The Effect of Trench Patches and Service Covers on Pavement Management

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The Effect of Trench Patches and Service Covers on Pavement Management

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Contents

EXECUTIVE SUMMARY 7

ABSTRACT 11

GLOSSARY 12

1 Introduction 13

2 Trench Patches and Service Cover Issues 14

2.1 Background 14
2.2 Best Practices for Road Opening Reinstatement 14
2.2.1 Specifications and Codes 14
2.2.2 Effective Technology 15
2.3 Effects of Trenches on Pavement Performance 15
2.4 Defects on Trench Patches 17
2.5 Issues Related to Service Covers 18
2.5.1 Service Covers in New Zealand Roads 18
2.5.2 Defects associated with Service Covers 19
2.6 Effects of Defective Trench Patches and Service Covers 19
2.6.1 Pavement Deterioration and Maintenance Cost 19
2.6.2 Road Maintenance Planning 20
2.7 Maintenance of Defective Reinstatement 21
2.7.1 Maintenance Period 21
2.7.2 Specifications for Repairing Deficiencies 21
2.7.3 Maintenance Category 22
2.8 Quality Assurance 22
2.9 Condition Assessment for Network Level Planning 23
2.10 Summary 24

3 Study Methodology 25

3.1 Background 25
3.2 Data Preparation 25
3.3 Selection of the Study Area 25
3.4 Impact of Trenches and Service Covers 25
3.5 Rating System Development 25
3.6 Sensitivity of Condition Rating Parameters 26
3.7 Pavement and Strength Characteristics 26
3.8 Deterioration of Sections with Trench Reinstatement 26
3.9 Appropriate Remedial Actions 27

4 Database Preparation 28

4.1 Background 28
4.2 Data Acquisition 28
4.3 Data Issues 28
4.4 Software Used 29
4.5 Preparation of Study Database 29
4.6 Summary 29

5 Selection of Study Network 30

5.1 Background 30
5.2 Study Network 30
5.3 Selection of Study Sections 30

6 Development of Rating System 31

6.1 Background 31
6.2 Objective of the Rating System 31
6.3 Rating Data Collection 31
6.4 Analysis of Distresses 31
6.5 Sensitivity of Distresses 32
6.6 Reinstatement Surface Index (RSI) 33
6.7 Field Validation of Rating System 33
6.8 Data Availability in RAMM 34
6.9 Summary 35

7 Effect of Trench Patches on Pavement Strength 36

7.1 Background 36
7.2 Survey Locations 36
7.3 Falling Weight Deflectometer Survey 36
7.4 Survey Layout 37
7.5 Data Analysis 37
7.5.1 Alfriston Rd (Section 1) 37
7.5.2 Ash Rd North Side and South Side (Section 2) 37
7.5.3 Harris Rd Section 1 North Side (Section 3) 38
7.5.4 Harris Rd Section 1 South Side (Section 3) 38
7.5.5 Harris Rd Section 2 North Side (Section 4) 38
7.5.6 Harris Rd Section 2 South Side (Section 4) 38
7.5.7 Wiri Station Rd (Section 5) 38
7.6 Discussion on FWD Survey Results 38
7.7 Impact of Trenching on Pavement Strength 39
7.7.1 Comparison of Granular Overlay Required 39
7.7.2 Comparison of Structural Number 39
7.8 Summary 40

8 Effect of Trench Patches and Service Covers on Pavement Deterioration 42

8.1 Background 42
8.2 Parameters for Comparison 42
8.3 Roughness Comparison 42
8.3.1 Increase in Roughness due to Longitudinal Trench 42
8.3.2 Increase in Roughness due to Transverse Trench 43
8.3.3 Increase in Roughness due to Service Covers 44
8.4 Increase in Deterioration due to Increase in Roughness 45
8.5 Summary 46

9 Effect of Trench Patch and Service Covers on Pavement Management 47

9.1 Background 47
9.2 dTIMS Analysis 47
9.3 dTIMS Analysis with Actual Network Data 47
9.4 dTIMS Analysis with Synthetic Data 47
9.5 Comparison of Effects 48
9.5.1 Agency Cost Comparison 48
9.5.2 VOC and TTC 49
9.5.3 Maintenance Regime 49

9.5.4 Pavement and Surface Life Cycle 50
9.6 Summary 51

10 Remedial Measures in Pavement Performance 52

10.1 Background 52
10.2 Remedial Measures 52
10.2.1 Treat Them Separately 52
10.2.2 Use RSI in Modelling 53
10.2.3 Cost Sharing 53

11 Conclusions and Further Work 54

11.1 Staus Quo 54
11.2 Outcomes 54
11.3 Recommendations 55
11.4 Further Work in Stage 2 56

12 References 58

Appendix A: Data Collection Form 60

Appendix B: Study Network 62

Appendix C: Sensitivity of Weightage Factors for RSI 65

Appendix D: FWD Survey Layout 66

Appendix E: FWD Survey Results 72

Appendix F: NZdTIMS Analysis Results 98

EXECUTIVE SUMMARY

Objectives

The research on the effects of trenches and service covers on pavement management is divided into two stages as follows:

- Stage 1: Detailed study and analysis; and
- Stage 2: Development of guidelines.

This report documents the research undertaken in Stage 1. Stage 2 of the research is scheduled for the next financial year, subject to approval by Transfund.

The objectives of Stage 1 were:

1. To assess the impact of trenches and service covers and their influence on pavement management systems.
2. To identify the effect of the condition of trench patches and service covers on the pavement deterioration prediction and treatment selection procedure.
3. To develop a comprehensive rating system for trench patches and service covers.
4. To recommend a preferred procedure that accounts for the detrimental effects of trenches and service covers on pavement performance and the determination of appropriate remedial treatments.

Methodology

A review of the assessment of the trench patches and service covers in pavement management was undertaken as the first stage of the research. National and international literature was collated for this task.

For the detailed investigation and analysis, thirty treatment length sections were selected. Preliminary selection of the road sections was carried out based on the analysis of the Road Opening Database (RON) and Road Assessment and Maintenance Management (RAMM) databases. Site inspection and verification of the data was also carried out before finalising the sites.

Development of a simple, yet comprehensive, rating system of trench patches and service covers was one of the main objectives of this study. Most of the condition parameters affecting the future performance of trench patch and treatment selection procedure were considered while developing the rating system. The condition parameters were defined by:

- type,
- extent (number or/and area),
- severity.

A comprehensive Data Collection Sheet (DCS) was used for collection of additional data. A composite index called Reinstatement Surface Index (RSI) was developed to assess the overall condition of reinstatement. The condition analysis was carried out to determine:

- Increase in roughness due to longitudinal trench.
- Increase in roughness due to transverse trench.
- Increase in roughness due to service covers.

Deflection testing using a falling weight deflectometer (FWD) was undertaken on the five sections to establish the relative loss of structural capacity resulting from the presence of trench patches. An investigation was also undertaken to compare the structural number (SNP) of the trench section with the adjacent original pavement area.

NZdTIMS analysis was undertaken to determine the effects of trenches and covers in pavement management in terms of agency cost, vehicle operating cost and maintenance regime.

Practitioners from the construction industry were consulted to identify the issues related to trenching and backfilling. Different remedial measures were recommended for use in pavement management or predictive modelling to address the issues raised by poorly reinstated trenches or covers.

Status Quo

The ideal situation would be to eliminate trenching operations from the pavement structure. This is unrealistic, but efforts should be made to improve systems and practices to accommodate the effects of trenching and backfilling in pavement management.

Specifications and best practices are available to some extent. They are necessary to ensure that the reinstatement is completed to a high standard. It appears that the specifications are not always properly followed, resulting in the early deterioration of the reinstated surface or pavement. However, there is a lack of documentation on maintaining reinstatements, post-trench tests and compaction methods to quantify the condition of the trench. Stage two of this research will investigate this further.

Most road controlling authorities in New Zealand use the RON database for storing road opening information. The format of the RON database differs significantly between different RCAs. Auckland City Council has the most comprehensive RON database of those considered in this study. Road network inventory and condition data is kept in the RAMM database. It was found that there is no correlation between these two databases for exchange of data. The referencing followed by these two systems is exclusive. This generated a lot of field inspection during the study for correlating data between the two systems.

Unfortunately, RAMM does not contain any inventory or condition data on trenches and service covers. RAMM 2003 has two data items under "Sealed Rating Survey"

that collect the number of trenches and covers greater than 10mm above or below the seal. The condition of trenches and service covers is not recorded in RAMM.

Outcomes

Failed joints appeared to be the most significant distress observed on trench patches. This was followed by rutting and structural cracking. A composite index called Reinstatement Surface Index (RSI) was developed in this study for visually assessing the condition of reinstatement. RSI varies from 1 (excellent condition) to 5 (very poor condition). Preliminary guidelines for recording RSI in the field were developed for use in RAMM rating surveys. Major distresses were included in the RSI expression. The weighting factors used were finalised based on a sensitivity analysis. The following equation is proposed for calculating RSI when distress information is available:

$$RSI = Min\ (5, (0.1*ACA + 0.16*AFJ + 0.05*RUT + 0.1*DEF + 0.08*DRG))$$

Trenches and service covers affect ride quality and in sometimes the safety performance of road networks. In some cases the joints have developed a 'lip' which had resulted in a sharp increase in roughness. Roughness was found to increase between:

- 2% and 90% due to longitudinal trenches.
- 10% and 80% due to transverse trenches.
- 20% and 300% due to service covers, which are higher than trenches.

Increased road roughness due to trenching operations affects the usefulness of road roughness as a measure of condition and/or performance of the road network, particularly in urban areas.

A desktop analysis of NDT data revealed that trenching activities severely affect the remaining pavement life and strength characteristics. Only in few cases the trenching activities increased or equalled the performance of the pavement structure. The analysis carried out in this study indicated that the pavement structure is affected by trenching and poor reinstatement. This was supported by:

- An increase in the granular overlay required for trench sections from 20% (1m away from trench) to 300% (3m away from trench);
- A reduction in the average SNP of trench sections by 5% (1m away from trench) and 12% (5m away from trench).
- A decrease in the SNP by 12% (1m away), 27% (3m away) and 42% (5m away. In some individual cases pavement deterioration can increase several fold.

Utility cuts increase road roughness and, therefore, increase vehicle operating costs and reduce the level of service for road users. The NZdTIMS analysis carried out under 'performance mode' concluded that:

- Overall, the predicted agency cost for maintaining the network is increased by 10% to 20% due to trenching.

- The increase in the predicted annual cost of maintaining a road section that has either a trench or service cover was found to be in the order of $7,000 to $17,000 per km depending on the given condition.
- Poorly reinstated trenches and covers have changed the maintenance regime, affecting both 'type of treatment' and 'timing of the treatment'.

Recommendations

Recommendations	Priority		
	High	Medium	Low
All RCAs adopt consistent approach for maintaining the RON database.		√	
RON and RAMM systems follow the same referencing to reduce non-compatibility issues.	√		
Include additional fields on inventory and condition of trenches and covers in RAMM rating survey.	√		
Use appropriate event codes in the data collection surveys.	√		
Exclude peak roughness and other condition values contributed by poorly reinstated trenches and defective service covers prior to deterioration modelling.	√		
Use RSI in the predictive modelling.		√	
Adopt dynamic sectioning in the predictive modelling for improving the credibility of the modelling particularly in urban areas.	√		
Transfund New Zealand peer review the codes of practices for utility reinstatements.	√		

Further Work in Stage 2

Stage 2 will include development of best practice guidelines and some of the high and medium priority recommendations from Stage 1. Broadly, the key steps will be:

Milestone	Objective
Investigate reinstatement methods	More detailed investigation on the compaction procedures adopted in the reinstatement.
Verifiy and validate RSI	RSI developed under Stage 1 will be verified on a broader network including other regions.
Incorporate RSI in modelling	RSI will be incorporated in the new deterioration modelling system; dTIMS CT scheduled to be released early next year.
Define sectioning principles	Develop dynamic homogeneous sectioning principles based on the extent and condition of the trenches and covers to incorporate in dTIMS CT.
Investigate and propose QA measures	Investigate and propose quality assurance measures to be adopted by RCAs immediately after the reinstatement.
Review and propose best practice guidelines	Review existing guidelines and propose best practice guidelines including cost sharing, etc.

ABSTRACT

This report describes the results of the project commissioned to investigate the effects of trench patches and service covers on pavement management. The main objective was to identify the effects of poorly reinstated and defective service covers on pavement management, in terms of pavement deterioration and pavement strength, and to recommend procedures to remedy the detrimental effects of trenches and service covers on pavement performance. The research was carried out in four stages: review of the available national and international literature; development of rating system; quantifying effects of trenching operation on pavement structure and performance characteristics; and identifying immediate remedial measures for adoption. Road Assessment and Maintenance Management (RAMM) and Road Opening Notice (RON) databases were compiled for three road controlling authorities. A comprehensive system was developed for inventory and condition data of trenches and covers. Preliminary guidelines were developed for visually assessing the condition of trenches and covers. Additional data items were recommended for inclusion in the RAMM rating survey. A deflection survey was undertaken to determine the effect of trenching on pavement and strength characteristics. Roughness was selected for detailed comparison of condition and performance of trench and trench-free sections. The difference in the cost of maintaining the road network due to the presence of trenches and covers was determined. Also, the change in the maintenance regime and the effects on pavement and surface lives were estimated. It was found that poor reinstatement decreases pavement performance and life, resulting in increased maintenance and pavement rehabilitation costs. Immediate remedial measures to be adopted in the deterioration modelling were identified. The objectives of Stage 2 of the research were also identified.

GLOSSARY

AMES	Asset Management and Engineering System
CC	City Council
CoP	Code of Practice
DC	District Council
DCS	Data Collection Sheet
DWK	Duffill Watts & King Ltd
dTIMS	Deighton's Total Infrastructure Management System
FWD	Falling Weight Deflectometer
FWP	Forward Works Programme
HDM-III	Highway Design and Maintenance Standards Model
HDM-4	Highway Development & Maintenance
HTC	Highway and Traffic Consultants
HSD	High Speed Roughness Data
LA	Local Authority
NDT	Non Destructive Testing
NZdTIMS	New Zealand dTIMS System
QA	Quality Assurance
RAMM	Road Assessment and Maintenance Management
RCA	Road Controlling Authority
RON	Road Opening Notice
RSI	Reinstatement Surface Index
SNP	Modified Structural Number
Standard NZ	Standard New Zealand
TLA	Territorial Local Authorities
Transfund	Transfund New Zealand
T&T	Tonkin & Taylor
TTC	Total Transportation Cost
UTMS	Utility Cut Management System
VOC	Vehicle Operating Cost

1 Introduction

The research on the effects of trenches and service covers on pavement management is divided into two stages as follows:

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The objectives of Stage 1 were:

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3. To develop a comprehensive rating system for trench patches and service covers.
4. To recommend a preferred procedure that accounts for the detrimental effects of trenches and service covers on pavement performance and the determination of appropriate remedial treatments.

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- Waitakere City Council,
- Christchurch City Council,
- Papakura District Council.

2 Trench Patches and Service Cover Issues

2.1 Background

Territorial Local Authorities (TLAs) are responsible for the transportation system that is vital to the economic health of city and district councils. Large amounts of money are being invested to construct and maintain road infrastructure.

Utility and telecommunications companies sometimes need to disturb the pavement structure to maintain or upgrade their services. These activities affect pavement performance and the impact of such activities has been a concern of Road Controlling Authorities (RCAs) for many years.

It is important that all stakeholders focus on how to minimise total maintenance costs related to trench patching. Vital to this is using the correct procedures for trench and service cover reinstatement.

2.2 Best Practices for Road Opening Reinstatement

It is in everyone's interest to get reinstatement right the first time. Sometimes the required standard of reinstatement is not achieved, only because of a lack of understanding and information. Good communication and liaison, backed up by an easily-worked and understood specification, will help achieve better results.

2.2.1 Specifications and Codes

Due to the importance of common codes and best practices for trench reinstatement the Public Utilities Street Act was passed in Britain in 1950. However, it was not until 1974 that utility and roading authorities in Britain reached sufficient mutual understanding for "A Model Agreement and Specifications" to be published covering reinstatements under this Act (Proffitt, 1987). It was reported some ten years later that about 50% of authorities in Britain had adopted the model agreement.

Gradual development of specifications and best practices for successful restoration of trenches in Australasia was initiated in the 1970's and early 1980's. Porter and Armstrong (1978) had reported on the Australian practice of trench backfilling and reinstatement. The issues related to the reinstatement of trench excavations within road reserves in New Zealand was reported by Olsen (1983). A preliminary study carried out by Proffitt (1987) identifies various issues relating to the process of trench excavation and reinstatement in New Zealand. This report states that, despite a large number of TLAs already having specifications for trench reinstatement, there is a lack of proper quality control. There is also no proper co-ordination between different TLAs in terms of sharing experience and implementing similar systems and procedures. Based on its recommendations, a series of trench reinstatement workshops were conducted to improve the performance of all roading and utility authorities in the practice of excavation, backfilling and reinstatement of road openings (DWK, 1990).

Various TLAs in New Zealand have implemented their own specifications and Codes of Practice (CoP). These documents are being modified, based on experience and technology development.

TLAs in the Auckland region and the Auckland Utility Operators Group (AUOG) have been working together since 2000 to produce a consistent set of standards for working on the road. The site construction, technical drawings and material specification of the CoP were completed and implemented as 'Module one' in November 2001.

This initiative led to developing a standard "Code of Practice for Working in the Road" for New Zealand. This CoP is being developed by New Zealand Standards and, when adopted, will become a national standard. This code (NZS CoP) is scheduled to be implemented in 2003. The code also includes general specifications for temporary and permanent surface reinstatement for different pavement structures. The basic principle is that the permanent resurfacing material should be similar in type, quality, texture, skid resistance and strength to the surrounding materials, and the reinstatement should not affect the adjacent pavement performance.

If used properly, this CoP will improve the quality of trench reinstatement.

2.2.2 Effective Technology

The adverse impact of road openings could be reduced by:

- Installing utility services below the road pavement layers.
- Trenchless technology - which will reduce the requirement of road openings.
- Using modern material (such as foam concrete) with negligible settlement properties.

However, it should be noted that a technology that is practical in some conditions might not always be useful in others. Careful implementation by an experienced practitioner is always required to ensure the best possible outcome.

2.3 Effects of Trenches on Pavement Performance

Several studies have been undertaken in different countries on the impact of utility cuts (trenches) on roadway performance. Most of these studies are focused on quantifying the effect of the road openings to estimate the cost of future maintenance works. Reinstatement is generally paid for by the service or utility operators. However, there is a lack of evidence to prove that utility operators share the increase in the future cost of maintenance due to trenching.

Studies conducted in San Francisco and the City of Seattle show that the presence of utility cuts (trenches) lowers pavement condition scores - indicating greater deterioration - compared with pavements of the same age with no utility cuts (DPW, 1998 and Nicholas Vallerga & Associates, 2000). Tarakji (1995) reported that increasing the number of cuts resulted in a reduction in the condition scores of the road. The study showed that, when compared with streets with fewer than three cuts, on average, streets with more than nine cuts had a 50% shorter service life.

Several studies were carried out using deflection testing to quantify the extent of damage due to utility cuts. Typically, deflection measurements are taken on the trench, adjacent to the trench and in a controlled area, i.e., away from the

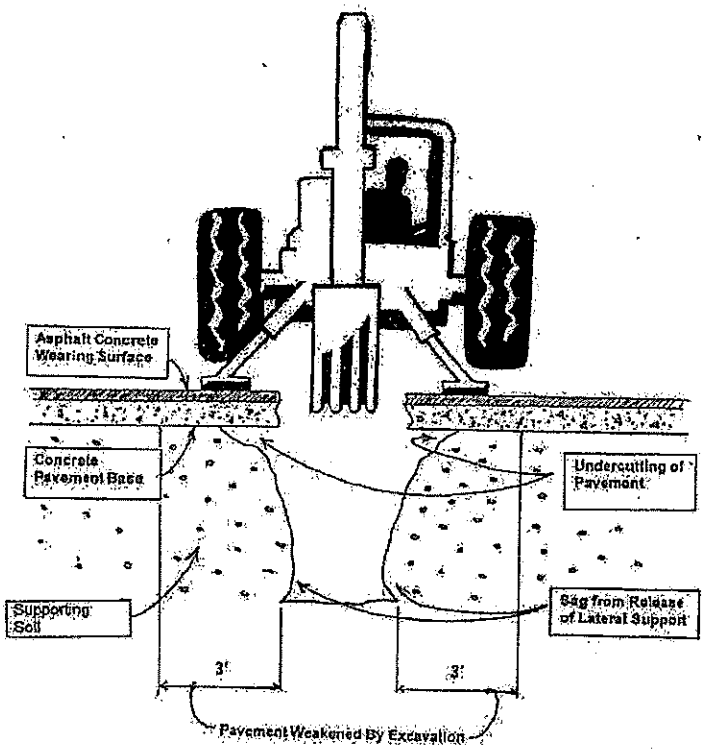
trench. Similarly, a number of studies used penetrometer testing to compare the strength of the pavement adjacent to the utility with the controlled sections (Shanin, M.Y. *el al.* 1996).

Nicholas Vallerga & Associates (2000) established the effect of trench patches on the strength of the pavement. Preliminary screening using comparisons of the average maximum deflection showed that, in the majority of the cases (57% of the sections considered), the presence of the utility cut adversely impacted on the roadway. Only 40% of concrete and composite sections were adversely affected, whereas, all of the asphalt sections required additional overlay thickness in the area of the utility cut compared with the control area. The results of deflection testing (Bodsci et al, 1995) indicated that damage extends up to 1m from the edges of the utility cut, and the average overlay thickness required to restore the pavement to its pre-utility cut strength was found to be 45 mm.

CHEC (1998) reported that, out of sixteen segments evaluated, 68% showed significant loss in strength as a result of being in the zone of influence around the trench of utility area. The increase in deflection values ranged from 0% to 74%. The loss in strength, defined in terms of additional asphalt thickness at the time of rehabilitation, ranged from 0 to 75 mm in thickness with an average of 33 mm. Trench width as well as subgrade soil type had no influence on the damage magnitude.

A link between the presence of utility cuts and accelerated pavement deterioration is accepted by most agencies. The recent San Francisco study concedes that high quality workmanship in the repair of utility trenches may reduce the structural damage to pavements, but contends that lower ride quality and increased cracking still result and, therefore, service life is diminished (Nicholas Vallerga & Associates, 2000).

The resulting reduction in pavement life, despite high quality workmanship when repairing the cut, can be explained by considering the trenching operation. The process of opening a trench causes drooping or slumping of the trench sides as the lateral support of the soil is removed. The degree of slumping is determined in part by the soil type, soil strength, moisture content of the soil, and depth of the trench. Quantifying the extent of slumping is very complex but, regardless of the extent, the adjacent pavement is adversely



affected. The "zone" of weakened pavement adjacent to the utility cut can fail more rapidly than other parts of the pavement. This can be observed in the field by the presence of fatigue (alligator) cracking occurring around the edges of the cut, or spalling around the cut edges.

In addition, the introduction of cuts is similar to the introduction of cracks on the pavement. If improperly sealed, water intrusion can occur, resulting in loss of fine materials from the underlying base and subgrade and, consequently, loss of pavement strength. This can occur even with the best patching or backfill practices if the edges of the cut are not properly sealed (Nicholas Vallerga & Associates, 2000).

From the overseas literature review it can be concluded that road openings, however well reinstated, will invariably weaken the pavement to some extent. A study is required to establish whether this is true in New Zealand.

2.4 Defects on Trench Patches

Several codes and best practices are available for ensuring reinstatement works are completed to a high degree of quality. However, for various reasons reinstated trenches can develop different types of defects.

Typical road surface defects related to trench reinstatements are:

- surface and pavement failure of existing pavement adjacent to the trench,
- settlement or bumps,
- cracking,
- flushing.

The most common problem is settlement of the trench surface arising from inadequate backfill compaction or use of inappropriate granular materials. Proffitt, (1987) has noted that re-use of existing material (if it is of good quality) is not necessarily a bad practice, but poor compaction is.

Rutting is observed where settlement happens on the reinstated longitudinal trench on a wheelpath. In the case of a settled transverse trench a short depression will be created, resulting in a bump for the passing vehicle.

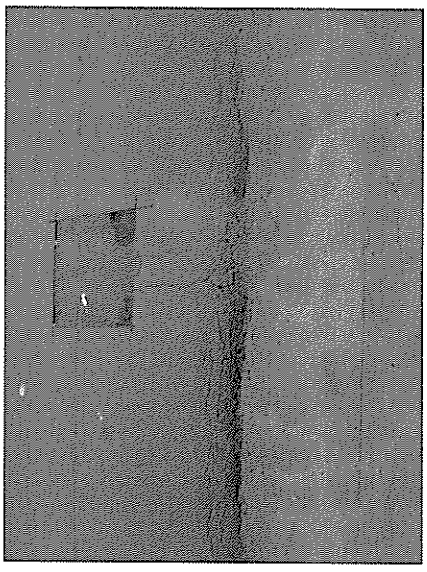


Figure 2.1: Rutting on Reinstated Trenches.

Cracking is another common defect generally observed on trench reinstatements. Cracks can be:

- joint cracks (longitudinal or lateral),
- structural cracks.

a) Joint crack b) Structural / fatigue crack

Figure 2.2: Cracks on Reinstated Trenches.

Surface cracking is generally observed on the existing pavement 100 - 200 mm away from the trench (Proffitt, 1987). Possibly this is due to the disturbance caused when the trench was opened or due to subsequent loading effects.

Lack of a proper joint between the new surface over the trench and the adjacent old surface is very common. This generally happens where asphalt mixes are used to reinstate surfaces.

Using different surface materials can result in a change in skid resistance causing safety issues, especially where longitudinal trench patching is carried out. For example, low surface friction (or skid resistance) is observed on reinstated patching when asphalt concrete used for reinstatement (and if the surrounding area is chip sealed).

Most TLAs in New Zealand require utility operators to remedy, or pay for, any deficiencies in their reinstatement work.

2.5 Issues Related to Service Covers

2.5.1 Service Covers in New Zealand Roads

Service covers are used for accessing underground utility and communications networks. They vary in shape (circular, rectangular or square) and size depending on their purpose. The size of the service covers found in New Zealand generally range from 200x200 mm to 600 x 1200 mm. They can be made from the following materials:

- steel,
- cast iron,
- galvanised steel,
- composite steel and concrete,
- aluminium.

Service covers usually consist of two parts:

- frame of the opening,
- cover.

2.5.2 Defects Associated with Service Covers

Service covers are not always constructed properly or maintained after rehabilitation of the road. Observed defects include:

- level of service cover (depressed/raised),
- surrounding surface distresses,
- loose ends of frame.

The depressed (lowered) level of a service cover is generally due to the level of the service cover not being increased after the pavement surface is overlaid. It could also be due to the design of the service cover with step down lid in comparison with the supporting frame. On the other hand, a raised service cover could be due to improper construction or settlement of the surrounding road. A difference in the level (either depressed or raised) of the service cover along the wheelpath creates bumps, resulting in a sharp increase in roughness. Road users generally try to avoid these service covers, resulting in a safety hazard.

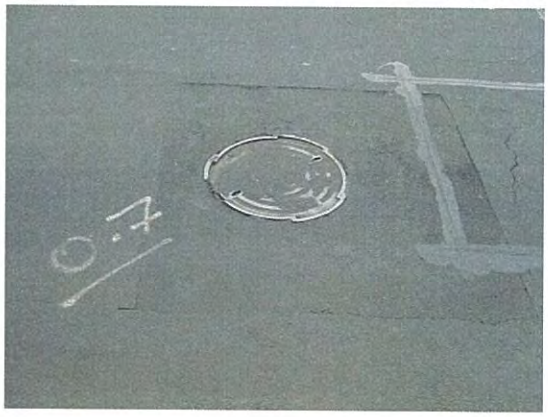
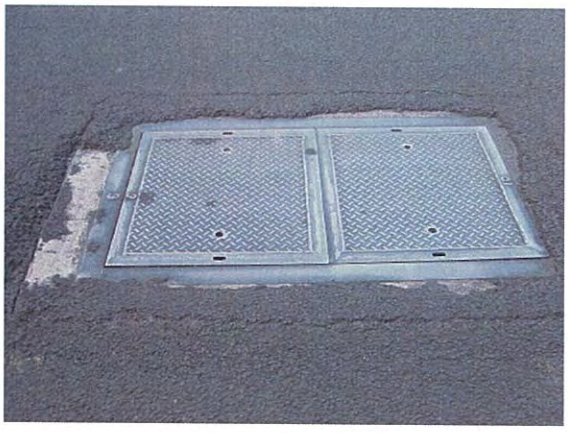


Figure 2.3: Service Cover on Wheelpath.

Large rectangular service covers have been introduced in recent years in New Zealand. Noise generated by improperly constructed or maintained rectangular covers has been an issue. To solve the rattling problem, utility operators have introduced service covers with a rubber gasket between the cover and the opening case.



Another concern is that they usually have less surface friction (skid resistance) in comparison with the surrounding surface, resulting in traffic safety issues.

Figure 2.4: Large Rectangular Service Covers.

2.6 Effects of Defective Trench Patches and Service Covers

2.6.1 Pavement Deterioration and Maintenance Cost

Defective trench patch and service covers not only affect the appearance of the road, but can also result in higher deterioration of the pavement (Roland, 2000).

This can be due to:

- Increased dynamic, incremental pavement loading due to bumps (high and low) service covers and patches.
- Poor compaction.
- Accumulation of water in the depressed area and ingress of water into pavement structure and subgrade through the 'joint' cracks.

An unpublished report on determining utility impacts on Auckland's road network (Scott, P. 2001) indicated that low quality trench reinstatement could:

- reduce road pavement life by as much as 10% - 15%
- increase road maintenance costs by 5% - 10%

Also it is estimated that utility related works on the road contribute to 1% to 2% of the road congestion within Auckland region.

2.6.2 Road Maintenance Planning

Defective trench patching and service covers will also influence pavement maintenance planning, including:

- Roughness characteristics of a carriageway and consequently road user costs on urban roads;
- Surface bumps due to depressed/raised trenches or covers could cause damage to vehicles, thus decreasing its effective life; and,
- Inaccurate selection of treatments in predictive modelling due to the high roughness caused by defective trench patches and service covers. This would affect the forward works programme.

The effect of trench patches and service covers to a large extent, is affected by their location and orientation. Generally, the impact is higher when a defect is located within the wheelpath (see Figure 2.5).

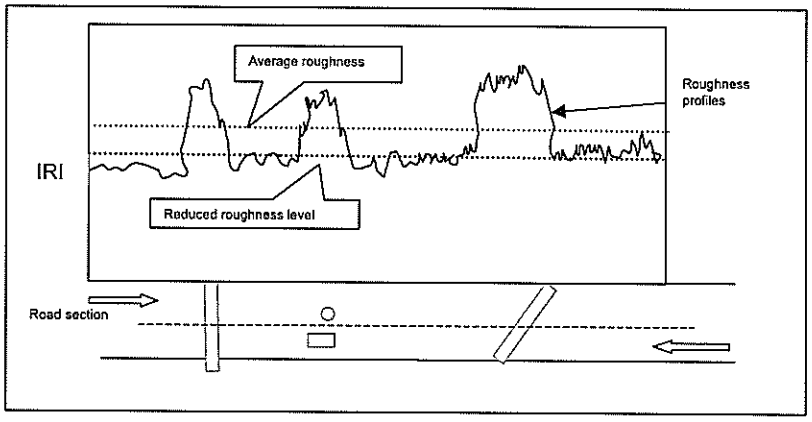


Figure 2.5: Effect of Trench Patches on Roughness.

2.7 Maintenance of Defective Reinstatement

Generally, trench reinstatements require post construction maintenance. In addition, a poorly reinstated opening or cut requires subsequent improvements to prevent further deterioration.

2.7.1 Maintenance Period

Proffitt (1987) states that inadequacy in pavement restoration may well show up within six months, especially in winter. Problems arising from improper backfilling may take twelve months or longer to surface, especially if the cause is located deeper. The twelve month maintenance period for reinstatement specified in Auckland City (1999) is generally sufficient. Also, the provision of a further twelve months maintenance period if the reinstated portion is repaired is quite useful. CoP (2001) requires that contractors maintain the trench for one year from the date the permanent reinstatement is completed plus another year for asset protection. Therefore, responsibility is extended to share the risk in the long term between the local authority and contractor / utility company.

2.7.2 Specifications for Repairing Deficiencies

HSMO (2002) specifies remedial actions for various defects during the guarantee period. When determining whether a reinstatement requires any remedial action, the quality of the reinstatement shall be assessed relative to the condition of the adjacent surface. The remedial actions specified by the code are mainly related to the repair of cracking and settlement.

Cracking along the interface of the reinstatement shall be repaired in accordance with the following methods:

- Cracks of between 2.5 mm and 10 mm open width at the surface to be repaired by filling with flexible bituminous sealant.
- Cracks between 10 mm and 15 mm open width at the surface to be repaired by filling with flexible bituminous sealant incorporating suitable fine aggregate and filler.
- Cracks greater than 15 mm open width to be repaired with up to two sealing operations (excluding the original sealing) during the guarantee period. Further cracking of the third seal shall require a surface repair with the removal of full depth of the existing surface or 40 mm, whichever is less.

The HSMO (2002) also requires that the effective width of the reinstatement shall be revised to include the actual width of the settled area (plus the reinstatement area) where significant settlement of the surface beyond the edges of the reinstatement has been shown, within reason, to have occurred as a direct result of the contractor's works.

Although most of the existing best practices and codes in New Zealand specify in detail how to properly reinstate the openings on the road, there are no specifications on maintenance of defective trench reinstatements. A large amount of maintenance carried out on defective trench reinstatements is done under routine maintenance.

Co-ordination between maintenance programmes and reinstatement of defective trenches and service covers can be improved. However, trenches will continue to be a major issue for urban authorities.

2.7.3 Maintenance Category

The level of maintenance required for defective trench reinstatement and service covers depends on the location, extent and severity of the defects.

Table 2.1: Maintenance for Different Defective Trench Patches.

Category	Activity
Trench Reinstatement	
Minor	Patching
	Crack filling
Medium	Rut/Depression filling
	Digout/ and heavy patches
	Milling and resurfacing
Major	Reconstruction of the reinstatement
	AC overlay of lane/section
Service Cover Reinstatement	
Minor	Patching surrounding area
	Crack filling
	Change of defective service covers
Medium	Rut filling
Major	Raising or lowering of the service cover
	AC overlay of lane/section

2.8 Quality Assurance

It is important that the best practices and codes are followed appropriately. It is a well-known fact that trench reinstatement can be enhanced for little or no extra cost if quality control is practised widely. The CoP (2002) provides the framework to connect the existing quality systems of the principal provider with those of the TLA. It specifies agreed stages for audits as set out below:

- **Stage 1:** Audits during the excavation and backfilling phases, including site safety, backfill, compaction and surface reinstatement.
- **Stage 2:** Audit immediately following permanent reinstatement.
- **Stage 3:** Final audit prior to the end of maintenance period.

During the audit process, include a field visit by the inspector to verify the acceptability of the parameters that characterise the quality of the trench reinstatement. The parameters included in the checklist for Stage 1 are:

- excavation,
- backfill and reinstatement of surrounding area,
- backfill material,
- compaction,
- sub-base,
- basecourse,
- surface finish.

In addition to the reinstatement specifications stated earlier, various simple tests can be used at different stages to ensure that the required quality is achieved. Foremen's heel mark, dynamic cone penetrometer and nuclear densometer, despite various deficiencies, were widely used during the eighties for this purpose (DWK, 1990). Moreover, Proffitt (1987) suggests the following methods of measuring air voids, or some other fairly explicit indices, for quality control:

- Measurement of the level of impact short of that needed for penetration. Use Clegg (soil) hammer and Smit (hammer).
- Adoption of geophysical methods making use of shear wave velocities, and/or attenuation.
- Use of hand driven bar probe made to vibrate at the resonant frequency of the soil.

Parameters included in the checklist for Stage 2 and 3 are:

- feature,
- edge depression/trips,
- surface depressions,
- surface crowning,
- edge cracking,
- texture depth,
- surface irregularity.

No specific threshold values / limits for considering the existence of these defects are specified in CoP (2002). The inspector or practitioner, usually defines the limits, based on experience.

2.9 Condition Assessment for Network Level Planning

The Road Assessment and Maintenance Management (RAMM) visual rating system implemented in New Zealand assesses the surface defects on the road, which can also be due to poorly reinstated road openings. However, as RAMM does not specifically identify whether a problem is directly related to the defective reinstatement, there is no possibility of defining appropriate remedial actions based on this rating system. Besides, no rating is currently carried out on defective service covers on the road.

Several defects may result from poorly reinstated trenches. It is easier to identify reasons for defects on newly constructed trench patches. However, as stated earlier, defects due to poorly reinstated trenches can appear after some time. Once a road is resurfaced or overlaid it is difficult to confirm whether defects are due to a poorly reinstated trench or to some other reason. For example, rutting (see **Figure 2.6**) on the utility cut reinstatement can be confirmed based on the road opening information available in the Road Opening Notice (RON) database.

Figure 2.6: Rutting on Reinstated Trench.

Some rating systems for identifying defects due to poor reinstatement have been developed overseas. A Utility Cut Management System (UCMS) visual survey was developed for asphalt concrete with nine pavement distresses that are most common to asphalt concrete utility cut patches (Bodsci et al, 1995). The present format of the data collection followed in New Zealand sometimes makes it difficult to assess the condition of trench patches and service covers.

2.10 Summary

A comprehensive desktop study carried out on road opening reinstatement and maintenance has shown that:

- Specifications and best practices are available to ensure that the reinstatement works can be completed to a high degree of quality. These specifications are not always properly implemented resulting in early deterioration of the reinstated surface or pavement.
- There is a lack of documentation on tests and rating methods to quantify the condition of a trench.
- There is a lack of application of QA procedures.
- Utility cuts affect ride and safety performance.
- Utility cuts increase road roughness, resulting in increased vehicle operating costs and reduced level of service for road users.
- Utility cuts decrease pavement performance and life, resulting in increased maintenance and pavement rehabilitation costs.
- There is a need to amend RAMM condition rating procedures.
- Increased roughness due to the presence of trench patches and service covers can should be filtered out prior to pavement deterioration modelling. Built records can be used to identify the type and location of trenches and service covers and can be compared against roughness values to determine any increase in roughness due to these.
- Increased road roughness due to reinstatements affects usefulness of road roughness as a measure of condition and/or performance of the road network, particularly in urban areas.
- Transfund may need to review or audit quality assurance procedures and codes of practices required for utility reinstatements as these affect the cost of road network maintenance.

3 Study Methodology

3.1 Background

The research included a desktop study of national as well as international literature related to the reinstatement of road openings and service covers. Available, relevant data was collated from TLAs and additional data collected to fill the data gaps in the historical information. Statistical analysis was carried out to confirm various issues.

The methodology used in this research is briefly described in this chapter.

3.2 Data Preparation

Data preparation included collection of Road Opening Notice (RON) and Road RAMM data from various TLAs. Additional data collection for the selected sites was carried out in the field. Missing historical information was acquired by interviewing maintenance engineers working in the area. AMES (Asset Management and Engineering System) and HTC internal database management systems were used for storing and analysis of the data. More details on the database preparation process are given in Chapter 4.

3.3 Selection of the Study Area

For the detailed investigation and analysis, thirty treatment length sections were selected. Preliminary selection of the road sections was carried out based on the analysis of the RON database and RAMM database. Site inspection and verification of the data was also carried out before finalising the sites. The following factors were considered while selecting the sections:

- different density and orientation of trench patches and service covers,
- sections with various traffic characteristics and roughness,
- trench patches with multiple defect types and condition,
- quality of trench backfilling and compaction,
- wearing course material and method of reinstating.

3.4 Impact of Trenches and Service Covers

A review of the assessment of the trench patches and service covers in pavement management was undertaken as the first stage of the research. Available national and international literature was used for this task.

3.5 Rating System Development

Development of a simple, yet comprehensive, rating system of trench patches and service covers was one of the main objectives of this study. Most of the condition parameters affecting the future performance of trench patch and treatment selection procedure were considered while developing the rating system. The condition parameters were defined by:

- type,
- extent (number or/and area),
- severity.

Different types of defects, including level difference (rise/depression) against the adjacent surface level and various surface distresses were considered. The defects were quantified by either the length or number or percentage area. Severity of defects was estimated based on the seriousness of the impact of the defects. Location and orientation of the defects were also recorded.

Appendix A provides the comprehensive Data Collection Sheet (DCS) used for collection of additional data. The DCS included more details than required for the network level assessment. Data was collected at a higher accuracy level. The reason for this was to capture all the required data for sensitivity analysis. Only a few parameters were used in the final rating system, which focused on quantifying the typical effect of the trenching on pavement management, specifically, through objective (visual) assessment.

3.6 Sensitivity of Condition Rating Parameters

The analysis of the data was carried out to define the sensitivity of the condition parameters to:

- Visually assess the condition of the trench and service covers.
- Determine the level of maintenance required for trench patches and service covers.

To provide an overall condition for a road section in terms of trench reinstatement, a composite index called Reinstatement Surface Index (RSI) was developed. Weighting factors were finalised for each distress, considering the effect of the distress on overall condition and maintenance cost of the road.

3.7 Pavement and Strength Characteristics

Deflection testing using a Falling Weight Deflectometer (FWD) was undertaken on five sections to establish the relative loss of structural capacity resulting from the presence of utility cuts (trench patch). This loss of structural capacity necessitates thicker overlays, thus increasing the cost of rehabilitation of a section having trench patch. An investigation was also undertaken to compare the structural number (SNP) of the trench section and adjacent to trench.

3.8 Deterioration of Sections with Trench Reinstatement

The effect of the poor reinstatement was investigated based on:

- existing condition,
- performance of road section.

The condition of the selected sections was compared using the new rating system developed in this project for the following three scenarios:

- Increase in roughness due to longitudinal trench.
- Increase in roughness due to transverse trench.
- Increase in roughness due to service cover.

3.9 Appropriate Remedial Actions

Practitioners from the construction industry were consulted to identify the issues relating to trenching and backfilling. Different remedial measures were recommended for use in the pavement management or predictive modelling to address the issues raised by poorly reinstated trenches or service covers.

4 Database Preparation

4.1 Background

Data for the road openings is kept in the RON database. The road condition and inventory data for the road network is kept in the RAMM database. This chapter briefly discusses obtaining data for the study and various issues identified while reviewing the existing data of various TLAs.

4.2 Data Acquisition

RON and/or RAMM data were made available from the following RCAs for the study:

- Auckland City Council,
- Manukau City Council,
- Papakura District Council,
- Waitakere City Council,
- Christchurch City Council.

4.3 Data Issues

A review of the RON database from different RCAs showed that the main purpose of this database is to register the road openings and their proposed completion. Information on the condition of the reinstatement is not recorded. Besides, the referencing system used in RON does not match with the standard RAMM road referencing system used to locate road openings. This has resulted in serious difficulties in locating road openings.

Condition data is available in the RAMM database. The RAMM rating system has the following condition parameters related to the surface distresses:

- alligator cracks - structural cracking along wheelpath,
- longitudinal cracks,
- joint cracks,
- rutting,
- patches.

The RAMM rating system does not specifically identify whether defects are due to defective trench patches and service covers, or some other reason. Use of specific event codes at the time of the condition / roughness survey will improve the credibility of the data. Auckland City Council's RON database appeared to be the most comprehensive of those considered in this study. It is recommended that the RON database use the same referencing system used by RAMM for ease of correlating data in these two systems.

4.4 Software Used

AMES database and HTC's internal software were used for data management and analysis. NZdTIMS and dTIMS Reporter Program were used to undertake dTIMS analysis and interpretation. T&T pavement analysis software was used to analyse FWD results.

4.5 Preparation of Study Database

Data available in RON and RAMM were imported into the project database.
A separate database was prepared for each RCA network.

The following tables from the RAMM database were obtained:

- treatment length,
- carriageway surface,
- top surface,
- rating,
- roughness,
- HSD roughness,
- HSD rut.

Additional data collected in the field for the selected sites was kept in the 'Raw Trench Condition' table. This data was later summarised in the 'Trench Data' table. Required data available in RAMM and RON were also summarised in the Trench Data table.

Locations of the reinstatements were related to RAMM referencing manually. Some of the techniques used include review of High Speed Data (HSD) roughness and rutting collected in short interval. Short sections with high roughness generally indicated the presence of some kind of defects. A substantial effort was required to match the reinstatement locations during the site visit.

4.6 Summary

Data available in the RON and RAMM databases was used in the study. Although some Councils have a comprehensive RON database (such as Auckland City Council), it was very difficult to correlate the data between RON and RAMM systems. The referencing followed by these two systems was exclusive. This generated a lot of field inspection in the study. It is recommended that these two systems follow the same referencing in future to reduce non-compatibility issues.

5 Selection of Study Network

5.1 Background

Selection of the study network is an important task as it affects the outcome of the research. A proper and appropriate study network leads to definite results, whereas an inappropriate network might produce inconclusive results. This chapter discusses the selection of the study network for this project.

5.2 Study Network

Databases were acquired from five RCAs. After the initial screening of the data, three databases were selected for the study. The final networks considered for the study were:

- Auckland City Council,
- Manukau City Council,
- Papakura District Council.

A thorough review of the availability of data was undertaken before selecting the study network and study sections. A preliminary site visit was also carried out to determine the suitability of the networks, in terms of existence of trench patches and service covers.

5.3 Selection of Study Sections

More than 90 sections were selected for preliminary screening. Inventory data such as road identification details (Road_id, Road name) and carriageway section details (carriageway number, start displacement, end displacement, start name and end name) where the trench patch or service cover were located were used for the initial screening.

Sections from Auckland CC and Papakura DC were selected for detailed analysis on condition and deterioration as these two Councils have the latest HSD data available. Sections from Manukau CC were selected to undertake FWD surveys to determine the impact of trenching on pavement and strength characteristics. A summary of the final sections selected for the analysis is given in Table 5.1.

Table 5.1: Summary of Study Network.

Network	Number of Cway Sections	Length (centreline Km)	Type of Analysis
Auckland CC	66	8.6	Condition and deterioration
Papakura DC	12	4.9	Condition and deterioration
Manukau CC	14	7.4	Pavement and strength

More details on the study sections are given in Appendix B.

6 Development of Rating System

6.1 Background

The RAMM Sealed Rating Survey records comprehensive information on the condition and the existence of the surface distresses. It is generally perceived to be one of the best systems available in the world. Unfortunately, RAMM does not collect information on inventory and condition of trench patches and service covers. This chapter discusses the development of the rating system and the analysis of the information collected for the study.

6.2 Objective of the Rating System

Ideally the rating system should be able to provide comprehensive details on the condition of the trench and service covers, including the extent and location details. However, the rating system developed in this project was aimed at assisting in:

- Presenting the overall condition of trench reinstatement.
- Identifying the specific trench related treatments.

6.3 Rating Data Collection

The data collection sheet used for the study is given in Appendix A. A preliminary visit was undertaken to select the sections prior to the rating survey. The road identification and carriageway section details were taken into the field to correlate the location of trenches and covers. Forty sections were selected for rating survey. Data was collected in the field by one team consisting of two survey crew. Only one team was used for the consistency of the rating data. Data was collected by 'walk through method'. A calibrated measuring wheel was used to measure the displacements.

6.4 Analysis of Distresses

During preliminary field inspection of trench patch sections, several distresses were found on the trench and adjoining surfaces. The surface distresses used in the predictive modelling and existing on the trench patches were identified for use in the study. The major distresses selected for recording in the field were:

- cracking longitudinal,
- cracking structural,
- cracking transverse,
- joints,

- rutting,
- depression/rise (relative level).

The existence of the above distresses on the 40 sections is depicted in Figure 6.1. Level of the distress was also shown along with the type, Level 1 indicating 'excellent' condition and Level 5 indicateing 'worst' condition. Refer to Table 6.1 for more details on the levels of distress.

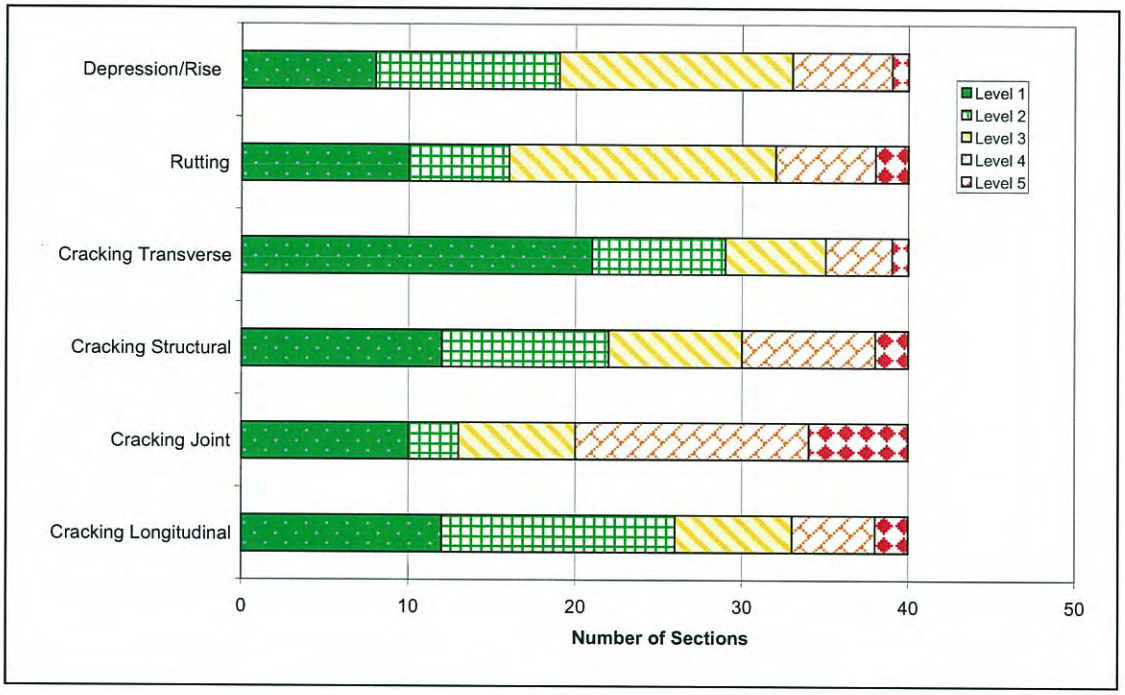


Figure 6.1: Existence of Distresses on Trench Patches.

Discussion

From Figure 6.1, it is evident that "Joints" are the predominant distress type observed, followed by rutting and structural cracking. In most cases the joints between the trench patch and adjoining surface have failed, exposing the underlying layers and allowing water to enter into the pavement structure. In some cases the joints have developed a 'lip' resulting in increased roughness.

6.5 Sensitivity of Distresses

The reinstated area can have various defects or distresses. However, the sensitivity of these defects on pavement management can be different when used in deterioration modelling. It is not possible to determine the effect of each individual defect as most of them overlap. However, a combined effect can be estimated easily. Hence, it was proposed to develop a composite index that takes into account most of the relevant distresses.

6.6 Reinstatement Surface Index (RSI)

Reinstatement Surface Index (RSI) is a composite index developed specifically to reflect the overall condition of the trench patch or service cover. A scale from 1 (excellent) to 5 (very poor) has been used where increasing value indicates poorer condition. The data collected for the selected sites was analysed to identify the sensitive condition parameters to be included in the RSI expression. Guidelines for visually assessing the trenches and covers in the field are given in Table 6.1.

Table 6.1: Guidelines for Assessing RSI.

RSI	Condition Level	Distress	Deformation	Roughness Difference
1	Excellent	Cracks <=0.1% or Failed Joints <1 %	No Rut or Deformation	<= 5%
2	Good	Cracks <=0.5% or Failed Joints <5 %	Rut <5 mm or Deformation <5 mm	<=10%
3	Moderate	Cracks <=5% or Failed Joints <7 %	Rut <10 mm or Deformation <10 mm	<=25%
4	Poor	Cracks <=10% or Failed Joints <15 %	Rut <20 mm or Deformation <20 mm	<=50%
5	Very poor	Cracks >10% or Failed Joints >15 %	Rut >20 mm or Deformation >20 mm	>50%

The major distresses such as structural cracking, joints, rutting, deformation and change in the roughness were considered in the RSI. The weighting factors were determined, based on the minimum and maximum values of the RSI. The sensitivity of the weighting factors used for each of the parameters was analysed. The following equation is proposed for estimating the RSI when distress information is available:

$$RSI = Min\ (5, (ACA*0.1 + AFJ*0.16 + RUT*0.05 + DEF*0.1 + DRG*0.08))$$

Where ACA = Area of structural and longitudinal cracking in %
AFJ = Area of failed joints in %
RUT = Rut depth in mm
DEF = Deformation in mm
DRG = Difference in roughness in %

The sensitivity of the weighting factors used is given in Appendix C. This equation is based on the principles used in the surface condition index (SCI) and surface defects index (SDI) in RAMM and surface integrity index (SII) in NZdTIMS for consistency.

6.7 Field Validation of Rating System

The preliminary field visit directed the development of the rating system. The data collection form given in Appendix A was used to collect inventory and condition data on trench patches and service covers. The parameters included in the field rating sheet were well represented to assess the condition of the trench patch and service covers. Minor refinement was required to the preliminary rating sheet by

including the location, in terms of wheelpath. Although the lane details were included during the analysis, it was found useful to also include the wheelpath details, particularly in the case of longitudinal trenches. Although the preliminary rating system and RSI developed in this study appeared to be appropriate, further verification of these two systems is recommended.

6.8 Data Availability in RAMM

The RAMM rating survey adopted by local authorities in New Zealand records comprehensive rating survey for sealed, unsealed pavements, footpaths and kerb and channels, as required by Transfund New Zealand. Unfortunately, RAMM does not include either location or condition rating of trench patches and service covers. RAMM 2003 introduced two new fields under "Rating Sealed Survey" that are related to trench patch or service cover. These two fields collect the following information:

- **Number of High or Low Service Covers**: Records the number of service covers 10mm above or below the seal falling under each rating section.
- **Number of High or Low Service Trenches:** Records the number of service trenches 10mm above or below the seal falling under each rating section.

Note that pavement digging and pavement layer information can also be stored in 'Pavement Layer' table in RAMM.

Discussion

The area of the reinstatement between different service trenches varies considerably and depends on the purpose of the trench, etc. This was supported by our field visits to three networks in Auckland region. The size of the service cover did not influence the overall assessment, as the difference in the area for different sizes of service covers is minimal.

Considering the fact that the RAMM rating information is being widely used in pavement deterioration modelling and for other road management purposes, it is proposed to include the data given in Table 6.2 in the RAMM rating survey.

Table 6.2: Additional Fields for RAMM Rating Survey.

Field	Description	Remarks
ATP	Area of Trench Patches	Replaces "Number of Service Trenches"
ASC	Area of Service Covers	"Number of Service Covers" can be used to estimate the area of service covers by assuming some default size for service covers.
RSI	Reinstatement Surface Index	New data item recording a value between 1 and 5 following the guidelines proposed in Table 6.1.

Although it is recommended that RSI be incorporated in RAMM, it is proposed that it be studied in detail in Stage 2 as RSI is recorded subjectively. Alternatives, such

as flagging sections with reinstatement or the extent of distress caused by reinstatement within inspection length, etc., shall be explored in Stage 2.

6.9 Summary

- Failed joints appeared to be the most significant type of distress observed on trench patches, followed by structural cracking and rutting. In some cases 'joints' had raised or lowered levels resulting in a sharp increase in roughness.

- Guidelines for objective (visual) assessment of the condition of reinstatements have been developed (refer Table 6.1). Major distresses were included in the RSI expression. The weighting factors used were finalised, based on sensitivity analysis.

- It is recommended that some additional fields be included in the RAMM rating survey (refer Table 6.2).

- It is recommended that appropriate event codes, such as roughness etc., be used in data collection surveys.

7 Effect of Trench Patches on Pavement Strength

7.1 Background

More recent studies have shown that high quality workmanship in the reinstatement may reduce structural damage to pavements while poor workmanship will reduce the pavement life. In most cases the resulting reduction in pavement life, despite high quality workmanship in reinstatement, can be attributed to trench operation. The process of opening the trench causes slumping of the sides as the lateral support of the soil is removed. Quantifying the slumping can sometimes become very complex but, regardless of the extent, the adjacent pavement is adversely affected. This zone of weakened pavement adjacent to the trench can fail more rapidly than other parts of the pavement.

In addition, improperly sealed trenches can allow water intrusion, resulting in loss of fine materials from the underlying base and subgrade and, consequently, loss of pavement strength. These effects typically are quantified by deflection tests. This chapter discusses the method of deflection testing and results of the testing.

7.2 Survey Locations

After a thorough review of the available data supplemented by field visits, Manukau City Council's road network was selected for determining the effect of trenches on pavement and strength characteristics. Five sections were selected within four RAMM carriageway sections. The details of the selected sites are given in Table 7.1.

Table 7.1: Sections for FWD Testing.

SNo	Road ID	Road Name	Cway ID	Trench Description	RSI	Reinstatement Condition
1	689	Alfriston Road	59	Longitudinal trench	2	Good
2	742	Ash Road	162	Transverse trench	2	Good
3 *	1447	Harris Road	1825	Transverse (skewed) trench	5	Very Poor
4 *	1447	Harris Road	1825	Transverse (skewed) trench	5	Very Poor
5	2693	Wiri Station Road	4772	Longitudinal trench	3	Moderate

* indicates two trenches were selected from one carriageway section.

7.3 Falling Weight Deflectometer Survey

Deflection testing using a falling weight deflectometer (FWD) was undertaken on the five selected sections to establish the relative loss of structural capacity resulting from the presence of trenches. This loss of structural capacity warrants thicker overlays, thus increasing the cost of rehabilitation of a section having a trench patch. The survey also aimed to determine the impact of trenching on structural number (SNP).

7.4 Survey Layout

The deflection survey was designed to capture the condition of the trench patch and the adjoining pavement. Survey sections were selected with consideration of the need for the trench patch to accommodate FWD testing equipment and be long enough to allow sufficient data samples to be taken for interpretation. At least five measurements were taken at each of four locations: on the trench; and approximately 1m, 3m and 5m away from the edge of the trench. A typical survey layout is shown in Figure 7.1. Deflection measurements away from the trench patch were taken on both sides, except for Wiri Station Road, where the trench was adjoined by kerb and channel. The detailed survey layout for each of the above sites is given in Appendix D.

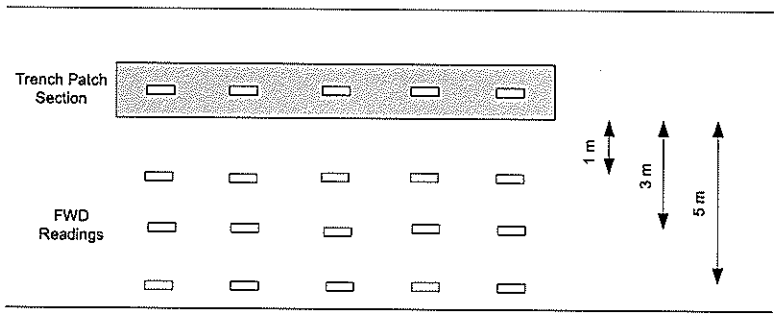


Figure 7.1: FWD Survey Layout.

7.5 Data Analysis

Deflectometer testing was undertaken on reinstated trenches followed by progressive testing further away from the trench. Back analysis was undertaken to assess the layer moduli, relating those in the trenches with those in the original pavement. The software supplied by Tonkin & Taylor allowed graphic interpretation of the data and a summary of results follows:

7.5.1 Alfriston Rd (Section 1)

Excellent moduli were obtained at all depths in the trench, with values higher or equal to those in the adjacent pavement. A long life is indicated for the entire pavement. The median SNP value of 4.3 for the reinstated trench is marginally higher than the original pavement's value.

7.5.2 Ash Rd North Side and South Side (Section 2)

The trench results and results those immediately adjacent (1m away from trench), are poor. The subgrade modulus exponent is typically low. This means that either the lower subbase has not been compacted or, more likely, the subgrade has become softened at the interface with the subbase, and the lack of a strong foundation has then resulted in lower moduli in the overlying layers. The test results further (5m) away from the trench improve markedly. It is possible that this effect is due to a naturally weaker subgrade in and beside the trench. However, it is at least as likely that water entered the trench prior to or during reinstatement. The trench and adjacent pavement is unlikely to provide good service for anything like the ESA/year

indicated and will have markedly shorter life than the original pavement. The median SNP value of 2.7 for the reinstated trench is lower than the original pavement value.

7.5.3 Harris Rd Section 1 North Side (Section 3)

The trench has an abnormally low subgrade modulus exponent, with implications similar to the Ash Road section. However, in this case the uppermost layer has been compacted very well, giving higher moduli than in the original pavement surface. This makes prediction of life more difficult as the good load spread may make up for the weakness at depth. There will probably be slightly more rutting in the trench than adjacent to it, but it may be some time before this is noticeable. The median SNP value of 3.6 for the reinstated trench is marginally lower than the original pavement value.

7.5.4 Harris Rd Section 1 South Side (Section 3)

The same comments apply as for the north side but, while the reinstatement is not so good at depth and the life will be shorter than the original pavement, the required design life should be achieved. The median SNP value of 4.4 for the reinstated trench is lower than the original pavement value.

7.5.5 Harris Rd Section 2 North Side (Section 4)

No layers have been reinstated to the same quality standard as the original pavement. Subgrade modulus exponent is low and all layer moduli, including the surface layer, are lower than the original but still reasonable in absolute terms. Pavement life will be much shorter than the original, although it will still be good for some years under the design ESA/year. The median SNP value of 3.6 for the reinstated trench is significantly lower than the original pavement value.

7.5.6 Harris Rd Section 2 South Side (Section 4)

The subgrade modulus exponent is low but variable. Other layer moduli are good and, while life will be slightly shorter than the original, the design ESA should be achieved. The median SNP value of 4.4 for the reinstated trench is marginally lower than the original pavement value.

7.5.7 Wiri Station Rd (Section 5)

Reinstatement is as good as the original for the full depth of the pavement. There is rather more non-uniformity of compaction in the upper layers than expected but it is not excessive. Both trench and original pavement should have similar lives, although somewhat less than 25 years, as intended for the indicated ESA/year. The median SNP value of 3.6 for the reinstated trench is very similar to the original pavement value.

The graphs and tables used for this interpretation are provided in Appendix E.

7.6 Discussion on FWD Survey Results

The results of the FWD survey show that the quality of trench reinstatement is variable, with predicted performance ranging from much better than that expected for the original pavement to much worse. In some cases it appears that the lower layers have minimal compaction while, in others, the weakness is in the upper layers.

A complementary study noting compaction procedures used in each case would provide a basis for future quality control. The poorest compaction techniques were those applied at Ash Road, while the best result (relative to the original pavement) was achieved at Alfriston Road.

7.7 Impact of Trenching on Pavement Strength

The impact of the trenching is determined at two different levels:

- **Project level**: a road section is studied in detail, e.g., pavement or rehab design of a road section.
- **Network level**: the entire network is considered at a strategic level, e.g., development of a forward works programme (FWP).

Granular overlay thickness is chosen for project level comparison while "structural number" is selected for network level. A summary of the comparison of granular overlay requirement and structural number is provided in Tables 7.2 and 7.3.

7.7.1 Comparison of Granular Overlay Required

Overlay requirement indicates the thickness of either asphalt or granular overlay, when placed on an existing pavement, required to overcome the strength deficiencies of the pavement and retain its structural integrity. The granular overlay requirement was calculated using back analysis. The estimated granular overlay in mm for 'on trench' and 'away from trench' is summarised in Table 7.2.

Table 7.2: Comparison of Granular Overlays in mm.

Road section	Trench	1m away	3m away	5m away	Comments
Alfriston Road	0	0	0	50	Original pavement weak
Ash Road	140	175	35	0	Trench section weak
Harris Road 1 north side	50	50	0	0	Trench section weak
Harris Road 1 south side	0	0	0	0	
Harris Road 2 north side	50	0	0	0	Trench section weak
Harris Road 2 south side	0	0	0	0	
Wiri Station Road	100	50	50	50	Trench section weak

7.7.2 Comparison of Structural Number

The modified structural number (SNP) is a number indicating the strength of the pavement. SNP is generally used for network level analysis, such as pavement deterioration modelling. SNP was calculated from back analysis for the surveyed sections and the median of the SNP for 'on trench' and 'away trench' is compared in Table 7.3.

Table 7.3: Comparison of Structural Number.

Road section	Trench	1m away	3m away	5m away	Comments
Alfriston Road	4.3	4.1	4.2	4.0	Original pavement weak
Ash Road	2.8	3.0	3.6	4.3	Trench section weak
Harris Road 1 north side	3.7	3.8	4.2	4.3	Trench section weak
Harris Road 1 south side	4.4	5.0	4.9	4.9	
Harris Road 2 north side	3.7	4.2	4.7	4.6	Trench section weak
Harris Road 2 south side	4.4	4.5	4.6	4.6	
Wiri Station Road	3.6	3.5	3.7	3.7	Trench section weak

7.8 Summary

At the project level, the granular overlay requirement for the trench section was found to be generally higher than for adjacent sections. On average, the increase in the granular overlay required for the trench sections varied between 20% (1m away) and 300% (3m away). This clearly indicates that the pavement structure is affected by trenching and poor reinstatement.

On average, the SNP decreased by 5% (1m away) and 12% (5m away) when compared with the SNP away from trench. In some individual cases, the decrease in the SNP was 12% (1m away), 27% (3m away) and 42% (5m away). This can increase pavement deterioration significantly. Average values for the selected sections are compared in Figure 7.2.

Overall, it can be concluded that trenching activities are affecting pavements and their strength considerably. In few cases, trenching activities are increasing or equalling the performance of the pavement structure compared with that of the adjoining structure. Note that this is a desk study of non-destructive testing (NDT) data undertaken without detailed knowledge of reinstatement procedures and materials, which also influence pavement life.

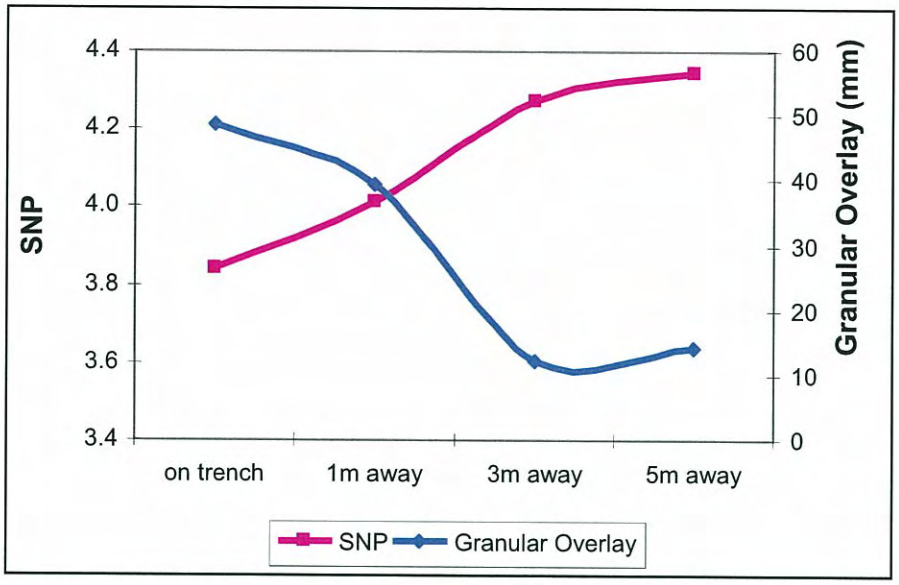


Figure 7.2: Comparison of SNP and Granular Overlays.

Further testing on the Papakura District Council road network is also scheduled. It is proposed that the results of these tests, including detailed investigations of Manukau City Council and Papakura District Council trench sections (in terms of method of reinstatement, materials used and quality assurance undertaken, etc.) will be discussed in Stage 2 of the study.

8 Effect of Trench Patches and Service Covers on Pavement Deterioration

8.1 Background

This chapter discusses the impact of trenches and service covers on pavement deterioration.

8.2 Parameters for Comparison

The major distresses existing on the trench and adjoining surface were described in Chapter 6. High speed data for roughness and rutting were also obtained for Papakura DC and Auckland CC at 1m intervals. After initial analysis of the data, HSD roughness appeared to be the best parameter for comparison of 'trench section' and adjacent section.

8.3 Roughness Comparison

The latest roughness data from local authorities was imported into the project database. It was categorised into different lanes, such as L1, L2, R1 and R2, etc., and into different wheelpaths, such as left wheelpath and right wheelpath. The trench patches and service covers were located on the disaggregated wheelpath data. The change in roughness due to trench patches or service covers was calculated. Difference in roughness was analysed for three scenarios:

- longitudinal trench,
- transverse trench,
- service cover.

RSI for trench patches and service covers recorded during the condition rating survey was used for determining the effect of condition (level of RSI) on increase in roughness.

8.3.1 Increase in Roughness due to Longitudinal Trench

A longitudinal trench was superimposed on the roughness data, including wheelpath and lane details. Where the trench was falling into one wheelpath (e.g., left or right) the roughness for different wheelpaths was compared. Where the trench patch extended over the entire lane (e.g., L1 or R1) either the adjacent lane (when multiple lanes existed) or the lane in the opposite direction of the traffic flow was used for comparison.

Increase in roughness due to longitudinal trenches is given in Figure 8.1 for different levels of RSI. Trenches with an RSI level of 5 (very poor) were rare and, therefore, the effect of this type of trench could not be evaluated. RSI levels were determined on the basis of the difference in roughness, condition of joints and existence of rutting/depression (given in Table 6.1).

The increase in roughness due to different longitudinal trenches varied from 5 NAASRA to above 90 NAASRA (2% to 90% increase).

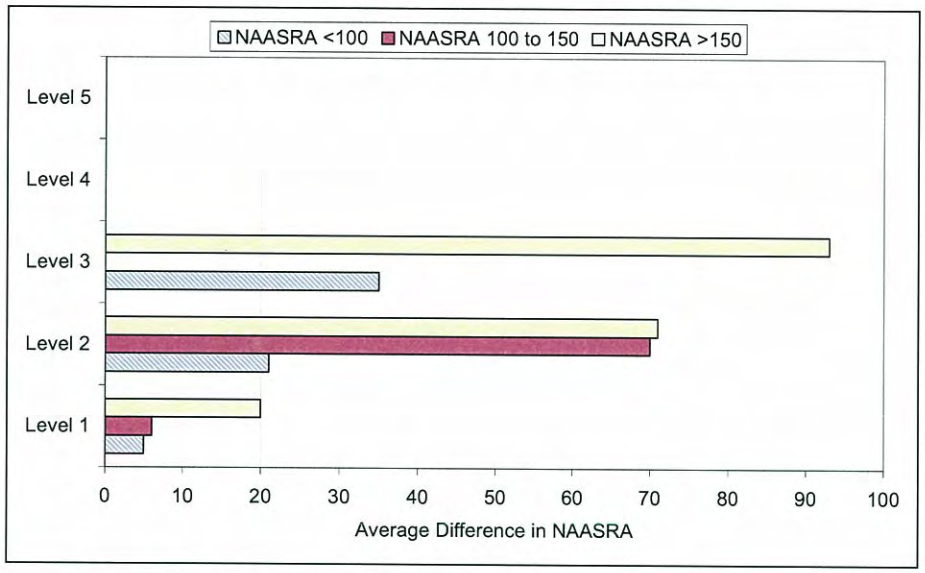


Figure 8.1: Increase in Roughness due to Longitudinal Trench.

8.3.2 Increase in Roughness due to Transverse Trench

Transverse trenches mostly extended over the entire width of the pavement and, in some cases, over one direction of traffic flow where there were dual carriageways (divided carriageway). Roughness value up to 5m on either side of the trench was averaged to compare with roughness on the trench section. Roughness for the full width or one direction of traffic flow was considered for comparison.

Transverse trenches with an RSI level of 1 (excellent) and level 5 (very poor) were almost non-existent within the study network. The increase in roughness varied from 15 NAASRA to 90 NAASRA (10% to 80% increase). The increase in roughness for different transverse trenches is given in Figure 8.2.

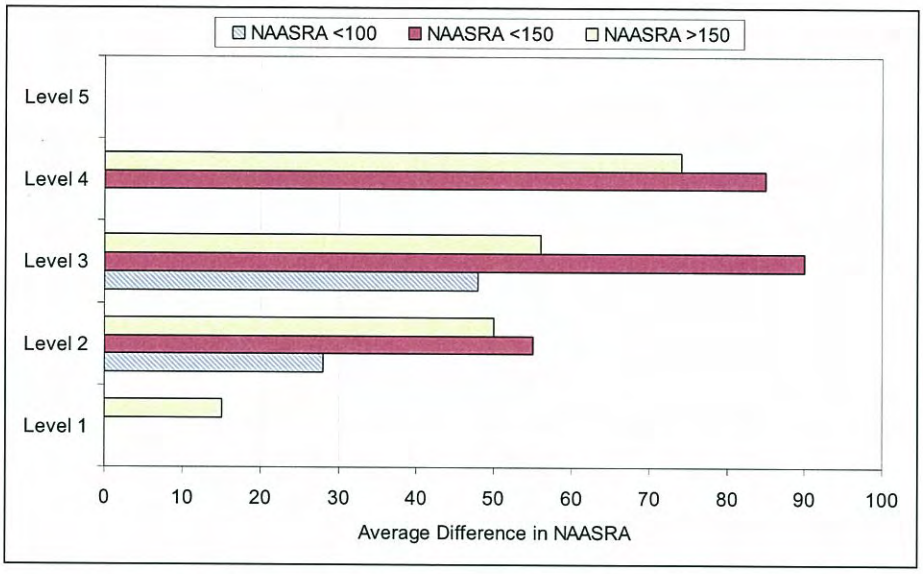


Figure 8.2: Increase in Roughness due to Transverse Trench.

8.3.3 Increase in Roughness due to Service Covers

The location of service covers is relatively important (compared with trench patches) as the area of influence of service covers either falls in a wheelpath or not. The location of service covers selected for the study (whether in a wheelpath or not) was decided in the field, based on vehicle movements. Wheelpath roughness values up to 5m on either side of the selected service covers were averaged for comparison.

Service covers with an RSI level of 5 (very poor) were not found within the study network. The increase in roughness due to the presence of service covers varied from 15 NAASRA to approximately 190 NAASRA (20% to over 300% increase) depending on the level of RSI of the service cover. The increase in the roughness is given in Figure 8.3.

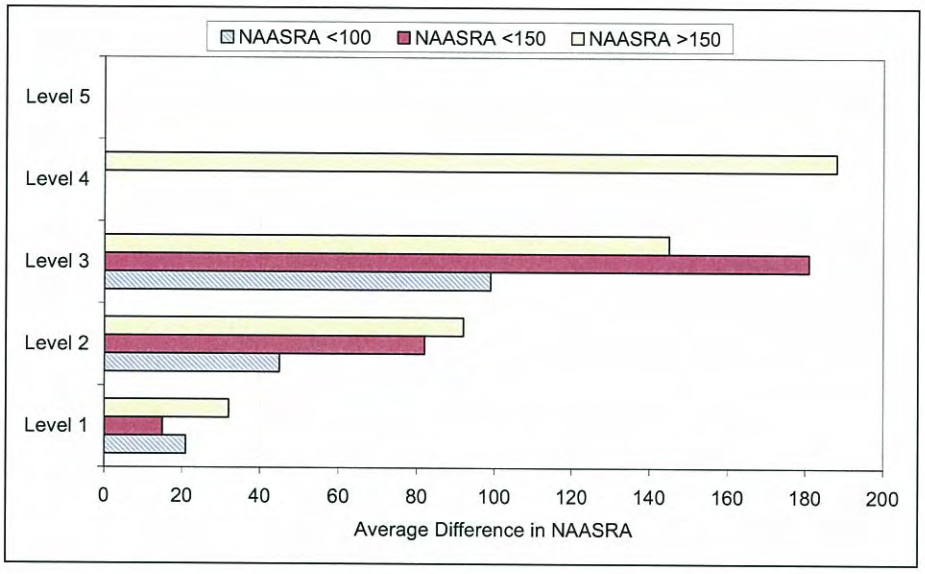


Figure 8.3: Increase in Roughness due to Service Covers.

8.4 Increase in Deterioration due to Increase in Roughness

The trenching operation itself affects the integrity of the pavement structure. Additionally, poor workmanship in backfilling and sealing of joints further weakens the pavement, causing a decrease in pavement structural capacity. The impacts of poorly reinstated trenches on pavement and strength were discussed in Chapter 7. Increase in roughness is described in the earlier sections of this chapter.

Models used for pavement deterioration in NZdTIMS are incremental in nature and dependent on the previous year values. When initial (year one of the analysis period) values are high, due to poor reinstatement or some other reason, the future predicted deterioration would follow the initial value. This may result in the application of higher maintenance treatments, such as rehabilitation, etc., at early pavement or surface age.

Roughness progression for 'do nothing' and 'routine only' scenarios is depicted in Figure 8.4 for 'with' and 'without' trench cases. As the initial roughness value was found to be higher on trenched sections, this difference was maintained throughout the analysis period. Note that the maximum value allowed for IRI is 20 in NZdTIMS.

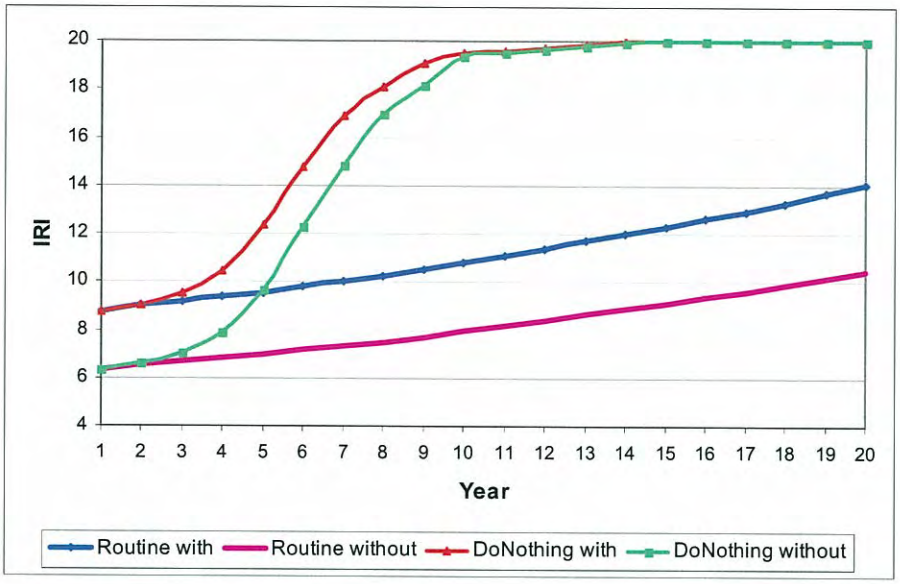


Figure 8.4: Roughness Progression 'With' and 'Without' Trenches

In NZdTIMS system the following scenarios are possible:

- **Do nothing**: Road section is left without any maintenance. Allowed to deteriorate until the section fails.
- **Routine only**: Routine maintenance only is applied throughout the analysis period.
- **Strategy**: Appropriate maintenance treatments (such as resurfacing, rehabilitation or reconstruction, etc.) are applied, based on the existing and predicted condition.

8.5 Summary

- After a thorough analysis of available data, supplemented by a field visit, roughness was selected to compare 'with' and 'without' trench scenarios.

- In almost in all cases, roughness was found to increase due to the presence of trenches or service covers. Inrease in roughness could not be evaluated for all of the cases (such as RSI level 5, etc) as these did not exist in the study network.

- Roughness was found to increase by 2% to 90% due to longitudinal trenches, whereas transverse trenches increased roughness between 10% and 80%. Service covers were found to increase roughness by 20% to 300%.

- Overall, trenched sections were found to deteriorate at a higher rate.

9 Effects of Trench Patch and Service Covers on Pavement Management

9.1 Background

Poorly reinstated trenches and service covers not only increase deterioration of the pavement, but also have severe impacts on pavement management. Combining the condition of the trench with that of the rating section would misrepresent the average condition for that section. This could result in the selection of an inappropriate treatment. This chapter discusses the effect of trenches and service covers on life cycle cost analysis.

9.2 dTIMS Analysis

The effects of trench patches and service covers on pavement management were determined by life cycle cost analysis through predictive modelling. The NZdTIMS system adopted by most RCAs in New Zealand was used for predictive modelling.

Twenty sections from Auckland CC were selected. The sections were chosen so that different lanes, or lanes in different directions of traffic flow, could be compared with each other. Also, care was taken to have representation of sections with longitudinal trenches, transverse trenches, service covers and a combination of these. The total length of the sections modelled was 2660m. The NZdTIMS set-up customised for Auckland CC by its dTIMS consultant in 2002 was used to estimate the impact of trenches. dTIMS analysis was undertaken for two scenarios:

- with actual network data,
- with synthetic data.

dTIMS analysis was carried out under 'performance' mode only.

9.3 dTIMS Analysis with Actual Network Data

dTIMS input file (dt2699) was taken from the 2002 analysis undertaken by Auckland CC and updated for condition, history and roughness data. Analysis was done in two phases:

With trench/cover: Averaged roughness data over a section was considered. (This was calculated by RAMM algorithm and saved in the 'treatment length' table which means this data would be used for dTIMS analysis under normal circumstances.)

Without trench/cover: Roughness for the lanes unaffected by either trench patches or service covers was used.

9.4 dTIMS Analysis with Synthetic Data

Comparison of the actual network data for sections 'with' and 'without' trenches showed that there was a substantial increase in roughness values due to the existence

of trench patches or service covers (refer to Chapter 8). The 'without trench' roughness values were reasonably higher and due for 'maintenance'. It was believed that this scenario underestimated the benefits of not having trenches or service covers in the life cycle cost analysis. Hence, dTIMS analysis was also carried out with synthetic data.

The dTIMS input file was updated for surface history and condition, assuming that the section was resurfaced within the last two years. Condition was reset to the initial values, as were pavement age and surface age. dTIMS analysis was carried out for 'with trench' and 'without trench' scenarios, similar to those outlined in Section 9.3.

9.5 Comparison of Effects

The effects of having trench patches or service covers within the pavement structure were compared under four categories:

- agency cost,
- VOC and TTC,
- maintenance regime,
- pavement and surface life cycle.

NZdTIMS outputs used for this comparison are given in Appendix F.

9.5.1 Agency Cost Comparison

Agency costs for maintaining the selected sections 'with trench' and 'without trench' were determined separately and summarised in Table 9.1 for actual network data and synthetic data. Per km maintenance costs were also compared.

Table 9.1: Comparison of Agency Costs.

Agency Cost	Actual Network Data			Synthetic Data		
	With trench ($ 000)	Without trench ($ 000)	Difference	With trench ($ 000)	Without trench ($ 000)	Difference
20 years total	1,868.0	1,777.7	5.1%	2,072.1	1,826.5	13.5%
First 5 years total *	893.8	801.9	11.4%	1,213.7	982.9	23.5%
Km per year (averaged over 20 years)	35.1	33.4	$ 1.7	38.9	34.3	$ 4.6
Km per year (averaged over first 5 years *)	67.2	60.3	$ 6,900	91.3	73.9	$ 17,400

* first five years from the start of maintenance cycle.

Discussion

Using actual network data, agency costs for maintaining the selected network increased 5 % (20 years) to 12 % (first 5 years). Costs increased 15% to 25% with synthetic data. This proved that the actual network data was underestimating the benefits of not having trench patches or service covers within the pavement structure

as the condition and surface age values suggested that the sections were due for some kind of maintenance even without the trenches. The increase in annual cost of maintenance of a trenched section was found to be in the order of $7,000 to $17,000 per km, depending on its given condition. Although these results are preliminary in nature, and valid for the sections considered in the analysis, it can be concluded that agency costs for maintaining the network generally increased by 10% to 20% where trench patches or service covers existed. Note that undiscounted cost values were used for comparison, derived from the 'performance mode' of NZdTIMS analysis.

9.5.2 VOC and TTC

Road users generally feel discomfort when travelling on poorly reinstated trenches or service covers, due to the existence of poor joints, other distresses and deformation or rutting. These are not quantified in the current NZdTIMS system. However, vehicle operating costs can be directly related to increase in roughness due to poor reinstatement. Vehicle operating costs and total transportation costs for 20 years are given in Table 9.2.

Table 9.2: Comparison of VOC and TTC.

Cost	Actual Network Data			Synthetic Data		
	With trench ($ 000)	Without trench ($ 000)	Percent Difference	With trench ($ 000)	Without trench ($ 000)	Percent Difference
Agency Cost	1,868	1,777	5.1	2,072	1,826	13.4
Vehicle Operating Cost	27,187	14,997	81.2	3,955	861	359.3
Total Transportation Cost	29,055	16,775	73.2	6,027	2,688	124.2

Discussion

The increase in vehicle operating costs outweighed the increase in agency costs. Poorly reinstated trenches and service covers not only increased agency costs, but also increased vehicle operating costs (paid by road users). Total transportation costs also increased due to the increase in agency costs and vehicle operating costs.

9.5.3 Maintenance Regime

The condition of trench patches and service covers was found to be different from adjoining surfacess (such as failed joints and depressions, etc.). The current RAMM rating system averages the trenched section and the adjoining section to arrive at the condition of a rating section. This may result in the selection of an inappropriate maintenance regime. The maintenance regime was analysed under two categories:

- type of treatment selected,
- timing of the treatment applied.

The dTIMS analysis considering 'with trench' and 'without trench' for actual network data and synthetic data are shown in Figure 9.1 and Figure 9.2. In both cases, the type of treatment and timing of treatment were affected by the presence of the poorly reinstated trenches or service covers.

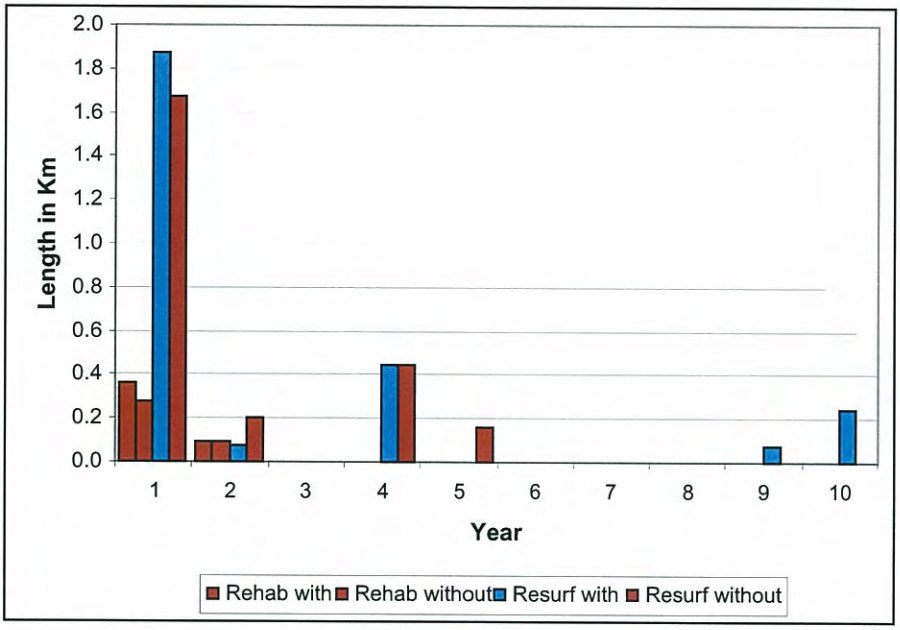


Figure 9.1: Comparison of Maintenance Regime with Actual Network Data.

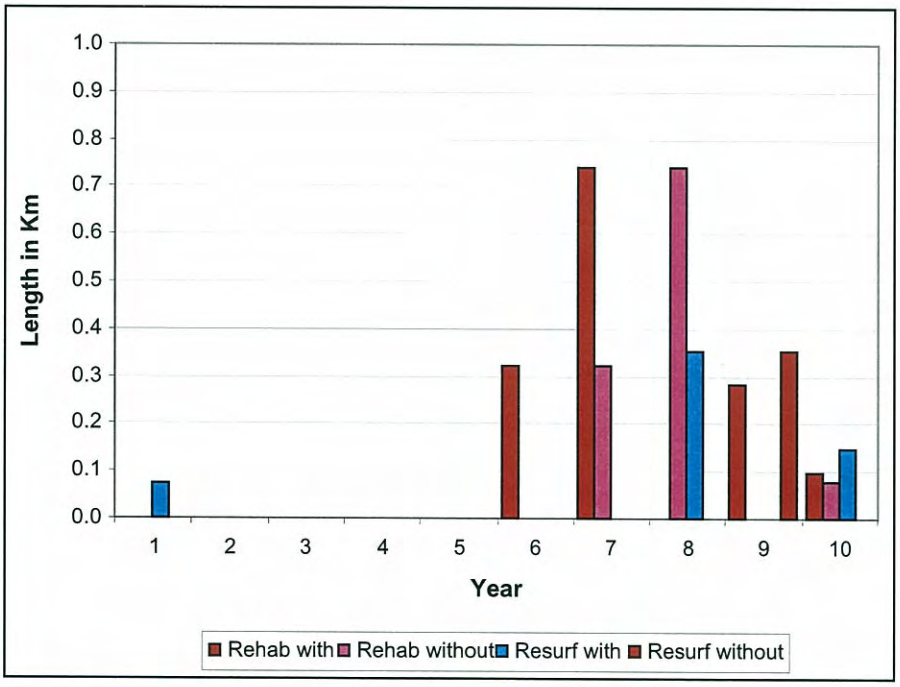


Figure 9.2: Comparison of Maintenance Regime with Synthetic Data.

9.5.4 Pavement and Surface Life Cycle

Poor reinstatement increased the amount of distress and roughness, resulting in a higher deterioration rate compared with adjoining surfaces. Due to this, treatments were applied three to six years sooner than for adjoining trench-free sections. In some cases, resurfacing was replaced with rehabilitation treatments, reducing normal pavement life.

9.6 Summary

NZdTIMS analysis was undertaken for 'with trench' and 'without trench' scenarios. The results are summarised below:

- Increase in agency costs for maintaining the selected network was found to be in the order of 5% to 12% using actual network data.

- It is believed that the actual network data underestimated the benefits of not having trenches, as the existing condition of the selected network suggested that the sections were due for some 'maintenance' even without trenches. Agency costs increased 15% to 25% with synthetic data.

- The increase in the annual cost of maintaining a trenched section was found to range from approximately $7,000 (actual network data) to $17,000 (synthetic data) per km, depending on its given condition.

- An increase in the VOC and TTC was also observed, due to poorly reinstated trenches. The increase in the VOC weighed the increase in agency costs.

- Poorly reinstated trenches and service covers have changed the maintenance regime for the selected network. Both 'type of treatment' and 'timing of the treatment' were affected by the presence of trenches.

- In most cases, pavement and surface lives were reduced by the presence of trenches within the study network.

10 Remedial Measures in Pavement Performance

10.1 Background

The issues and problems associated with poorly reinstated trenches and service covers could be addressed in the field by adopting best practices and following the quality measures set out by various authorities. However, the status of the guidelines and quality assurance procedures are scheduled to be addressed in the Stage 2 of the project. This chapter discusses the procedure for remedying the detrimental effects of trench patches and service covers on pavement performance through proper predictive modelling.

10.2 Remedial Measures

The ideal situation would be to eliminate trenching operations and keep the pavement structure free from any digging or backfilling. The fact is that trench patches and service covers will continue to exist. We need to make some kind of allowance for these in our pavement management systems. Most RCAs are already using NZdTIMS as a tool for preparing their forward works programmes (FWP) and justifying maintenance budgets. Transfund New Zealand also considers the outputs from dTIMS analysis for allocating funds between different RCAs. Hence, the following measures are recommended for reducing the impact of trench patches and service covers in deterioration modelling or pavement management:

- Treat them separately.
- Use RSI in modelling.
- Share costs.
- Apply appropriate reinstatement standards.
- Implement QA procedures.

10.2.1 Treat Them Separately

Treat the trenched sections in the modelling as 'exclusive'. Apply dynamic homogeneous sectioning principles to divide them into separate sections. If 10% or more of the surface area is affected by a trench patch or service cover then treat it as a separate analysis section. Sometimes, a lane or lanes in one direction of traffic flow will need to be treated as a separate section. The discussions we had with maintenance practitioners indicated that there is a reduction in the credibility of NZdTIMS results in urban areas, sometimes due to trenching operations. Treating trenched sections as different analysis sections would help improve the credibility of predictive modelling, particularly in urban areas.

NZdTIMS analysis was carried out under 'performance mode' to estimate the benefits of treating trenched sections as 'exclusive'. dTIMS was run for two scenarios:

- sections having trench or cover,
- sections free from trench or cover.

Twenty sections considered for the analysis therefore formed 40 sections (20 with trench and 20 without trench). A summary of agency costs is given in Table 10.1.

Table 10.1: Comparison of Agency Costs with Dynamic Sectioning.

Agency Cost	With trench Lanes ($ 000)	Without trench Lanes ($ 000)	Percent Difference
20 years total	1,340.6	1,049.9	27.6
First 5 years total	815.7	501.3	62.7
Km/year for 20 years	25.2	19.7	27.9
Km/year for first 5 years	61.3	37.7	62.5

There is a difference of almost 30% in agency costs in modelling trenched sections separately. This can be implemented readily in predictive modelling with a little effort in collecting trench patch and service cover data, as outlined in Table 6.2, and by applying sectioning principles.

10.2.2 Use RSI in Modelling

The RSI developed in this study can be used in predictive modelling to apply proper maintenance treatment, in terms of type and time. This additional data may be included in the RAMM Sealed Rating Survey. By incorporating RSI in the dTIMS set-up, it is possible to control the maintenance treatment to be applied on the network.

The present dTIMS set-up is scheduled to be transferred to a new platform, dTIMS CT in the next year. It is recommended that RSI be incorporated in predictive modelling when the new system is available. This will ensure consideration of the advantages and constraints in the new system.

The implications of including RSI in the RAMM survey will be discussed in Stage 2 of the study as this requires further verification. Verification of the appropriateness of the current maintenance treatments used in the NZdTIMS System on trenched sections is also required.

10.2.3 Share Costs

RCAs should consider the option of cost sharing with utility organisations. If a trench width exceeds a certain limit, say 1.5 m or wider, then it is recommended that the utility company shares the cost with the council for restoration of the pavement integrity and resurfacing.

More options and the viability of these recommendations, including quality assurance measures, will be considered in detail in the Stage 2 of this study.

11 Conclusions and Further Work

11.1 Status Quo

The ideal situation would be to eliminate trenching operations from the pavement structure. This is unrealistic, but efforts should be made to improve systems and practices to accommodate the effects of trenching and backfilling in pavement management.

Specifications and best practices are available to some extent. They are necessary to ensure that the reinstatement is completed to a high standard. It appears that specifications are not always followed properly, resulting in early deterioration of the reinstated surface or pavement. However, there is a lack of documentation on maintaining reinstatements, post-trench tests and compaction methods to quantify the condition of the trench. Stage two of this research investigates this further.

Most road controlling authorities in New Zealand use the RON database for storing road opening information. The format of the RON database differs significantly between different RCAs. Auckland City Council has the most comprehensive RON database of those considered in this study. Road network inventory and condition data is kept in the RAMM database. It was found that there is no correlation between these two databases for exchange of data. The referencing followed by these two systems is exclusive. This generated a lot of field inspection during the study for correlating data between two systems.

11.2 Outcomes

Failed joints appear to be the most significant distress observed on trench patches. This is followed by rutting and structural cracking. Unfortunately, RAMM does not include any inventory and condition data on trench patches or service covers. RAMM 2003 includes two data items to be collected under "Sealed Rating Survey" that only collect the number of trench patches and service covers with more than 10mm above or below the seal. The condition of trench patches and service covers is not recorded in RAMM. A composite index called Reinstatement Surface Index (RSI) was developed in this study for visually assessing the condition of reinstatement. RSI varies from 1 (excellent condition) to 5 (very poor condition). Preliminary guidelines for recording RSI in the field were developed for use in RAMM rating surveys. Major distresses were included in the RSI expression. The weighting factors used were finalised based on a sensitivity analysis. The following equation is proposed for calculating RSI when distress information is available:

$$RSI = \text{Min}\,(5, (0.1*ACA + 0.16*AFJ + 0.05*RUT + 0.1*DEF + 0.08*DRG))$$

Trench patches and service covers affect ride quality and, sometimes, the safety performance of road networks. In some cases, the joints develop a 'lip' which results in a sharp increase in roughness. Roughness was found to increase between:

- 2% and 90% due to longitudinal trenches,

- 10% and 80% due to transverse trenches,
- 20% and 300% due to service covers.

Increased road roughness due to trenching operations affects the usefulness of road roughness as a measure of condition and/or performance of the road network, particularly in urban areas.

A desktop analysis of non-destructive testing (NDT) data revealed that trenching activities severely affect the pavement life and strength. Only in a few cases did trenching activities increase or equal the performance of the adjoining pavement. This study indicated that pavement structure is affected by trenching and poor reinstatement. This was supported by:

- An increase in the granular overlay required for trench sections from 20% (1m away from trench) to 300% (3m away from trench).
- A reduction in average SNP of trench sections by 5% (1m away from trench) and 12% (5m away from trench).
- A decrease in the SNP by 12% (1m away), 27% (3m away) and 42% (5m away). In some cases it can increase pavement deterioration significantly.

Utility cuts increase road roughness and, therefore, increase vehicle operating costs and lower road user level of service. The NZdTIMS analysis carried out under 'performance mode' concluded that:

- Overall, predicted agency costs for maintaining the network increased by 10% to 20% due to trenching.
- The predicted annual cost of maintaining a road section that has either a trench patch or service cover was found to increase approximately $7,000 to $17,000 per km, depending on its given condition.
- Poorly reinstated trenches and service covers have changed the maintenance regime. Both 'type of treatment' and 'timing of the treatment' are affected by the presence of trenches

11.3 Recommendations

- RON and RAMM systems follow the same referencing to reduce non-compatibility issues (high priority).

- Include additional fields on inventory and condition of trench patches and service covers (given in Table 6.2) in the RAMM rating survey (high priority).

- Use appropriate event codes in data collection surveys for filtering out the outliers caused by trench patches or service covers (high priority).

- Exclude peak roughness and other condition values caused by poorly reinstated trenches and defective service covers prior to pavement deterioration modelling (high priority).

- Adopt dynamic sectioning principles in the predictive modelling to improve the credibility of modelling, particularly in urban areas (high priority).
- Transfund New Zealand peer review the codes of practices for utility reinstatements as these affect the cost of network maintenance (high priority).
- Implement appropriate reinstatement standards (high priority).
- Implement QA procedures (high priority).
- All RCAs adopt a consistent approach for maintaining the RON database (medium priority).
- Use RSI in predictive modelling (medium priority).

11.4 Further Work in Stage 2

As discussed in Chapter 1 of this report, this research is divided into two stages. Stage 2 will include the development of best practice guidelines and some of the high and medium priority recommendations from Stage 1. Broadly, Stage 2 will include:

- **Reinstatement Methods**: More detailed investigation will be undertaken to study the compaction procedures adopted in the reinstatement of trenches on the selected network. Five sections considered for FWD survey in Stage 1 will be investigated further. Also, more deflection surveys to be undertaken by Papakura District Council will also become study sections in Stage 2.
- **Verification and Validation of RSI**: The preliminary Reinstatement Surface Index (RSI) developed in Stage 1 will be verified on a broader network including other regions. Modifications to RSI will be carried out, where applicable, and a final RSI (including guidelines for objective assessment) will be proposed.
- **Incorporate RSI in Modelling**: RSI will be incorporated in the new deterioration modelling system, dTIMS CT. This is scheduled to be released early next year for testing and preliminary implementation. Any additional development and modifications identified by user feedback is expected to proceed further. Incorporation of RSI can be executed at this stage of dTIMS CT implementation.
- **Define Sectioning Principles**: Principles for dynamic homogeneous sectioning based on the extent and condition of the trench patches and service covers will be defined and incorporated in dTIMS CT. At this stage, it is proposed that interfacing and conversion of RAMM data will be included in dTIMS CT. Sectioning can be applied at this stage.

- **Investigate and Propose Quality Assurance Measures**: More detailed investigations will be undertaken to assess the existing quality assurance measures adopted immediately after reinstatement. Appropriate quality assurance measures will be collated from literature and proposed for practical adoption by TLAs and utility organisations.

- **Review and Propose Best Practice Guidelines**: Existing guidelines will be reviewed and best practice guidelines for adoption by TLAs will be proposed. This will include exploring different options, such as cost sharing, etc.

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Appendix A: Data Collection Form

Referencing Data

Road_ID
Road Name
Treatment Length ID
Start_m
End_m
Start_name
End_name

RON Data

Existing

RAMM Rating Data

	Survey Date	Alligate	Longit	Joint	Rut			
Available								
Collected								

Comments

Latest Roughness in NAASRA

End		L1	L2	R1	R2
10					
20					
30					
40					
50					
60					
70					
80					
90					
100					

End	L1	L2	R1	R2
110				
120				
130				
140				
150				
160				
170				
180				
190				
200				

Comments

Trench Patches and Service Cover Defects

SN	Cond. Index	Type (T / S)	Start in m	End in m	Lane	Length in m	Width/Dia. in m	Location (W / N)	Rais/Depr. (R/D/L/0)	Cracking				Comments
										Joint	Struc.	Longit.	Trans	
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

Condition Index (Based on Engineering Judgement - Site observation)

1	Excellent	Passed
2	Good	
3	Moderate	
4	Poor	Failed
5	Very poor	

Distress level

1	Nodefects
2	<5 % defect
3	5 to 20 % defects
4	20 to 60 % defects
5	more than 60% defects

Type

T	Trench Patches
S	Service Cover

Raised/Depressed

L	Levelled
R	Raised
D	Depressed
O	Other state

Location

W	On wheelpath
N	Not on wheelpath

Level

1	No observed rutting/depression
2	Depth < 10 mm
3	Depth 10 mm to 30 mm
4	Depth 30 mm to 50 mm
5	Depth > 50 mm

Lane

L1	Left lane 1
L2	Left lane 2
L3	Left lane 3
L4	Left lane 4
R1	Right lane 1
R2	Right lane 2
R3	Right lane 3
R4	Right lane 4

Appendix B: Study Network

Road_id	Road Name	Cway_no	From	To	Start	End	Length
Auckland City Council							
23	Albert St (Ho)	1477	Customs St West	Wolfe St	0	96	96
23	Albert St (Ho)	1478	Wolfe St	Swanson St	96	196	100
23	Albert St (Ho)	1479	Swanson St	Wyndham St	196	311	115
23	Albert St (Ho)	1480	Wyndham St	Kingston St	311	400	89
23	Albert St (Ho)	1481	Kingston St	Victoria St West	400	495	95
23	Albert St (Ho)	1482	Victoria St West	113/117 Albert St	495	562	67
23	Albert St (Ho)	1483	113/117 Albert St	Wellesley St West	562	718	156
449	Fanshawe St	1650	Albert St	Federal St	0	92	92
449	Fanshawe St	3277	Federal St	Hobson St	92	201	109
449	Fanshawe St	3276	Hobson St	Nelson St	201	422	221
525	Gilles Ave	1332	Kimberley Road	King George Road	2066	2242	176
525	Gilles Ave	1329	Epsom Ave	Ranfurly Road	1555	1727	172
557	Great South Rd	6593	666 Gsr ("Central Park")	453/455 Great South Rd	3900	4089	189
557	Great South Rd	6594	453/455 Great South Rd	688/690 Great South Rd	4089	4251	162
557	Great South Rd	6595	688/690 Great South Rd	Greenpark Rd	4251	4480	229
557	Great South Rd	6596	Greenpark Rd	726/728 Great South Rd	4480	4650	170
557	Great South Rd	6597	726/728 Great South Rd	Station Rd	4650	4842	192
627	Hobson St	1755	Fanshawe St	Swanson St	0	110	110
627	Hobson St	1756	Swanson St	Wyndham St	110	223	113
627	Hobson St	1757	Wyndham St	Kingston St	223	317	94
627	Hobson St	1758	Kingston St	Victoria St West	317	412	95
627	Hobson St	1759	Victoria St West	Wellesley St West	412	630	218
710	Khyber Pass Rd	586	Symonds St	Burleigh St	0	160	160
710	Khyber Pass Rd	3464	Burleigh St	Grafton Rd	160	297	137
729	Kitchener Street	1815	Wellesley Street East	Victoria Street East	0	29	29
683	Karangahape Rd	1785	Symonds St	Liverpool St	0	133	133
683	Karangahape Rd	1786	Liverpool St	Queen St	133	207	74
683	Karangahape Rd	1787	Queen St	Pitt St	207	424	217
884	Mayoral Dr	3899	Queen Street	Wakefield Street	592	761	169
1057	Pitt St	1923	Hobson St	Vincent St	0	129	129
1057	Pitt St	1924	Vincent St	Greys Ave	129	231	102
1057	Pitt St	1925	Greys Ave	Poynton Ter	231	310	79
1057	Pitt St	1926	Poynton Ter	Karangahape Rd	310	408	98
1081	Princes St (CBD/HO)	1940	Bowen Ave	27/29 Princes St	141	299	158
1081	Princes St (CBD/HO)	1942	27/29 Princes St	Alfred St	299	493	194
1093	Queen St	1955	Customs St West	Shortland St	0	190	190

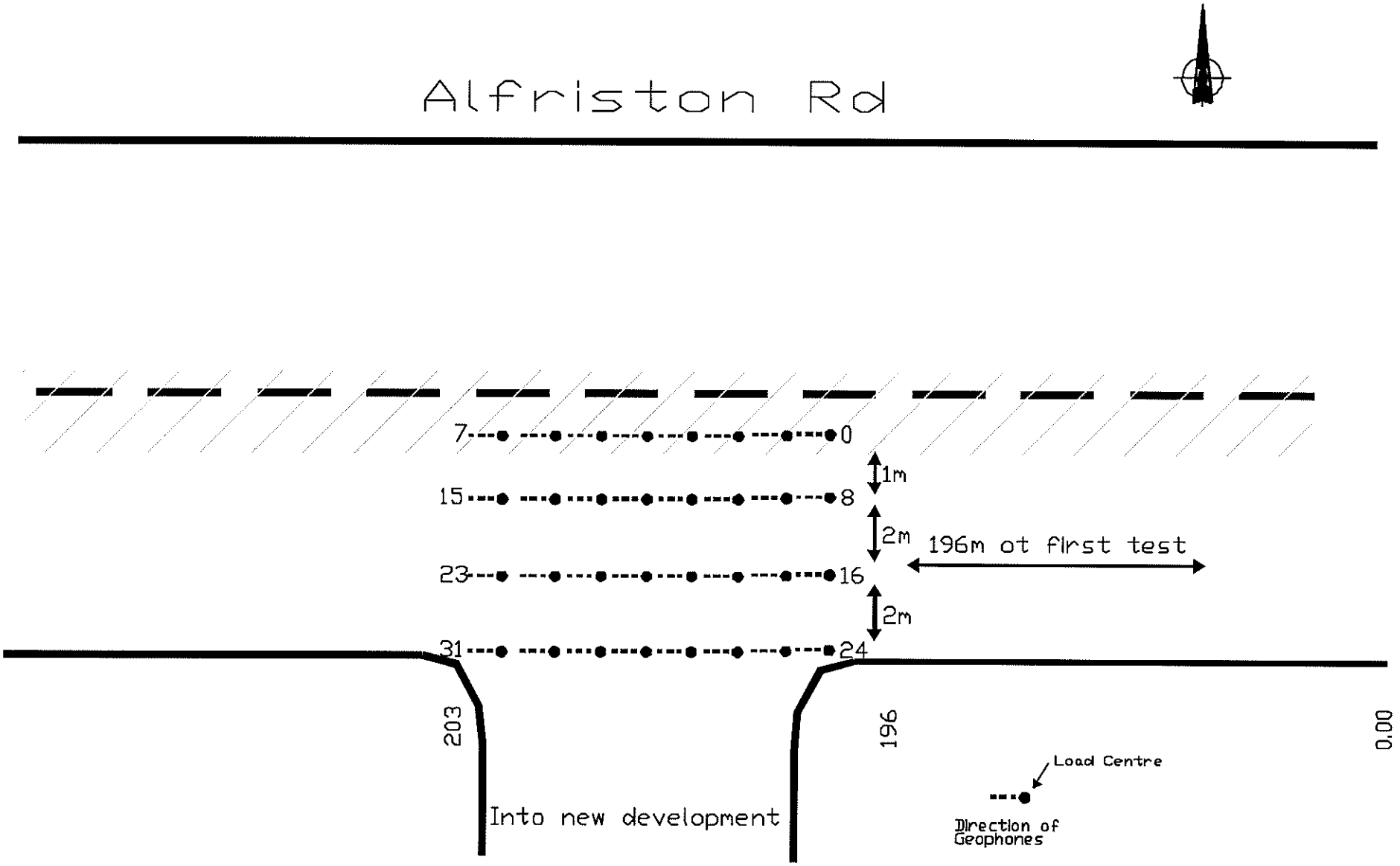
	(CBD/HO)						
1093	Queen St (CBD/HO)	1956	Shortland St	Wyndham St	190	311	121
1093	Queen St (CBD/HO)	1957	Wyndham St	Durham St West	311	405	94
1093	Queen St (CBD/HO)	1958	Durham St West	Victoria St East	405	498	93
1094	Queen St (CBD/HO)	1963	Mayoral Dr	Turner Street	1095	1248	153
1244	Shortland St	3684	Queen St	High St	0	75	75
1244	Shortland St	3685	High St	Fields Lane	75	189	114
1244	Shortland St	3686	Fields Lane	Bankside St	189	338	149
1182	St Lukes Rd	5241	Wagener Pl	Kingsway Ave	1913	2183	270
4447	Station Rd (Onehunga)	6729	Olive Rd	Fairfax Ave	677	934	257
1296	Symonds St (CBD/HO)	1574	Grafton Rd	20/22 Symonds St	260	433	173
1296	Symonds St (CBD/HO)	1573	20/22 Symonds St	Wellesley St East	433	561	128
1296	Symonds St (CBD/HO)	1969	Wakefield St	Airedale St	833	910	77
1296	Symonds St (CBD/HO)	1968	Airedale St	City Rd	910	1058	148
1296	Symonds St (CBD/HO)	1967	City Rd	Karangahape Rd	1058	1218	160
1296	Symonds St (CBD/HO)	1688	Karangahape Rd	M'Way Bridge (N End)	1218	1431	213
1337	The Drive	1453	Greenlane West (N Side)	Arcadia Rd	522	617	95
1337	The Drive	1454	Arcadia Rd	Rangiatea Rd	617	719	102
1337	The Drive	1455	Rangiatea Rd	Onslow Ave	719	880	161
1337	The Drive	1456	Onslow Ave	Atherton Rd	880	1004	124
1402	Victoria St East	2178	Queen St	High St	0	74	74
1402	Victoria St East	1679	High St	Kitchener St	74	138	64
1429	Wakefield St	3757	Queen St	Mayoral Dr	0	160	160
1429	Wakefield St	3758	Mayoral Dr	St Paul St	160	236	76
1429	Wakefield St	3759	St Paul St	Mount St	236	342	106
1429	Wakefield St	3760	Mount St	Wakefield St Ext	342	392	50
1429	Wakefield St	8384	Wakefield St Ext	Symonds/Airedale	392	508	116
1455	Wellesley St West	3773	Queen St	Elliot St	0	87	87
1455	Wellesley St West	3774	Elliot St	Albert St	87	177	90
1455	Wellesley St West	3775	Albert St	Federal St	177	266	89
1455	Wellesley St West	3776	Federal St	Hobson St	266	352	86
Papakura District Council							
47	Averill Street	688	Great South Road	Railway Street West	0	141	141
57	Boundary Road	675	N.I.M.T. Railway	Hunua Road	674	1473	799
57	Boundary Road	676	Opaheke Road	N.I.M.T. Railway	0	674	674
59	Broadway	673	Great South Road	Railway Street West	0	262	262
78	Clevedon Road	647	Broadway	Marne Road	0	311	311
90	Dominion Road	626	Sheehan Ave	Settlement Road	941	1448	507

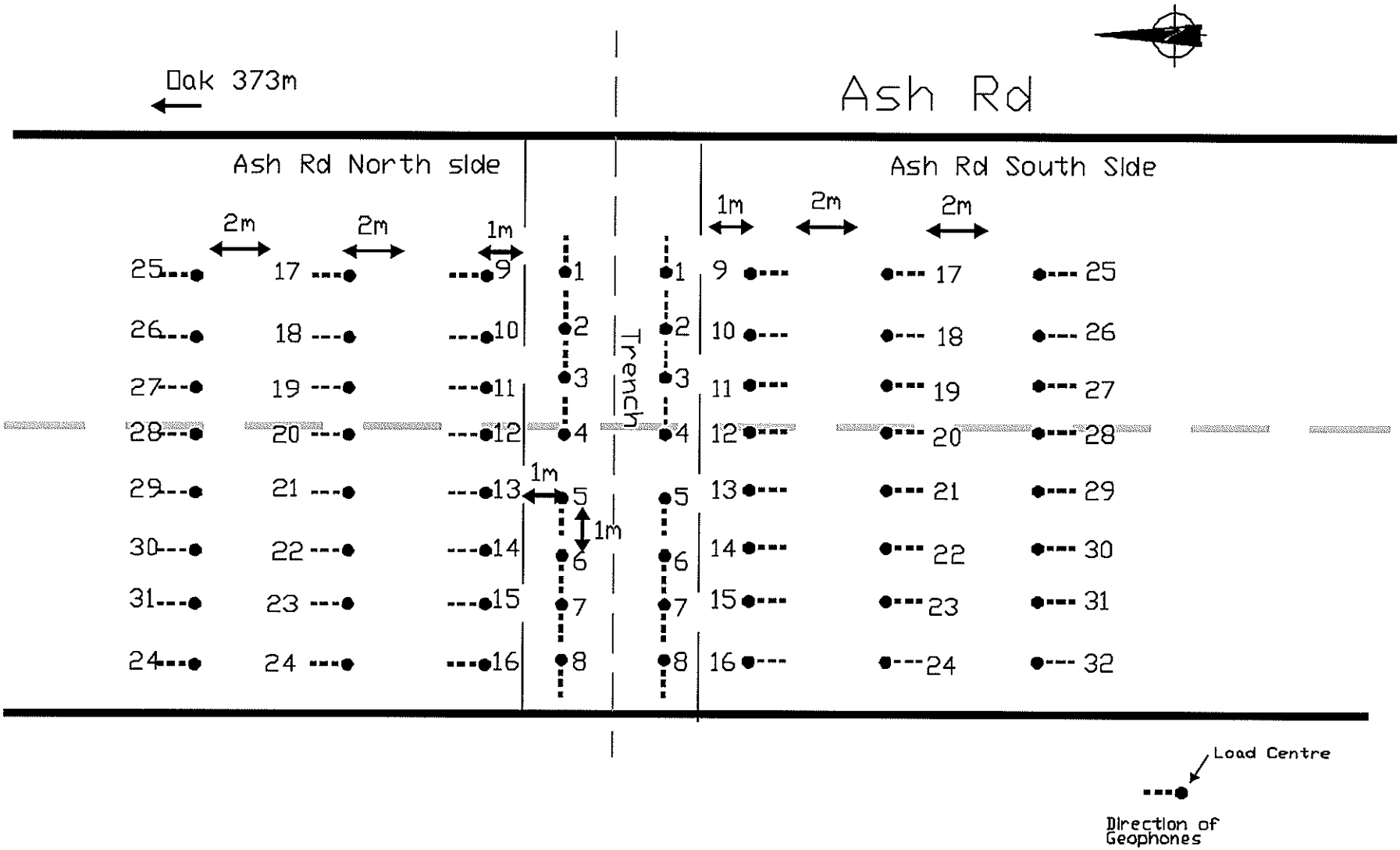
116	Great South Road	576	O'Shannessey Street	Elliott Street	4326	4591	265
129	Hunua Road	544	Settlement Road	Parker Street	0	639	639
177	Opaheke Road	470	Boundary Road	Lorelei Pl	1235	1562	327
177	Opaheke Road	471	Liverpool Street	Boundary Road	804	1235	431
183	O'Shannessey Street	461	Great South Road	Broadway	0	429	429
230	Subway Road	373	Great South Road	Porchester Road	0	130	130
Manukau City Council							
689	Alfriston Road	59	Shifnal Dr	Sarlee Dr	1142	1295	153
742	Ash Road	164	Wiri Station Road	Road Narrows	0	73	73
742	Ash Road	163	Road Narrows	Oak Road	73	282	209
742	Ash Road	162	Oak Road	Kerrs Road	282	744	462
1205	East Tamaki Road	5090	Hills Road	Preston Road	2375	2846	471
1411	Green Mount Road	1754	Nandina Ave	Ti Rakau Dr	949	1226	277
1447	Harris Road	1825	Allens Road	Crookes Road	0	391	391
1447	Harris Road	1824	Crookes Road	Neales Road	391	818	427
1447	Harris Road	1822	Green Mount Road	Cryers Road North	971	1486	515
2060	Pakuranga Road	3040	The Link	Road Narrows	5922	5993	71
2060	Pakuranga Road	3039	Road Narrows	Botany Road	5993	6082	89
2492	Ti Rakau Dr	5230	Harris Road	Green Mount Road	3222	3606	384
2492	Ti Rakau Dr	5231	Green Mount Road	Huntington Dr	3606	3921	315
2693	Wiri Station Road	4772	Druces Road	Ash Road	17800	21400	3600

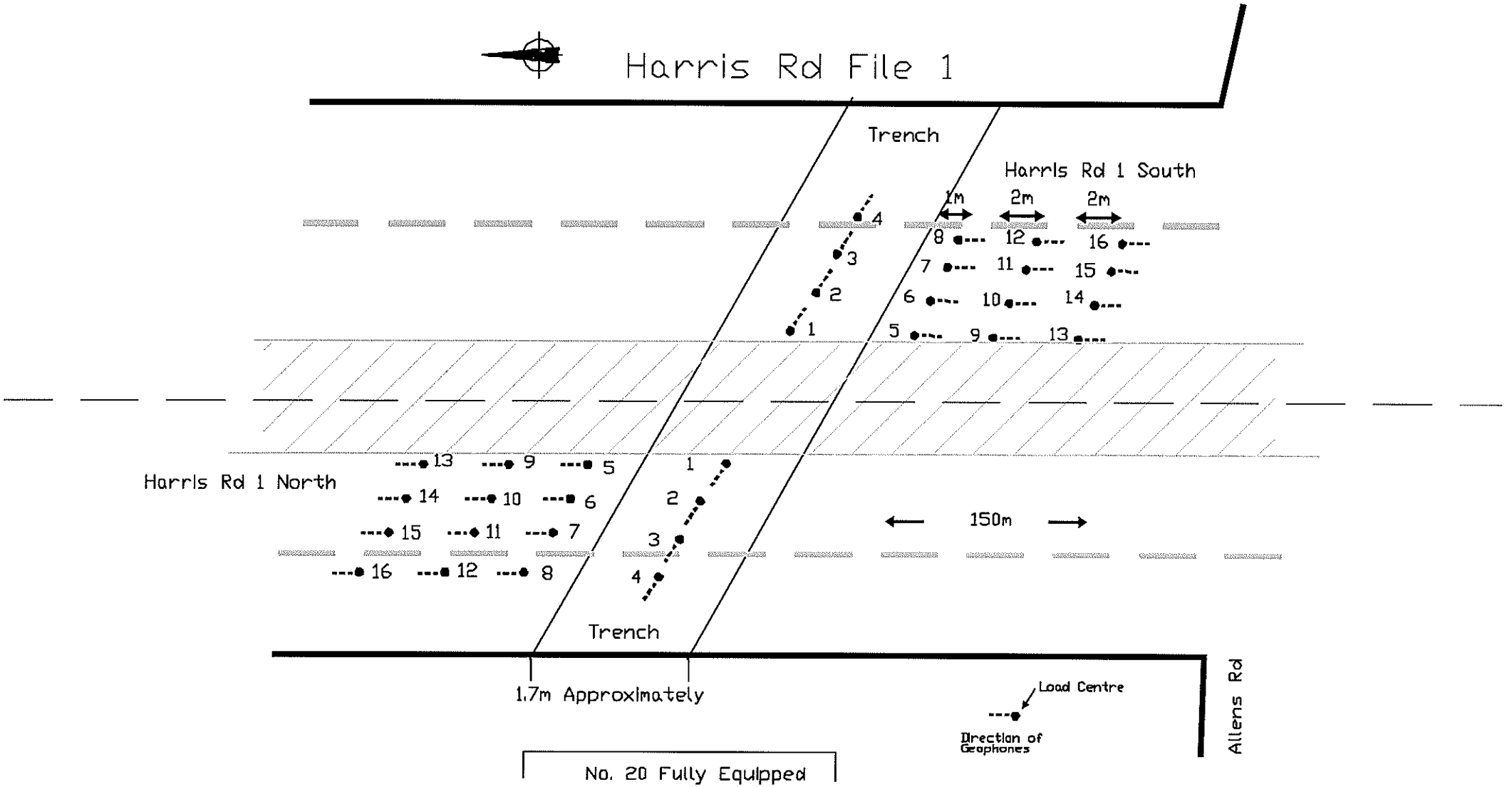
Appendix C: Sensitivity of Weightage Factors for RSI

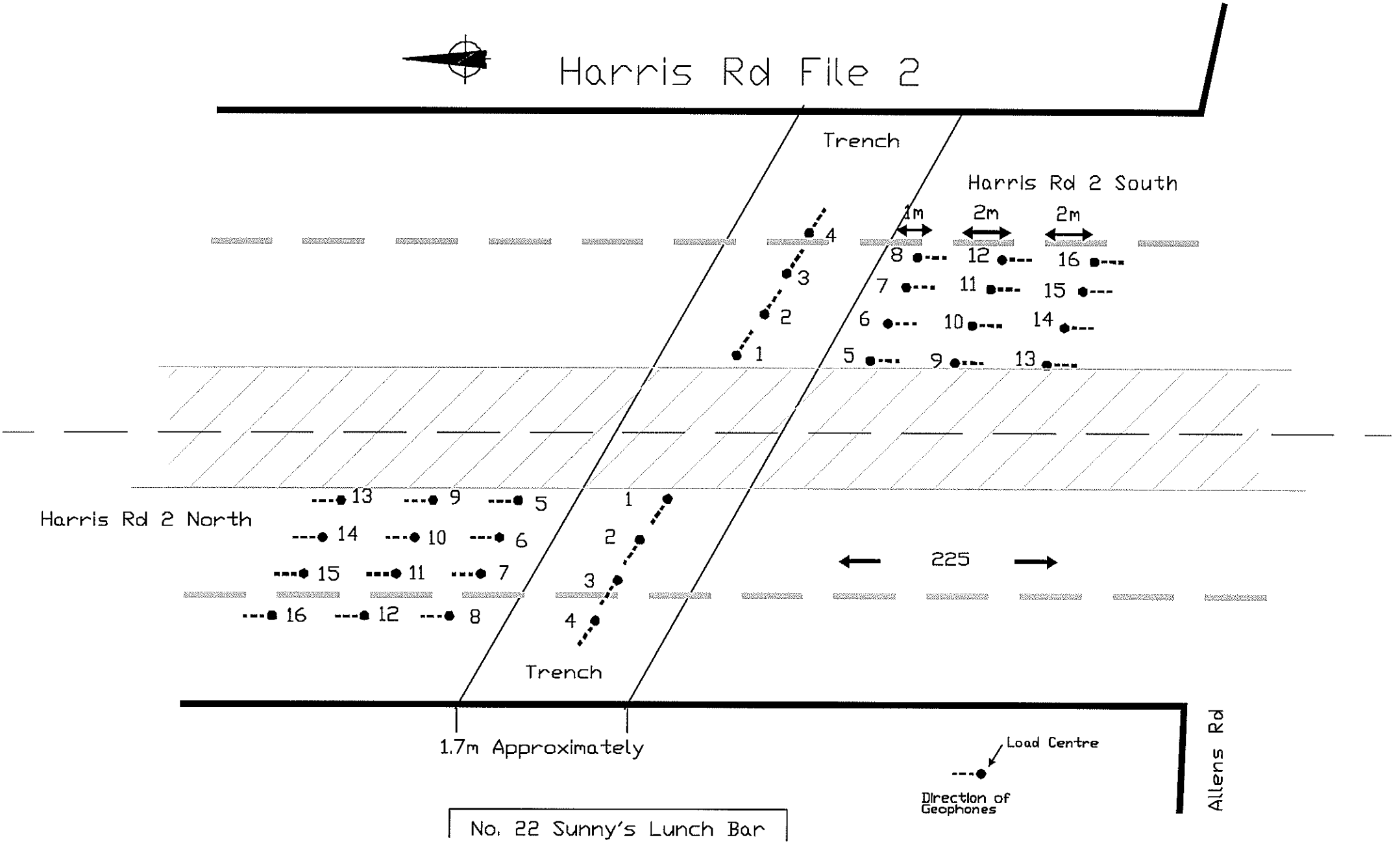
0.1	0.16	0.05	0.1	0.08	factor
cracking	joints	rut	deformation	roughness	RSI
5	25	5	5	25	7.3
1	0	0	0	0	0.1
5	0	0	0	0	0.5
10	0	0	0	0	1.0
25	0	0	0	0	2.5
50	0	0	0	0	5.0
100	0	0	0	0	10.0
2	**1**	0	0	0	0.4
2	**5**	0	0	0	1.0
2	**10**	0	0	0	1.8
2	**25**	0	0	0	4.2
2	**50**	0	0	0	8.2
2	**100**	0	0	0	16.2
2	3	**1**	0	0	0.7
2	3	**5**	0	0	0.9
2	3	**10**	0	0	1.2
2	3	**25**	0	0	1.9
2	3	**50**	0	0	3.2
2	3	**100**	0	0	5.7
2	3	5	**1**	0	1.0
2	3	5	**5**	0	1.4
2	3	5	**10**	0	1.9
2	3	5	**25**	0	3.4
2	3	5	**50**	0	5.9
2	3	5	**100**	0	10.9
2	3	5	5	**1**	1.5
2	3	5	5	**5**	1.8
2	3	5	5	**10**	2.2
2	3	5	5	**25**	3.4
2	3	5	5	**50**	5.4
2	3	5	5	**100**	9.4

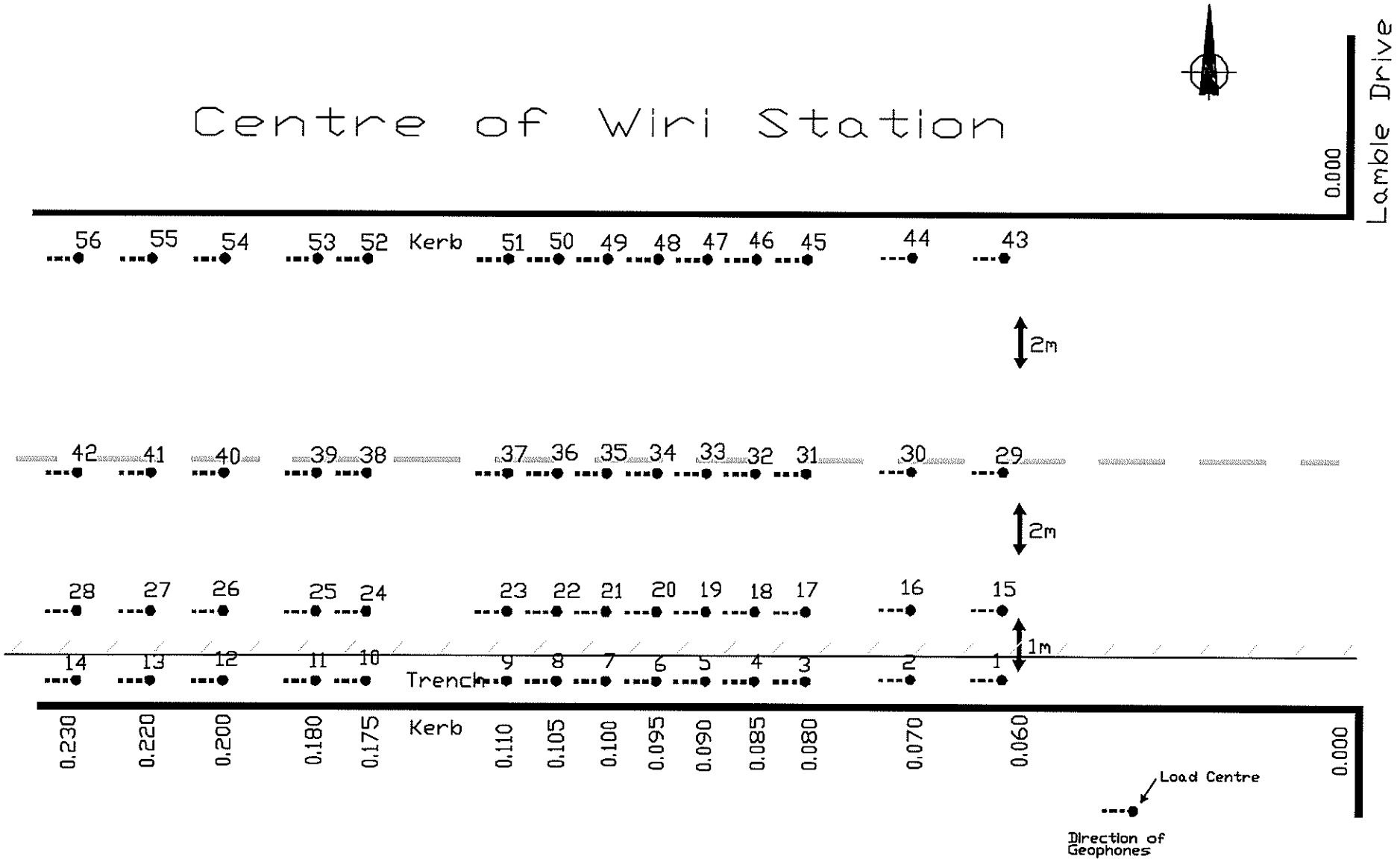
Appendix D: FWD Survey Layout


Alfriston Rd
7
0
1m
15
8
2m
196m ot first test
23
16
2m
31
24
203
196
0.00
Load Centre
Into new development
Direction of Geophones


Oak 373m
Ash Rd
Ash Rd North side
Ash Rd South Side
2m
2m
1m
1m
2m
2m
Trench
1m
1m
25 17 9 1 1 9 17 25
26 18 10 2 2 10 18 26
27 19 11 3 3 11 19 27
28 20 12 4 4 12 20 28
29 21 13 5 5 13 21 29
30 22 14 6 6 14 22 30
31 23 15 7 7 15 23 31
24 24 16 8 8 16 24 32
Load Centre
Direction of Geophones


Harris Rd File 1
Trench
Harris Rd 1 South
1m
2m
2m
4
3
2
1
8
12
16
7
11
15
6
10
14
5
9
13
Harris Rd 1 North
13
9
5
1
14
10
6
2
15
11
7
3
16
12
8
4
150m
Trench
1.7m Approximately
Load Centre
Direction of Geophones
Allens Rd
No. 20 Fully Equipped


Harris Rd File 2
Trench
Harris Rd 2 South
1m
2m
2m
4
3
2
1
8
12
16
7
11
15
6
10
14
5
9
13
Harris Rd 2 North
13
9
5
14
10
6
15
11
7
16
12
8
1
2
3
4
225
Trench
1.7m Approximately
Allens Rd
Load Centre
Direction of Geophones
No. 22 Sunny's Lunch Bar


Centre of Wiri Station
Lamble Drive
0.000
56 55 54 53 52 Kerb 51 50 49 48 47 46 45 44 43
2m
42 41 40 39 38 37 36 35 34 33 32 31 30 29
2m
28 27 26 25 24 23 22 21 20 19 18 17 16 15
1m
14 13 12 11 10 9 8 7 6 5 4 3 2 1
Trench
0.230 0.220 0.200 0.180 0.175 Kerb 0.110 0.105 0.100 0.095 0.090 0.085 0.080 0.070 0.060
0.000
Load Centre
Direction of Geophones

Appendix E: FWD Survey Results

FWD Pavement Structural Evaluation
PROJECT: Alfriston Rd Trenching Survey

Job Number: 890463
Test Date: 15/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
0	31	125	100	100		M/4	0.25758	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
0	7.5	2500	1789	16	14	4.34	0	99	99	4
7.5	15.5	1222	1038	18	16	4.12	0	99	73.7	4
15.5	23.5	1003	848	24	22	4.24	0	99	99	4
23.500	31.000	881	827	22	12	4.0	-0.1	47	4	4

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
0	7.5	7.5	0	300
7.5	15.5	8	0	280
15.5	23.5	8	0	230
23.500	31.000	7.500	50	370

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Alfriston Rd Trenching Survey

Job Number: 890463
Test Date: 15/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

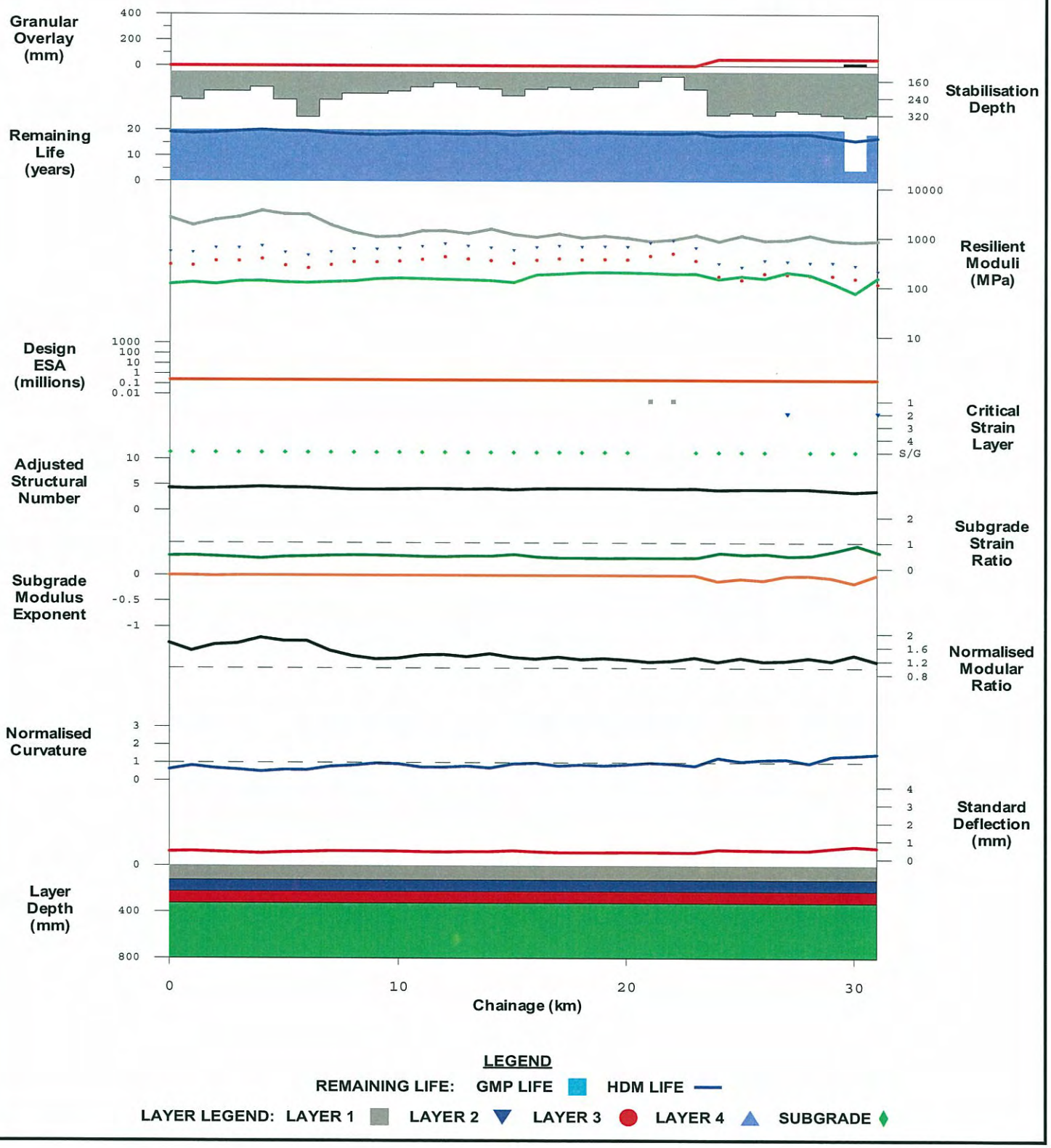
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
0.000	2500	513	283		115	14	99.0	125	100	100		4	0.43	0.2576	4.3	300	0
1.000	1789	495	274		124	16	99.0	125	100	100		4	0.45	0.2576	4.2	280	0
2.000	2296	613	339		116	15	99.0	125	100	100		4	0.41	0.2576	4.3	300	0
3.000	2631	612	338		131	16	99.0	125	100	100		4	0.38	0.2576	4.4	270	0
4.000	3498	673	372		133	17	99.0	125	100	100		4	0.34	0.2576	4.6	270	0
5.000	2986	495	273		124	16	99.0	125	100	100		4	0.39	0.2576	4.5	280	0
6.000	2963	437	242		122	15	99.0	125	100	100		4	0.41	0.2576	4.5	290	0
7.000	1800	509	281		128	16	99.0	125	100	100		4	0.44	0.2576	4.2	280	0
8.000	1269	585	323		131	16	98.7	125	100	100		4	0.46	0.2576	4.1	270	0
9.000	1038	579	320		146	18	99.0	125	100	100		4	0.46	0.2576	4.1	260	0
10.000	1083	602	333		151	19	99.0	125	100	100		4	0.44	0.2576	4.1	250	0
11.000	1372	656	362		148	18	99.0	125	100	100		4	0.41	0.2576	4.2	250	0
12.000	1388	743	410		143	18	99.0	125	100	100		4	0.40	0.2576	4.2	260	0
13.000	1222	669	370		140	18	99.0	125	100	100		4	0.43	0.2576	4.1	260	0
14.000	1497	622	344		136	17	99.0	125	100	100		4	0.42	0.2576	4.2	270	0
15.000	1159	555	307		125	16	73.7	125	100	100		4	0.48	0.2576	4.0	280	0
16.000	1031	637	352		177	22	99.0	125	100	100		4	0.40	0.2576	4.2	230	0
17.000	1204	681	376		187	23	99.0	125	100	100		4	0.37	0.2576	4.3	220	0
18.000	1003	651	360		198	25	99.0	125	100	100		4	0.38	0.2576	4.2	210	0
19.000	1089	660	365		201	25	99.0	125	100	100		4	0.37	0.2576	4.3	210	0
20.000	990	654	361		199	25	99.0	125	100	100		4	0.38	0.2576	4.2	210	0
21.000	848	777	430		195	24	99.0	125	100	100		1	0.38	0.2576	4.2	210	0
22.000	916	873	482		186	23	99.0	125	100	100		1	0.37	0.2576	4.2	220	0
23.000	1129	623	344		189	24	99.0	125	100	100		4	0.38	0.2576	4.3	220	0
24.000	846	298	165		146	22	47.0	125	100	100		4	0.52	0.2576	4.0	260	0
25.000	1107	255	141		168	24	68.3	125	100	100		4	0.50	0.2576	4.1	240	0
26.000	883	345	190		151	23	63.2	125	100	100		4	0.49	0.2576	4.1	250	0
27.000	911	329	182		200	26	89.7	125	100	100		2	0.47	0.2576	4.1	210	0
28.000	1112	310	172		178	23	99.0	125	100	100		4	0.48	0.2576	4.1	230	0
29.000	881	310	171		120	17	25.0	125	100	100		4	0.59	0.2576	3.8	290	0
30.000	827	272	150		77	12	4.4	125	100	100		4	0.70	0.2576	3.6	370	20
31.000	862	210	116		155	19	18.4	125	100	100		2	0.62	0.2576	3.8	250	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Alfriston Rd Trenching Survey



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Ash Rd Trenching Survey North Side

Job Number: 890463
Test Date: 14/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	32	100	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	8.5	593	493	6	4	2.72	-0.381	0.1	0	4
8.5	16.5	810	316	6	4	2.74	-0.342	0.1	0	4
16.5	24.5	1256	925	7	6	3.2	-0.333	2.4	0.2	4
24.500	32.000	2968	1517	18	16	4.3	-0.1	99	19	4

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	8.5	7.5	160	640
8.5	16.5	8	210	600
16.5	24.5	8	70	570
24.500	32.000	7.500	0	370

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Ash Rd Trenching Survey North Side

Job Number: 890463
Test Date: 14/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

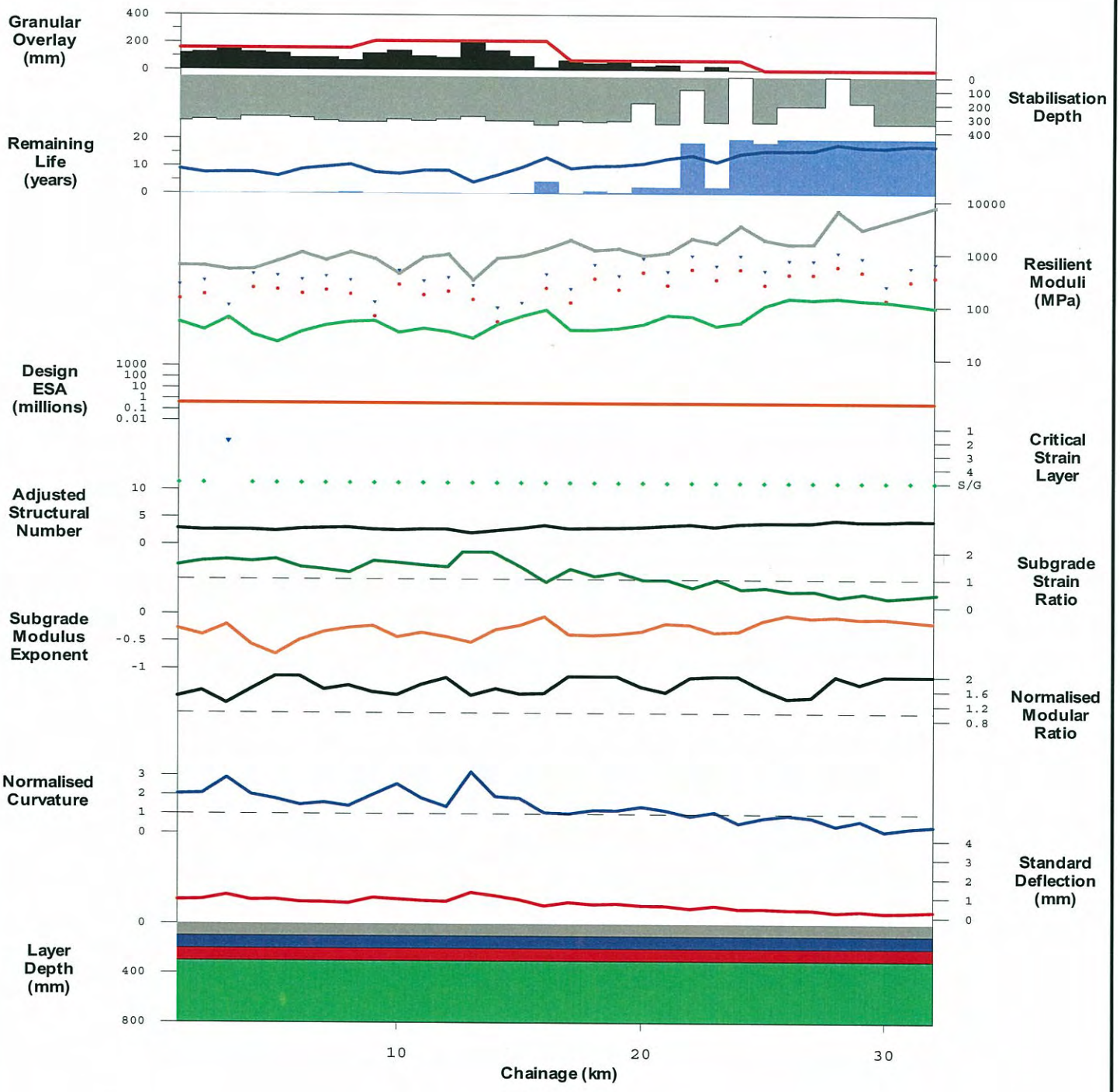
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	593	252	139		50	8	0.1	100	100	100		4	0.89	0.4293	2.9	470	120
2.000	584	303	168		36	6	0.0	100	100	100		4	0.92	0.4293	2.7	530	130
3.000	493	103	57		61	10	0.0	100	100	100		2	1.15	0.4293	2.7	420	160
4.000	506	406	224		29	6	0.1	100	100	100		4	0.90	0.4293	2.7	570	130
5.000	718	378	209		21	4	0.0	100	100	100		4	0.92	0.4293	2.5	640	120
6.000	1051	318	176		33	6	0.1	100	100	100		4	0.79	0.4293	2.9	560	90
7.000	755	369	204		44	8	0.2	100	100	100		4	0.77	0.4293	3.0	500	90
8.000	1073	309	171		51	8	0.4	100	100	100		4	0.72	0.4293	3.2	480	70
9.000	797	118	65		53	8	0.0	100	100	100		4	1.01	0.4293	2.7	450	120
10.000	418	467	258		32	5	0.1	100	100	100		4	0.94	0.4293	2.6	570	140
11.000	840	299	165		38	6	0.1	100	100	100		4	0.85	0.4293	2.8	540	100
12.000	970	349	193		33	6	0.1	100	100	100		4	0.82	0.4293	2.8	570	90
13.000	316	245	135		25	4	0.0	100	100	100		4	1.28	0.4293	2.1	600	210
14.000	810	93	51		45	7	0.0	100	100	100		4	1.12	0.4293	2.6	480	140
15.000	901	116	64		65	11	0.2	100	100	100		4	0.90	0.4293	3.0	410	100
16.000	1239	405	224		86	11	4.4	100	100	100		4	0.59	0.4293	3.6	370	20
17.000	1814	215	119		36	6	0.2	100	100	100		4	0.77	0.4293	2.9	550	70
18.000	1169	613	338		36	6	1.0	100	100	100		4	0.67	0.4293	3.0	570	50
19.000	1256	379	210		39	7	0.4	100	100	100		4	0.72	0.4293	3.1	540	60
20.000	925	809	447		46	8	2.5	100	100	100		4	0.60	0.4293	3.2	520	30
21.000	1041	463	256		69	11	2.4	100	100	100		4	0.60	0.4293	3.5	420	40
22.000	1951	922	510		65	11	18.7	100	100	100		4	0.45	0.4293	3.7	450	0
23.000	1589	592	327		43	7	2.4	100	100	100		4	0.59	0.4293	3.3	530	30
24.000	3444	921	509		50	9	28.7	100	100	100		4	0.42	0.4293	3.8	520	0
25.000	1849	473	261		104	16	18.7	100	100	100		4	0.44	0.4293	4.0	340	0
26.000	1517	741	409		143	19	64.4	100	100	100		4	0.38	0.4293	4.0	270	0
27.000	1536	734	406		135	19	57.3	100	100	100		4	0.38	0.4293	4.0	290	0
28.000	6636	1048	579		145	20	99.0	100	100	100		4	0.24	0.4293	4.5	280	0
29.000	2968	826	456		131	19	99.0	100	100	100		4	0.31	0.4293	4.3	300	0
30.000	30014	243	134		124	18	99.0	100	100	100		4	0.22	0.4293	4.3	320	0
31.000	13455	546	302		111	17	99.0	100	100	100		4	0.25	0.4293	4.4	340	0
32.000	7781	653	361		96	16	99.0	100	100	100		4	0.29	0.4293	4.4	370	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Ash Rd Trenching Survey North Side



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Ash Rd Trenching Survey South Side

Job Number: 890463
Test Date: 14/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	32	100	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	8.5	675	629	6	5	2.88	-0.468	0.2	0.1	4
8.5	16.5	959	354	9	6	3.35	-0.402	2.3	0.1	4
16.5	24.5	3685	1694	12	11	4.01	-0.247	40.8	8.2	4
24.500	32.000	4069	2194	14	13	4.2	-0.2	53	24	4

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	8.5	7.5	120	600
8.5	16.5	8	140	610
16.5	24.5	8	0	470
24.500	32.000	7.500	0	400

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Ash Rd Trenching Survey South Side

Job Number: 890463
Test Date: 14/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

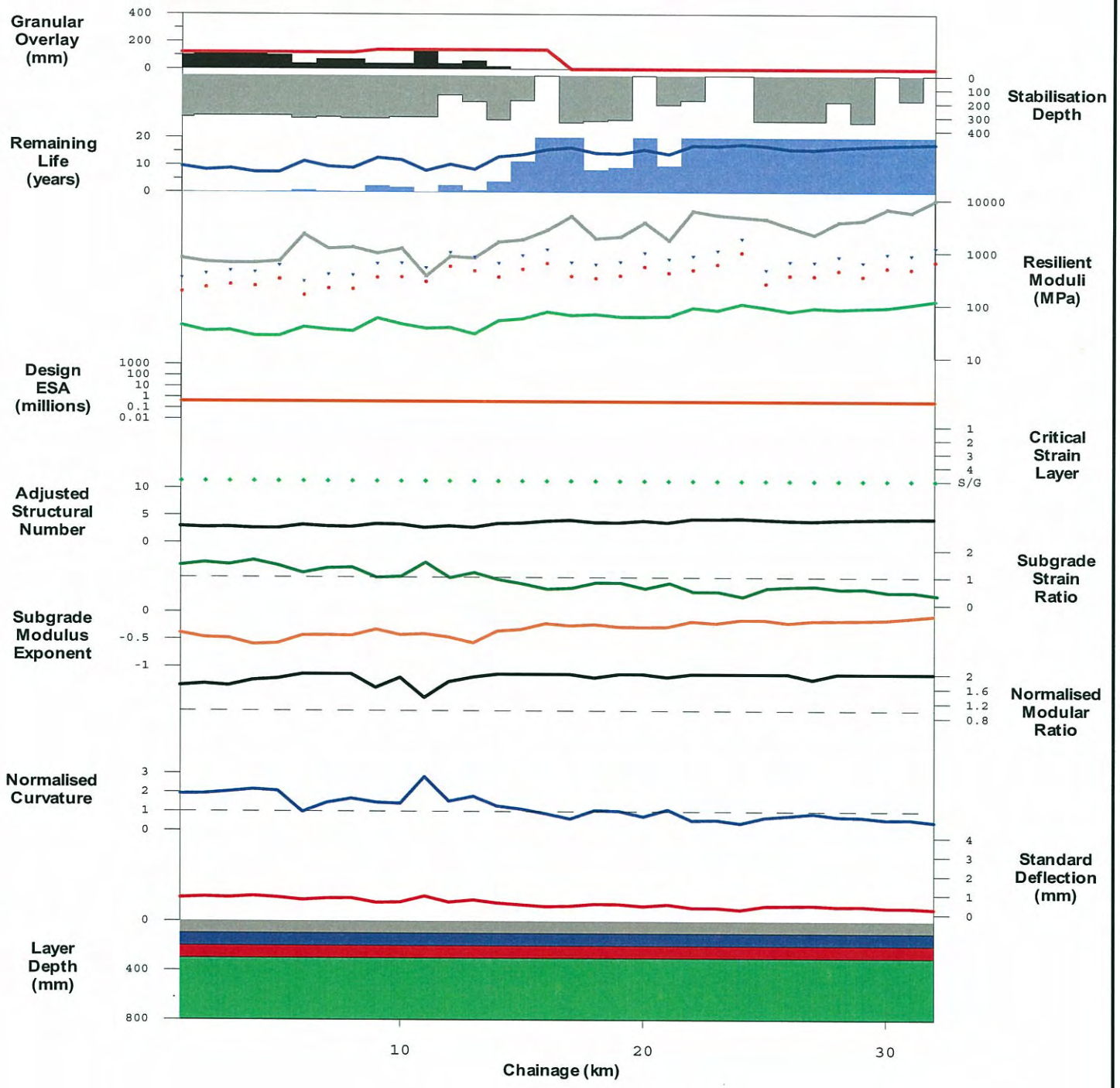
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	772	324	179		41	7	0.2	100	100	100		4	0.87	0.4293	3.0	500	100
2.000	659	389	215		32	6	0.1	100	100	100		4	0.92	0.4293	2.8	550	110
3.000	629	441	244		33	6	0.1	100	100	100		4	0.88	0.4293	2.9	540	110
4.000	632	416	230		26	5	0.1	100	100	100		4	0.96	0.4293	2.7	590	120
5.000	675	559	309		26	5	0.2	100	100	100		4	0.88	0.4293	2.7	600	100
6.000	2205	277	153		38	7	0.7	100	100	100		4	0.76	0.4293	3.3	530	40
7.000	1184	373	206		34	6	0.3	100	100	100		4	0.82	0.4293	3.0	550	70
8.000	1248	363	201		32	6	0.2	100	100	100		4	0.85	0.4293	2.9	560	70
9.000	959	601	332		56	11	2.3	100	100	100		4	0.61	0.4293	3.5	450	40
10.000	1180	614	339		43	9	1.8	100	100	100		4	0.64	0.4293	3.4	500	40
11.000	354	501	277		36	6	0.1	100	100	100		4	0.94	0.4293	2.8	530	140
12.000	838	975	539		37	7	2.5	100	100	100		4	0.64	0.4293	3.1	550	40
13.000	779	804	444		28	6	0.7	100	100	100		4	0.76	0.4293	2.8	610	60
14.000	1570	615	340		50	10	3.9	100	100	100		4	0.58	0.4293	3.5	480	20
15.000	1732	863	477		55	10	11.3	100	100	100		4	0.51	0.4293	3.6	470	0
16.000	2648	1118	618		74	13	53.7	100	100	100		4	0.41	0.4293	4.0	420	0
17.000	4874	637	352		64	12	40.8	100	100	100		4	0.44	0.4293	4.2	450	0
18.000	1827	582	321		67	12	8.2	100	100	100		4	0.54	0.4293	3.8	420	0
19.000	1971	652	360		60	11	9.1	100	100	100		4	0.52	0.4293	3.7	450	0
20.000	3685	967	534		60	11	47.5	100	100	100		4	0.43	0.4293	4.0	470	0
21.000	1694	739	408		61	11	9.7	100	100	100		4	0.52	0.4293	3.7	450	0
22.000	6155	843	466		89	15	99.0	100	100	100		4	0.34	0.4293	4.4	380	0
23.000	5124	1073	593		80	14	99.0	100	100	100		4	0.35	0.4293	4.3	400	0
24.000	10688	1797	993		105	17	99.0	100	100	100		4	0.24	0.4293	4.4	360	0
25.000	4292	462	256		90	15	39.8	100	100	100		4	0.44	0.4293	4.3	370	0
26.000	3036	658	364		76	13	28.5	100	100	100		4	0.45	0.4293	4.0	400	0
27.000	2194	642	355		88	15	24.0	100	100	100		4	0.46	0.4293	4.0	370	0
28.000	3772	815	450		84	14	62.7	100	100	100		4	0.40	0.4293	4.2	380	0
29.000	4069	633	350		87	14	52.5	100	100	100		4	0.41	0.4293	4.2	380	0
30.000	6691	915	505		90	14	99.0	100	100	100		4	0.34	0.4293	4.3	380	0
31.000	5781	870	481		103	16	99.0	100	100	100		4	0.34	0.4293	4.4	340	0
32.000	9743	1203	665		121	17	99.0	100	100	100		4	0.27	0.4293	4.4	310	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Ash Rd Trenching Survey South Side



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 1 Trenching Survey North Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	16	100	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	4.5	1617	575	11	7	3.65	-0.598	4.6	2.4	4
4.5	8.5	639	633	20	15	3.76	-0.433	18.7	4.2	4
8.5	12.5	942	699	35	30	4.22	-0.224	99	33.5	1
12.500	16.000	979	970	39	36	4.3	-0.2	99	99	1

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	4.5	3.5	50	640
4.5	8.5	4	50	410
8.5	12.5	4	0	220
12.500	16.000	3.500	0	260

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 1 Trenching Survey North Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

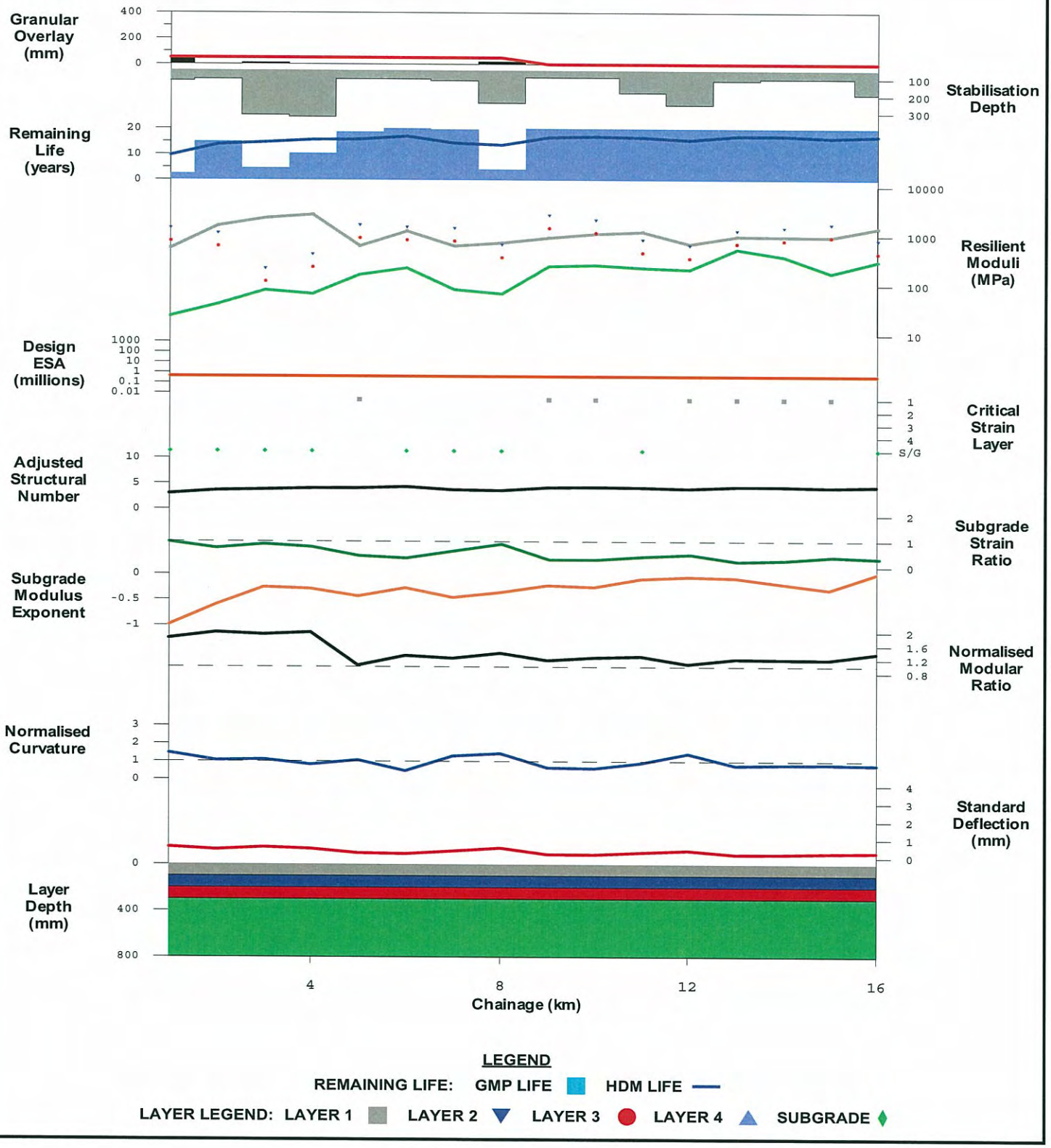
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	575	1450	801		24	7	2.4	100	100	100		4	0.60	0.4293	3.0	640	40
2.000	1617	1143	631		42	11	14.9	100	100	100		4	0.47	0.4293	3.6	540	0
3.000	2314	221	122		81	15	4.6	100	100	100		4	0.59	0.4293	3.8	380	10
4.000	2724	429	237		68	13	10.3	100	100	100		4	0.51	0.4293	4.0	420	0
5.000	633	1672	924		167	39	18.7	100	100	100		1	0.27	0.4293	4.1	260	0
6.000	1279	1520	840		228	44	99.0	100	100	100		4	0.23	0.4293	4.3	220	0
7.000	639	1451	801		84	20	19.7	100	100	100		4	0.39	0.4293	3.8	380	0
8.000	738	674	372		69	15	4.2	100	100	100		4	0.55	0.4293	3.6	410	20
9.000	942	2657	1468		249	45	99.0	100	100	100		1	0.20	0.4293	4.2	220	0
10.000	1131	2132	1178		264	50	99.0	100	100	100		1	0.20	0.4293	4.3	210	0
11.000	1229	843	466		231	35	99.0	100	100	100		4	0.31	0.4293	4.2	210	0
12.000	699	654	361		213	30	33.5	100	100	100		1	0.41	0.4293	4.0	220	0
13.000	1004	1286	710		548	79	99.0	100	100	100		1	0.20	0.4293	4.4	170	0
14.000	979	1468	811		390	68	99.0	100	100	100		1	0.20	0.4293	4.3	170	0
15.000	970	1716	948		179	36	99.0	100	100	100		1	0.25	0.4293	4.2	260	0
16.000	1455	811	448		313	39	99.0	100	100	100		4	0.29	0.4293	4.3	170	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Harris Rd Section 1 Trenching Survey North Side



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 1 Trenching Survey South Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	16	125	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	4.5	2466	950	18	15	4.36	-0.293	99	57.5	4
4.5	8.5	3193	1876	32	24	5	-0.023	99	99	4
8.5	12.5	2863	1665	31	24	4.94	-0.032	99	99	4
12.500	16.000	3063	1742	32	27	4.9	0.0	99	99	4

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	4.5	3.5	0	500
4.5	8.5	4	0	260
8.5	12.5	4	0	270
12.500	16.000	3.500	0	230

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 1 Trenching Survey South Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

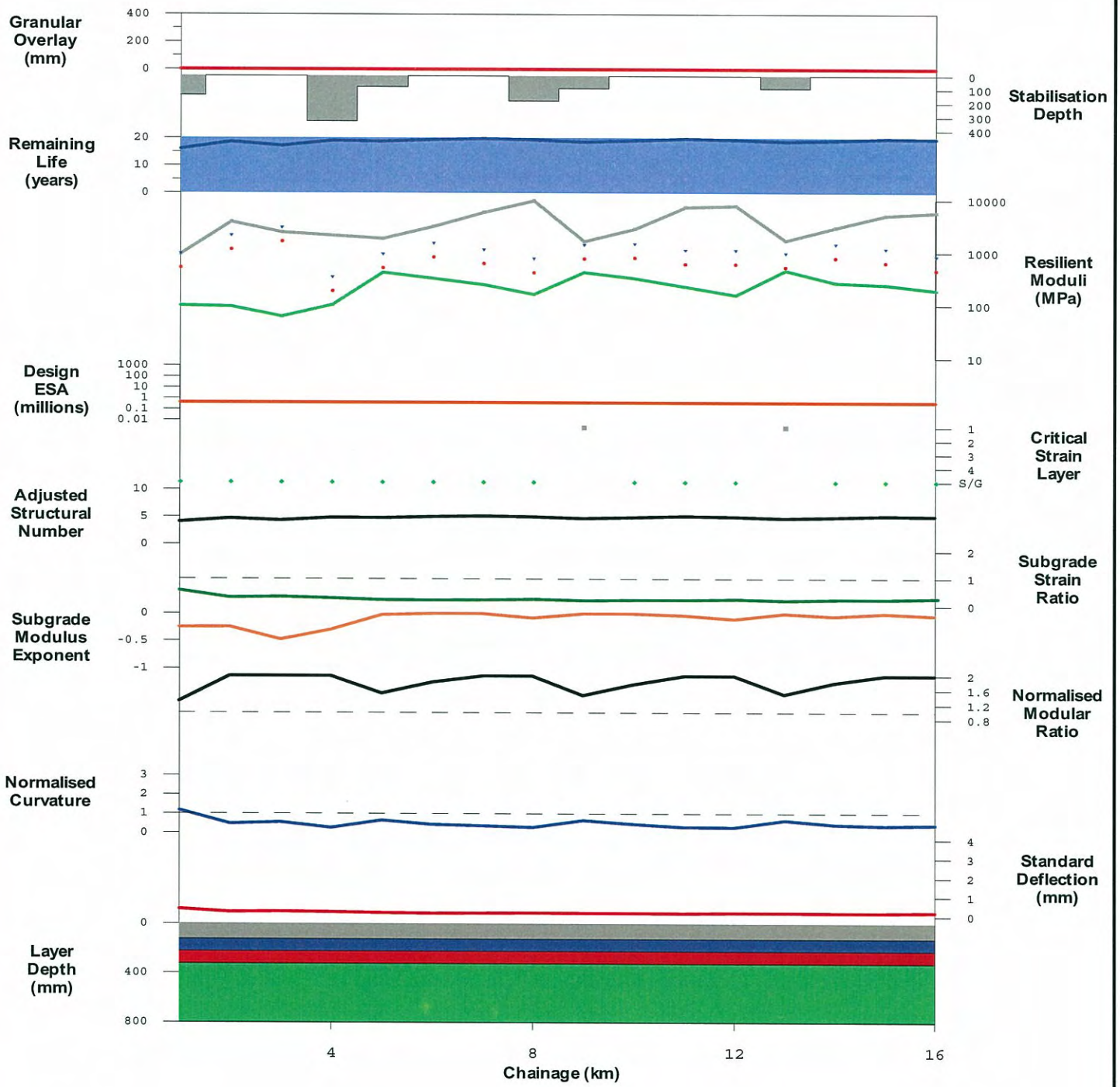
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	950	950	525		101	19	57.5	125	100	100		4	0.40	0.4293	4.1	350	0
2.000	3871	2110	1166		96	18	99.0	125	100	100		4	0.25	0.4293	4.7	390	0
3.000	2466	2991	1652		62	15	99.0	125	100	100		4	0.27	0.4293	4.4	500	0
4.000	15025	343	190		103	20	99.0	125	100	100		4	0.24	0.4293	4.8	380	0
5.000	1876	940	519		425	56	99.0	125	100	100		4	0.20	0.4293	4.8	170	0
6.000	3193	1506	832		329	41	99.0	125	100	100		4	0.18	0.4293	5.0	170	0
7.000	5891	1140	630		253	32	99.0	125	100	100		4	0.19	0.4293	5.2	190	0
8.000	9779	768	424		165	24	99.0	125	100	100		4	0.21	0.4293	5.0	260	0
9.000	1665	1416	782		430	54	99.0	125	100	100		1	0.19	0.4293	4.7	170	0
10.000	2863	1465	809		332	42	99.0	125	100	100		4	0.18	0.4293	4.9	170	0
11.000	7375	1121	619		230	31	99.0	125	100	100		4	0.18	0.4293	5.1	210	0
12.000	7831	1112	614		159	24	99.0	125	100	100		4	0.21	0.4293	5.0	270	0
13.000	1742	978	540		472	59	99.0	125	100	100		1	0.20	0.4293	4.8	170	0
14.000	3063	1443	798		275	38	99.0	125	100	100		4	0.19	0.4293	4.9	190	0
15.000	5142	1179	652		252	32	99.0	125	100	100		4	0.20	0.4293	5.2	190	0
16.000	5795	847	468		196	27	99.0	125	100	100		4	0.22	0.4293	5.1	230	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Harris Rd Section 1 Trenching Survey South Side



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 2 Trenching Survey North Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	16	125	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	4.5	589	555	10	10	3.66	-0.4	4.4	1.7	4
4.5	8.5	841	697	31	27	4.22	-0.124	99	36.7	1
8.5	12.5	1526	1515	39	34	4.69	0	99	99	1
12.500	16.000	1210	1061	41	36	4.6	0.0	99	99	1

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	4.5	3.5	50	530
4.5	8.5	4	0	290
8.5	12.5	4	0	190
12.500	16.000	3.500	0	220

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 2 Trenching Survey North Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

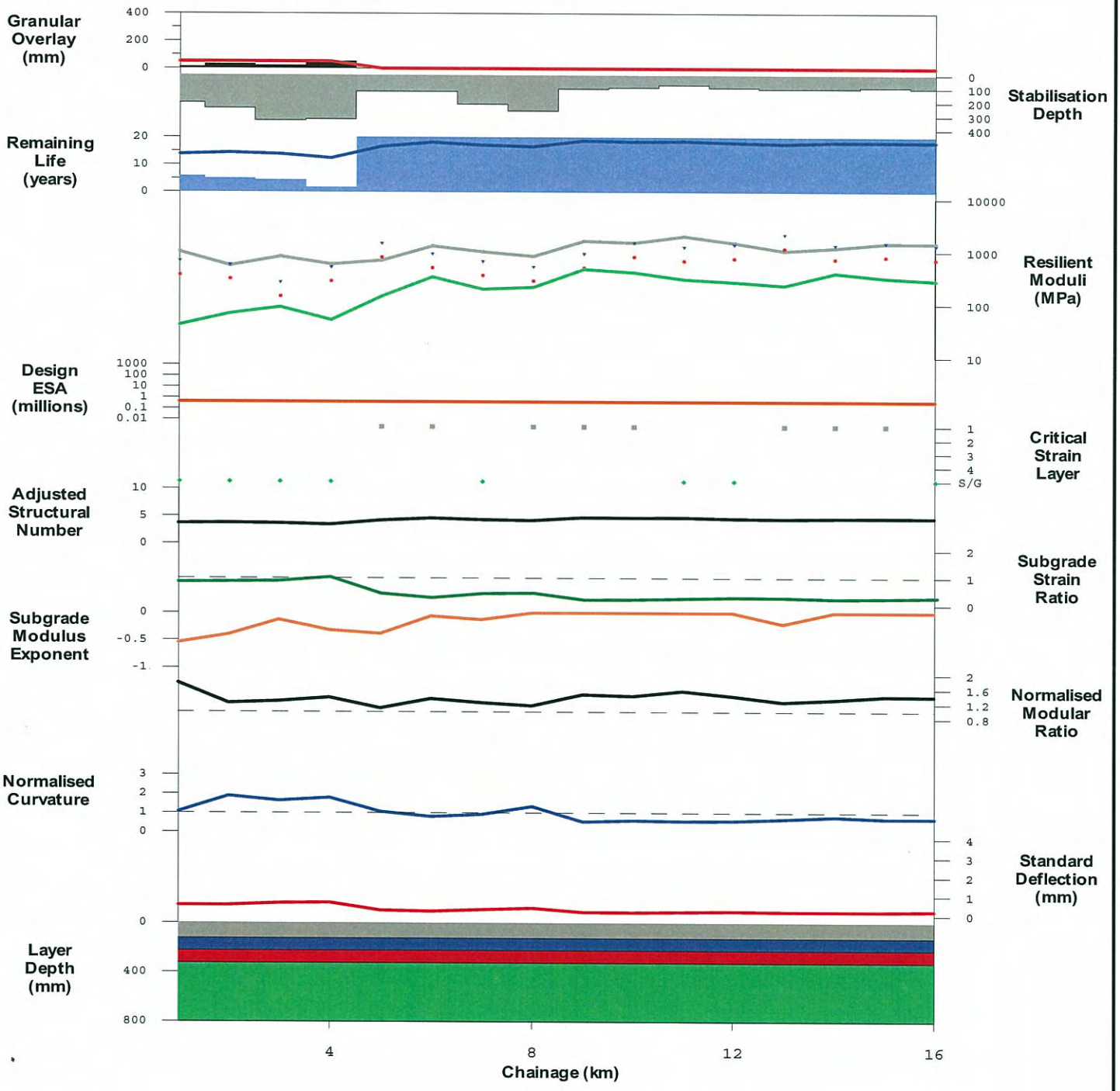
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	1015	668	369		42	10	5.8	125	100	100		4	0.57	0.4293	3.7	530	10
2.000	555	567	313		69	16	5.0	125	100	100		4	0.58	0.4293	3.8	410	30
3.000	827	264	146		91	14	4.4	125	100	100		4	0.67	0.4293	3.7	360	20
4.000	589	510	282		52	10	1.7	125	100	100		4	0.70	0.4293	3.4	470	50
5.000	697	1450	801		146	32	36.7	125	100	100		1	0.30	0.4293	4.2	290	0
6.000	1316	916	506		341	48	99.0	125	100	100		1	0.24	0.4293	4.6	170	0
7.000	1021	659	364		200	31	99.0	125	100	100		4	0.34	0.4293	4.4	230	0
8.000	841	520	287		219	27	99.0	125	100	100		1	0.41	0.4293	4.2	210	0
9.000	1640	926	512		483	60	99.0	125	100	100		1	0.20	0.4293	4.8	170	0
10.000	1526	1491	824		418	52	99.0	125	100	100		1	0.20	0.4293	4.7	170	0
11.000	2030	1237	684		311	39	99.0	125	100	100		4	0.22	0.4293	4.7	170	0
12.000	1515	1376	760		275	34	99.0	125	100	100		4	0.24	0.4293	4.6	190	0
13.000	1061	2126	1174		236	41	99.0	125	100	100		1	0.22	0.4293	4.5	220	0
14.000	1210	1335	737		406	51	99.0	125	100	100		1	0.22	0.4293	4.6	170	0
15.000	1474	1464	809		326	41	99.0	125	100	100		1	0.22	0.4293	4.6	170	0
16.000	1463	1302	719		290	36	99.0	125	100	100		4	0.24	0.4293	4.6	180	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Harris Rd Section 2 Trenching Survey North Side



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 2 Trenching Survey South Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	16	100	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	4.5	4784	1868	16	16	4.42	-0.497	99	32.9	4
4.5	8.5	4050	1783	36	19	4.51	-0.24	99	99	4
8.5	12.5	3554	1784	36	21	4.55	-0.203	99	99	4
12.500	16.000	2269	2162	40	24	4.6	-0.2	99	99	4

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	4.5	3.5	0	530
4.5	8.5	4	0	480
8.5	12.5	4	0	440
12.500	16.000	3.500	0	430

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Harris Rd Section 2 Trenching Survey South Side

Job Number: 890463
Test Date: 16/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

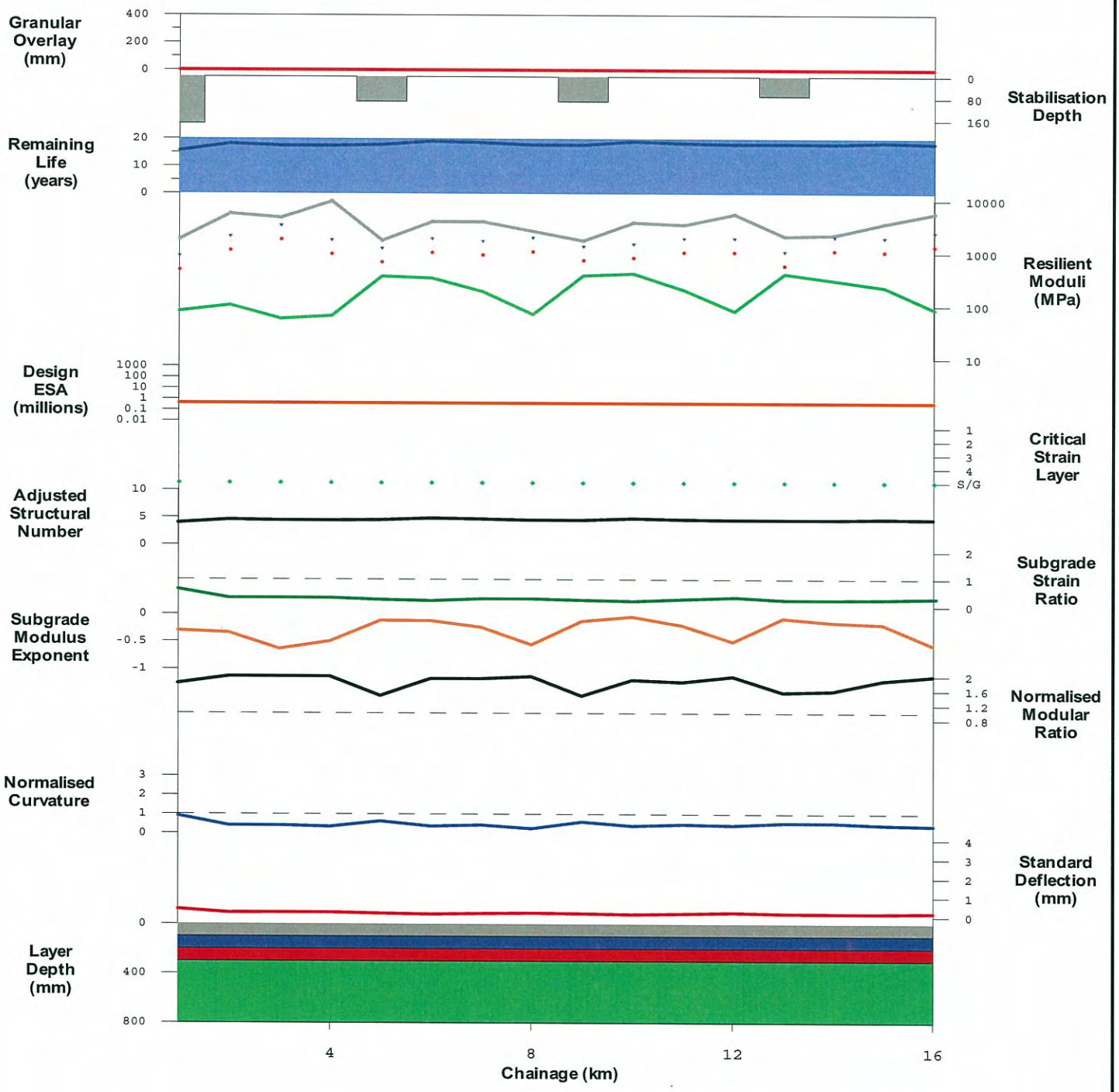
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	1868	889	491		81	16	32.9	100	100	100		4	0.41	0.4293	4.0	390	0
2.000	5697	2083	1151		105	22	99.0	100	100	100		4	0.23	0.4293	4.6	370	0
3.000	4784	3337	1844		58	17	99.0	100	100	100		4	0.24	0.4293	4.4	530	0
4.000	9800	1773	980		66	16	99.0	100	100	100		4	0.25	0.4293	4.4	490	0
5.000	1783	1245	688		373	58	99.0	100	100	100		4	0.20	0.4293	4.5	170	0
6.000	4050	1889	1044		342	53	99.0	100	100	100		4	0.15	0.4293	4.8	180	0
7.000	4063	1712	946		192	36	99.0	100	100	100		4	0.19	0.4293	4.7	250	0
8.000	10801	1970	1088		71	19	99.0	100	100	100		4	0.22	0.4293	4.5	480	0
9.000	1784	1354	748		386	61	99.0	100	100	100		4	0.19	0.4293	4.5	170	0
10.000	3894	1515	837		423	58	99.0	100	100	100		4	0.16	0.4293	4.8	170	0
11.000	3554	1923	1063		207	36	99.0	100	100	100		4	0.19	0.4293	4.7	240	0
12.000	5654	1938	1071		82	21	99.0	100	100	100		4	0.24	0.4293	4.6	440	0
13.000	2162	1076	595		418	60	99.0	100	100	100		4	0.20	0.4293	4.6	170	0
14.000	2269	2046	1131		312	51	99.0	100	100	100		4	0.17	0.4293	4.6	190	0
15.000	3762	1949	1077		229	40	99.0	100	100	100		4	0.18	0.4293	4.7	230	0
16.000	5746	2461	1360		88	24	99.0	100	100	100		4	0.21	0.4293	4.6	430	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Harris Rd Section 2 Trenching Survey South Side



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

FWD Pavement Structural Evaluation
PROJECT: Wiri Station Rd Trenching Survey

Job Number: 890463
Test Date: 15/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

Pavement Model

Chainage From	Chainage To	L1	L2	L3	L4	Surface Type	MESA	Design Period	DPSR	NAASRA
1	56	100	100	100		M/4	0.4293	25	1	99

Structural Evaluation (ELMOD) & Sub-Sectioning of Uniform Treatment Intervals

Chainage From	Chainage To	Layer 1 Modulus Median	Layer 1 Modulus 10%ile	Subgrade CBR Median	Subgrade CBR 10%ile	SNP Median	N Median	Life (years) Median	Life (years) 10%ile	Critical Layer
1	14.5	1825	585	11	6	3.55	-0.075	5.4	0.2	4
14.5	28.5	1577	924	11	8	3.5	-0.076	4	1.7	4
28.5	42.5	1492	110	13	11	3.68	-0.057	5.9	0	4
42.500	56.000	1374	1137	13	10	3.7	0.0	7	2	4

Drainage Inferences (from subgrade modulus exponent - n): * Check asterisked sub-sections above.

Recommendations for Rehabilitation
Nominal Granular Overlay

Chainage From	Chainage To	Length (km)	Granular Overlay (mm)	Minimum Reconstruction or Widening Depth (mm)
1	14.5	13.5	100	460
14.5	28.5	14	50	440
28.5	42.5	14	50	390
42.500	56.000	13.500	50	420

Note - overlay thickness is determined as 90 percentile strengthening for each section to accommodate the design traffic, but greater thicknesses may be required for shape correction or to meet minimum basecourse thickness and subbase drainage requirement

FWD Pavement Structural Evaluation
PROJECT: Wiri Station Rd Trenching Survey

Job Number: 890463
Test Date: 15/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
1.000	2496	452	250		65	9	6.7	100	100	100		4	0.59	0.4293	3.7	430	10
2.000	2574	273	151		65	9	3.1	100	100	100		4	0.68	0.4293	3.5	430	20
3.000	1123	388	214		101	14	6.6	100	100	100		4	0.63	0.4293	3.6	340	10
4.000	709	316	174		96	14	2.5	100	100	100		4	0.73	0.4293	3.4	340	50
5.000	791	325	180		119	15	7.0	100	100	100		4	0.67	0.4293	3.6	300	10
6.000	3522	178	98		79	11	5.4	100	100	100		4	0.65	0.4293	3.7	390	10
7.000	2277	243	134		86	11	4.8	100	100	100		4	0.68	0.4293	3.6	370	20
8.000	3022	344	190		87	12	12.7	100	100	100		4	0.56	0.4293	3.9	370	0
9.000	5545	168	93		74	10	9.6	100	100	100		4	0.61	0.4293	3.7	410	0
10.000	1825	412	228		91	13	9.3	100	100	100		4	0.58	0.4293	3.8	360	0
11.000	990	315	174		110	14	5.9	100	100	100		4	0.68	0.4293	3.5	320	20
12.000	585	306	169		66	8	0.4	100	100	100		4	0.91	0.4293	3.0	420	100
13.000	791	288	159		49	6	0.2	100	100	100		4	0.95	0.4293	2.8	490	100
14.000	1894	256	141		59	7	1.1	100	100	100		4	0.79	0.4293	3.2	460	40
15.000	1436	427	236		80	12	5.0	100	100	100		4	0.61	0.4293	3.7	390	20
16.000	1054	436	241		68	11	2.1	100	100	100		4	0.67	0.4293	3.5	420	40
17.000	1505	344	190		66	10	2.0	100	100	100		4	0.68	0.4293	3.5	430	40
18.000	1356	358	198		75	11	2.7	100	100	100		4	0.69	0.4293	3.5	400	30
19.000	1743	318	176		88	12	5.3	100	100	100		4	0.64	0.4293	3.6	360	10
20.000	1901	355	196		64	8	2.6	100	100	100		4	0.69	0.4293	3.4	440	30
21.000	1577	349	193		62	8	1.7	100	100	100		4	0.73	0.4293	3.3	440	40
22.000	2100	346	191		104	13	12.7	100	100	100		4	0.59	0.4293	3.8	330	0
23.000	1940	371	205		82	11	6.1	100	100	100		4	0.61	0.4293	3.7	380	10
24.000	2393	442	244		134	17	44.3	100	100	100		4	0.46	0.4293	4.1	280	0
25.000	1846	354	195		150	19	38.8	100	100	100		4	0.50	0.4293	4.0	260	0
26.000	1342	439	243		110	14	12.5	100	100	100		4	0.59	0.4293	3.7	320	0
27.000	1769	379	209		68	8	3.0	100	100	100		4	0.68	0.4293	3.4	420	30
28.000	924	329	182		100	12	4.0	100	100	100		4	0.72	0.4293	3.5	340	30
29.000	2414	404	223		84	13	10.9	100	100	100		4	0.54	0.4293	3.9	380	0
30.000	1396	476	263		80	13	5.9	100	100	100		4	0.58	0.4293	3.7	390	10
31.000	2059	333	184		81	13	5.9	100	100	100		4	0.59	0.4293	3.8	380	10
32.000	110	175	97		97	13	0.0	100	100	100		1	1.45	0.4293	2.8	340	220
33.000	1492	282	156		94	12	4.5	100	100	100		4	0.68	0.4293	3.5	350	20
34.000	1481	387	214		83	12	4.8	100	100	100		4	0.63	0.4293	3.6	380	20
35.000	2058	301	166		82	11	4.9	100	100	100		4	0.66	0.4293	3.6	380	10
36.000	2400	388	214		74	11	7.0	100	100	100		4	0.59	0.4293	3.7	410	10
37.000	3480	347	192		96	12	19.5	100	100	100		4	0.54	0.4293	3.9	340	0
38.000	2881	282	156		105	13	15.5	100	100	100		4	0.57	0.4293	3.9	330	0
39.000	1701	307	170		105	13	8.7	100	100	100		4	0.63	0.4293	3.7	330	0
40.000	1260	348	192		95	13	5.2	100	100	100		4	0.64	0.4293	3.6	350	20
41.000	1245	321	177		128	16	13.8	100	100	100		4	0.60	0.4293	3.7	290	0
42.000	1114	445	246		96	13	6.7	100	100	100		4	0.62	0.4293	3.6	350	10
43.000	2009	352	195		91	13	8.7	100	100	100		4	0.57	0.4293	3.8	360	0

FWD Pavement Structural Evaluation
PROJECT: Wiri Station Rd Trenching Survey

Job Number: 890463
Test Date: 15/05/2003
Overlay: Granular (mm)

Seasonal Factor: 1
Isotropic Modulus: 330 MPa

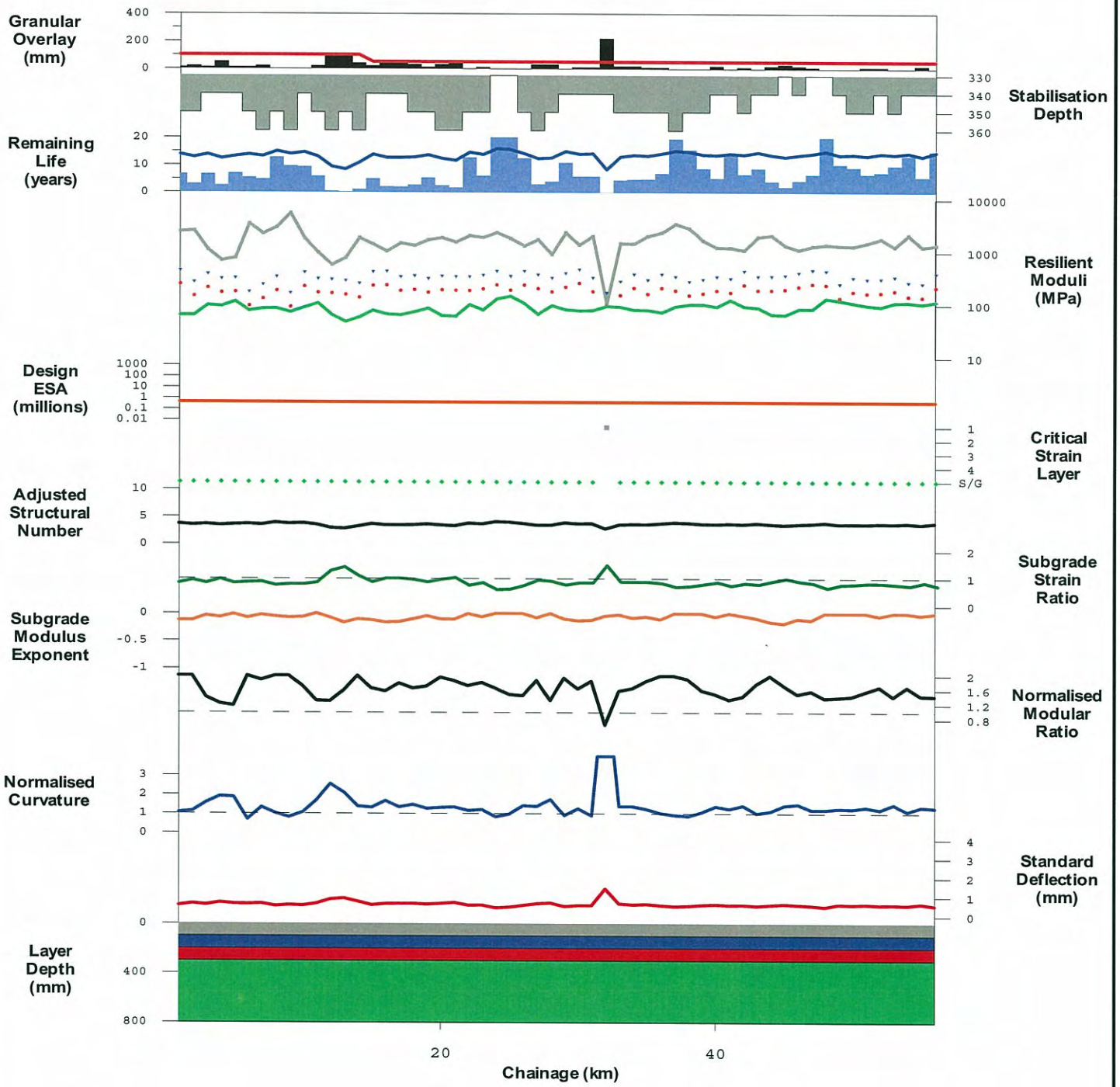
FWD Data Summary

Chainage	Resilient Moduli					CBR	Life	Layer Depths				Critical	Deflection	ESA	SNP	Depth	Overlay
	E1	E2	E3	E4	Esg			1	2	3	4	Layer		average/yr		RCN	Granular
(km)	(MPa)						(yrs)	(mm)					(mm)	(millions)		(mm)	(mm)
44.000	2120	354	195		68	10	4.1	100	100	100		4	0.62	0.4293	3.6	420	20
45.000	1374	366	202		67	11	2.1	100	100	100		4	0.66	0.4293	3.5	420	30
46.000	1137	412	228		86	13	4.3	100	100	100		4	0.62	0.4293	3.6	370	20
47.000	1326	464	256		86	13	6.6	100	100	100		4	0.58	0.4293	3.7	370	10
48.000	1415	446	246		135	17	27.1	100	100	100		4	0.52	0.4293	3.9	280	0
49.000	1350	252	139		124	16	10.2	100	100	100		4	0.65	0.4293	3.6	290	0
50.000	1322	332	183		112	14	9.1	100	100	100		4	0.63	0.4293	3.7	310	0
51.000	1534	310	171		101	13	6.7	100	100	100		4	0.65	0.4293	3.6	330	10
52.000	1831	316	175		95	13	7.3	100	100	100		4	0.61	0.4293	3.7	350	10
53.000	1296	344	190		113	14	9.7	100	100	100		4	0.62	0.4293	3.7	310	0
54.000	2143	272	150		114	14	13.4	100	100	100		4	0.59	0.4293	3.8	310	0
55.000	1286	258	143		107	14	5.6	100	100	100		4	0.67	0.4293	3.6	320	20
56.000	1388	397	219		119	15	15.0	100	100	100		4	0.57	0.4293	3.8	300	0

PAVEMENT STRUCTURAL ANALYSIS

FALLING WEIGHT DEFLECTOMETER SURVEY

Wiri Station Rd Trenching Survey



LEGEND

REMAINING LIFE: GMP LIFE HDM LIFE

LAYER LEGEND: LAYER 1 LAYER 2 LAYER 3 LAYER 4 SUBGRADE

Appendix F: NZdTIMS Analysis Results

1. Real Network Data Analysis – With Trench

Summary of Funding Requirements

Summary of Funding Requirements

Analysis Set: M_ALL
Network: ALL ROADS

Year	Funding Requirements for Budget Scenarios, $1000	Min Cost Str	Routine Only
	Unlimited		
2002	36.2	36.2	36.2
2003	697.8	42.8	42.8
2004	93.8	49.0	49.0
2005	28.4	77.9	77.9
2006	73.8	66.6	66.6
2007	27.9	53.9	53.9
2008	28.1	75.8	75.8
2009	28.3	59.6	59.6
2010	28.8	56.5	56.5
2011	40.5	32.4	32.4
2012	72.1	32.6	32.6
2013	62.1	32.8	32.8
2014	118.5	38.5	38.5
2015	192.9	31.4	31.4
2016	29.0	38.9	38.9
2017	91.6	31.9	31.9
2018	64.2	36.9	36.9
2019	55.0	48.0	48.0
2020	70.0	77.4	77.4
2021	28.6	50.2	50.2
Total Agency Cost	**1,868.0**	**969.5**	**969.5**

Analysis Period Summary:			
PV of Agency Cost	1,868.0	969.5	969.5
PV of Vehicle Operation Cos	27,187.5	122,539.6	122,539.6
PV of Total Transportation Cost	29,055.5	123,509.1	123,509.1
Benefit Cost Ratio	106.1		
NPV of Agnecy Cost	-898.4		
NPV of Total Transportation Cost	94,453.7		

Length of Treatments

Year	SRA	SRL	SOL	SOA	MOA	MOL	MRL	MMA	MRA	MYL	AWT	RSL	RSS	RSP	RSD	RSM	Routine
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2003	0.175	0	0	0	1.8	0	0.189	0	0	0	0	0.075	0	0	0	0	0.429
2004	0	0	0	0	0.077	0	0	0.095	0	0	0	0	0	0	0	0	2.496
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2006	0	0	0	0	0.257	0	0	0	0	0	0	0.189	0	0	0	0	2.222
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2011	0	0	0	0	0.075	0	0	0	0	0	0	0	0	0	0	0	2.593
2012	0	0	0	0	0.244	0	0	0	0	0	0	0	0	0	0	0	2.424
2013	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0	2.52
2014	0	0	0	0	0.479	0	0	0	0	0	0	0	0	0	0	0	2.189
2015	0	0	0	0	0.956	0	0	0	0	0	0	0	0	0	0	0	1.712
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2017	0	0	0	0	0.092	0	0	0.095	0	0	0	0	0	0	0	0	2.481
2018	0	0	0	0	0.257	0	0	0	0	0	0	0	0	0	0	0	2.411
2019	0	0	0	0	0.133	0	0	0	0	0	0	0	0	0	0	0	2.535
2020	0	0	0	0	0.189	0	0	0	0	0	0	0	0	0	0	0	2.479
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668

SRA AC Reconstruction
SRL ST Reconstruction
SOL Thick Granular Overlay
SOA Thick Asphalt Overlay
MOA Thin Asphalt Overlay
MOL Thick Granular Overlay
MRL Rip and Remake with ST
MMA Mill and Replace
MRA Rip and Remake with AC
MYL Recycle
AWT Area Wide Treatment
RSL Resurfacing with Large Chip
RSS Resurfacing with Small Chip
RSP Resurfacing with Special Chip
RSD Resurfacing with Double Chip
RSM Resurfacing Minimum
Routine Routine Maintenance

2. Real Network Data Analysis – Without Trench

Summary of Funding Requirements

Summary of Funding Requirements

Analysis Set: M_ALL
Network: ALL ROADS

Year	Funding Requirements for Budget Scenarios, $1000	Min Cost Str	Routine Only
	Unlimited		
2002	36.2	36.2	36.2
2003	526.4	42.8	42.8
2004	114.5	49.0	49.0
2005	29.1	77.9	77.9
2006	74.9	66.6	66.6
2007	57.0	53.9	53.9
2008	28.0	75.8	75.8
2009	28.2	59.6	59.6
2010	28.7	56.5	56.5
2011	29.9	32.4	32.4
2012	32.1	32.6	32.6
2013	62.3	32.8	32.8
2014	173.5	38.5	38.5
2015	115.3	31.4	31.4
2016	47.1	38.9	38.9
2017	107.2	31.9	31.9
2018	91.9	36.9	36.9
2019	97.2	48.0	48.0
2020	69.9	77.4	77.4
2021	28.3	50.2	50.2
Total Agency Cost	**1,777.7**	**969.5**	**969.5**

Analysis Period Summary:

PV of Agency Cost	1,777.7	969.5	969.5
PV of Vehicle Operation Cos	14,997.4	81,259.2	81,259.2
PV of Total Transportation Cost	16,775.1	82,228.7	82,228.7
Benefit Cost Ratio	82.0		
NPV of Agnecy Cost	-808.1		
NPV of Total Transportation Cost	65,453.6		

Length of Treatments

Year	SRA	SRL	SOL	SOA	MOA	MOL	MRL	MMA	MRA	MYL	AWT	RSL	RSS	RSP	RSD	RSM	Routine
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2003	0.089	0	0	0	1.597	0	0.189	0	0	0	0	0.075	0	0	0	0	0.718
2004	0	0	0	0	0.204	0	0	0.095	0	0	0	0	0	0	0	0	2.369
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2006	0	0	0	0	0.257	0	0	0	0	0	0	0.189	0	0	0	0	2.222
2007	0	0	0	0	0.162	0	0	0	0	0	0	0	0	0	0	0	2.506
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2013	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0	2.52
2014	0	0	0	0	0.809	0	0	0	0	0	0	0	0	0	0	0	1.859
2015	0	0	0	0	0.52	0	0	0	0	0	0	0	0	0	0	0	2.148
2016	0	0	0	0	0.114	0	0	0	0	0	0	0	0	0	0	0	2.554
2017	0	0	0	0	0.166	0	0	0.095	0	0	0	0	0	0	0	0	2.407
2018	0	0	0	0	0.39	0	0	0	0	0	0	0	0	0	0	0	2.278
2019	0	0	0	0	0.162	0	0	0	0.075	0	0	0	0	0	0	0	2.431
2020	0	0	0	0	0.189	0	0	0	0	0	0	0	0	0	0	0	2.479
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668

SRA AC Reconstruction
SRL ST Reconstruction
SOL Thick Granular Overlay
SOA Thick Asphalt Overlay
MOA Thin Asphalt Overlay
MOL Thick Granular Overlay
MRL Rip and Remake with ST
MMA Mill and Replace
MRA Rip and Remake with AC
MYL Recycle
AWT Area Wide Treatment
RSL Resurfacing with Large Chip
RSS Resurfacing with Small Chip
RSP Resurfacing with Special Chip
RSD Resurfacing with Double Chip
RSM Resurfacing Minimum
Routine Routine Maintenance

3. Synthetic Data – With Trench

Summary of Funding Requirements

Summary of Funding Requirements

Analysis Set: M_ALL
Network: ALL ROADS

Year	Funding Requirements for Budget Scenarios, $1000	Min Cost Str	Routine Only
	Unlimited		
2002	33.2	33.2	33.2
2003	35.6	33.3	33.3
2004	33.1	33.5	33.5
2005	33.2	33.7	33.7
2006	33.4	33.9	33.9
2007	33.7	34.2	34.2
2008	276.3	35.3	35.3
2009	483.6	36.8	36.8
2010	98.9	43.2	43.2
2011	251.4	47.2	47.2
2012	103.5	52.0	52.0
2013	47.6	61.2	61.2
2014	77.7	67.2	67.2
2015	102.9	62.0	62.0
2016	29.5	74.7	74.7
2017	40.8	65.6	65.6
2018	41.7	60.4	60.4
2019	61.1	87.5	87.5
2020	34.4	74.9	74.9
2021	220.5	39.9	39.9
Total Agency Cost	**2,072.1**	**1,009.6**	**1,009.6**

Analysis Period Summary:			
PV of Agency Cost	2,072.1	1,009.6	1,009.6
PV of Vehicle Operation Cos	3,955.3	19,484.8	19,484.8
PV of Total Transportation Cost	6,027.4	20,494.4	20,494.4
Benefit Cost Ratio	14.6		
NPV of Agnecy Cost	-1,062.6		
NPV of Total Transportation Cost	14,466.9		

Length of Treatments

Year	SRA	SRL	SOL	SOA	MOA	MOL	MRL	MMA	MRA	MYL	AWT	RSL	RSS	RSP	RSD	RSM	Routine
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2003	0	0	0	0	0	0	0	0	0	0	0	0.075	0	0	0	0	2.593
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2008	0	0	0	0	0	0	0	0	0.322	0	0	0	0	0	0	0	2.346
2009	0	0	0	0	0	0	0	0	0.739	0	0	0	0	0	0	0	1.929
2010	0	0	0	0	0.352	0	0	0	0	0	0	0	0	0	0	0	2.316
2011	0	0	0	0	0	0	0	0	0.284	0	0	0	0	0	0	0	2.384
2012	0	0	0	0	0.149	0	0	0.095	0	0	0	0	0	0	0	0	2.424
2013	0	0	0	0	0.114	0	0	0	0	0	0	0	0	0	0	0	2.554
2014	0	0	0	0	0.349	0	0	0	0	0	0	0	0	0	0	0	2.319
2015	0	0	0	0	0	0	0.189	0	0	0	0	0	0	0	0	0	2.479
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2017	0	0	0	0	0.075	0	0	0	0	0	0	0	0	0	0	0	2.593
2018	0	0	0	0	0	0	0	0	0	0	0	0.189	0	0	0	0	2.479
2019	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0	2.52
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2021	0	0	0	0	1.073	0	0	0	0	0	0	0	0	0	0	0	1.595

SRA AC Reconstruction
SRL ST Reconstruction
SOL Thick Granular Overlay
SOA Thick Asphalt Overlay
MOA Thin Asphalt Overlay
MOL Thick Granular Overlay
MRL Rip and Remake with ST
MMA Mill and Replace
MRA Rip and Remake with AC
MYL Recycle
AWT Area Wide Treatment
RSL Resurfacing with Large Chip
RSS Resurfacing with Small Chip
RSP Resurfacing with Special Chip
RSD Resurfacing with Double Chip
RSM Resurfacing Minimum
Routine Routine Maintenance

4. Synthetic Data – Without Trench

Summary of Funding Requirements

Summary of Funding Requirements

Analysis Set: M_ALL
Network: ALL ROADS

Year	Funding Requirements for Budget Scenarios, $1000		Min Cost Str	Routine Only
	Unlimited			
2002	33.2		33.2	33.2
2003	33.3		33.3	33.3
2004	33.5		33.5	33.5
2005	33.7		33.7	33.7
2006	33.9		33.9	33.9
2007	34.2		34.2	34.2
2008	276.7		35.3	35.3
2009	484.1		36.8	36.8
2010	99.4		43.2	43.2
2011	89.6		47.2	47.2
2012	33.1		52.0	52.0
2013	34.8		61.2	61.2
2014	71.6		67.2	67.2
2015	37.2		62.0	62.0
2016	39.6		74.7	74.7
2017	41.8		65.6	65.6
2018	44.4		60.4	60.4
2019	91.5		87.5	87.5
2020	49.8		74.9	74.9
2021	231.1		39.9	39.9
Total Agency Cost	**1,826.5**		**1,009.6**	**1,009.6**

Analysis Period Summary:

PV of Agency Cost	1,826.5	1,009.6	1,009.6
PV of Vehicle Operation Cos	861.9	4,579.0	4,579.0
PV of Total Transportation Cost	2,688.4	5,588.6	5,588.6
Benefit Cost Ratio	4.6		
NPV of Agnecy Cost	-816.9		
NPV of Total Transportation Cost	2,900.2		

Length of Treatments

Year	SRA	SRL	SOL	SOA	MOA	MOL	MRL	MMA	MRA	MYL	AWT	RSL	RSS	RSP	RSD	RSM	Routine
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2003	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2004	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2006	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2008	0	0	0	0	0	0	0	0	0.322	0	0	0	0	0	0	0	2.346
2009	0	0	0	0	0	0	0	0	0.739	0	0	0	0	0	0	0	1.929
2010	0	0	0	0	0.352	0	0	0	0	0	0	0	0	0	0	0	2.316
2011	0	0	0	0	0	0	0	0	0.077	0	0	0	0	0	0	0	2.591
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2014	0	0	0	0	0.257	0	0	0	0	0	0	0	0	0	0	0	2.411
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2019	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0.338	2.182
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.189	2.479
2021	0	0	0	0	1.073	0	0	0	0	0	0	0	0	0	0	0.095	1.5

SRA AC Reconstruction
SRL ST Reconstruction
SOL Thick Granular Overlay
SOA Thick Asphalt Overlay
MOA Thin Asphalt Overlay
MOL Thick Granular Overlay
MRL Rip and Remake with ST
MMA Mill and Replace
MRA Rip and Remake with AC
MYL Recycle
AWT Area Wide Treatment
RSL Resurfacing with Large Chip
RSS Resurfacing with Small Chip
RSP Resurfacing with Special Chip
RSD Resurfacing with Double Chip
RSM Resurfacing Minimum
Routine Routine Maintenance

5. Sectioning Analysis – With Trench

Summary of Funding Requirements

Summary of Funding Requirements

Analysis Set: M_ALL
Network: ALL ROADS

Year	Funding Requirements for Budget Scenarios, $1000	Min Cost Str	Routine Only
	Unlimited		
2002	22.0	22.0	22.0
2003	695.4	25.3	25.3
2004	47.4	40.8	40.8
2005	16.1	36.1	36.1
2006	40.6	40.0	40.0
2007	16.2	23.1	23.1
2008	16.4	38.4	38.4
2009	16.6	33.6	33.6
2010	16.7	18.9	18.9
2011	25.8	19.0	19.0
2012	32.4	21.9	21.9
2013	26.0	22.3	22.3
2014	50.0	18.2	18.2
2015	67.9	26.1	26.1
2016	97.6	34.4	34.4
2017	41.2	28.0	28.0
2018	16.3	34.8	34.8
2019	39.9	21.1	21.1
2020	16.6	29.7	29.7
2021	39.4	28.1	28.1
Total Agency Cost	**1,340.6**	**561.6**	**561.6**

Analysis Period Summary:

PV of Agency Cost	1,340.6	561.6	561.6
PV of Vehicle Operation Cos	20,906.1	185,921.2	185,921.2
PV of Total Transportation Cost	22,246.7	186,482.9	186,482.9
Benefit Cost Ratio	211.8		
NPV of Agnecy Cost	-778.9		
NPV of Total Transportation Cost	164,236.2		

Length of Treatments

Year	SRA	SRL	SOL	SOA	MOA	MOL	MRL	MMA	MRA	MYL	AWT	RSL	RSS	RSP	RSD	RSM	Routine
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2003	0.413	0	0	0	1.07	0	0.189	0	0.569	0	0	0.075	0	0	0	0	0.352
2004	0	0	0	0	0.075	0	0	0.095	0	0	0	0	0	0	0	0	2.498
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2006	0	0	0	0	0.257	0	0	0	0	0	0	0.189	0	0	0	0	2.222
2007	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2011	0	0	0	0	0.087	0	0	0	0	0	0	0	0	0	0	0	2.581
2012	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0	2.52
2013	0	0	0	0	0.077	0	0	0	0	0	0	0	0	0	0	0	2.591
2014	0	0	0	0	0.33	0	0	0	0	0	0	0	0	0	0	0	2.338
2015	0	0	0	0	0.528	0	0	0	0	0	0	0	0	0	0	0	2.14
2016	0	0	0	0	0.675	0	0	0.095	0	0	0	0	0	0	0	0	1.898
2017	0	0	0	0	0.332	0	0	0	0	0	0	0	0	0	0	0	2.336
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2019	0	0	0	0	0.189	0	0	0	0	0	0	0	0	0	0	0	2.479
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2021	0	0	0	0	0.222	0	0	0	0	0	0	0	0	0	0	0	2.446

SRA AC Reconstruction
SRL ST Reconstruction
SOL Thick Granular Overlay
SOA Thick Asphalt Overlay
MOA Thin Asphalt Overlay
MOL Thick Granular Overlay
MRL Rip and Remake with ST
MMA Mill and Replace
MRA Rip and Remake with AC
MYL Recycle
AWT Area Wide Treatment
RSL Resurfacing with Large Chip
RSS Resurfacing with Small Chip
RSP Resurfacing with Special Chip
RSD Resurfacing with Double Chip
RSM Resurfacing Minimum
Routine Routine Maintenance

6. Sectioning Analysis – Without Trench

Summary of Funding Requirements

Summary of Funding Requirements

Analysis Set: M_ALL
Network: ALL ROADS

Year	Funding Requirements for Budget Scenarios, $1000	Min Cost Str	Routine Only
	Unlimited		
2002	22.0	22.0	22.0
2003	282.1	25.3	25.3
2004	130.1	40.8	40.8
2005	16.7	36.1	36.1
2006	41.0	40.0	40.0
2007	31.4	23.1	23.1
2008	16.2	38.4	38.4
2009	16.4	33.6	33.6
2010	16.7	18.9	18.9
2011	17.1	19.0	19.0
2012	32.5	21.9	21.9
2013	56.8	22.3	22.3
2014	53.0	18.2	18.2
2015	53.6	26.1	26.1
2016	67.6	34.4	34.4
2017	57.3	28.0	28.0
2018	31.7	34.8	34.8
2019	60.1	21.1	21.1
2020	16.3	29.7	29.7
2021	31.3	28.1	28.1
Total Agency Cost	**1,049.9**	**561.6**	**561.6**

Analysis Period Summary:			
PV of Agency Cost	1,049.9	561.6	561.6
PV of Vehicle Operation Cos	14,906.6	85,521.4	85,521.4
PV of Total Transportation Cost	15,956.5	86,083.1	86,083.1
Benefit Cost Ratio	144.6		
NPV of Agnecy Cost	-488.3		
NPV of Total Transportation Cost	70,126.6		

Length of Treatments

Year	SRA	SRL	SOL	SOA	MOA	MOL	MRL	MMA	MRA	MYL	AWT	RSL	RSS	RSP	RSD	RSM	Routine
2002	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2003	0.089	0	0	0	1.597	0	0.189	0	0	0	0	0.075	0	0	0	0	0.718
2004	0.09	0	0	0	0.114	0	0	0.095	0	0	0	0	0	0	0	0	2.369
2005	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2006	0	0	0	0	0.257	0	0	0	0	0	0	0.189	0	0	0	0	2.222
2007	0	0	0	0	0.162	0	0	0	0	0	0	0	0	0	0	0	2.506
2008	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2009	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2012	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0	2.52
2013	0	0	0	0	0.42	0	0	0	0	0	0	0	0	0	0	0	2.248
2014	0	0	0	0	0.389	0	0	0	0	0	0	0	0	0	0	0	2.279
2015	0	0	0	0	0.43	0	0	0	0	0	0	0	0	0	0	0	2.238
2016	0	0	0	0	0.296	0	0	0.095	0	0	0	0	0	0	0	0	2.277
2017	0	0	0	0	0.464	0	0	0	0	0	0	0	0	0	0	0	2.204
2018	0	0	0	0	0.162	0	0	0	0	0	0	0	0	0	0	0	2.506
2019	0	0	0	0	0.189	0	0	0	0.075	0	0	0	0	0	0	0	2.404
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.668
2021	0	0	0	0	0.148	0	0	0	0	0	0	0	0	0	0	0	2.52

SRA AC Reconstruction
SRL ST Reconstruction
SOL Thick Granular Overlay
SOA Thick Asphalt Overlay
MOA Thin Asphalt Overlay
MOL Thick Granular Overlay
MRL Rip and Remake with ST
MMA Mill and Replace
MRA Rip and Remake with AC
MYL Recycle
AWT Area Wide Treatment
RSL Resurfacing with Large Chip
RSS Resurfacing with Small Chip
RSP Resurfacing with Special Chip
RSD Resurfacing with Double Chip
RSM Resurfacing Minimum
Routine Routine Maintenance