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ANNUAL SUMMARY REPORT

Project Title: P8 Evaluate the performance of the Transport Network Reconstruction Program (TNRP)
(Year 1 – 2014/15)

Project No: 007189

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Client: Queensland Department of Transport and Main Roads

Date: September 2015

AN INITIATIVE BY:
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Queensland Government Australia

P8 EVALUATE THE PERFORMANCE OF THE TRANSPORT NETWORK RECONSTRUCTION PROGRAM (TNRP)

SUMMARY

The Transport Network Reconstruction Program (TNRP) is the largest flood recovery work undertaken in the history of Queensland. The Department of Transport and Main Roads (TMR) engaged ARRB Group to conduct a research project under the National Asset Centre of Excellence (NACOE) agreement to evaluate the performance of the TNRP flood repair works. The key objective of this project is to identify best practices and lessons learnt during the flood recovery program. This interim report presents the findings from Year 1 of the three-year research project.

A scoping study was conducted in Year 1. Key tasks that have been accomplished are as follows:

- Conduct a workshop with participants from the State Program Office (SPO) and Regional Program Offices (RPOs).
- Conduct on-site interviews with three RPOs (Central West, South West and Fitzroy).
- Collate information received from the SPO/RPOs workshop and on-site interviews.
- Investigate early age performance information on pavement treatments based on the ARMIS data.
- Identify specific areas for future study.

The project team organised a workshop with staff from the SPO and RPOs in October 2014. The main objective was to identify challenges and lessons learnt during the program; this was held before the TNRP officially ended in December 2014.

Although regions have different environments, some similar pavement challenges were observed across the entire program. Some of the common issues identified are as follows:

- Moisture ingress into the pavement system through subgrade saturation, direct moisture ingress into pavements due to high watertables and overflow were the primary causes of pavement failure. Increasing the width of sealing and raising vertical alignment of roads should effectively reduce pavement damage in subsequent flood events.
- After the flooding event, additional pavement damage occurred after the road was opened to traffic, as the pavement materials were still in a weak condition.
- The most common pavement treatment adopted was cement modification of existing material. Sprayed seal surfacing was the most common surfacing treatment. The long-term performance of the cement modification treatment should be monitored.
- Strengthening the subgrade and dealing with expansive soils was often required as part of the restoration work. The subgrade strength and its reactivity play a significant role in the performance of the pavement. Several proven technologies were used to strengthen the subgrade.

In the study, it was found that the ARMIS database provides consistency and the necessary level of detail to quantify and identify general trends in the treatment selection criteria from the regions. An ARMIS data viewer tool was

developed to assist with the processing of the available data. The tool provides a mechanism to interrogate the vast amount of data, highlight key pavement treatments and provide a geospatial view of the available pavement treatment data. It also allows for assessment of the early life performance of the TNRP works.

The dominant pavement treatments determined through the ARMIS data viewer tool are generally in line with high-level summary statistics provided by the RPOs during the workshop. It was found that the top three pavement treatments (by length) were:

- cement modified base
- granular re-sheeting (unsealed road)
- granular overlay or remove and replace.

Sprayed seal was the most frequent surfacing used with the majority of the road repairs located in rural areas. Although not extensive, there were some subgrade improvements done during the program.

A number of key pavement-related issues/findings were identified as follows:

- Local knowledge of the region is crucial in the success of flood restoration work. Most RPOs provided the required local knowledge in co-operation with the rest of the design and construction teams. In some regions, the local knowledge has been formalised as regional guidelines.
- Adequate pavement testing is essential to the selection of an appropriate treatment.
- Drainage is important in terms of the performance of pavements. The primary failure mode was due to moisture ingress into the main pavement structure. Measures such as full-width sealing, well-maintained seals and longitudinal surface and/or sub-surface drains are important.
- Some emergent works remain in place as the final pavement treatment. The performance of these treatments is unknown but where possible these could be monitored in future assessment.
- Some regions used the treatment of granular base over stabilised subbase, which is not the preferred treatment included in the TNRP design guidelines.
- Lime stabilisation of subgrade is promising for regions with reactive subgrade soil.

It is noted that the pavement treatments are still at the early stages of design life, and further monitoring of their performance is recommended.

As part of this year’s study, specific areas were identified for study in future years of the project, details of which are provided in the report, grouped into the following four categories:

- collate information from the TNRP projects to provide future guidelines
- monitor pavement treatment projects
- monitor pavement, emergency and maintenance treatments
- monitor sprayed seal treatments.

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1 INTRODUCTION

1.1 TNRP Flood Repairs

The Department of Transport and Main Roads (TMR) engaged ARRB Group to conduct a research project under the NACOE agreement to evaluate the performance of the TNRP flood repair works. The key objective of this project is to identify best practices and lessons learnt and to evaluate the early life performance of pavement works during the $6 billion flood restoration program.

1.2 Purpose of the Project

The purpose of the project is to identify key findings from the largest flood restoration program ever undertaken in Queensland and Australia. This project will document the key lessons learnt in pre-construction and construction activities, innovative practices and techniques, improved processes and guidelines for future major pavement restoration programs. This would allow the evaluation of the pavement outcomes at both the material treatment level and the network risk level realised from this extensive investment.

1.3 Tasks in Year 1

Year 1 of this three-year study began in 2015. The primary focus of Year 1 is to undertake a detailed scoping study to identify areas to focus the research investigation. Tasks that have been carried out in Year 1 to achieve the aims and objectives include:

- Conduct a workshop with participants from the State Program Office (SPO), Regional Program Offices (RPOs) and TMR.
- Undertake field trips to three RPOs (Central West, South West and Fitzroy).
- Collate information received from the SPO/RPOs workshop and any additional data from the field trips.
- Investigate pavement treatments and early life performance based on the ARMIS data.
- Identify specific areas for future study.

1.4 Structure of the Report

Following the introduction, the information and findings collected during the SPO/RPOs workshop are summarised in Section 2. Based on ARMIS data received this year, detailed statistics of the pavement treatment types and early life performance evaluations are presented in Section 3. This information provided the project team with a network-wide view of the pavement treatments carried out in TNRP.

Section 4 outlines parts of the TNRP design guidelines that relate to pavement repairs. Furthermore, some regional design guidelines that were developed as part of the TNRP are also reported. Section 5 reports the findings from the site visit to the South West, Central West and Fitzroy districts. The purpose of the site visit was to have an ‘on-the-ground’ overview of selected TNRP projects as well as providing an opportunity for the project team to interact with staff from different TMR districts. Section 6 presents the summary of findings from the work undertaken in Year 1, which includes the scoping for future years’ work.

2 SPO/RPO WORKSHOP

2.1 Introduction

At the start of the project, it was realised that input from the SPO and RPOs was important to define the scope of the project. The project team gathered as much information as possible before the TNRP officially ended in December 2014.

On 9 October 2014, SPO and RPOs were invited to attend a scoping workshop in Brisbane. The meeting agenda included:

- RPO presentations to provide an overview of the TNRP works in their respective district
- group discussion sessions with RPOs to identify challenges and lessons learnt
- summary of best practices and lessons learnt
- prioritisation of issues of interest.

Due to time constraints, many participants needed to leave early to meet travel commitments. As a result, the prioritisation exercise was not fully completed. However, a broad consensus was reached on the top priorities.

2.1.1 Workshop Participants and Documents Requested from RPOs

Representatives from the following RPOs attended the workshop together with SPO staff:

- Central West
- Darling Downs
- Far North Queensland
- Fitzroy
- South West
- Wide Bay/Burnett.

The participants represented a broad spectrum of roles in the TNRP including program managers, TMR staff, consultants and construction supervisors. These groups provided a representative view of practices across Queensland. A list of workshop participants is provided in Appendix A. Each RPO was requested to provide documentation to support the workshop, as listed below. It is noted that not all the requested information was provided to the project team during the workshop:

- copies of RPO learning workshop outcomes
- RPO reports that pertain to pavements
- summary information on pavement treatments used for reconstruction (e.g. project number, section, pavement treatment, design life and original failure mode)
- top 5–10 most common treatments
- top 5–10 major projects
- emergency works treatments used
- top five projects where deviations from standards or TNRP guidelines were successfully undertaken
- details of process used to undertake initial network assessments (e.g. pre-inspection desktop data, inspection-site-data collected, interpretation of National Disaster Recovery Relief and

Recovery Arrangement (NDRRA) eligibility rules, interpretation of TNRP guidelines, local regional rules).

2.1.2 Workshop Discussions and Documents Requested from RPO

During the workshop, participants were divided into groups according to their geographical locations or role within the TNRP. Table 2.1 lists the workshop questions presented to the participants.

Table 2.1: Workshop questions

Category	Question number	Workshop questions
RPO challenges	1	In hindsight, what key things under your control would you change to achieve better pavement outcomes?
	2	Is there one particular pavement risk that keeps you awake at night?
	3	In pavement outcome terms, was there anything out of your control that you would like to have changed?
	4	What pavement-related thing in your RPO do you think the rest of the state should know about?
	5	Did you define 'fitness-for-purpose'? How did you define it? What is the significance for TMR?
	6	How much of your 'emergency works' remained as a final treatment?
Making a difference to TMR 'business as usual'	7	Did the program delivery model, which gathered people from outside of regional areas (often Brisbane) affect pavement treatment outcomes at all? Explain.
	8	(a) What proportion of your projects used a regional standard over a traditional TMR standard? (b) What were the key regional standards used?
	9	What key pavement design or construction innovation(s) made a difference? Are there any that could improve future TMR business?
	10	Can you identify key learnings in regard to: (a) improved quality (b) new products (c) change in practices (d) changes/modifications to specifications (e) pavements that you believe are worth monitoring closely to compare performance over time (f) what provided cost savings whilst maintaining pavement integrity (g) what 'disaster' (unexpected)/poor performance did you encounter. What did you learn from this?
	11	Did you change your approach to select pavement treatments over time (from the start to the end of the project)? If yes, why?
	12	Have your treatments been well tested for (a) higher than expected early-life traffic loading (b) flooding (c) other?
	13	What excited you most about pavement and surfacing treatments on the program?
Availability of information and improved approach in future program	14	What was your understanding of the NDRRA eligibility rules for pavement damage caused by pavement saturation?
	15	Although there were some versions issued, are there any additions, detractions or improvements to the TNRP Guidelines that could assist a future reconstruction program?
	16	Thinking about the materials used in the program, where do you think the most can be learned?
	17	For pavement treatments, what key 'start-up' documentation should be assembled to assist any future reconstruction program?

2.1.3 Key Pavement and Treatment Statistics

During the RPOs presentations, key pavement and treatment statistics were provided. Table 2.2 summarises the information from presentations made by Central West, Far North, Fitzroy, Wide Bay/Burnett and South West districts. Darling Downs district did not give a presentation during the workshop.

Table 2.2: Key pavement and treatment statistics provided by RPOs

Key areas	Central West district	Far North district	Fitzroy district	Wide Bay/Burnett district	South West district
Length of road reconstructed under TNRP	Total: 1456 km ($517m in value)	Total: 746 km ($500.6m in value) 27.5 km NH ($84.5m) 517 km SSR ($402.3m) 16.5 km LRRS ($13.8m)	Total: 780 km ($880m in value)	Total: 313 km (2010–11 event) 119 km (2013 event)	Total: 1644 km ($910m in value)
Top four treatments	▪ Unbound overlay over stabilised top-up gravel with existing base	▪ Gravel overlay ($253.7m) ▪ Remove and replace ($59.9m) ▪ Gravel resheet ($50.7m) ▪ Overlay and cement stabilise ($38.4m)	▪ Stabilised subbase followed by granular overlay ▪ Top-up 50 mm nominal material and stabilise to 200 mm depth ▪ Asphalt overlay	▪ Granular overlay and cement modify 200 to 250 mm depth (with widening) Class B ▪ Granular overlay and cement modify 200 mm depth (no widening) Class C ▪ Nominal 150 mm asphalt inlay/overlay, Class C ▪ 50 mm granular overlay cement modify to 200 mm depth, Class D	▪ Full width widening and overlay (30%) ▪ Full width rehabilitation (30%) ▪ Overlay (25%) ▪ Maintenance (15%)
% TNRP pavement with no design life	—	40%	45% ($400m)	—	Maintenance treatment (15%)
% TNRP pavement with design life of 5 years	—	1%	Nil	—	—
% TNRP pavement with design life of 10 years	—	10%	21% ($180m)	All Class B and C treatment types	Design life reduced to 10 years near the end of the program, in response to changes in the TNRP guideline
% TNRP pavement with design life 20 years	—	49%	34% ($300m)	—	Majority, roads with 100–1000 ESAs

2.2 Summary of Workshop Discussions

RPOs provided input to identify challenges, lessons learnt and the prioritisation of issues. Detailed responses from RPOs to each of the workshop questions are presented in Appendix B. Further discussion on key topics listed below is provided in this section:

- primary modes of pavement failures after the flooding event
- main differences between TNRP and the usual pavement repair and rehabilitation projects
- NDRRA events eligibility rules and pavement design life
- fitness-for-purpose
- local knowledge with respect to materials, design and construction
- availability of local pavement materials
- typical standard treatments and use of regional standards
- pavement resilience
- emergent work repairs
- adequate pre-construction investigation and testing
- sealing practices.

2.2.1 Primary Modes of Pavement Failures after the Flooding Event

Participants agreed that the majority of the pavement failures linked to low strength and saturated subgrade. In particular, this is true for areas with highly reactive subgrade material, such as in black soil regions. Black soils typically have a low subgrade California Bearing Ratio (CBR) value and high swelling potential. Limited pavement sealing width and the fact that a lot of the flooded areas are located in flat terrain can lead to prolonged periods of saturated subgrade conditions. In some districts, longitudinal cracks propagating through pavement treatment works have been observed. It is speculated that these cracks are caused by changes in moisture content of the reactive subgrade, which is consistent with current pavement and earthworks knowledge.

While saturated subgrade can be one of the pavement failure modes, pavement failure can also occur due to a high water-table near the pavement over long periods of time. The situation not only saturates the subgrade but also allows direct moisture ingress into the pavement causing failure.

There was a consensus that the following three measures are effective to limit pavement failure after flooding events:

- seal to full width of the pavement (including shoulder sealing)
- improve longitudinal side drains (e.g. clearing out or re-establishing drains, moving water further away from pavement, or use alternative side drain designs)
- raise the pavement level to reduce moisture ingress.

2.2.2 Main Differences between TNRP and the Usual Pavement Repair/Rehabilitation Projects

Pavement repairs and rehabilitation are core activities for TMR. The key aspects of TNRP which the workshop participants believe to be different to the traditional roadwork projects are as follows:

- Time constraints – relates to the pre-defined period in which TNRP construction needs to be completed. The time constraints put a greater demand on the pavement materials and skills required. Another complication is that pavement failures are not always immediately evident after a flooding event. Failures can occur soon after the weakened pavement has been re-opened to traffic.

- Scope change – changes in the funding eligibility rules often led to scope changes during the TNRP.
- Volume of work – concurrent construction works across multiple districts put pressure on available resources (e.g. personnel, equipment and materials) leading to higher cost, which also puts pressure on funding.

2.2.3 NDRRA Events Eligibility Rules and Pavement Design Life

Participants often pointed to the inconsistency of the funding eligibility rules. The following three broad aspects were discussed:

- Timeframe of damages reported after initial assessment period – refers to pavement damage that does not occur immediately after the flooding. Pavement damage from traffic after the flood can occur well after the flood damage assessment period.
- Inconsistency in stakeholders' interpretation – RPOs, Queensland Reconstruction Authority (QRA) and federal agencies often have different interpretations of the funding eligibility rules.
- Changes to the funding and eligibility rule over the course of TNRP. This often leads to continuing scope changes and affects the pavement treatment selection and nominated design life.

The eligibility rules have a profound effect on the type of treatments and design life adopted. Some participants indicated that changes to the eligibility rules severely restricted the pavement design life adopted. Some RPOs indicated that the design life has been reduced from 20 years to 10 years, and in some cases maintenance treatment was selected to fit within the allocated funds. Some indications of the pavement design life adopted are summarised in Table 2.2, which vary by region and the road class.

2.2.4 Fitness-for-purpose

All participants from RPOs indicated that they had control over the application of the fitness-for-purpose concept during TNRP. The general philosophy was to match pavement treatments to the allocated funding, with more funds being allocated to roads at the top of the road hierarchy.

The fitness-for-purpose concept can be implemented by adopting design exceptions, selection of maintenance treatment, and deferment of treatment to a future Queensland Transport and Roads Investment Program (QTRIP). There are some inherent risks in this approach.

2.2.5 Local Knowledge with Respect to Materials, Design and Construction

Participants pointed out that local knowledge is an important factor during the TNRP works. RPOs were comfortable with the level of local knowledge that each RPO had. Some districts indicated that when inputs from TMR district staff had been incorporated during the development of the pavement solutions, good outcomes were generally observed.

There are a number of areas where local knowledge is needed. Areas include assessment of the pavement during initial funding application, availability of locally sourced materials, and construction practices when handling local materials.

2.2.6 Availability of Local Pavement Material

A large number of projects are located in remote areas where the high-quality crushed rock is not readily available. RPOs discussed different ways to work with these local pavement materials. Some of the practices may be innovations while others are simply adopting regional construction practices developed over the years.

One district reported that the TNRP works increased the local quarries' capabilities to manufacture Type 2.1 (CBR > 80%) unbound granular material that meets the TMR standard specification. This will benefit future roadwork projects as higher quality material becomes available for remote work sites.

2.2.7 Typical Standard Treatments and Use of Regional Standards

Participants provided some typical standard treatment details that they have used in their districts. These typical cross-sections are being compiled to make them available as a future reference.

A review of the common pavement treatments reveals that there are some standard pavement treatments being applied across Queensland in TNRP. There are regional preferences for pavement treatments for strategic roads and less robust treatments used for second-order roads. As a result, the distribution of pavement treatments adopted across each region varies. Further details on the distribution of pavement treatments are provided in Section 3.

2.2.8 Pavement Resilience

In the TNRP Design Guideline, resilience is defined as the ability to absorb a disaster event and return to a state of acceptable operating conditions. RPOs indicated some pavement sections performed well during subsequent floods.

For example, the Darling Downs district reported good pavement resilience with the use of lime stabilised subgrade in combination with a foamed bitumen stabilised base layer. These pavement sections performed well in a subsequent flood event.

Other districts reported pavement treatment types that have survived subsequent floods, including modified base and unbound granular base over stabilised subbase. Most TNRP pavement restoration works are at the early stage of life, and a longer monitoring period is therefore required to assess the pavement resilience of these treatments.

2.2.9 Emergent Work Repairs

Emergent work repairs are works carried out to restore public access shortly after flooding events. These are often temporary patching works carried out in all regions. The percentage of emergent works that remain as final treatments varies across regions. RPOs reported between 1-2% to 20-40% of emergent works retained as final treatments.

The high percentage of some emergent works being retained as final treatments is mainly due to changes in funding. Furthermore, the maintenance treatments were performing well at the time of the funding refinements. The long-term performance of these treatments is currently unknown.

2.2.10 Adequate Pre-construction Investigation and Testing

Some regions emphasised the importance of having adequate pavement testing. It was noted that adequate pavement testing should be conducted early in the project. Early testing allows pavement treatment solutions to be refined before construction begins. It also provides an opportunity for RPOs to have a better handling of the laboratory testing capacity.

Adequate investigation and testing are often time-consuming. The laboratory testing capacity should not be overlooked. The test results provide important information to RPOs, such as:

- Material characteristics of existing pavement material – this affects the level of recycling and quantity of imported material that are required for a project.
- Careful selection of the stabilising agent and application rate reduces the risk of pavement cracking and allows RPOs to lock-in the supply of stabilising agents early in the pavement program.

- Subgrade characteristics are important aspects of pavement design and construction – this is usually determined using laboratory and field testing.

2.2.11 Sealing Practices

A prime coat followed by a double seal is a common treatment, although some regional variations exist. Some RPOs reported bleeding seals in their TNRP projects. The sealing practice under TNRP is currently being reviewed by another NACOE research project (P36) entitled *Initial Seals in Queensland*.

2.3 Risks, Innovations and Sites Suggested by RPOs for Further Monitoring

Participants were asked to report on the risks of TNRP works undertaken in their districts, and innovations that they believe others in the state should be aware of. A list of sites for performance monitoring was recommended by RPOs and is presented in this section.

2.3.1 Key Pavement Risks – Treated Pavements (Post-flood Event)

RPOs were asked to identify key pavement risks for treatments that were used in their districts. The pavement risks identified were:

- seal designs (risk of bleeding and embedment issues)
- saturated subgrades that were not treated and left in the final pavement structure
- early cracking due to overdosage in the cementitious modified layer
- emergent works that were initially intended to be a temporary treatment, but no subsequent permanent treatment was applied.

2.3.2 Pavement Technology Successfully Applied During TNRP

RPOs were asked to identify pavement innovations that they have successfully implemented. After reviewing the list of innovations reported by the RPOs, the project team concluded that many of the pavement treatments were not true innovations. Quite often, some of the treatments had previously been implemented in other regions. The list of treatments is summarised in Table 2.3.

Table 2.3: Pavement treatments successfully applied during TNRP

Pavement innovations
Use of 1% general blended (GB) cement in base allows early trafficking. In particular, this addresses the issue on the moisture sensitivity of some granular material
In situ modification of Type 3 unbound granular material
Improve strength of white rock (with CBR < 80) through cementitious modification
Lime stabilisation of subgrades
Instead of lime, cement was used as the secondary agent in foamed bitumen stabilisation work
Use of geotextile/fabric layers and geogrids for construction over low-strength subgrade areas
Use of slag blends as a stabilising agent to increase working time and control of shrinkage cracking
Bitumen treated base (BTB)
Single pass mixing during cement modification to avoid degradation of existing materials
Improve side-track trafficability by using 3% cementitious stabilising agent
Process control for remote pavements – Local Government Area (LGA) often reduces the testing requirement of proven process
Use of repeated load triaxial (RLT) test to characterise behaviour of granular base material
RPOs coordinate the supply of quarry material

2.3.3 Sites for Future Monitoring Nominated by RPOs

RPOs suggested some pavement sites for future monitoring. Details of the monitoring sites are presented in Table 2.4. It was noted that most of the pavement treatments were only completed within the last few years, and long-term performance information is not yet available.

Table 2.4: Sites suggested by RPOs for future monitoring

RPO	Road	Job no.	Pavement treatments
Central West district	Landsborough Highway (a) 208/13B (Augathella – Tambo) – LGA 208 (Blackall – Tambo Regional Council) (b) 205/13E (Barcaldine – Longreach) – LGA 205 (Barcaldine Regional Council) (c) 241/13E (Barcaldine – Longreach) – LGA 241 (Longreach Regional Council)		Different 150 mm overlay types over 200 mm cement stabilised subbase of WQ35 top-up material mixed with existing pavement (7-days UCS 1–1.5 MPa)
Far North district	Bruce Highway (Ingham – Innisfail) (10N) near El-Arish Range (LGA 216 – Cassowary Coast Regional Council)	216/10N/660	Foamed bitumen stabilisation
	Mulligan Highway (Lakeland – Cooktown) (34C) near Black Mountain (LGA 220)		Stabilisation of Type 3 gravels
South West district	Warrego Highway – Miles to Roma (18D)	259/18D/650	Bitumen treated base
	Warrego Highway – Miles to Roma (18D) West of Jackson	259/18D/650 259/18D/67H (reseal)	Cracked modified pavement – (note: ch. 57–61.1 km, Type E full width stabilising treatment with 10 mm AMC5 primerseal,14 mm S0.7S seal 250 mm 3% cement: slag (35:65) was cracking post-construction. The design life is 20 years.
	Carnarvon Highway (Roma – Injune) 24A, near St George		Marginal material

2.4 Prioritisation of Issues

Participants were asked to prioritise the issues; they were identified as follows:

- To minimise the pavement damage from future flooding events, it is important to keep water away from the pavement. This can be achieved by maintaining seals in good condition and ensuring that table drains and side drains are properly maintained. Both measures will reduce the amount of moisture ingress into the pavement. It was also highlighted that overseas research suggests that sealed shoulders are extremely effective in keeping moisture out of the pavement.
- Three types of pavement treatments were identified for further study, namely cement modification/cement stabilisation, foamed bitumen stabilisation, and the use of geogrids and geotextile for subgrade improvements.
- Better funding submission guidelines would be useful. (It is noted that issues surrounding funding eligibility and funding submission requirements are outside the scope of this project).

3 PAVEMENT TREATMENT TYPES BY REGIONS

3.1 Introduction

The information collected during the workshop provided an understanding of the types of treatments used in various regions. Work descriptions used in the workshop varied by region. This complicated the task of summarising TNRP treatments at a state-wide level or retrieving pavement treatment information of a particular road.

TMR's ARMIS database provides both consistency and the level of detail required. An ARMIS data viewer tool was developed to manage the vast amount of collected data. The tool is designed to be highly customisable to allow for interrogation of various pavement-related issues.

This section provides a brief description of the tool, presents a high-level summary of the data, outlines some detailed findings on specific issues, reports early-age pavement performance and recommends areas for further investigation. It is noted that only high-level summary and selected screenshots from the tool are presented in this report. The tool has been provided to TMR in an electronic format.

3.2 ARMIS Data Viewer Tool

The ARMIS data viewer consists of a query tool, a Microsoft Access database, and a reporting tool in Microsoft Excel format. An electronic copy of the tool has been provided as part of Year 1 project deliverables.

The query tool uses input from a subset of the ARMIS data. A series of queries designed to interrogate the data for various topics was developed. The outcome of this process is to export a master table to Microsoft Excel for reporting and mapping.

The reporting tool allows flexibility for charts to be dynamically controlled by the user. A series of predefined standard charts is presented to illustrate the findings. A high-level summary is provided at the state-wide level and more detailed summaries are provided for the districts.

3.2.1 Data Source and Coverage

The ARMIS data is the main data source for the tool. It is understood that not all TNRP data has been entered into the ARMIS database, It is estimated that about 75% of the data have been uploaded, and this will be confirmed in Year 2 of the study.

As at April 2015, there were approximately 58 500 rows of ARMIS data. This represents 4950 lane kilometres of pavement works under TNRP from 2010 to 2014. Table 3.1 provides a breakdown of TNRP work by the district.

Table 3.1: TNRP treatment length across Queensland

District	Lane-km (km)
South West	995
Central West	962
Fitzroy	645
North West	642
Wide Bay/Burnett	450
Far North	374
Mackay/Whitsunday	334

District	Lane-km (km)
Darling Downs	285
Northern	179
South Coast	48
North Coast	23
Metropolitan	13
Total	**4950**

The following attributes were included in the ARMIS database:

- TNRP project reference
- location reference
- inventory
- pavement layer information
- traffic count information
- road condition data.

A financial summary spreadsheet for most TNRP work was also used to complement the above data set. The financial summary spreadsheet should be updated using the most recent data available in Year 2.

Condition data collected using the traffic speed deflectometer (TSD) was made available at a later stage of this project through another NACOE project (A9). TSD data will be incorporated in the Year 2 program to enhance the pavement condition monitoring.

Only significant pavement treatments were recorded in ARMIS. This includes work that changed the road configuration in terms of road width, depth and pavement type over extensive lengths. Maintenance patching to repair local failures was not recorded.

In Year 1, the focus of the analysis was to report the final pavement treatment used under the TNRP program. The analysis did not consider whether the alignment was raised (i.e. overlay) as a result of the pavement restoration work, nor did it consider if the material was imported or the existing pavement material was reused. These aspects can be investigated in the future.

3.2.2 Treatment Cataloguing

For each ARMIS entry (100 m section), an ARMIS layer code was logged for every layer in each lane. The main function of the query tool is to translate these codes into discernible treatment types. The treatment types are grouped into a higher treatment class for ease of summarising and presentation.

The transformation matrix in Table 3.2 was used to summarise the treatment classes.

Table 3.2: Treatment category

No.	Treatment class	Treatment type	ARMIS layer code
1	Surfacing only	Asphalt only	G, H, I and M (Fabric)
		Sprayed seal only	J, K, L, N and M (Fabric)
2	Bitumen stabilised	Bitumen treated base	D (except D1)
		Foam bitumen stabilised base	D1
3	Cement stabilised	Cement modified base	C4 or B3
		Cement modified on cement treated base (CTB)	
		CTB	C1, C2, C3
		CTB on cement modified base	
4	Granular and cement stabilised subbase/base	Cement modified on granular	(C4 or B3) on B
		CTB on granular	C1, C2, C3 on B
		Granular on cement modified	B on (C4 or B3)
		Granular on CTB	B on C1, C2, C3
5	Granular only (unsealed)	Granular re-sheeting (unsealed)	B as top layer
6	Granular only (with seal surfacing)	Granular layer	B with seal/asphalt as top layer
7	Other	Concrete floodway	E

Unfortunately, the ARMIS database does not provide key design parameters necessary to differentiate cement modification and stabilisation treatments. It is speculated that some of the treatments identified as cement stabilised may be, in fact, cement modification, and vice versa.

For subgrade treatments the following ARMIS layer codes were used:

- A5 for stabilised subgrade
- A6 for rock fill
- C5 for lime stabilised subgrade.

3.3 Data Interpretation

The ARMIS data viewer tool provided a summary of pavement treatment information as presented in Table 3.3 with more specific treatment types tabulated in Table 3.4. The geospatial layout of the TNRP treatments is illustrated in Figure 3.1 along with the locations where reactive soils are present. Expanded views of selected districts from Figure 3.1 are shown in Figure 3.2. A graphical breakdown of the different pavement treatments lengths is provided in Figure 3.3.

Table 3.3: Summary of TNRP treatment class (km)

District	No treatment	Bitumen stabilised base	Cement stabilised base	Granular and stabilised subbase / base	Granular only (sealed)	Granular only (unsealed)	Surfacing only	Other
Central West	29.4		174.4	147.6	46.5	530.0	32.9	1.3
Darling Downs	7.3	58.3	95.2	43.0	36.4	2.2	41.9	0.4
Far North	12.5	21.1	72.2	49.7	100.0	101.2	17.1	0.5
Fitzroy	40.4		343.7	117.5	11.8	86.6	44.1	0.6
Mackay/Whitsunday	2.9	63.7	137.9	61.3	22.6	21.5	24.4	
Metropolitan	0.2	0.8	10.1		1.1		0.5	
North Coast	1.6		4.8	1.8	9.3		5.6	0.1
North West	95.0	2.5	393.4	13.8	42.9	53.1	41.4	
Northern	0.4	53.5	97.8	13.9	6.6		6.3	
South Coast	2.8	3.6	9.0	10.5	15.3		6.2	0.3
South West	79.9	41.2	401.3	233.7	48.9	43.2	146.6	0.3
Wide Bay/Burnett	16.6	0.2	307.5	26.5	44.8	0.2	52.3	2.2
Total	**289.0**	**244.9**	**2047.3**	**719.3**	**386.2**	**838.0**	**419.3**	**5.7**
Percentage (%)	**5.8**	**4.9**	**41.4**	**14.5**	**7.8**	**16.9**	**8.5**	**0.1**

Table 3.4: TNRP treatment type summary (km)

District	Asphalt only	Sprayed seal only	Bitumen treated base	Foam bitumen stabilised base	Cement modified base	Cement modified on CTB	Cement modified on granular	Granular on cement modified	CTB	CTB on cement modified base	CTB on granular	Granular on CTB	Granular layer	Granular resheeting (unsealed)	Concrete (floodway)	No treatment	Total
Central West	1.4	31.5			174.4		51.5	96.1					46.5	530	1.3	29.4	962
Darling Downs	28.8	13.1	9.3	49	94.7		16.9	26.1	0.5				36.4	2.2	0.4	7.3	285
Far North	10.6	6.5	0.8	19.1	72.2	1.2	16.5	25.2			4.1	3.9	100	101.2	0.5	12.5	374
Fitzroy	7.5	36.6			337.7		18.1	97.2	6			2.2	11.8	86.6	0.6	40.4	645
Mackay/Whitsunday	3.1	21.3			110.2	26	40.8	11.1	27.7	37.7	2.4	7	22.6	21.5		2.9	334
Metropolitan	0.2	0.3	0.8		10.1								1.1			0.2	13
North Coast	0.9	4.7			3.5		0.6	1.1	1.3			0.1	9.3		0.1	1.6	23.2
North West	4.2	37.2		2.5	378		5.4	8.2	15.4		0.2		42.9	53.1		95	642
Northern	3	3.3			95.3	53.5	3.3	9.4	2.5		1.2		6.6			0.4	179

District	Asphalt only	Sprayed seal only	Bitumen treated base	Foam bitumen stabilised base	Cement modified base	Cement modified on CTB	Cement modified on granular	Granular on cement modified	CTB	CTB on cement modified base	CTB on granular	Granular on CTB	Granular layer	Granular resheeting (unsealed)	Concrete (floodway)	No treatment	Total
South Coast	6	0.2	0.5	3.1	9		7.1				1.6	1.8	15.3		0.3	2.8	48
South West	5.5	141.1	41.2		401.3		144.6	89.1					48.9	43.2	0.3	79.9	1045
Wide Bay/Burnett	30.9	21.4			306.9	0.2	23.5	2	0.6		0.2	0.8	44.8	0.2	2.2	16.6	450
Grand total	**102.1**	**317.2**	**52.6**	**73.7**	**1993.3**	**80.9**	**328.3**	**365.5**	**54**	**37.7**	**9.7**	**15.8**	**386.2**	**838**	**5.7**	**289**	**4950**
Percentage of total (%)	**2.1**	**6.4**	**1.1**	**1.5**	**40.3**	**1.6**	**6.6**	**7.4**	**1.1**	**0.8**	**0.2**	**0.3**	**7.8**	**16.9**	**0.1**	**5.8**	**100**

Figure 3.1: TNRP treatment type map – state overview

Figure 3.2: TNRP treatment type map – selected districts

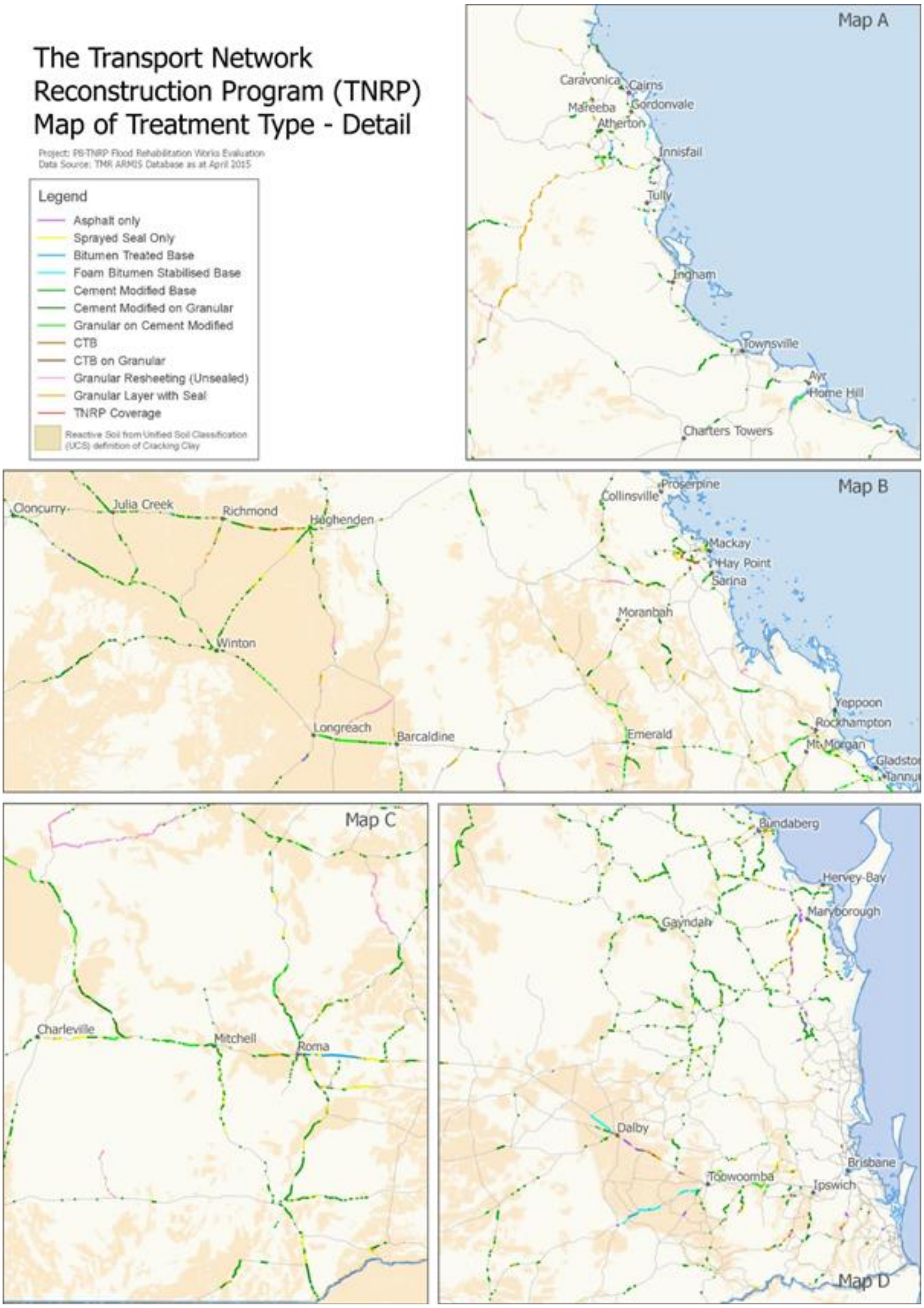
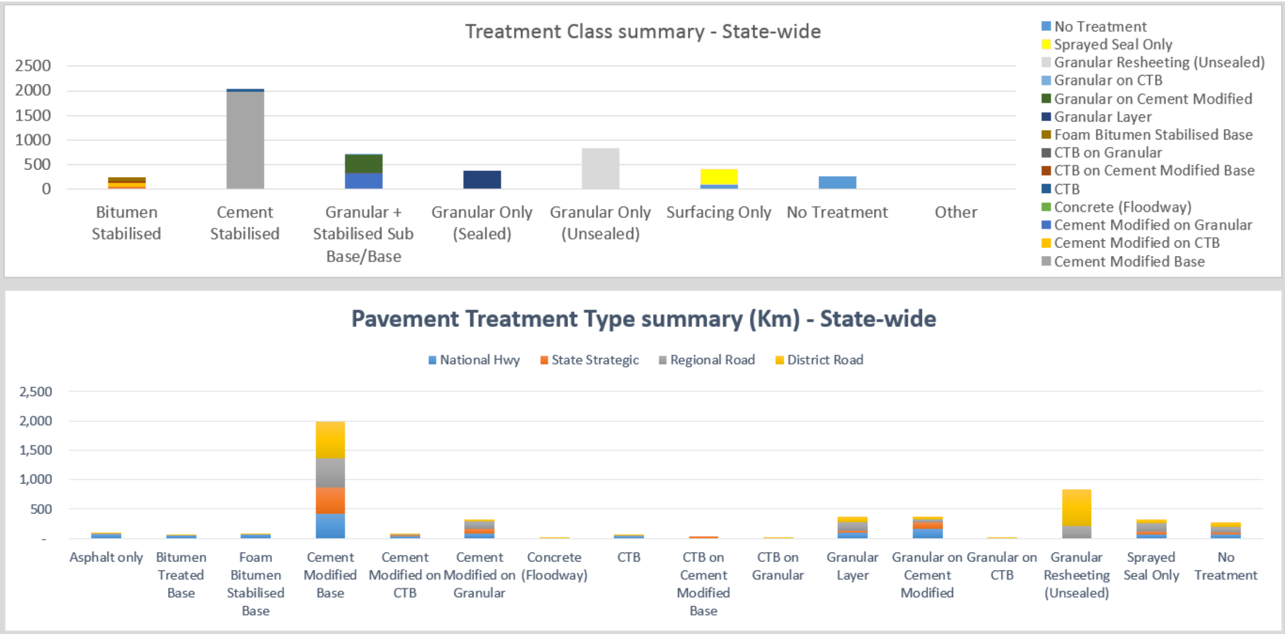


Figure 3.3: Treatment class and type



From the total length analysed, 289 km or 5.8% was categorised as 'no treatment'. A closer look at the data reveals that this was due to either no ARMIS layer entry being made or the construction date entered was earlier than the flooding events. Note that for the purpose of treatment categorisation, an arbitrary date of 1 January 2010 was used to mark the start of the TNRP in the database.

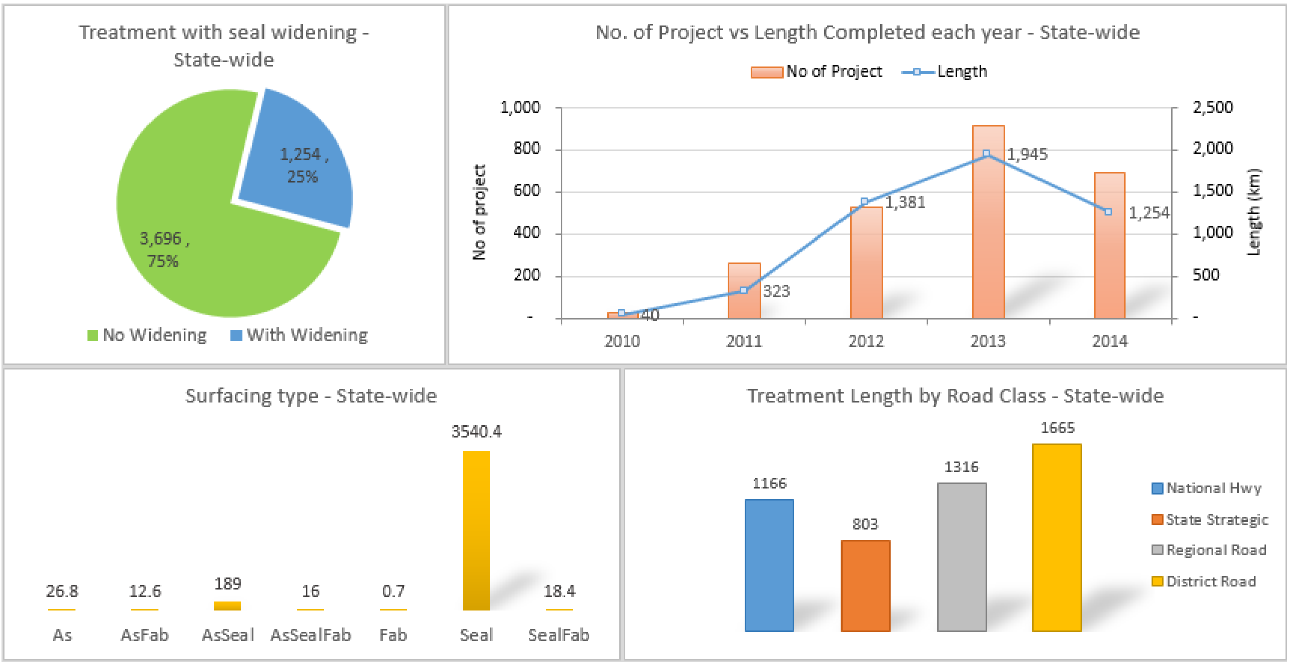
During the SPO/RPOs workshop, it was noted that RPOs often selected different treatments based on availability of funding and the strategic importance of the road. Therefore, it is logical to summarise the pavement treatments by road class into the national highway, state strategic, regional and district. A summary is presented in Table 3.5.

Table 3.5: Summary of pavement treatments by road class (km)

Treatment type	National highway	State strategic	Regional	District	Total
Asphalt only	67.0	5.0	11.0	19.1	102.1
Sprayed seal only	60.6	49.8	144.5	62.3	317.2
Bitumen treated base	50.8			1.8	52.6
Foam bitumen stabilised base	66.4		3.1	4.2	73.7
Cement modified base	422.6	453.5	486.5	630.7	1993.3
Cement modified on CTB	34.5	11.7	18.8	15.9	80.9
Cement modified on granular	90.4	79.4	115.3	43.2	328.3
Granular on cement modified	169.4	99.0	56.7	40.4	365.5
CTB	29.7	1.4	16.0	6.9	54.0
CTB on cement modified base	0.5	37.2			37.7
CTB on granular	2.2	2.1	2.9	2.5	9.7

Treatment type	National highway	State strategic	Regional	District	Total
Granular on CTB	2.6		2.6	10.6	15.8
Granular layer	93.9	36.7	144.7	110.9	386.2
Granular re-sheeting (unsealed)	1.8	1.2	207.4	627.6	838.0
Concrete (floodway)	0.2	0.2	2.8	2.5	5.7
No treatment	73.3	25.3	104.0	86.4	289.0
Totaltotal	1165.9	802.5	1316.3	1665	4949.7
Percentage of total (%)	**23.6**	**16.2**	**26.6**	**33.6**	**100.0**

Figure 3.4: State-wide summary of program features (part 1)



The following observations were made after analysing the above data:

- Table 3.3 presents the most common treatment classes used across the state:
  - — cement stabilised/modified layer (41.4%)
  - — granular layer with cement stabilised/modified layer as base or subbase (14.5%)
  - — granular re-sheeting of unsealed road (16.9%).
- The map in Figure 3.1 suggests that cement modified base, on its own or with a layer of granular material as base or subbase is the preferred treatment. There are also considerable lengths of foamed bitumen stabilised base constructed on reactive subgrade located west of Toowoomba and Dalby. These sections are potential candidates for long-term pavement performance monitoring.
- Cement modified base is the most used treatment type across the state (total 1993 km). It is followed by granular re-sheeting (total 838 km). The granular re-sheeting is mainly used on the district and regional roads in the Central West and Far North districts.
- When comparing treatments across road classes it was noted that:

    - cement modification/stabilisation was the dominant treatment used widely in all road classes
    - a high percentage (73%) of upside-down (or inverted) pavements, that is pavements with a granular base over a cement modified/stabilised layer, was used in higher-order roads (national and state strategic). For lower-order roads, gravel re-sheeting of unsealed roads was the dominant treatment
    - bitumen treated base and foamed bitumen stabilised base were used almost exclusively along the National Highway
- The number of pavement-specific projects delivered through the four years of operation of the TNRP is shown in Figure 3.4. The districts proved that they can manage multiple contracts with various degrees of complexity simultaneously. At the peak of construction, some districts delivered more than 130 projects for the year. This includes 139 projects being delivered in Fitzroy district in 2013 and 138 projects in South West district in 2014.
- Sprayed seals were used widely across the TNRP, although sufficient information on the specific sprayed seal types used is not available in ARMIS. Asphalt surfacing was used for only a small part of the network repaired with the total pavement length of asphalt-only treatment being 100 km. The length of pavement with a sprayed-seal-only treatment (reseal) is 316 km, which also represents a small portion of the repairs. The reseal treatment appears to be independent of the class of road.
- Despite an early interest in the use of foamed bitumen stabilisation, the treatment was not used widely. Reasons may be related to the cost or availability of testing/construction equipment during the TNRP, as well as the high moisture subgrade environment. Districts that used these treatments include:
    - Darling Downs (49 km)
    - Far North (19.1 km)
    - South Coast (3.1 km)
    - North West (2.5 km).
- The workshop revealed that there were significant lengths of road widened during the TNRP. Figure 3.4 confirms that 25% of the treated roads were widened. The length of treatment with widening is evenly distributed across the road classes.

Figure 3.5: State-wide summary of program features (part 2)

The following observations were made after analysing the data in Figure 3.5:

- Significant lengths of roads were restored with the available funding. Central West and North West districts were able to achieve the greatest length of repair per dollar spent, which may be due to the extensive length of unsealed roads in those districts.
- Repair costs per kilometre of road varied between districts, even for districts with similar length of repair. This may be due to treatment types or underlying subgrade conditions.

- Upside-down (or inverted) pavements were adopted in almost all districts except for Metropolitan, with greater use in Fitzroy, Central West and South West districts.
- Upside-down pavements were used in all road classes but represent a small percentage of the total stabilised treatments. A significant proportion was used on the national highway.
- Subgrade stabilisation was used in most districts, with North West, Darling Downs and Mackay/Whitsunday districts using the largest amount.

3.4 Findings and Risks from Pavement Treatment Investment

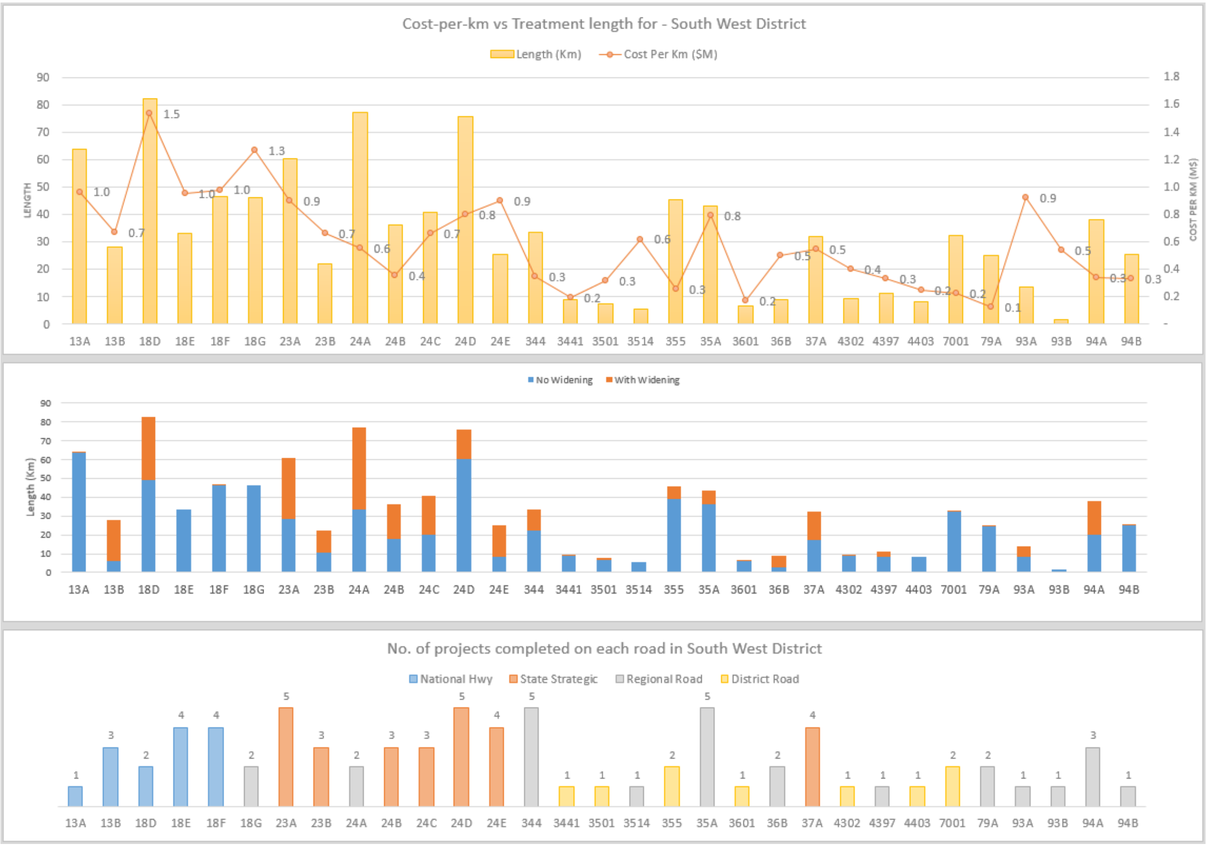
Value for money is the driving force behind treatment selection. Figure 3.6 provides a preliminary screening of the investment value (cost per kilometre against length treated).

3.4.1 Comparison Tool

For each district, the reporting tool provides three charts for screening the investment value.

The top chart in Figure 3.6 gives an indication of the value for money for different projects. The next two charts provide information on the amount of widening and the number of projects carried out on the road due to multiple flood events.

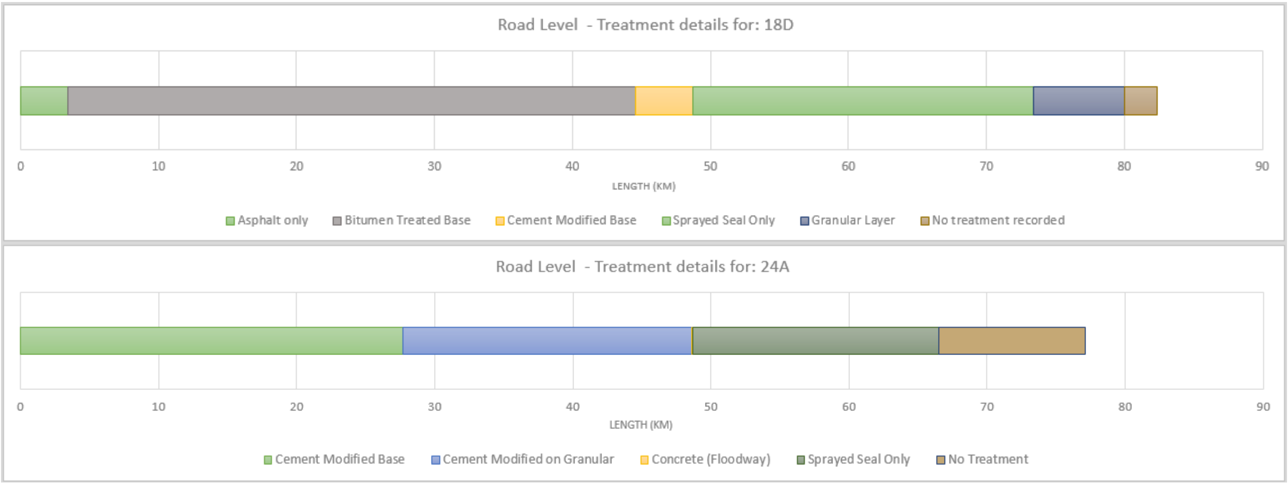
Figure 3.6: Investment risk identifier – example for South West district



The reporting tool can also provide a breakdown of the treatment types on each road. As an example, Figure 3.7 compares the treatments used for road 18D and 24A in South West district.

While the total length reconstructed is similar, the cost of restoring road 18D is more than twice the cost for road 24A. The difference can be explained by the type of pavement treatment selected for road 18D (national road) and road 24A (regional road). For 18D, a more expensive pavement treatment involving the construction of bitumen treated base was used. On the other hand, a lower-cost cement modified base treatment was used on road 24A.

Figure 3.7: Treatment type by road



3.4.2 *Roads with High Return on Investment*

Table 3.6 shows the roads with the highest return on investment (in terms of length constructed) determined based on value for money (VfM) defined by the repair length divided by cost per kilometre. The top 10 for national highways and the top 5 for state roads are presented.

This project collated information on the design, treatment types, cost and construction practice. A performance validation of these roads under a long-term monitoring program is therefore necessary. Once validated, TMR will have a suite of cost-effective treatments with documented practices that can be incorporated in the flood reconstruction guidelines.

Table 3.6: Roads with high return by road class

Road class	Rank	Road ID	District	Cost per kilometre ($M)	Length (km)	VfM factor
National highway	1	14C	North West	0.2	63.8	354.47
	2	13G	Central West	0.3	54.5	155.98
	3	14D	North West	0.3	44.0	147.05
	4	13H	North West	0.5	56.8	126.01
	5	13B	Central West	0.7	80.0	118.94
	6	14B	North West	0.2	20.1	113.81
	7	14E	North West	0.2	21.2	98.16
	8	13A	South West	1.0	63.8	66.08
	9	18D	Darling Downs	1.5	97.0	63.00
	10	18F	South West	1.0	46.7	47.61
Regional road	1	79A	South West	0.1	25.0	197.96
	2	99C	Central West	0.4	57.4	155.61
	3	188	Fitzroy	0.1	15.2	146.35
	4	24A	South West	0.6	77.0	138.74
	5	99D	Central West	0.4	47.1	133.26

Road class	Rank	Road ID	District	Cost per kilometre ($M)	Length (km)	VfM factor
State strategic	1	24B	South West	0.4	36.3	102.21
	2	26A	Fitzroy	1.0	97.6	99.39
	3	24D	South West	0.8	75.6	94.45
	4	23A	South West	0.9	60.1	66.22
	5	24C	South West	0.7	40.6	61.27
District road	1	89B	Far North	0.2	129.3	791.59
	2	85A	Fitzroy	0.1	40.5	611.35
	3	5703	North West	0.1	43.9	545.24
	4	78A	North West	0.2	121.3	490.56
	5	443	Central West	0.2	62.8	411.42

3.4.3 Roads with High Investment

There are sites which are inherently costly for road reconstruction, for example, reactive subgrade areas, sites with unstable geotechnical conditions and remote areas that demand high establishment cost and long material haulage.

The likelihood of pavement failure becomes lower as the road class increases due to the higher design standards. At the same time, the consequences of failure typically increase as the road class increases. Sections with high investment costs are identified in Table 3.7 and will be reviewed in Year 2 of the project to determine the associated reasons for the high costs and the performance of the high-cost treatment.

Table 3.7: Roads with low return on investment by road class

Road class	Rank	Road ID	District	Cost per KM ($m)	Length (km)	VfM factor
National highway	1	10G	Mackay/Whitsunday	4.1	8.1	1.98
	2	10L	Northern	3.0	7.7	2.61
	3	10H	Mackay/Whitsunday	3.8	11.6	3.07
	4	10F	Fitzroy	1.0	3.3	3.39
	5	10A	Wide Bay/Burnett	0.6	2.4	3.82
	6	10J	Mackay/Whitsunday	2.3	9.9	4.25
	7	10K	Mackay/Whitsunday	3.2	14.3	4.43
	8	15B	North West	0.7	3.7	5.21
	9	10N	Far North	3.3	19.2	5.87
	10	10P	Far North	1.7	11.0	6.55
Regional road	1	93E	Central West	3.4	1.7	0.50
	2	856	Mackay/Whitsunday	6.4	3.8	0.60
	3	163	Wide Bay/Burnett	4.7	3.2	0.68
	4	166	Wide Bay/Burnett	21.6	18.8	0.87
	5	809	Far North	1.4	1.4	0.97
State strategic	1	16D	Central West	2.1	2.0	0.96
	2	33B	Mackay/Whitsunday	5.8	12.1	2.10

Road class	Rank	Road ID	District	Cost per KM ($m)	Length (km)	VfM factor
	3	98A	Mackay/Whitsunday	3.4	14.0	4.09
	4	19C	Wide Bay/Burnett	1.6	8.1	5.01
	5	16C	Central West	0.8	5.1	6.64
District road	1	5324	Mackay/Whitsunday	6.3	3.4	0.54
	2	1632	Wide Bay/Burnett	3.8	3.4	0.91
	3	5302	Mackay/Whitsunday	3.9	7.6	1.94
	4	486	Wide Bay/Burnett	2.0	4.4	2.23

3.4.4 Emergent Works Left as Final Treatment

Emergent work is a short-term maintenance treatment intended to restore access and is not meant to be a long-term solution. Leaving emergent works as a final treatment can result in premature deterioration depending on the treatment and site conditions. It was intended to confirm the proportion of such work. This task, however, was not achieved in Year 1 and may be pursued further in Year 2. It is noted that the lack of documentation on emergent work can be a problem.

3.5 Early Life Pavement Performance

3.5.1 Pavement Condition Index (PCI)

Pavement performance is measured by converting the current condition in ARMIS to the PCI. The procedure used to calculate the PCI is as follows:

1. The road condition attributes used include: roughness (IRI) in outer wheel path, 80th percentile of rut depth (mm), and crocodile cracking extent (% of area).
2. For every 100 m pavement section, the extent of roughness, rutting and crocodile cracking is converted into bins of good, fair, poor, bad and no data using criteria in Table 3.8.
3. The worst among the three condition attributes was selected as representative PCI for the section.

Table 3.8: Condition bins for PCI

Condition attribute	Good	Fair	Poor	Bad
Roughness (IRI)	0–3.8	3.8–5.5	5.5–8	> 8
Rutting (mm)	0–10	10–20	20–30	> 30
Crocodile crack (%)	0–15	15–30	30–50	> 50

It should be noted that the most recent data for the condition attributes was not always available. To increase the availability of performance data, information from the last three years, going as far back as 2013, was used. Of the three attributes, the extent of crocodile cracking has a wider data coverage and is therefore often reflected in the PCI.

The criteria used to determine the condition bins for PCI in Table 3.8 are considered applicable to higher-order roads and may not adequately reflect the assessments for lower-order roads. The criteria for the condition bins will be reviewed to refine the criteria for each road class as part of the deliverable for Year 2 of the project.

3.5.2 Current Condition Reporting based on PCI

A summary of condition distribution for all pavement works under TNRP is presented in Table 3.9 and Figure 3.8.

A review of the data indicates that there is a significant number of roads with no condition data (935 km). The majority of these are unsealed roads (827 km) which are not typically surveyed for roughness and rutting and for which cracking assessment is irrelevant.

Table 3.9: PCI distribution by treatment type by length (km)

District	No data	Good	Fair	Poor	Bad	Total	Percentage of poor and bad (%)
Asphalt only	4.3	83.5	8.4	4.1	1.8	102.1	5.8
Sprayed seal only	2.0	285.6	26.7	2.9		317.2	0.9
Bitumen treated base		52.3	0.3			52.6	0.0
Foam bitumen stabilised base		66.6	6.7	0.4		73.7	0.5
Cement modified base	41.4	1767.6	139.3	31.4	13.6	1993.3	2.3
Cement modified on CTB		75.6	2.7	1.8	0.8	80.9	3.2
Cement modified on granular	0.2	281.3	29.4	6.6	10.8	328.3	5.3
Granular on cement modified	2.3	341.5	19.5	1.0	1.2	365.5	0.6
CTB	0.2	48.6	3.9	0.1	1.2	54	2.4
CTB on cement modified base		37.7				37.7	0.0
CTB on granular		9.6		0.1		9.7	1.0
Granular on CTB		14.2	1.5	0.1		15.8	0.6
Granular layer	6.4	338.2	22.8	4.8	14.0	386.2	4.9
Granular re-sheeting (unsealed)	828.1	8.8	1.1			838	0.0
Concrete (floodway)	1.5	3.1	0.9	0.2		5.7	3.5
No treatment	53.4	203.4	27.5	3.1	1.6	289	1.6
Total	**939.8**	**3617.6**	**290.7**	**56.6**	**45**	**4949.7**	**2.1**

Figure 3.8: Condition distribution (PCI) vs length by treatment type

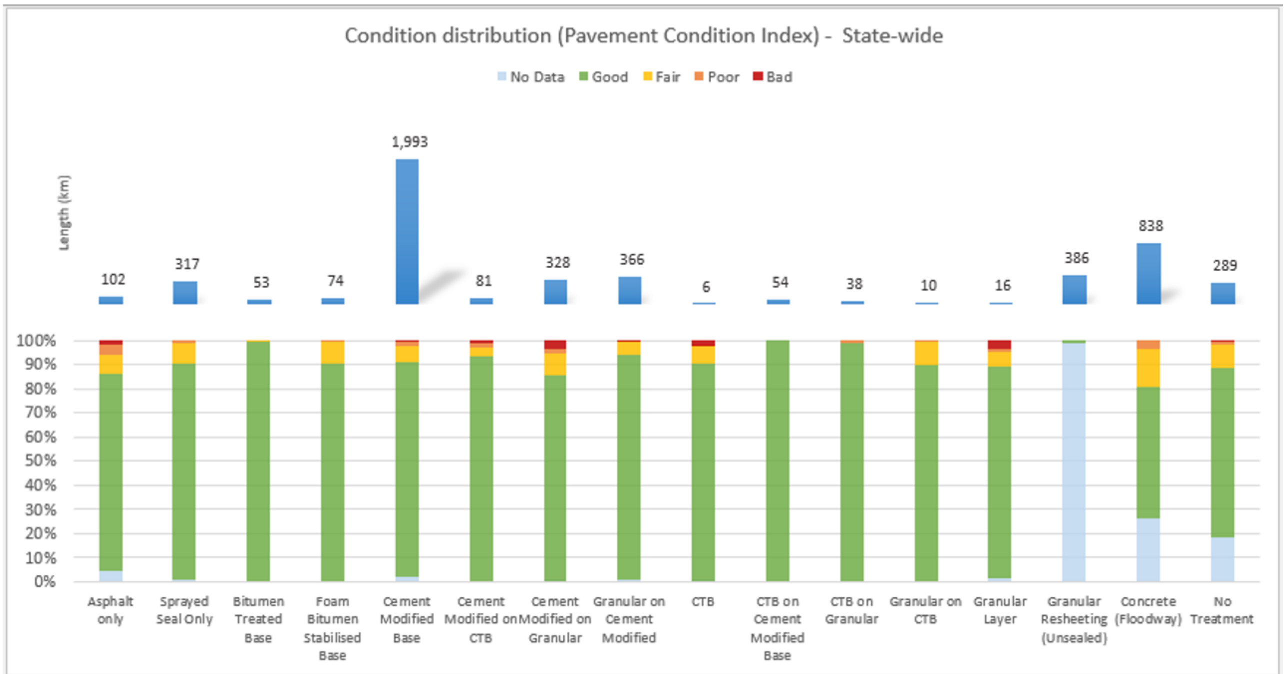


Figure 3.8 and Table 3.9 give an indication of the early age pavement performance. There are 102km of roads in poor and bad condition. A further 291 km show signs of early deterioration, currently in fair condition.

Year 2 of the project will continue to monitor the condition of TNRP repaired roads. Those roads currently in poor or bad condition will be monitored for signs of early deterioration and those in fair condition will be on the priority list to be monitored.

3.5.3 TNRP Works Currently in Poor to Bad Condition

Table 3.10 and Figure 3.9 present the PCI distribution of pavement sections in TNRP restoration works by length.

Five districts, including the Central West, Far North, North Coast, North West and Wide Bay/Burnett, have more than 10% of the repaired length showing significant early deterioration (i.e. pavement is in fair, poor or bad condition).

Table 3.10: PCI distribution of pavement sections by length (km)

District	No data	Good	Fair	Poor	Bad	Total	Percentage of poor and bad (%)
Central West	528.4	378.8	28.4	15.7	10.8	962.1	2.8
Darling Downs	7.8	252.0	18.2	5.8	0.9	284.7	2.4
Far North	110.2	229.2	24.1	8.8	2.0	374.3	2.9
Fitzroy	96.7	498.6	44.1	1.0	4.3	644.7	0.8
Mackay/Whitsunday	21.3	307.0	4.5	0.7	0.8	334.3	0.4
Metropolitan		11.5	1.2			12.7	0.0
North Coast		20.6	2.6			23.2	0.0
North West	105.6	457.9	46.1	10.6	21.9	642.1	5.1
Northern		170.4	4.8	2.1	1.2	178.5	1.8

District	No data	Good	Fair	Poor	Bad	Total	Percentage of poor and bad (%)
South Coast		43.6	4.1			47.7	0.0
South West	65.6	864.9	59.4	4.3	0.9	995.1	0.5
Wide Bay/Burnett	4.2	383.1	53.2	7.6	2.2	450.3	2.2
Total	**939.8**	**3617.6**	**290.7**	**56.6**	**45.0**	**4949.7**	**2.1**

Figure 3.9: TNRP works performance map (PCI) – June 2015

Pavement in poor and bad condition on the national highways poses a higher risk. There are 18 km of pavement in poor and bad condition as shown in Table 3.11. Most of this is located on road 14D between Richmond to Julia Creek in the North West district as shown in Map B in Figure 3.9. This is a relatively new section, treated with seal over a cement modified base in 2013.

Lower-order roads that have deteriorated rapidly are as follows:

- The Carnarvon Highway (24D) from Roma to Injune in the South West district. The road has been treated with a seal over cement modified base. Although low in severity, this state strategic road has over 20 km showing signs of early deterioration.
- Richmond to Winton road (5803), a district road from Richmond to Winton in the North West district was treated with a seal over cement modified base and has 17 km in poor or bad condition.
- Kennedy Developmental Road (99D) between Boulia and Winton in Central West has over 18 km of regional road that is in condition with a further 12 km that is in fair condition.

Table 3.11: Poor to bad condition roads in each road class

Road class	Poor (km)	Bad (km)	Total (km)
National highway	8.2	10.2	18.4
State strategic	6.6	5.6	12.2
Regional road	18.1	12.6	30.7
District road	23.7	16.6	40.3
Total	**56.6**	**45.0**	**101.6**

3.5.4 Condition of Trial Sections Suggested by Districts/RPOs

Sites suggested by RPOs for long-term monitoring are listed in Table 2.4. Figure 3.10, Figure 3.11 and Figure 3.12 summarise the current condition of the nominated roads for three districts.

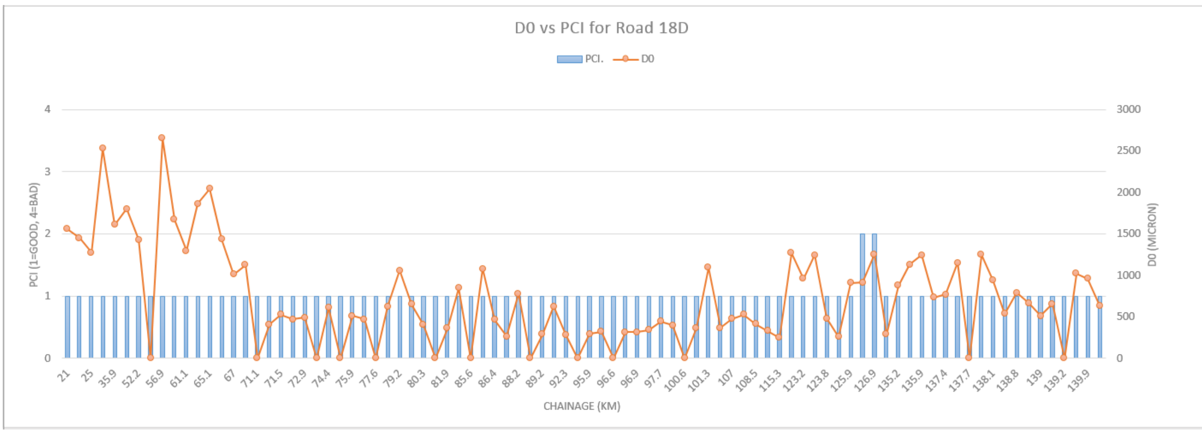
Figure 3.10: Condition of candidate monitoring section in the Central West district

Figure 3.11: Condition of candidate monitoring section in the Far North district

Figure 3.12: Condition of candidate monitoring section in the South West district

The estimated PCI condition of pavement sections was compared to TSD data. An example of the comparison is shown in Figure 3.13 for the Warrego Highway (18D). The figure shows that the strength information generally provides a useful complement to the pavement condition assessment. An exception is for the section between chainage 21 and 71 km. The TSD data shows relatively high deflections (indicating accelerated pavement deterioration) that are in good condition and does not show significant pavement deterioration. Future work can be carried out to improve the understanding of both sets of data.

Figure 3.13: TSD vs PCI example



4 PAVEMENT DESIGN METHODOLOGY

The TNRP design guidelines (Department of Transport and Main Roads 2013c) were developed by TMR to guide designers of reconstruction works. The guidelines are considered important because of a large number of contractual staff working on the program who may not be familiar with TNRP eligibility requirements and Queensland's materials and TMR's design and construction practices. The intention of these guidelines is summarised as follows:

- Reference all relevant TMR and Austroads design documents.
- Clarify appropriate application of design criteria for TNRP.
- Emphasise the need to identify and address contributory causes of pavement and subgrade damage.
- Provide new and updated design criteria that are not yet included in TMR design documentation, for example, criteria to improve resilience and to deliver more fit-for-purpose solutions, especially for 'brownfield sites'.

The TNRP design guidelines only serve as guidance. During the review of SPO/RPO workshop material, it was found that some regions have developed supplementary regional guidelines and specifications to meet their needs. Some of the modifications in which the project team is aware of are summarised in this section.

The road elements damaged during the floods of 2010-11 included pavements, batter slopes and structures such as bridges, culverts and floodways. The majority of the damage involved pavements.

4.1 TNRP Design Guidelines

The TNRP design guidelines generally follow the current design technical policies and standards. For pavement works, these policies and standards include (in order of precedence):

- The TNRP design guidelines (Department of Transport and Main Roads 2013c)
- TMR supplementary manuals and specifications (as authorised by the regional manager)
- TMR specifications and technical standards and standard specifications, for design of pavement rehabilitation treatments
  - *Pavement Rehabilitation Manual* (Department of Transport Queensland 1992)
  - AGPT05/11 *Guide to Pavement Technology - Part 5: Pavement Evaluation and Treatment Design* (Austroads 2011)
- TMR specifications and technical standards and standard specifications, for design of new pavements
  - *Pavement design supplement: supplement to 'Part 2: Pavement Structural Design of the Austroads Guide to Pavement Technology* (Department of Transport and Main Roads 2013a)
  - AGPT02-12 *Guide to Pavement Technology - Part 2: Pavement Structural Design* (Austroads 2012).

The design documents are referenced in Chapter 6 of the TNRP design guidelines (Department of Transport and Main Roads 2013c).

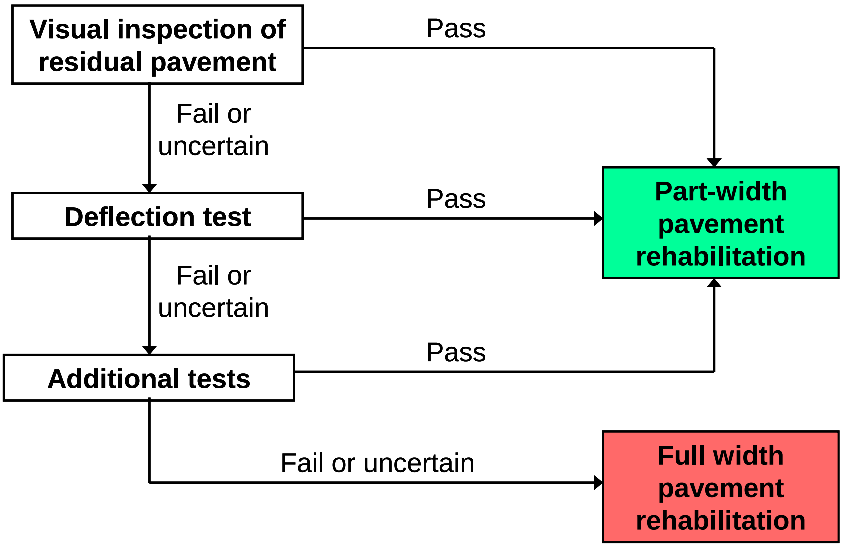
Methods recommended in the TNRP design guidelines for improving resilience are as follows:

- Improve pavement drainage by

  - reinstating or deepening of table drains
  - cleaning subsoil drains and culverts
  - repairing surface cracks
  - adding a geotextile seal
  - incorporating a drainage blanket at subgrade level.
- Reduce the impact of shoulder and embankment batter erosion by
  - providing increased flood protection on the downstream side of floodways
  - increasing under-drainage capacity for waterways.

The pavement works undertaken in TNRP can be grouped into pavement patching, part-width pavement rehabilitation, and full-width pavement rehabilitation. A diagram from the TNRP design guidelines is shown in Figure 4.1 which illustrates the process to determine the suitability of the residual pavement and subgrade. It is noted that deflection testing plays a significant role in this assessment. The process shown was adopted to ascertain an appropriate rehabilitation treatment where project timelines did not allow a full suite of tests to be undertaken.

Figure 4.1: Determination of the suitability of the residual pavement and subgrade under a part-width pavement rehabilitation treatment



Source: Department of Transport and Main Roads (2013c).

4.2 Regional Design and Construction Guidelines

Details of the specifications and guidelines that some RPOs have implemented are presented below.

4.2.1 South West District

A pavement treatment selection guide was prepared by the South West district. The document guides site inspections and the selection of various pavement treatments (Aurecon 2011).

4.2.2 Darling Downs District

The Darling Downs district developed a pavement design methodology for the low-order roads (Department of Transport and Main Roads 2011). Low-order roads will be considered as roads that meet the following criteria:

- priority 2 and 3, other and special
- daily equivalent standard axles (ESAs) < 1000 at year of opening (ESA per heavy vehicle factor of 2.52)
- in situ subgrade CBR > 3 (established with DCP)
- damaged section > 300 m in length.

The pavement design methodology provides selection criteria for various pavement restoration treatments with the intent to restore the pavement to its pre-event condition and provide consistent pavement performance between the surrounding road network and the restored pavement. The treatment details are summarised in Table 4.1.

Table 4.1: Summary of Darling Downs pavement restoration treatment for low-order roads

Treatment type (low-order roads)	Selection criteria	Treatment details
A – Granular overlay (design life five years minimum)	▪ Deflection greater than tolerable deflections ▪ Not low-lying and no height restrictions	▪ Repair significant pavement failures. May include subgrade treatments ▪ Add 'make up' material if insufficient pavement depth exists ▪ Rework to suitable depth 200–300 mm with an appropriate binder. A target UCS of 1.0–1.2 MPa ▪ Sealing regime (PMB or fabric seal)
B – Granular overlay in low-lying area (Expected design life 2–5 years) post-construction deflection testing to be carried out	▪ Deflection greater than tolerable deflections ▪ In low-lying areas and have height restrictions	▪ Repair significant pavement failures. May include subgrade treatments ▪ Add nominal 75 mm of 'make up' material ▪ Final surface not to increase by more than 50 mm ▪ Rework to suitable depth 250 mm with appropriate binder. A target UCS of 1.0–1.2 MPa ▪ Sealing regime (PMB or fabric seal)
C – Granular inlay (Expected design life 2–5 years) post-construction deflection testing to be carried out	▪ Discrete segments of low-lying road (e.g. floodways) within larger sections of road being restored with other treatment ▪ Height restriction	▪ Repair significant pavement failures. May include subgrade treatments ▪ Remove and replace 150 mm of pavement material ▪ Rework to suitable depth 250 mm with appropriate binder. A target UCS of 1.0–1.2 MPa ▪ Sealing regime (PMB or fabric seal)
D – Granular overlay for surface correction (Expected design life 2–5 years) post-construction deflection testing to be carried out	▪ Pavement failures > 20% or ▪ Roughness > 110 counts/km ▪ Deflection less than tolerable deflection	▪ Repair significant pavement failures. May include subgrade treatments ▪ Add 50 mm 'make up' material ▪ Rework to suitable depth 250 mm with appropriate binder. A target UCS of 1.0–1.2 MPa ▪ Sealing regime (PMB or fabric seal)

Treatment type (low-order roads)	Selection criteria	Treatment details
E – Asphalt overlay for surface correction (Expected design life 2–5 years) post-construction deflection testing to be carried out	▪ Pavement failures > 20% ▪ Roughness > 110 counts/km ▪ Deflection less than tolerable deflection	▪ Placement of asphalt/slurry corrector layer (nominal 20–50mm) to achieve a target reduction in roughness counts of 30 counts/km ▪ Sealing regime (PMB or fabric seal)

Note: The design subgrade for treatment types A to E was determined using the dynamic cone penetrometer (DCP).

The tolerable deflection is to be determined from the design traffic using either:

- chart 1 from Appendix G of the *Pavement Rehabilitation Manual* (Department of Transport Queensland 1992)
- tolerable deflection limits provided by Darling Downs district.

4.2.3 Central West District

A pavement design methodology report by Sinclair Knight Merz (2011) was published to outline the design approach used in the Central West district. It was noted that some of the design practices deviate from Department of Transport and Main Roads (2013a). The primary reasons for this deviation include availability of good quality aggregate, economics, climate and soil types. The need for the design methodology report was identified during a workshop held in Barcaldine on 23 May 2011. The report also suggested that the performance of the WQ35 base used in the district be investigated further to verify its suitability for use with the future traffic.

4.2.4 Fitzroy District

The project team was not aware of any supplementary design guidelines issued by the Fitzroy RPO. The limited design report provided suggested that the granular pavements were designed using the current Austroads empirical chart method. For other pavement types that contain bound layers (e.g. cement modified, foamed bitumen stabilised base etc.), a mechanistic-empirical design methodology utilising CIRCLY has been used.

4.2.5 Mackay/Whitsunday and Wide Bay/Burnett Districts

Based on the information provided, the project team was not aware of any supplementary design guidelines issued by the Mackay/Whitsunday and Wide Bay/Burnett regions. The designs undertaken were based on the current TMR design documentation for new and rehabilitated pavements. However, some inconsistency was noted in the way that the in situ cement modified layer is modelled. This may be due to the subsequent revision of TNRP design guidelines pertaining to the modelling of this material.

5 FINDINGS FROM FIELD TRIP TO SELECTED DISTRICTS

In April 2015, the NACOE project team (comprising staff from ARRB Group and TMR Engineering and Technology Branch) visited the Central West, South West and Fitzroy districts. The purpose of the trip was to gain a better understanding of the early life performance of selected TNRP pavement restoration work. Monitoring sites recommended by the district as presented in Section 2.3.3 were visited. The trip also helped in gathering additional project-specific data to augment the information provided during the SPO/RPOs workshop.

The trip also provided the opportunity to gather additional data and granular base samples to evaluate the performance of modified C granular base as part of a separate NACOE P4 Year 2 research project.

5.1 ROMA – Barcaldine – Emerald Trip

The trip was undertaken in April 2015 and the key findings were as follows:

- Early pavement performance was visually assessed along the Warrego Highway (Roma – Charleville) and Landsborough Highway (Morven – Longreach). The majority of the TNRP works were found to be structurally sound but with some areas exhibiting distress, which included longitudinal cracks (due to seasonal subgrade movement) and flushing of sprayed seal surfacing.
- Some quarries were visited which supplied gravel base material for projects along different sections of the Warrego and Landsborough Highway. The project team obtained laboratory data on the quarry material for further analysis (in conjunction with NACOE *Modified C Granular Base* project).
- The traffic speed deflectometer (TSD) maximum deflection measurements taken in 2014 showed good correlation with the expected performance of treatments along Landsborough Highway. The application of TSD as a tool to assist TNRP assessment will be explored further.
- Central West district shared information regarding its modified grading curves for WQ35 base material. Trial sections along Landsborough Highway (Barcaldine – Longreach), 13E, were visited to set up medium to long-term performance monitoring. The objective is to assess the performance of different gravel base overlay materials (e.g. Type 2.3, WQ35 and WQ35 with a modified grading). At this stage, early life performance is comparable across the different granular overlays.
- In the Fitzroy district, visual assessment of selected TNRP projects was conducted. The projects included the TNRP pavement sections along the Gregory Highway (27A) and Dawson Highway (46C). The sections with the cement modified base treatment were found to be structurally sound with no observed distress.

6 SUMMARY AND SCOPING FOR FUTURE YEAR STUDY

6.1 Summary

The purpose of this project is to identify key findings from the largest flood restoration program conducted in Queensland. This involves documenting the key lessons learnt, identifying pavement treatments performed along with their early age pavement performance.

This interim report presents the findings in Year 1. The focus of Year 1 was to gather information from the SPO/RPOs in addition to accessing the TMR ARMIS database for treatment cataloguing. These activities were used to scope the topics for future study, which is the key deliverable for Year 1. The key tasks of the scoping phase were as follows:

- Conduct a workshop with participants from the SPO and RPOs.
- Conduct on-site interviews with three RPOs (Central West, South West and Fitzroy).
- Collate information received from the SPO/RPOs workshop and on-site interviews.
- Investigate early age performance information of pavement treatments based on the ARMIS data.
- Identify specific areas for future study.

Pavement rehabilitation and maintenance are core activities of TMR. However, the flood recovery efforts performed under the TNRP involved unique challenges. These challenges included the need to complete construction within an accelerated time frame, adapting to constant scope refinements arising from changes in funding eligibility rules, and limited availability of resources (e.g. personnel, equipment, and materials) in different districts across Queensland. Although different environments existed between the various districts, a common finding was that moisture ingress into the pavement often leads to pavement failure. The problems with moisture ingress are complicated by pavements located on flat terrain with underlying reactive subgrade. Increasing the sealing width and raising the vertical alignment of roads was reported to reduce pavement damage in subsequent floods.

It appears that each RPO used different treatment selection criteria and selected various categories of pavement treatments. The choice of the treatments and the nominated design life were based on several factors, for example, funding availability, the strategic importance of the road, value for money, availability of local materials, availability of equipment, and maintenance preferences of the region.

The ARMIS database provides consistency and the necessary level of detail to quantify and identify general trends in the treatment selection criteria from the regions. An ARMIS data viewer tool was developed to assist with analysing the vast amount of collected data. The tool provides a mechanism to interrogate the vast amount of data, highlight key pavement treatments and provide a geospatial view of the available pavement treatment data. It also allows for assessment of the early life performance of the TNRP works.

The dominant pavement treatments determined through the ARMIS data viewer tool are generally in line with high-level summary statistics provided by the RPOs during the workshop. It was found that the top three pavement treatments (by length) were:

- cement modified base
- granular re-sheeting (unsealed road)
- granular overlay or remove and replace.

Sprayed seal was the most frequent surfacing used with the majority of the road repairs located in rural areas. Although not extensive, there were some subgrade improvements done during the program.

The RPOs prioritised three types of pavement treatments for further study, namely cement modification or stabilisation, foamed bitumen stabilisation, and the use of geogrids and geotextile for subgrade improvements.

The project identified pavements impacted by multiple flooding events and pavements suggested by the RPOs for condition monitoring. These identified pavement sections covering a range of different treatments and could be studied in future years.

A number of key pavement-related issues/findings were identified as follows:

- Local knowledge of the region is crucial in the success of flood restoration work. Most RPOs provided the required local knowledge in co-operation with the rest of the design and construction teams. In some regions, the local knowledge has been formalised as regional guidelines.
- Adequate pavement testing is essential to the selection of an appropriate treatment.
- Drainage is important in terms of the performance of pavements. The primary failure mode was due to moisture ingress into the main pavement structure. Measures such as full-width sealing, well-maintained seals and longitudinal drains are all very important.
- Some emergent works remain in place as the final pavement treatment. The performance of these treatments is unknown but where possible, will be monitored during future assessment.
- Some regions used the treatment of granular base over stabilised subbase, which is not the preferred treatment denoted in the TNRP design guidelines.
- Lime stabilisation of subgrade is promising for regions with reactive subgrade soil.

6.2 Early Performance based on Available Condition Data

Many of the findings outlined in this report are undergoing validation through performance evaluation. An early pavement life assessment using the PCI was employed with the following results:

- As anticipated, the majority of the works carried out under the TNRP are performing well with 90% in good condition.
- There are 100 km of pavement (2.5% of the TNRP work) which have deteriorated rapidly to poor or bad condition in the last two to three years. Year 2 of the project will investigate these failures to determine trends.
- Furthermore, 291 km of pavement (approximately 7% of the TNRP work) is in fair condition. The sections have been identified for further monitoring.

Year 2 will refine the assessment process used in Year 1 by incorporating the results of the TSD. Also, TMR will have additional pavement condition information available for the TNRP network.

6.3 Areas for Future Study

The next phase of the scoping study is to narrow down the study areas for the rest of the project. The potential topics for further study are listed in Table 6.1, grouped into four categories:

- collate information from the TNRP projects to provide future guidelines
- monitor pavement treatment projects

- monitor pavement, emergency and maintenance treatments
- monitor sprayed seal treatments.

The topics to be investigated in further detail will be discussed with the TMR project manager at the beginning of Year 2 of the research project.

Table 6.1: Potential topics for future study

Topic number	Topics	Findings from Year 1 scoping study	Justification for further study
COLLATE INFORMATION			
1	Collate standard drawings of pavement treatments	▪ RPOs provided typical pavement treatment drawings used. This covers a wide range of technology options adopted in the TNRP. ▪ Compiling and categorising the drawings is needed for wider circulation.	▪ Standard drawings can reduce response time in design and construction in future flooding events. ▪ With new findings from this project and other related NACOE projects, transfer knowledge onto standard drawings for wider circulation to industry and across TMR.
2	Collate drawings for concrete pavements over floodways	▪ Concrete floodways have been used in TNRP and these are typically over the top of different drainage structures. They are mainly located in regional or district roads. ▪ In remote areas, high-quality concrete that meets the requirement of MRTS40 may not be available.	▪ Current Austroads and TMR guidelines for concrete pavements are designed for high-speed or high-volume roads. Thickness, slab dimension and reinforcing details may not be applicable. ▪ MRTS40 QA requirements (testing frequency, trial mix, and flexural strength) may exceed requirements appropriate for floodway pavements. This elevates the construction cost of these resilient pavements for floodways.

Topic number	Topics	Findings from Year 1 scoping study	Justification for further study
3	Develop a single stand-alone document for guiding the repair of flood affected pavements	▪ Pavement design criteria for flood-affected pavements have been provided in Version 2 of the TNRP design guidelines (Department of Transport and Main Roads 2013c). The document covers a broad range of topics, and there is extensive referencing to other design manuals. ▪ TMR Engineering and Technology (E & T) presentation and findings from the material collected in the Year 1 study need to be incorporated into a stand-alone document.	▪ A stand-alone document specifically focused on pavement restoration after flooding events will be useful for the industry and TMR.
MONITOR – PAVEMENT TREATMENT PROJECTS			
4	Monitor and document the performance of the bitumen treated base (BTB) method	▪ BTB was used mainly on Warrego Highway 18D (approx. 63 km). ▪ It is a relatively new pavement technology. ▪ Some sections show minor rutting and bleeding seals.	▪ This technology has not been widely adopted in Queensland. The standard specification, and technical note is not available.
5	Investigate the use of TSD as a screening tool to evaluate TNRP pavement treatment works	▪ Deflection measurement is important for pavement rehabilitation. TSD measurements effectively delineate different pavement treatment sections along Landsborough Highway (13E). ▪ Strength data complements the current PCI method of assessment.	▪ Deflection testing is important and is used in different stages of TNRP (i) pre-flood evidence (ii) flood damage assessment (iii) input to rehabilitation design (iv) remaining life estimation in post-construction. TSD, which is a next-generation deflection testing device, has the potential to provide fast measurements at regular time intervals. This provides TMR with additional evidence to scope and justify funding eligibility for future flood events.

Topic number	Topics	Findings from Year 1 scoping study	Justification for further study
6	Evaluate performance of 'upside-down' pavements	▪ Approx. 380 km of upside-down pavement was used in TNRP. This comprises (i) granular over cement modified (ii) granular over CTB. The majority was used in Fitzroy, Central West and South West. ▪ Most of the pavements are located on the national highway network, as well as state strategic roads. ▪ RPOs did not report problems with the upside-down pavements. The workshop highlighted that the seal must be maintained to ensure no moisture ingress.	▪ Significant lengths of road were built using the upside-down approach. This may be contradicting the recommended treatment detailed in the TNRP design guidelines, which do not recommend granular over CTB. ▪ These pavements need to be identified and performance monitored.
7	Investigate the extent of early cracking failure in pavements due to 'over-dosage' of cement stabilisation treatment	▪ Some RPOs expressed concerns at over-dosage of cement modified/stabilised layer. Approximately 1986 km of cement modified base treatment has been used throughout the network across all road classes as a stress alleviating membrane (SAM) seal is typically used to safeguard cracking from the cement modified layer. ▪ A project site was identified in the South West region where the previously modified pavement was severely cracked.	▪ Given the significant length of cement modified base treatment used across the state, it is important to monitor the condition of these pavements. ▪ It is anticipated that overdosage issues will show up during early age of pavement life.
8	Monitor and further study the trial section along Landsborough Highway (13E) where different granular base materials were used	▪ The Central West RPO has set up a trial section along 13E which uses a range of granular base material over a stabilised subbase. ▪ The region is interested in monitoring this site, and identifying the best solution. ▪ The site visit in April 2015 by the project team did not identify a substantial difference in performance at this stage.	▪ 13E is an upside-down pavement and different granular base was used. The finding helps TMR to select appropriate granular overlay material.
9	Reduced standards have been adopted on some lower order roads. Assess their performance and the associated risk	▪ To meet budget and local constraints, RPOs used reduced design standards and guidelines. For example, Darling Downs region has implemented regional guidelines for low-order roads. At this stage the length where this has been applied is unknown.	▪ Regional standards and guidelines are important. However, it is important for TMR to monitor the performance of these pavements and compare it with other roads that were designed to the current engineering standard.

Topic number	Topics	Findings from Year 1 scoping study	Justification for further study
10	Evaluate the performance of treatments where high-slag blend has been used	▪ High-slag blend has the advantage of prolonged working time and longer-term strength gain. ▪ This has been used in some regions, particularly in South West where it was reported that 100% of the work used it.	▪ Long lengths of pavement were modified and stabilised. The performance of the high-slag blend should be evaluated and the results compared with results of other forms of stabilising agents.
11	Evaluate and monitor early life performance of TNRP treatments using available condition data	▪ Not all roads restored in TNRP have had recent condition data collected. ▪ TSD strength data should be incorporated.	▪ Early age monitoring is also essential to TMR. ▪ A better assessment of early age performance can be provided by updating available condition data in Year 2 and Year 3 of the project.
12	Compare performance of section with and without seal widening	▪ There has been a significant amount of seal widening done under TNRP (25%). ▪ There is a need to confirm long-term performance and potential benefit.	▪ The majority of the widening works were funded by the state. This can be included in the guidelines if proven more beneficial in the long-run.
13	Evaluate and monitor the performance of stabilised subgrade on its own or when combined with other treatment	▪ Subgrade stabilisation was highly recommended as an area of interest from the workshop.	▪ Documented performance of stabilised subgrade.
▪ **MONITOR PAVEMENT, EMERGENCY AND MAINTENANCE TREATMENTS**			
14	Evaluate performance of emergent repairs used for permanent works	▪ Emergent works were carried out shortly after the flood event to restore traffic access of the affected road network. Fitzroy and Darling Downs regions have both reported that some of the emergent works have remained as final treatment. ▪ Due to the nature of emergent works, there is usually a lack of documentation and records.	▪ Emergent works are often carried out under road maintenance performance contracts. The emergent works are often temporary in nature. ▪ TMR needs to identify the extent and type of these treatments. It is likely that emergent works can fail at an early stage.
▪ **MONITOR SPRAYED SEAL TREATMENTS**			

Topic number	Topics	Findings from Year 1 scoping study	Justification for further study
15	Investigate seal embedment issues over foamed bitumen stabilised base and bitumen treated base	▪ A total of 69 km of foamed bitumen stabilised pavement was built as part of the TNRP. Far North district indicated seal embedment issues in this type of pavement.	▪ In past projects, TMR indicated foamed bitumen stabilised pavements have many advantages, which include early trafficking and resilient to flooding events. However, it has not been used as extensively as it was anticipated at the beginning of the TNRP program. It is important to study the reason which caused the seal embedment issues.

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APPENDIX A LIST OF TNRP WORKSHOP PARTICIPANTS

Table A 1: List of TNRP workshop participants

TNRP organisation	Name	Email
SPO and RPO (Wide Bay)	Stephen Mallows	stephen.j.mallows@tmr.qld.gov.au
SPO	Rob Gourgaud	robb.z.gourgaud@tmr.qld.gov.au
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RES/ARRB/TMR	Phil Hunt	phil@roadeng.com.au

APPENDIX B SUMMARY OF RPO RESPONSES AT TNRP WORKSHOP

During the workshop, there were a number of sessions where the participants were divided in groups according to the RPO office that they represented. A summary of the RPO responses is provided in Table B 1.

Near the end of the workshop, the participants were asked to separate into three groups based on their roles within the RPOs. Groups included program management staff, design staff and construction staff. A summary of responses is presented in Table B 2.

Table B 1: Summary of RPO responses at TNRP workshop

Questions	South West region	Wide Bay region	Far North region	Fitzroy and Darling Downs region
	Workshop session – RPO challenges			
A1. In hindsight, what key thing under your control would you change to achieve better pavement outcomes?	More pavement testing, e.g.: - CBR - understanding existing pavement	a) Knowledge of maintenance history (i.e. cement modification patches info for RPO) b) Improved scoping or identification of: - site extents - defect type - additional pavement investigations	More pavement investigation: (a) FWD in particular (b) improve the accuracy of ARMIS information (c) target investigation frequency to match FWD results (d) better classification of fine material and existing material: - lime demand - UCS/MATTA for CMB/CTB and FBS (e) lime – work with suppliers on price, supply shortage causes major issue for FBS (f) survey drainage and formation structure	(a) Pre-construction process: - early investigation - consider subgrade treatment in design phase - lateral thinking - local knowledge and early constructability consultation - consider revised material availability and/or uses (b) Construction process: - improve communication (design and construct team) - improve experience of field personnel - improve industry skills
A2. Is there one particular pavement risk that keeps you awake at night?	Early failures, e.g.: (a) cracking (b) rutting (c) bleeding seals (d) BTB performance	a) Pavement cracking - over-modified pavement - low-cost treatments due to funding constraints b) Seal designs not a high risk – in almost all cases, variable sprayer used for second seas.	(a) Saturated subgrade incorporated under pavements (b) Seal embedment issues - particularly for foamed bitumen layer - this affects all pavements (c) Possible remedies to seal embedment issues: - avoid cutter in seals	(a) Expansive black soil (b) Class D treatment (maintenance) Focus on rideability (c) Emergency work needs to be chosen correctly, because emergent work can be both 'temporary' and 'permanent'

Questions	South West region	Wide Bay region	Far North region	Fitzroy and Darling Downs region
			- reduce bitumen content in foamed bitumen layer - rolling patterns	
A3. In pavement outcome terms, was there anything out of your control that you would like to have changed?	a) QRA pre-agreement to works and design guidelines agreed upfront b) Time	(a) Funding for 10–20 year treatments, treat failure mechanism instead of surface failure (b) Available road corridor width to treat subgrade: - traffic management - manage pavement (c) Experienced contractors to carry out large rehabilitation program	(a) QRA timing: - SPO timing - TMR requirements (b) Building in the wet season	(a) Funding to achieve pavement design life (b) Obtain resilience/improvement Guideline to 'build for original' is false economy because long-term maintenance and whole-of-life-cost (WOLC) not considered (c) Time to start
A4. What one (pavement) thing in your RPO do you think the rest of the State should know about?	a) High-slag blend b) BTB c) Crushing of marginal materials	(a) Back-calculation of subgrade CBR based on total age of pavement to determine a whole-of-life CBR or 85% CBR (b) Construction stage: - focus on skills of supervisors - grader operator to achieve a good outcome	(a) Bulking contracts for supplying the following: - particularly gravel supply - seals (b) FBS or granular base over stabilised subbase (c) Principal supply – no PICR	Use lime stabilisation and foamed bitumen. In some cases approximately 80% of existing pavement material can be re-used
A5. Did you define 'fitness-for-purpose'? How did you define it? What is the significance for TMR?	a) Yes b) Client driven c) Overall program focus	a) Fit-for-purpose understood by TMR and RPO b) Better treatment on higher-order roads c) Later in program, having contractors completing construction on higher-order roads only before funding constraints required reduction in scope and less design in later programs to meet time constraints	(a) Yes b) Match expectation to solution This is reviewed by TMR staff (c) Yes, reduction in pavement thickness as well as material and geometry changes	(a) Yes We define it (b) It relates to strategic intent of network (c) Accept a higher risk in minor road, but improve the overall network
A6. How much of your 'emergency works'	Approximately 10%	Emergency total $85m, say $10–$20m	Approximately 1–2%	Approximately 20–40%

Questions	South West region	Wide Bay region	Far North region	Fitzroy and Darling Downs region
remained as a final treatment?		emergency as final treatment, also with second seal in reconstruction		
A7. Did the program delivery model, which gathered people from outside of regional areas (often Brisbane) affect pavement treatment outcomes at all? Explain.	Yes RPO had good local knowledge	RPO worked closely with TMR local knowledge and achieved good outcome	Not really, there was significant regional experience in the entire process: (a) assessment (b) design (c) construction	In the delivery model, it is important to have input from local knowledge
	Workshop session – make a difference to TMR 'business as usual'			
B1. (a) What proportion of your projects used a regional standard over traditional TMR standard? (b) What are these key regional standards?	Regional standard: (a) high-slag blend - 100% (b) seal designs - ≈ 90% (using S0.3B binder)	60% used regional standards Regional standard: (a) 100–150 mm overlay, modified (b) single pass modification to limit breakdown of existing pavement materials	(a) 0% (b) Know standards, applied effectively c) Also, important to have experienced construction superintendents	a) Darling Downs region issued the low-order road methodology, approximately 25% of the network adopted b) Registered Professional Engineer of Queensland (RPEQ) design sign-off vs RPO risk
B2. What key pavement design or construction innovation(s) made a difference? Are there any that could improve future TMR business as usual?	(a) Cement modification of white rock to achieve CBR 80 (b) Crushing of oversized rock	Targeted pavement investigations: a) FWD in sensitive/risky areas	(a) Use Type 5 as a select fill or subbase (CBR 15)/working platform This reduces pavement thicknesses (b) Utilise FBS with cement, not lime (c) Rework existing FBS with lime only (d) Use of geotextile for subgrade control	(a) Lime and/or foamed bitumen (b) 1% cement in overlay to avoid DOS issue This keeps future rehabilitation options open (c) RLT test Refined understanding of behaviour of gravel (d) Cement modification (specify UCS performance)

Table B 2: Workshop participants responses during the workshop – information on improved approach for future program

Questions	Group 1	Group 2	Group 3
C1. What was your understanding of the NDRRA eligibility rules for pavement damage caused by pavement saturation?	(a) Uncertainty – effects due to trafficking of roads where damage is not realised for several months (b) Saturation causing incremental damage eligibility	(a) Guidelines were well defined initially (but not signed off by QRA or federal) The eligibility rules changed mid-program (b) The scoping work still being	(a) Whether we can increase formation width/seal width overlay (b) Interim seal width criteria not clear

Questions	Group 1	Group 2	Group 3
	(c) Evidence required to demonstrate eligibility is not clear: - photos don't always demonstrate extent of defect - ARMIS can show increase in defect, but what if within intervention level? (d) Low confidence that federal determination of guidelines will remain consistent (e) Recognise Qld state and federal still have not reached agreement (f) Federal guideline should have recognised pre-existing condition of network (g) Political ability for Qld state to continue to apply weight restriction on network while saturated	done to previous process and/or standards (c) Rules changed Onus of proof, and then applied retrospectively (d) Delayed on-set of pavement damage which occurs 3–4 months after events Is it still eligible? (e) Works deemed eligible at P1/P2 stage (by QRA/EMQ) are later deemed ineligible (f) Pavement design life guide Changed from 20 years to 10 years RPEQ sign-off required but reluctance to sign-off on 'sub-standard' designs (g) Delayed on-set of pavement damage which occurs 3–4 months after events Is it still eligible? (h) Photo frequency requirements need to be changed, vary from 500 m to 200 m	(c) Drainage (extension of existing drainage structure) (d) Partial/full width pavement damage Assessment done over a very short period of time (e) 'Onus of proof' For example, is it sensible to leave short sections of road pavement? (f) Better technology to assess structural strength at regular intervals This can supplement visual assessment information which may be subjective (g) Funding submission (Phase 1) needs to be done more accurately and competently, otherwise this can lock-up repair options (h) Constructability
C2. Although there were a number of versions issued, are there any additions, detractions or improvements to the TNRP Guidelines that could assist a future reconstruction program?	(a) Clarification for RPEQ sign-off against information in TNRP design guidelines Address legal and liability issues (b) Betterment Inability to source (in some cases for minor roads) to achieve betterment, i.e. Increase culvert size before pavement rehabilitation works (c) Guidelines generally good and provided clarity of design aspects: - on-going uncertainty of ability to fund pavement design life - pre-1976 culverts – defects not funded.	(a) Agreement on guidelines with QRA/federals, prior to applying them (b) Means of establishing eligibility: - details of evidence required - photos frequency etc. (c) Definition of 'ineligible works' (d) Interpretation of 'current civil engineering standards' vs replacing 'like-for-like' (e) Review of eligibility, require TMR staff time (f) Guides on approach to 'design exceptions' Distinguish between 'personal/company liability' vs	(a) Guidelines to specify some testing to assist design (as already referenced in TMR *Pavement Rehabilitation Manual* (Department of Transport Queensland 1992): - TNRP list of referenced documents (b) Stepping outside TNRP guidelines, requires RPEQ agreement and client acceptance Party to carry the liability not clear (c) Improve definition for 'formation widening' (d) Get agreement from federal on TNRP guidelines early in the program

Questions	Group 1	Group 2	Group 3
		'state liability' (g) Clarification on widening, for example: - consequential widen - seal widening on existing formation	(e) Improve eligibility requirement for drainage structure (f) Clarification of design document hierarchy (noted TNRP guidelines already presented)
C3. Thinking about the materials used in the program, where do you think the most can be learned?	(a) Timeframe for delivery created a spike in demand, increasing costs (b) Performance of pavements where geogrids were used (c) Adjustment to WQ35 was made following findings from TNRP (d) Increases to future RMPC costs to maintain roads with varying treatments, i.e. granular pavements with inlay asphalt repairs (e) Performance of BTB in South West region	(a) Cement modified base course (b) Prime vs primer seal (c) Embedment (d) Bleeding (e) Foamed bitumen In terms of resilience: (a) Lime stabilised subgrade as standard treatment (design standard developed) (b) Increased funding for programmed rehabilitation/resurfacing (c) Sealing shoulders to protect pavement from water entry (d) Improve longitudinal drainage	Assess advantages and disadvantages between options: a) cement modified base over granular b) granular over cement modified subbase
C4. In relation to pavements, what key 'start-up' documentation should be assembled to assist any future reconstruction program?	a) Sufficient photographs (eligibility) b) Some RPOs did not know what asset information TMR held c) Need to reality test Chartview data, as a guide/desktop tool only d) Method of record keeping and storage of scoping data e) Consistent defect scoping records – process, records, determination f) In some districts, high number of culverts difficult to track design and construction works g) A challenge is having sufficient TMR staff (local knowledge) to guide assessments	(a) Better pre-disaster pavement information - improved ARMIS data - maybe FWD testing (carried out during dry conditions) (b) Understanding of what works in the district (c) Local knowledge (d) Opportunities for using novel treatments e.g. foamed bitumen	(a) No district people at the time of flood damage identification (b) Published standard for NDRRA (c) Logging procedure