Technical Note TN192

Pavement rehabilitation – Investigation and analysis

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1 Introduction

The purpose of this Technical Note is to outline a broad approach for the investigation, sampling and testing of existing pavement materials and subgrade for undertaking a pavement rehabilitation design. This Technical Note brings together best-practice pavement investigation processes into a practical guide for pavement designers.

This Technical Note is to be read in conjunction with the Transport and Main Roads *Pavement Rehabilitation Manual*, *Pavement Design Supplement* and *Materials Testing Manual*.

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2 Purpose of pavement investigation

A successful pavement rehabilitation design studies the existing pavement to determine the mode of failure and, subsequently, determine suitable rehabilitation treatment options for the pavement (refer to Chapter 2 of the Transport and Main Roads *Pavement Rehabilitation Manual*). It would be unwise, for example, to invest rehabilitation funds into a structural overlay if the underlying pavement was likely to continue to fail and distress. A structural overlay may be suitable if the existing pavement is sound or if any underlying problem of the existing pavement is addressed.

Accordingly, the main purpose of the pavement investigation is to study the existing pavement and accurately define the mode of failure and causes.

3 Pavement investigation scope

To help define the pavement investigation brief, the pavement designer must first consider the project scope. Relevant project scope information may include:

- proposed works (for example pavement rehabilitation, widening, realignment, duplication, shape correction and so on)
- extent of start and finish chainages or features
- delivery timeline
- funding and budget constraints
- pavement design parameters (for example, design life, project reliability, expected heavy vehicle growth rate)
- topography, nature of adjacent land use and geology
- climate
- road geometry and cross-section information
- project constraints (for example, urban or residential surroundings, environmental sensitivity, traffic management, availability and location of quarried materials, hydraulic considerations)

- types, condition and location of drainage and other structures, and
- types and locations of utilities and services.

Throughout the pavement investigation and analysis process, the pavement designer should refer to the project scope to ensure that the pavement design intent is being met. As current detailed design processes often extend over long-time periods, it is wise to undertake reviews of the proposed pavement design so the pavement design remains compatible with the final type cross-section(s) and geometry.

4 Sources of pavement investigation data

Once the pavement investigation brief has been clearly defined from the project scope, information regarding the pavement profile(s) and materials can be gathered from various sources as outlined in the following sections.

4.1 Desktop review

Prior to undertaking onsite investigation works, the pavement designer must collect, correlate and review all available historical data. Sources of relevant historical data may include the following:

- A Road Management Information System (ARMIS) database – Transport and Main Roads *Chartview* is an excellent tool to obtain job / pavement history, pavement configuration, traffic details, pavement condition data – roughness, rutting, cracking, deflection (TSD – Traffic Speed Deflectometer), historic pavement maintenance costs (RMPC) – email ET_PMG_Director_Pavement_Rehabilitation@tmr.qld.gov.au for information on accessing the ARMIS database

  NOTE: While the data are often extremely useful, errors sometimes exist; accordingly, the data should be verified as consistent with onsite conditions.

- Digital Video Road (DVR) database – video history of a road over several years is particularly useful if recent surfacing treatment(s) mask underling works and condition:
  - areas of distress can be identified by conducting a low-level visual inspection using DVR
- historical and As-Constructed drawings – Transport and Main Roads Geospatial Information Management System (GIMS) database is a quick and easy way to gather this information – email ET_PMG_Director_Pavement_Rehabilitation@tmr.qld.gov.au for information on accessing the GIMS database
- maintenance records (see ARMIS database previously) and local construction personnel
- historical pavement investigation data – check with the local Transport and Main Roads Soil laboratory (email ET_PMG_Director_Pavement_Rehabilitation@tmr.qld.gov.au for information on accessing Soils laboratories), Program Managers and recordkeeping for previous pavement investigations on adjacent parts of the road network, and
- drive or walk through the site and undertake a visual inspection.

4.2 Visual inspection

Visual assessment

A documented, detailed visual assessment is essential to the pavement investigation process. If previous underlying condition is masked by recent surfacing works, review DVR records as per

Section 4.1. It is often advantageous to undertake the visual assessment after surface deflection analysis (and Ground Penetrating Radar (GPR) analysis, if required) has been undertaken as this allows the visual assessment of areas with differing structural response (this will help to identify the need for a structural inspection). If no project level deflection has been undertaken, review the most recent network level TSD data in ARMIS.

A visual inspection should be undertaken to:

- determine the condition of the existing pavement such as surface type and condition, deformation, cracking, edge defects and shoulders, patches and potholes
- accommodate general site conditions such as topography, geology, drainage, water table, site constraints, services, road geometry and land use
- record the type, severity and extent of pavement distress (as per Transport and Main Roads *Pavement Rehabilitation Manual*), and
- identify any constraints on the type and extent of pavement treatments.

4.3 Groundwater

Groundwater must be investigated to determine:

- level of the permanent groundwater table at the time of the investigation and seasonal variation
- occurrence of a perched water table condition and its level
- estimated rates of inflow to excavations
- effects of de-watering on water table levels and on adjacent structures, and
- potential aggressiveness of the soil and groundwater, for example SO_4, Cl, pH and Total Dissolved Solids (TDS).

4.4 Non-destructive pavement investigation

The pavement designer can obtain further information regarding the pavement strength, profile and materials through non-destructive investigation. These work operations may include:

- Surface deflections

  Falling Weight Deflectometer (FWD): Surface deflections define the pavement's structural response to load. They can be used to determine homogeneous pavement sections that, in turn, provide remaining pavement life through back analysis and required structural overlay depths. It is also useful to define areas of interest for destructive testing. It is common to undertake FWD testing prior to visual assessment as this guides area of differing structural response, which could be an indicator of condition or pavement depth.

- GPR

  This technology is useful to identify underground obstructions such as service utilities, culvert decks and so on. When coupled with accurate coring and auguring, it can be used to define materials layer, type, extents, and depths. Even by itself, GPR may be a useful tool. Refer to Section 2.8 of the *Pavement Rehabilitation Manual* for more information about GPR.

4.5 Destructive pavement investigation

Before the commencement of destructive pavement investigation, the pavement designer must undertake a holistic review of the pavement investigation scope, desktop pavement data and non-destructive pavement investigation data. The designer will use the existing data to determine the laboratory test outcomes and define suitable examination and sampling locations. To do this, the pavement designer should consider the following:

- Review the available data.

  The aim of this task is to define areas of existing pavement that can be grouped into 'typical' or homogeneous sections. This typically involves the consideration of:

  - condition data (refer Section 4.1)
  - visual assessment (refer Section 4.2)
  - surface deflection (FWD or TSD) data (refer Section 4.4), and
  - As-Constructed drawings (refer Section 4.1).

The purpose of reviewing available data is to source samples from each material type experienced on the project so that duplicate testing is minimised.

- within the project limits, are there areas of existing pavement where there are 'outliers' or areas that exhibit more severe failures and require additional investigation or differing treatment?
- by reviewing the available data, will the investigation be able to identify (or confirm) the pavement failure mechanism?
- typically, the data might include grading, Atterbergs, California Bearing Ratios (CBRs)(lab soaked, unsoaked), moisture content, Maximum Dry Density / Optimum Moisture Content (MDD / OMC) relationship for designated pavement layers and subgrade
- areas of pavement realignment and/or widening (where applicable) need to be investigated along with the existing road formation, and
- identify the most likely treatment option(s) and preliminary pavement design (based on assumptions) for various sections of pavement and identify the type of material testing required to investigate the proposed design; for example, if a treatment option includes stabilisation of existing materials, sufficient sampling (to 'X' depth) will be required to achieve a range of Unconfined Compressive Strength (UCS) tests. The reason for undertaking this approach is to minimise investigation costs by minimising the chance of additional investigations to obtain more samples.

  There are many circumstances where a pavement investigation reveals certain unknown aspects that lead to further investigations at a later time.

Collecting pavement samples and undertaking laboratory testing is typically the most expensive part of the pavement investigation process. It is, therefore, recommended that the pavement designer attempts to 'optimise' the testing locations by ensuring all information is reviewed.

The pavement designer must also consider which testing operation would be most suitable to gather relevant pavement data. Destructive pavement investigation operations may include:

- **Coring of bound materials** (asphalt and stabilised materials) – 150mm diameter cores can be used to define layers, depths, stripping (bitumen loss in asphalt); laboratory UCS testing (cementitious) and laboratory indirect tensile strength testing to obtain resilient moduli. In the field, further auguring through lower unbound pavement layers may be required to obtain Dynamic Cone Penetrometer (DCP) testing of the subgrade.
- **Auguring** will give a disturbed sample. It is generally used for the recording of existing material layers, depth and obtaining samples for laboratory testing. The auger size is usually 300mm diameter. At the bottom of the augured hole, an insitu DCP test to determine insitu subgrade CBR will be undertaken to a depth of between 450–750mm.
- **Trenching** (within the existing road formation) – trenching is often considered where there is a high chance of an inconsistent cross-section. Cracking and major defects, such as rutting, may wish to be examined at all layers in the existing pavement structure.
- **Test pits** (outside the existing road formation) – test pits are typically undertaken to define the natural subgrade properties for excavations and to investigate potential embankment material for widening of pavements.
- Any combination of these may be used.

These work operations must record the type, properties and thickness of each material layer. Clearly traceable material samples should also be gathered during the work operations for further laboratory testing. DCP testing of the insitu subgrade and/or general fill material should also be undertaken at each testing location.

Two examples of typical testing regimes for various material types are provided in appendices A and B as a guide to practitioners. This Technical Note does not claim to be fully comprehensive and may indicate excessive testing but it outlines the required engineering assessment processes to arrive at a suitable testing regime.

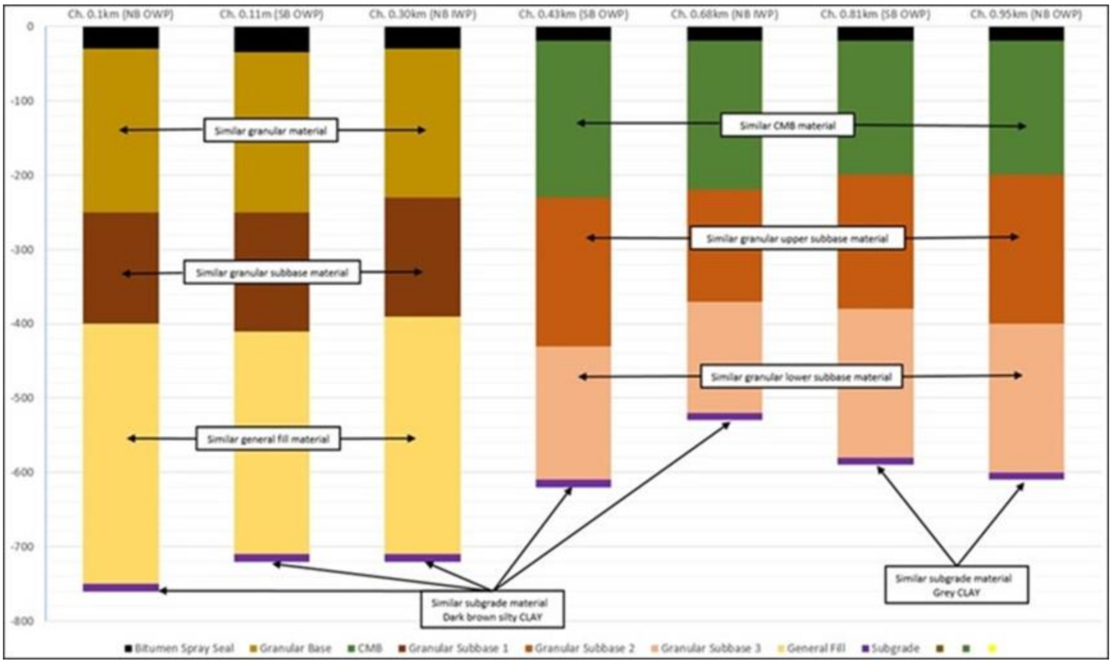
5 Analysis of pavement investigation data

Once all the data from the pavement investigation has been collated and reviewed, the pavement designer must determine a suitable material laboratory testing schedule. It is typical for the pavement designer to review the pavement profiles and determine any 'similar' pavement profiles and materials. Table 5 shows an example of how to collate the pavement profile data.

Table 5 – Insitu pavement profiles

Example Highway (123A) Ch. 0.00–1.00km – Insitu Materials – Layer Depths (mm)									
No.	**Location**	**Bitumen spray seal**	**Granular base**	**CMB**	**Granular subbase 1**	**Granular subbase 2**	**Granular subbase 3**	**General fill**	**Subgrade**
T_1	Ch. 0.1km (NB OWP)	-30	-220		-150			-350	-10
T_2	Ch. 0.11m (SB OWP)	-35	-215		-160			-300	-10
T_3	Ch. 0.30km (NB IWP)	-30	-200		-160			-320	-10
T_4	Ch. 0.43km (SB OWP)	-20		-210		-200	-180		-10
T_5	Ch. 0.68km (NB IWP)	-20		-200		-150	-150		-10
T_6	Ch. 0.81km (SB OWP)	-20		-180		-180	-200		-10
T_7	Ch. 0.95km (NB OWP)	-20		-180		-200	-200		-10

Figure 5 – Summary of insitu pavement profiles identifying 'similar' materials



6 Material laboratory testing

The pavement designer must ensure that the laboratory testing provides data which will be relevant for the design approach. The laboratory testing should allow the pavement designer to determine accurately the properties of the existing pavement material and the support conditions on which the existing pavement structure is constructed. A laboratory testing schedule must be prepared that optimises the number and type of tests to reflect the project scope, design approach and budget.

Some laboratory tests to consider are:

- Characterisation testing which will assist in determining the properties and strength of the existing materials. As a minimum, the following testing should be undertaken as shown in Table 6.

Table 6 – Material laboratory testing for existing pavement material

Laboratory test	Test layer	Test Method No.
Moisture contents	All	AS 1289.2.1.1
Atterberg limits and weighted Plasticity Index (PI)	Base and subbase	Q104A
		Q105
		Q106
	Fill and subgrade	AS 1289.3.9.1
		AS 1289.3.2.1
		AS 1289.3.3.1
		AS 1289.3.4.1
		Q252
Particle size distribution (PSD)	Base and subbase	Q103A
	Fill and subgrade	AS 1289.3.6.1
Dry density-moisture relationship	Fill and subgrade	AS 1289.5.1.1
4-day soaked CBR (1 Point), including swell @ 95% std compaction @ 100% OMC	Fill and subgrade	AS 1289.6.1.1
4-day soaked CBR (4 Point) @ 100% std compaction @ 100% OMC	Base and subbase	Q113A

Other testing to be considered depending on site conditions, treatment and/or stabilisation plan:

- AS 1289.3.8.1 *Methods of testing soils for engineering purposes, Method 3.8.1: Soil classification tests – Dispersion – Determination of Emerson class number of a soil*
- Q115 – Unconfined Compressive Strength (UCS) of cementitious or lime stabilised materials
- Q120B – Organic Content
- Q131B / AS 1289.4.2.1 *Methods of testing soils for engineering purposes, Method 4.2.1: Soil chemical tests – Determination of the sulfate content of a natural soil and the sulfate content of the groundwater – Normal method*
- ferric oxide content, and/or
- Q315 or AGPT/T232 *Stripping potential of asphalt and tensile strength ratio*:
  - the laboratory conditioning and compaction temperature to be used for Warm Mix Asphalt (WMA) mixes shall be determined in accordance with Q323
  - the freeze/thaw moisture conditioning of specimens detailed in Section 5.2 of AGPT/T232 is mandatory, and
- AS 2891.13.1 *Methods of sampling and testing asphalt, Method 13.1: Determination of the resilient modulus of asphalt – Indirect tensile method*.

Testing to assist in determining the insitu performance and equilibrium state of the existing materials:

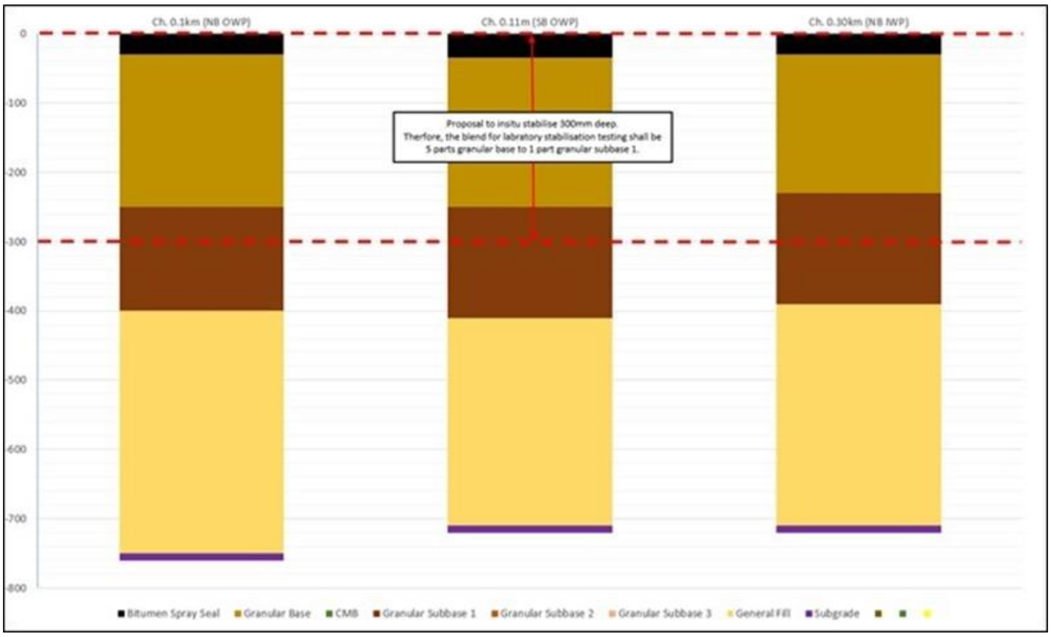
- Q102A *Moisture content* (relative moisture when compared to OMC), and

- Q114B *Insitu CBR using Dynamic Cone Penetrometer (DCP)*. This test should be undertaken during the pavement investigation site works.

Testing to assist in determining the suitability of existing materials for insitu (or plant-mix) stabilisation:

- refer to Transport and Main Roads' *Materials Testing Manual*, and
- the pavement designer must consider the location and depths of the proposed stabilisation so the laboratory testing accurately reflects the situation likely to be encountered onsite (Figure 6 following is an example).

Figure 6 – Example of blending materials for laboratory testing



Laboratory testing should be undertaken by a Transport and Main Roads Registered Construction Materials Testing Supplier.

7 Failure mechanism

Through analysis of the pavement investigation data, the pavement designer should confirm or identify the pavement failure mechanism(s). The determination of the pavement failure mechanism is the key element which needs to be addressed in the proposed pavement rehabilitation design solution. More details are provided in the Transport and Main Roads *Pavement Rehabilitation Manual*.

8 Proposed pavement design

Using the gathered investigation data and laboratory testing results, the pavement designer can undertake the rehabilitation pavement design in accordance with Transport and Main Roads *Pavement Rehabilitation Manual* and *Pavement Design Supplement*.

9 Check suitability of pavement design (material and geometrics)

Materials

Once a proposed pavement design has been nominated, the pavement designer must review the laboratory test results to determine if this proposed design remains functional / achievable; for example, checking the design assumptions are actually achieved by the laboratory tested materials.

The pavement designer may also undertake additional laboratory testing to optimise the pavement design solution; for example, this may include further testing to optimise stabilising agents, thus minimising project costs without compromising structural integrity.

Geometrics

The shape and profile of the existing road may affect the composition of the existing pavement and new pavement material in the final pavement structure for an insitu stabilisation / modification project. This is especially so for the pavements on reactive clay subgrades that exhibit high roughness or large deformations and movement. Accordingly, it is incumbent on the pavement designer to check that the material laboratory testing actually reflects the range of outcomes that are possible, based on the final geometric design shown on the contract drawings and documents. Further UCS laboratory testing for various material blends may be required to confirm that the design remains appropriate. This could be coupled with a specified UCS testing regime by the Contractor early in the Contract works to the designer to ensure that the design aims are being met.

Appendices

Appendix A – Destructive testing schedule for small to medium size project

Proposed preliminary rehabilitation treatments

The pavement designer should use the information from the project scope, desktop, surface deflection and site assessment procedures (Section 4) and determine the likely pavement treatment types. This will guide the type of destructive testing required. These 'likely treatments' are still subject to the information and analysis of the detailed destructive test results, and may be changed upon review.

Treatment area A: Chainages 21,000–22,500 (anticipate 150mm deep base + 200mm subbase on clay)

Widen existing pavement (300mm approx.), stabilise existing and widened pavement (250mm); overlay with unbound granular pavement 150mm (approx.).

Treatment area B: Chainages 22,500–24,750, raised vertical geometry (0.5m–0.75m) for flood mitigation purposes: NO pavement investigation required, imported embankment (min soaked CBR 20), new pavement.

Treatment area C: Chainages 24,750–25,600 (old 5m sealed pavement, anticipate 150mm deep pavement on clayey sand), widen (150mm approx.) and overlay 300mm approx. unbound granular.

Table A1 – Sampling for testing schedule for small to medium size project

<table>
<tr><td colspan="3"></td><th colspan="3">Location of testing</th></tr>
<tr><th>Layer</th><th>Tests required</th><th>Reason</th><th>Chainage</th><th>Lane</th><th>Wheelpath</th></tr>
<tr><td rowspan="12">Surfacing
Base
Subbase

Most efficient method of sampling to be determined by testing agency</td><td rowspan="10">1. Classify material
2. Depth
3. Visual moisture content description (compared to OMC)
4. Moisture content
5. MDD / OMC**
6. Grading and Atterbergs**
7. Soaked CBR**</td><td rowspan="10">To record existing materials and insitu conditions and strength of material.

Do not test material from every location if samples are identical.</td><td colspan="3">Area A</td></tr>
<tr><td>21,100</td><td>1 & 2</td><td>I & O & Sh</td></tr>
<tr><td>21,500</td><td>1 & 2</td><td>I & O & Sh</td></tr>
<tr><td>21,900</td><td>1 & 2</td><td>I & O & Sh</td></tr>
<tr><td>22,250</td><td>1 & 2</td><td>I & O & Sh</td></tr>
<tr><td>22,450</td><td>1[##] & 2</td><td>I & O & Sh</td></tr>
<tr><td colspan="3">Area C</td></tr>
<tr><td>24,800</td><td>1</td><td>O & Sh</td></tr>
<tr><td>25,200</td><td>2</td><td>O & Sh</td></tr>
<tr><td>25,550</td><td>1</td><td>O & Sh</td></tr>
<tr><td colspan="5">**2 tests per material type [##]Trench and record rut profile in each layer</td></tr>
<tr><td>8. UCS
Mixes to be confirmed once initial review of all pavement investigation results by designer</td><td>Design trials per material type:
• GB (1%, 2%, 3%) 7 and 28 day
• GB / Slag (60/40) (1%, 2%, 3%, 4%) 7 and 28 day</td><td colspan="3">Locations as above
Keep base and subbase samples separate (may be combined in lab for UCS testing – to be confirmed after above testing is completed)</td></tr>
<tr><td>Subgrade or top of earthworks</td><td>9. DCP (50–750mm or refusal, whichever is the lesser)</td><td>Subgrade support conditions BEFORE DISTURBANCE</td><td colspan="3">All locations as above</td></tr>
<tr><td>Subgrade or earthworks</td><td>10. Classify material
11. Depth
12. Visual moisture content description</td><td>Subgrade type, classification, and depths, visual moisture based on experience</td><td colspan="3">All locations as above</td></tr>
</table>

			Location of testing		
Layer	**Tests required**	**Reason**	**Chainage**	**Lane**	**Wheelpath**
Subgrade (outside of pavement for widening)	13. DCP 14. Classify material 15. Grading & Atterbergs** 16. Depth profile 17. Visual moisture content description 18. Soaked CBR**	Subgrade strength information for widening design	Area A: All Chainages as above		
			L and R: +3m from road edge		
			Area B: All Chainages as above		
			Left only: +4m from road edge		
	**2 tests per material type (0–300mm only)				

Appendix B – Larger projects – initial auguring investigation

In larger projects, the pavement designer may choose to undertake an initial auguring investigation (due to its relative quickness), analyse the augur results, and then undertake a 'targeted' trenching investigation to collect additional samples for laboratory testing.

Table B1 – Example of investigation location schematic

Auger Position	Northbound		Southbound		Notes
Chainage	OWP	IWP	IWP	OWP	
0					
0.05					Visual inspection identified an area of major potholing and rutting in NB and SB lanes from Ch. 0.09km–0.13km.
0.1	T_1		T_2		
0.15					
0.2					
0.25					
0.3		T_3			
0.35					
0.4					ARMIS data showed a change in pavement structure from Ch. 0.40km onwards.
0.45				T_4	Visual inspection identified a change of seal at Ch. 0.44km.
0.5					
0.55					
0.6					
0.65					
0.7		T_5			Visual inspection identified an area of minor rutting and crocodile cracking in the NB and SB lanes from Ch. 0.65km–0.80km.
0.75					
0.8				T_6	
0.85					
0.9					
0.95	T_7				Visual inspection identified an area of transverse block cracking in the NB lane from Ch. 0.85km–1.00km.
1.00					