	1.97	2.84	1.44	1.99	3.02	1.52	2.11	3.08	1.46	2.16	2.22	1.03	2.03	2.05	1.01	1.98	2.15	1.09
13	40B	SB4V	22.40	22.50	2.11	2.30	1.09	2.11	2.51	1.19	2.26	2.64	1.17	2.21	2.23	1.01	2.08	2.05	0.99	2.06	2.15	1.04
14					2.25		1.24	2.36		1.23	2.46		1.23	2.26		1.02	2.02		1.07	1.97		1.11
15																						
16	40B	SB3V	62.60	62.70	2.53	2.46	0.97	2.41	2.27	0.94	2.49	2.27	0.91	2.37	2.40	1.01	2.12	2.38	1.12	2.30	2.57	1.12
17	40B	SB3V	62.70	62.80	2.50	2.59	1.04	2.58	2.38	0.92	2.45	2.54	1.04	2.48	2.67	1.08	2.27	2.63	1.16	2.41	2.94	1.22
18	40B	SB3V	62.80	62.90	2.41	2.60	1.08	2.34	2.63	1.12	2.38	2.52	1.06	2.42	2.86	1.18	2.22	2.74	1.23	2.35	2.94	1.25
19	40B	SB3V	62.90	63.00	2.29	2.67	1.17	2.20	2.73	1.24	2.30	2.53	1.10	2.15	2.88	1.34	1.84	2.71	1.47	1.88	2.86	1.52
20	40B	SB3V	63.00	63.10	2.38	2.59	1.09	2.45	2.37	0.97	2.21	2.59	1.17	1.93	2.82	1.46	1.84	2.53	1.38	1.77	2.93	1.66
21					2.42		1.07	2.40		1.04	2.37		1.06	2.27		1.21	2.06		1.27	2.14		1.35
22																						

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio
2	40C	SB4S	29.9	30	1.57	2.31	1.47	1.51	1.88	1.25	1.38	1.97	1.43	1.38	2.1	1.52	1.46	1.98	1.36	1.28	1.78	1.39
3	40C	SB4S	30	30.1	1.65	2.34	1.42	1.57	1.98	1.26	1.43	2.28	1.59	1.46	2.31	1.58	1.42	2.25	1.58	1.23	2.15	1.75
4	40C	SB4S	30.1	30.2	1.52	2.19	1.44	1.41	2.03	1.44	1.33	2.28	1.71	1.31	2.16	1.65	1.11	2.15	1.94	1.12	2.16	1.93
5	40C	SB4S	30.2	30.3	1.5	2.2	1.47	1.41	2.14	1.52	1.32	2.35	1.78	1.26	2.24	1.78	1.3	1.98	1.52	1.09	2.1	1.93
6	40C	SB4S	30.3	30.4	1.43	2.4	1.68	1.48	2.07	1.40	1.38	2.4	1.74	1.34	2.3	1.72	1.33	2.01	1.51	1.17	2.04	1.74
7	40C	SB4S	30.4	30.5	1.68	2.4	1.43	1.6	2.17	1.36	1.37	2.52	1.84	1.35	2.54	1.88	1.33	1.93	1.45	1.3	2.26	1.74
8					1.56		1.48	1.50		1.37	1.37		1.68	1.35		1.69	1.33		1.56	1.20		1.75
9																						
10	40C	SB3S	33.1	33.2	2.05	2.43	1.19	1.93	2.38	1.23	1.73	2.65	1.53	2.03	2.24	1.10	1.51	2.66	1.76	1.51	2.58	1.71
11	40C	SB3S	33.2	33.3	2	2.58	1.29	1.93	2.36	1.22	2.07	2.24	1.08	2.16	2.13	0.99	1.78	2.62	1.47	1.76	2.44	1.39
12	40C	SB3S	33.3	33.4	1.99	2.43	1.22	1.7	2.47	1.45	1.56	2.49	1.60	1.53	2.58	1.69	1.49	2.51	1.68	1.36	2.56	1.88
13	40C	SB3S	33.4	33.5	1.88	2.54	1.35	1.89	2.55	1.35	1.77	2.51	1.42	1.84	2.62	1.42	1.8	2.41	1.34	1.54	2.46	1.60
14	40C	SB3S	33.5	33.6	2	2.65	1.33	1.98	2.75	1.39	1.94	2.74	1.41	1.98	2.82	1.42	1.83	2.73	1.49	1.71	2.64	1.54
15	40C	SB3S	33.6	33.7	1.98	2.7	1.36	1.94	2.78	1.43	1.93	2.69	1.39	1.95	2.79	1.43	1.81	2.81	1.55	1.71	2.7	1.58
16	40C	SB3S	33.7	33.8	2.03	2.61	1.29	1.97	2.69	1.37	2	2.64	1.32	1.98	2.64	1.33	1.79	2.7	1.51	1.74	2.69	1.55
17	40C	SB3S	33.8	33.9	1.87	2.72	1.45	2.01	2.69	1.34	1.92	2.56	1.33	1.87	2.63	1.41	1.74	2.7	1.55	1.77	2.68	1.51
18	40C	SB3S	33.9	34	1.87	2.6	1.39	1.88	2.75	1.46	2.03	2.23	1.10	1.69	2.56	1.51	1.65	2.72	1.65	1.59	2.65	1.67
19	40C	SB3S	34	34.1	1.84	2.82	1.53	1.77	2.67	1.51	1.8	2.55	1.42	1.78	2.6	1.46	1.94	2.49	1.28	1.44	2.67	1.85
20					1.95		1.34	1.90		1.38	1.88		1.36	1.88		1.38	1.73		1.53	1.61		1.63
21																						
22	40C	SB5S	37.8	37.9	2.28	2.62	1.15	2.04	2.54	1.25	1.99	2.46	1.24	1.95	2.48	1.27	1.79	2.38	1.33	1.78	2.49	1.40
23	40C	SB5S	37.9	38	2.26	2.56	1.13	1.99	2.49	1.25	2.02	2.42	1.20	1.89	2.43	1.29	1.78	2.19	1.23	1.76	2.38	1.35
24	40C	SB5S	38	38.1	2.21	2.47	1.12	1.94	2.44	1.26	2.14	2.4	1.12	2.02	2.27	1.12	1.81	2.19	1.21	1.7	2.28	1.34
25	40C	SB5S	38.1	38.2	2.2	2.58	1.17	1.98	2.6	1.31	2	2.52	1.26	1.98	2.31	1.17	1.82	2.21	1.21	1.75	2.61	1.49
26	40C	SB5S	38.2	38.3	1.98	2.58	1.30	1.85	2.5	1.35	1.78	2.39	1.34	1.85	2.51	1.36	1.73	2.34	1.35	1.67	2.42	1.45
27	40C	SB5S	38.3	38.4	1.61	2.31	1.43	1.63	2.24	1.37	1.57	2.13	1.36	1.43	2.14	1.50	1.65	1.82	1.10	1.41	2.09	1.48
28	40C	SB5S	38.4	38.5	1.75	2.32	1.33	1.69	2.21	1.31	1.67	2.05	1.23	1.75	2.03	1.16	1.63	2.02	1.24	1.4	2	1.43
29	40C	SB5S	38.5	38.6	1.95	2.57	1.32	1.89	2.44	1.29	1.87	2.37	1.27	1.75	2.43	1.39	1.73	2.4	1.39	1.61	2.41	1.50
30					1.90		1.24	1.88		1.30	1.88		1.25	1.83		1.28	1.74		1.26	1.64		1.43
31																						

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	ROAD ID	CODE	TDIST START	TDIST END	SPTD OWP	SPTD BWP	2001 Ratio	SPTD OWP	SPTD BWP	2002 Ratio	SPTD OWP	SPTD BWP	2003 Ratio	SPTD OWP	SPTD BWP	2004 Ratio	SPTD OWP	SPTD BWP	2005 Ratio	SPTD OWP	SPTD BWP	2006 Ratio
2	45A	SB1S	100.6	100.7	1.85	2.4	1.30	1.58	2.4	1.52	1.39	2.15	1.55	1.4	2.22	1.59	1.17	2.16	1.85	1.13	2.08	1.84
3	45A	SB1S	100.7	100.8	1.8	2.35	1.31	1.68	2.45	1.46	1.42	2.22	1.56	1.42	2.03	1.43	1.24	2.25	1.81	1.19	2.05	1.72
4	45A	SB1S	100.8	100.9	1.73	2.26	1.31	1.68	2.32	1.38	1.4	2.07	1.48	1.38	2.04	1.48	1.27	2.26	1.78	1.21	1.95	1.61
5	45A	SB1S	100.9	101	1.67	2.33	1.40	1.65	2.17	1.32	1.43	2.02	1.41	1.36	2.19	1.61	1.22	2.09	1.71	1.31	2.1	1.60
6	45A	SB1S	101	101.1	1.76	2.41	1.37	1.91	2.22	1.16	1.58	2.25	1.42	1.66	2.28	1.37	1.46	2.17	1.49	1.42	2.19	1.54
7	45A	SB1S	101.1	101.2	1.77	2.5	1.41	1.86	2.28	1.23	1.67	2.23	1.34	1.5	2.23	1.49	1.31	2.08	1.59	1.3	2.22	1.71
8	45A	SB1S	101.2	101.3	1.68	2.48	1.48	1.75	2.36	1.35	1.42	2.32	1.63	1.37	2.32	1.69	1.25	2.2	1.76	1.22	2.33	1.91
9	45A	SB1S	101.3	101.4	1.7	2.53	1.49	1.75	2.49	1.42	1.47	2.5	1.70	1.43	2.46	1.72	1.29	2.37	1.84	1.29	2.39	1.85
10	45A	SB1S	101.4	101.5	1.8	2.52	1.40	1.71	2.44	1.43	1.5	2.39	1.59	1.43	2.41	1.69	1.32	2.26	1.71	1.32	2.39	1.81
11	45A	SB1S	101.5	101.6	1.77	2.61	1.47	1.8	2.47	1.37	1.59	2.57	1.62	1.48	2.37	1.60	1.35	2.29	1.70	1.33	2.32	1.74
12					1.75		1.39	1.74		1.36	1.49		1.53	1.44		1.57	1.29		1.72	1.27		1.73
13																						
14	45A	SB2S	101.9	102	1.9	2.66	1.40	1.82	2.55	1.40	1.66	2.25	1.36	1.64	2	1.22	1.44	2.29	1.59	1.41	2.19	1.55
15	45A	SB2S	102	102.1	1.96	2.8	1.43	1.84	2.82	1.53	1.63	2.44	1.50	1.55	2.29	1.48	1.49	2.27	1.52	1.33	2.2	1.65
16	45A	SB2S	102.1	102.2	1.86	2.87	1.54	1.8	2.78	1.54	1.48	2.52	1.70	1.42	2.36	1.66	1.48	2.18	1.47	1.31	2.27	1.73
17	45A	SB2S	102.2	102.3	1.99	2.77	1.39	1.95	2.7	1.38	1.6	2.38	1.49	1.56	2.36	1.51	1.55	2.35	1.52	1.48	2.38	1.61
18	45A	SB2S	102.3	102.4	1.84	2.52	1.37	1.85	2.53	1.37	1.69	2.23	1.32	1.63	2.36	1.45	1.48	2.3	1.55	1.61	2.35	1.46
19	45A	SB2S	102.4	102.5	1.96	2.58	1.32	1.84	2.62	1.42	1.71	2.35	1.37	1.62	2.31	1.43	1.44	2.33	1.62	1.58	2.31	1.46
20	45A	SB2S	102.5	102.6	1.86	2.4	1.29	1.87	2.52	1.35	1.71	2.26	1.32	1.55	2.31	1.49	1.44	2.13	1.48	1.38	2.28	1.65
21	45A	SB2S	102.6	102.7	1.66	2.23	1.34	1.68	2.35	1.40	1.45	2.16	1.49	1.4	2.26	1.61	1.35	2.02	1.50	1.27	2.21	1.74
22	45A	SB2S	102.7	102.8	1.64	2.27	1.38	1.55	2.27	1.46	1.41	2.1	1.49	1.39	2.13	1.53	1.47	1.73	1.18	1.28	2.09	1.63
23	45A	SB2S	102.8	102.9	1.69	2.11	1.25	1.66	2.06	1.24	1.5	2.1	1.40	1.53	2.06	1.35	1.35	1.84	1.36	1.33	1.99	1.50
24	45A	SB2S	102.9	103	1.75	2.15	1.23	1.69	2.14	1.27	1.6	2.15	1.34	1.54	2.13	1.38	1.38	1.95	1.41	1.24	1.97	1.59
25	45A	SB2S	103	103.1	1.63	2.25	1.38	1.54	2.24	1.45	1.35	2.12	1.57	1.39	2.08	1.50	1.43	1.98	1.38	1.22	2.06	1.69
26	45A	SB2S	103.1	103.2	1.89	2.32	1.23	1.71	2.31	1.35	1.7	2.21	1.30	1.52	2.1	1.38	1.42	2.04	1.44	1.43	2.23	1.56
27	45A	SB2S	103.2	103.3	2.05	2.53	1.23	2.08	2.42	1.16	1.78	2.41	1.35	1.73	2.27	1.31	1.96	2.05	1.05	1.54	2.35	1.53
28					1.83		1.34	1.78		1.38	1.59		1.43	1.53		1.45	1.48		1.43	1.39		1.60
29																						

Appendix E Sample ARMIS Surface Texture Data (Unsorted)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ROAD_SECTION_ID	CARRIAGEWAY_CODE	TDIST_START	TDIST_END	LANE_CODE	SMTD_OWP	STD_OWP	SPTD_OWP	SMTD_BWP	STD_BWP	SPTD_BWP	RATING_DATE	SURVEY_ID
2	28A	1	9	9.1	1	0.88	0.18	2.19	0.95	0.25	2.36	18-MAY-01	C0301E
3	28A	1	9	9.1	1	0.85	0.18	2.13	0.71	0.19	1.78	18-JUN-02	C0302D
4	28A	1	9	9.1	1	0.23	0.06	0.58	0.79	0.2	1.97	18-APR-05	N0305D
5	28A	1	9	9.1	1	0.19	0.04	0.48	1	0.28	2.52	08-MAY-06	N0306E
6	28A	1	9	9.1	1	1.06	0.17	2.66	1.04	0.19	2.61	15-JUN-07	N0307F
7	28A	1	9	9.1	1	0.63	0.16	1.58	0.97	0.18	2.44	06-MAR-03	U0303C
8	28A	1	9	9.1	1	0.65	0.19	1.64	0.75	0.19	1.88	12-MAY-04	U0304E
9	28A	1	9.1	9.2	1	0.87	0.2	2.16	0.82	0.2	2.03	18-MAY-01	C0301E
10	28A	1	9.1	9.2	1	0.79	0.18	1.97	0.78	0.19	1.94	18-JUN-02	C0302D
11	28A	1	9.1	9.2	1	0.24	0.05	0.6	0.71	0.21	1.76	18-APR-05	N0305D
12	28A	1	9.1	9.2	1	0.19	0.04	0.47	1.06	0.23	2.65	08-MAY-06	N0306E
13	28A	1	9.1	9.2	1	1.08	0.19	2.69	1.06	0.23	2.64	15-JUN-07	N0307F
14	28A	1	9.1	9.2	1	0.66	0.17	1.64	0.77	0.19	1.92	06-MAR-03	U0303C
15	28A	1	9.1	9.2	1	0.64	0.19	1.6	0.92	0.24	2.29	12-MAY-04	U0304E
16	28A	1	9.2	9.3	1	0.85	0.28	2.12	0.94	0.28	2.34	18-MAY-01	C0301E
17	28A	1	9.2	9.3	1	0.75	0.35	1.89	0.89	0.25	2.23	18-JUN-02	C0302D
18	28A	1	9.2	9.3	1	0.27	0.06	0.65	0.5	0.25	1.24	18-APR-05	N0305D
19	28A	1	9.2	9.3	1	0.27	0.07	0.66	0.45	0.17	1.12	08-MAY-06	N0306E
20	28A	1	9.2	9.3	1	1.15	0.18	2.87	1.15	0.2	2.85	15-JUN-07	N0307F
21	28A	1	9.2	9.3	1	0.71	0.3	1.77	0.83	0.25	2.09	06-MAR-03	U0303C
22	28A	1	9.2	9.3	1	0.69	0.3	1.74	0.59	0.32	1.45	12-MAY-04	U0304E
23	28A	1	9.3	9.4	1	0.54	0.36	1.37	0.65	0.31	1.61	18-MAY-01	C0301E
24	28A	1	9.3	9.4	1	0.28	0.12	0.69	0.32	0.13	0.81	18-JUN-02	C0302D
25	28A	1	9.3	9.4	1	0.29	0.07	0.72	0.29	0.1	0.74	18-APR-05	N0305D
26	28A	1	9.3	9.4	1	0.25	0.11	0.64	0.29	0.09	0.71	08-MAY-06	N0306E
27	28A	1	9.3	9.4	1	1.14	0.18	2.84	1.04	0.2	2.62	15-JUN-07	N0307F
28	28A	1	9.3	9.4	1	0.27	0.11	0.68	0.3	0.12	0.76	06-MAR-03	U0303C
29	28A	1	9.3	9.4	1	0.34	0.21	0.84	0.3	0.15	0.73	12-MAY-04	U0304E
30	28A	1	9.4	9.5	1	0.58	0.37	1.45	0.87	0.29	2.18	18-MAY-01	C0301E
31	28A	1	9.4	9.5	1	0.39	0.21	0.97	0.55	0.25	1.38	18-JUN-02	C0302D
32	28A	1	9.4	9.5	1	0.22	0.05	0.55	0.37	0.14	0.93	18-APR-05	N0305D
33	28A	1	9.4	9.5	1	0.18	0.05	0.46	0.23	0.06	0.57	08-MAY-06	N0306E

Appendix F Sample ARMIS Surface Texture Data (Sorted)

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ROAD_SECTION_ID	CARRIAGEWAY_CODE	TDIST_START	TDIST_END	LANE_CODE	SMTD_OWP	STD_OWP	SPTD_OWP	SMTD_BWP	STD_BWP	SPTD_BWP	RATING_DATE	SURVEY_ID
2	28A	1	9	9.1	1	0.88	0.18	2.19	0.95	0.25	2.36	18-MAY-01	C0301E
3	28A	1	9.1	9.2	1	0.87	0.2	2.16	0.82	0.2	2.03	18-MAY-01	C0301E
4	28A	1	9.2	9.3	1	0.85	0.28	2.12	0.94	0.28	2.34	18-MAY-01	C0301E
5	28A	1	9.3	9.4	1	0.54	0.36	1.37	0.65	0.31	1.61	18-MAY-01	C0301E
6	28A	1	9.4	9.5	1	0.58	0.37	1.45	0.87	0.29	2.18	18-MAY-01	C0301E
7	28A	1	9.5	9.6	1	0.66	0.23	1.66	1.1	0.28	2.74	18-MAY-01	C0301E
8	28A	1	9.6	9.7	1	0.49	0.29	1.22	1.28	0.27	3.2	18-MAY-01	C0301E
9	28A	1	9.7	9.8	1	0.43	0.14	1.07	1.27	0.23	3.18	18-MAY-01	C0301E
10	28A	1	9.8	9.9	1	0.47	0.15	1.18	1.41	0.26	3.53	18-MAY-01	C0301E
11	28A	1	9.9	10	1	0.63	0.23	1.58	1.21	0.28	3.01	18-MAY-01	C0301E
12	28A	1	10	10.1	1	0.66	0.23	1.67	1.2	0.24	3	18-MAY-01	C0301E
13	28A	1	10.1	10.2	1	0.51	0.19	1.27	0.97	0.21	2.44	18-MAY-01	C0301E
14	28A	1	10.2	10.3	1	0.51	0.17	1.28	0.97	0.21	2.43	18-MAY-01	C0301E
15	28A	1	10.3	10.4	1	0.65	0.27	1.63	0.95	0.24	2.36	18-MAY-01	C0301E
16	28A	1	10.4	10.5	1	0.8	0.23	2	1.13	0.26	2.81	18-MAY-01	C0301E
17	28A	1	10.5	10.6	1	0.98	0.2	2.46	1.28	0.25	3.19	18-MAY-01	C0301E
18	28A	1	10.6	10.7	1	0.91	0.19	2.28	1.22	0.24	3.05	18-MAY-01	C0301E
19	28A	1	10.7	10.8	1	0.8	0.2	2	1.24	0.26	3.1	18-MAY-01	C0301E
20	28A	1	10.8	10.9	1	0.73	0.2	1.8	1.32	0.28	3.29	18-MAY-01	C0301E
21	28A	1	10.9	11	1	0.73	0.17	1.83	1.39	0.26	3.48	18-MAY-01	C0301E
22	28A	1	11	11.1	1	0.86	0.19	2.15	1.45	0.26	3.61	18-MAY-01	C0301E
23	28A	1	11.1	11.2	1	0.85	0.23	2.12	1.36	0.25	3.41	18-MAY-01	C0301E
24	28A	1	11.2	11.3	1	0.68	0.22	1.7	1.43	0.28	3.57	18-MAY-01	C0301E
25	28A	1	11.3	11.4	1	0.52	0.27	1.31	1.27	0.26	3.15	18-MAY-01	C0301E
26	28A	1	11.4	11.5	1	0.44	0.19	1.1	1.22	0.24	3.03	18-MAY-01	C0301E
27	28A	1	11.5	11.6	1	0.51	0.2	1.27	1.05	0.27	2.62	18-MAY-01	C0301E
28	28A	1	11.6	11.7	1	0.49	0.22	1.23	1.14	0.22	2.84	18-MAY-01	C0301E
29	28A	1	11.7	11.8	1	0.33	0.13	0.83	1.28	0.24	3.19	18-MAY-01	C0301E
30	28A	1	11.8	11.9	1	0.25	0.08	0.61	1.38	0.27	3.45	18-MAY-01	C0301E
31	28A	1	11.9	12	1	0.27	0.11	0.68	1.18	0.25	2.95	18-MAY-01	C0301E
32	28A	1	12	12.1	1	0.39	0.22	0.98	1.06	0.25	2.65	18-MAY-01	C0301E
33	28A	1	9	9.1	1	0.85	0.18	2.13	0.71	0.19	1.78	18-JUN-02	C0302D

Appendix G Sample ARMIS Layer Data (Sorted)

Road	Cway	Lane	Start	End	Layer	Layer	Depth	Job Number	Layer Date
22B	1	1	34.34	34.45	1	G1	30	029/22B/746	18-MAR-99
22B	1	1	34.45	34.65	1	K1	14	35/22B/802	14-APR-00
22B	1	1	35.65	36.81	1	K1	14	35/22B/802	14-APR-00
22B	1	1	36.81	37.68	1	L1	14	35/22B/709	06-NOV-02
22B	1	1	37.68	39.17	1	K1	14	35/22B/802	14-APR-00
22B	1	1	42.63	42.75	1	K1	14	35/22B/802	14-APR-00
22B	1	1	42.75	43.48	1	L1	14	35/22B/709	06-NOV-02
22B	1	1	43.48	43.61	1	L1	14	35/22B/709	06-NOV-02
22B	1	1	43.61	43.73	1	K1	14	35/22B/802	14-APR-00
22B	1	1	46.78	47.28	1	K1	14	35/22B/802	14-APR-00
22B	1	1	47.28	47.68	1	GU	80	35/22B/522	30-JUN-00
22B	1	1	47.68	47.92	1	K1	14	35/22B/802	14-APR-00
22B	1	1	47.92	48.7	1	K1	14	110/22B/803	15-APR-00
22B	1	1	48.7	48.92	1	K1	14	110/22B/803	15-APR-00
22B	1	1	48.92	48.95	1	K1	14	110/22B/708	24-JAN-03
22B	1	1	50.21	52.74	1	K1	14	110/22B/708	24-JAN-03
22B	1	1	52.74	52.78	1	K1	14	110/22B/803	15-APR-00
22B	1	1	52.79	55.66	1	K1	14	110/22B/803	15-APR-00
22B	1	1	55.66	55.69	1	K1	14	110/22B/704	04-DEC-97
22B	1	1	57.48	57.78	1	K1	14	110/22B/704	04-DEC-97
22B	1	1	57.78	58.02	1	K1	14	110/22B/708	24-JAN-03
22B	1	1	62.42	62.65	1	K1	14	110/22B/708	24-JAN-03
22B	1	1	62.65	62.77	1	K1	14	110/22B/703	21-DEC-96
22B	1	1	62.77	63.47	1	K1	14	110/22B/703	21-DEC-96
22B	1	1	63.47	64.83	1	K1	14	110/22B/703	21-DEC-96
22B	1	1	64.83	64.99	1	K1	14	110/22B/708	24-JAN-03
22B	1	1	67.14	67.67	1	K1	14	110/22B/708	24-JAN-03
22B	1	1	67.67	67.68	1	K1	14	110/22B/709	21-APR-05
22B	1	1	67.68	69.25	1	K1	14	110/22B/709	21-APR-05
22B	1	1	69.25	69.35	1	K1	14	110/17B/716	16-MAR-00
22B	1	1	69.35	69.49	1	K1	14	110/17B/716	16-MAR-00
22B	1	1	69.49	69.59	1	K1	14	110/17B/716	16-MAR-00
22B	1	1	34.34	34.45	2	K1	20	405	01-FEB-67
22B	1	1	34.45	34.65	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	35.65	36.81	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	36.81	37.68	2	K1	14	35/22B/802	14-APR-00
22B	1	1	37.68	39.17	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	42.63	42.75	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	42.75	43.48	2	K1	14	35/22B/802	14-APR-00
22B	1	1	43.48	43.61	2	K1	14	35/22B/802	14-APR-00
22B	1	1	43.61	43.73	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	46.78	47.28	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	47.28	47.68	2	K1	14	35/22B/802	14-APR-00
22B	1	1	47.68	47.92	2	K1	7	35/22B/802	07-JUN-99
22B	1	1	47.92	48.7	2	K1	7	110/22B/803	07-JUN-99
22B	1	1	48.92	48.95	2	K1	14	110/22B/803	15-APR-00
22B	1	1	48.95	49.68	2	KU	20	301	02-JAN-83
22B	1	1	49.68	50.21	2	KU	20		01-JAN-90
22B	1	1	50.21	52.74	2	K1	14	301	12-NOV-90
22B	1	1	52.74	52.78	2	K1	7	110/22B/803	07-JUN-99
22B	1	1	52.79	55.66	2	K1	7	110/22B/803	07-JUN-99
22B	1	1	55.66	55.69	2	KU	20		01-JAN-90
22B	1	1	55.78	57.48	2	KU	20		01-JAN-91
22B	1	1	57.48	57.78	2	K1	14	301	11-NOV-88
22B	1	1	57.78	58.02	2	K1	14	110/22B/704	04-DEC-97
22B	1	1	58.02	59.48	2	K1	14	110/22B/701	09-JUN-95
22B	1	1	62.23	62.38	2	K1	14	110/22B/701	09-JUN-95
22B	1	1	62.38	62.42	2	KU	20		01-JAN-88
22B	1	1	64.99	65.55	2	KU	20		01-JAN-86
22B	1	1	65.55	65.69	2	K1	14	110/22B/702	23-FEB-96
22B	1	1	67.67	67.68	2	K1	14	110/22B/702	23-FEB-96
22B	1	1	67.68	69.25	2	K1	14		20-NOV-91
22B	1	1	69.25	69.35	2	K1	14	301	01-MAR-87
22B	1	1	69.49	69.59	2	K1	14	301	01-MAR-87
22B	1	1	34.34	34.45	3	B1	100	405	01-FEB-67
22B	1	1	34.45	34.65	3	D1	200	35/22B/802	07-JUN-99
22B	1	1	34.65	34.83	3	D1	200	35/22B/802	07-JUN-99

Appendix H Sample ARMIS Asset Data (Sorted)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Dist	REGION	ROAD ID	C Code	TDIST_START	TDIST_END	NETWORK_NAME	S Width	AGE	SEAL_DATE	SEAL_TYPE	LAYER	LAYER_1_DESCRIPTION	P Width	AADT	%_HV	YEAR	Speed
9786	3	S	40B	1	55	56	State Strategic	10.02	3.1	17-APR-05	Spray Seal	K2	PMB Spray Seal	11.14	2672	16.7	2007	100
9787	3	S	40B	1	56	57	State Strategic	10.256	1.8	24-AUG-06	Spray Seal	K2	PMB Spray Seal	11.32	2672	16.7	2007	100
9788	3	S	40B	1	57	58	State Strategic	9	0.5	17-DEC-07	Spray Seal	K2	PMB Spray Seal	10	2672	16.7	2007	100
9789	3	S	40B	1	58	59	State Strategic	10.232	0.5	17-DEC-07	Spray Seal	K2	PMB Spray Seal	11.212	3249	15.3	2007	100
9790	3	S	40B	1	59	60	State Strategic	9.3	0.5	17-DEC-07	Spray Seal	K2	PMB Spray Seal	10.3	3267	15.3	2007	100
9791	3	S	40B	1	60	61	State Strategic	8.75	2.3	11-FEB-06	Spray Seal	K1	Bitumen Spray Seal	10.01	3267	15.3	2007	100
9792	3	S	40B	1	61	62	State Strategic	8.012	7.6	14-NOV-00	Spray Seal	K1	Bitumen Spray Seal	9.972	3267	15.3	2007	100
9793	3	S	40B	1	62	63	State Strategic	8	7.6	14-NOV-00	Spray Seal	K1	Bitumen Spray Seal	10	3267	15.3	2007	100
9794	3	S	40B	1	63	64	State Strategic	9.359	3.5	26-JUL-00	Spray Seal	K2	PMB Spray Seal	9.687	3267	15.3	2007	100
9795	3	S	40B	1	64	65	State Strategic	11.07	2.7	07-OCT-05	Spray Seal	K2	PMB Spray Seal	11.435	3267	15.3	2007	100
9796	3	S	40B	1	65	66	State Strategic	11.11	2.7	07-OCT-05	Spray Seal	K2	PMB Spray Seal	12.055	3267	15.3	2007	100
9797	3	S	40B	1	66	67	State Strategic	10.13	2.7	07-OCT-05	Spray Seal	K2	PMB Spray Seal	11.13	3267	15.3	2007	100
9798	3	S	40B	1	67	68	State Strategic	9.518	2.7	07-OCT-05	Spray Seal	K2	PMB Spray Seal	10.518	3267	15.3	2007	80
9799	3	S	40C	1	0	1	State Strategic	16.687	10.1	22-APR-98	Spray Seal	K1	Bitumen Spray Seal	17.477	3203	17	2007	60
9800	3	S	40C	1	1	2	State Strategic	9.765	6	29-MAY-02	Spray Seal	K2	PMB Spray Seal	11.095	3203	17	2007	100
9801	3	S	40C	1	2	3	State Strategic	8.564	2.7	06-OCT-05	Spray Seal	K2	PMB Spray Seal	9	3203	17	2007	100
9802	3	S	40C	1	3	4	State Strategic	8.6	2.7	06-OCT-05	Spray Seal	K2	PMB Spray Seal	9	3203	17	2007	100
9803	3	S	40C	1	4	5	State Strategic	9.55	4.4	04-JAN-04	Spray Seal	K1	Bitumen Spray Seal	9.95	3203	17	2007	100
9804	3	S	40C	1	5	6	State Strategic	8.566	8.9	01-JUL-99	Spray Seal	K1	Bitumen Spray Seal	8.955	3203	17	2007	100
9805	3	S	40C	1	6	7	State Strategic	8.496	8.9	01-JUL-99	Spray Seal	K1	Bitumen Spray Seal	8.792	3203	17	2007	100
9806	3	S	40C	1	7	8	State Strategic	8.482	8.9	01-JUL-99	Spray Seal	K1	Bitumen Spray Seal	9.004	3203	17	2007	100
9807	3	S	40C	1	8	9	State Strategic	7.914	9.1	06-MAY-99	Spray Seal	K1	Bitumen Spray Seal	9.938	3203	17	2007	100
9808	3	S	40C	1	9	10	State Strategic	7	9.2	31-MAR-99	Spray Seal	K1	Bitumen Spray Seal	10.6	3203	17	2007	100
9809	3	S	40C	1	10	11	State Strategic	7.47	8.8	19-AUG-99	Spray Seal	K1	Bitumen Spray Seal	10.398	3203	17	2007	100
9810	3	S	40C	1	11	12	State Strategic	7.04	6.2	27-MAR-02	Spray Seal	K1	Bitumen Spray Seal	9.02	3203	17	2007	100
9811	3	S	40C	1	13	14	State Strategic	7.016	6.1	23-APR-02	Geotextile Seal	K2	PMB Spray Seal	9	3203	17	2007	100
9812	3	S	40C	1	14	15	State Strategic	8	4.3	20-FEB-04	Spray Seal	K2	PMB Spray Seal	9	3203	17	2007	100
9813	3	S	40C	1	15	16	State Strategic	8.66	4.3	20-FEB-04	Spray Seal	K2	PMB Spray Seal	9.66	3203	17	2007	100
9814	3	S	40C	1	16	17	State Strategic	8.25	4.3	20-FEB-04	Spray Seal	K2	PMB Spray Seal	9.25	3203	17	2007	100
9815	3	S	40C	1	17	18	State Strategic	9.165	4.3	20-FEB-04	Spray Seal	K2	PMB Spray Seal	10.61	3629	14.5	2007	100
9816	3	S	40C	1	18	19	State Strategic	8.33	4.3	20-FEB-04	Spray Seal	K2	PMB Spray Seal	10.33	4420	11.1	2007	100
9817	3	S	40C	1	19	20	State Strategic	9.85	4.3	20-FEB-04	Spray Seal	K2	PMB Spray Seal	11.5	4420	11.1	2007	80
9818	3	S	40C	1	21	22	Regional Roads	16.987	9.7	23-SEP-98	Dense Graded .	K1	Bitumen Spray Seal	17.607	4094	10.2	2007	60
9819	3	S	40C	1	22	23	Regional Roads	10.46	9.2	31-MAR-99	Spray Seal	K1	Bitumen Spray Seal	12.18	3431	7.8	2007	100
9820	3	S	40C	1	23	24	Regional Roads	9.055	9.2	31-MAR-99	Spray Seal	K1	Bitumen Spray Seal	10.625	3431	7.8	2007	100
9821	3	S	40C	1	24	25	Regional Roads	7.46	9	20-MAY-99	Spray Seal	K1	Bitumen Spray Seal	9.46	3431	7.8	2007	100