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Performance-based Evaluation Protocol for Non-standard Granular Pavement Materials

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SUMMARY

Non-standard materials have a long history of successful performance in low-volume sealed roads in Queensland. The satisfactory performance of these materials relies on expertise specific to the individual material including in identifying, winning, constructing and maintaining pavements incorporating these non-standard materials. In addition, performance relies on appropriate pavement structural design and drainage considerations in combination with traffic load spectrum assessments.

The purpose of this Material Assessment Procedure for Non-standard Materials is to systemise and summarise Queensland Department of Transport and Main Roads' (QTMR's) knowledge and experience with these materials. This includes data from QTMR's extensive literature library in addition to regional practitioner input.

The Material Assessment Procedure for Non-standard Materials developed for this project is a case-by-case risk assessment tool for the use of selected non-standard materials for pavements of sealed roads with low traffic volumes and loadings. It comprises a four-phase assessment. These phases are:

- Phase 1: Context risk
- Phase 2: Material risk and Application evaluation
- Phase 3: Secondary material assessment
- Phase 4: Usage risk and risk control guidance.

Material-specific guidance covering material handling, design, construction and maintenance considerations are also referenced.

This report presents the evidence and justification for the development of a material assessment procedure. Feedback from pavement practitioners on the suitability and applicability of the assessment procedure has also been included.

Given the outputs of the procedure were not able to be verified from feedback and the recent completion of Austroads project AAM6144 (Sustainable roads through fit-for-purpose use of available materials) which investigated a similar material risk assessment procedure combined with whole of life cycle cost considerations, it has been decided that there will be no further development of the procedure included in this document.

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1 INTRODUCTION

Non-standard pavement materials have a long history of successful performance in low-volume sealed, unbound granular pavements on the state controlled road network of Queensland. The satisfactory performance of these materials relies on technical expertise and expertise specific to the individual material, including in identifying, winning, constructing and maintaining pavements incorporating these non-standard materials. In addition, performance relies on appropriate pavement structural design and drainage considerations in combination with traffic load spectrum assessments.

This report presents the evidence and justification for the development of a material assessment procedure. The procedure is presented in Appendix A.

1.1 MATERIAL RISK ASSESSMENT

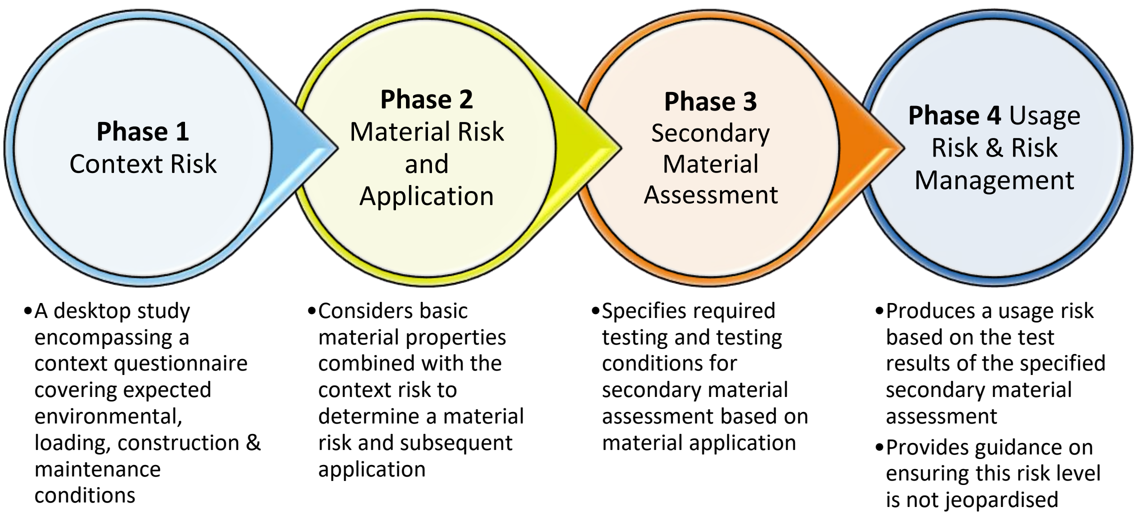
The purpose of this Material Assessment Procedure for Non-standard Materials (MAP) is to systemise and summarise QTMR's knowledge and experience to date with use of these materials in the contexts (e.g. traffic loadings) described.

The MAP is a case-by-case risk assessment tool which informs which project specific risk-assessment for the use of selected non-standard materials in low-volume sealed unbound granular road pavement applications. The procedure comprises a four-phase assessment shown in Figure 1.1: questionnaire

- Phase 1: Context Risk
- Phase 2: Material Risk and Application evaluation
- Phase 3: Secondary Material Assessment
- Phase 4: Usage Risk and Risk Control Guidance.

Material-specific guidance covering material handling, design, construction and maintenance considerations is also provided.

Figure 1.1 Framework of Material assessment procedure for non-standards materials



1.2 RULES FOR THE USE OF THE ASSESSMENT

As the MAP is based on, and calibrated through, past pavement performance observations and data (for roads on the state controlled road network in Queensland), an initial project screening is required to exclude design scenarios which may not be applicable to this calibration, resulting in a usage risk that is not accurate.

For a project to be eligible for use of this MAP, the 20-year design traffic loading must typically be less than 5×10^6 ESAs, or approximately 500 ESAs/day (two directions).

The MAP is not intended to be used for projects which do not conform to these criteria.

1.3 MATERIAL TYPES COVERED BY THE ASSESSMENT

Common non-standard pavement materials used throughout Queensland by QTMR for unbound granular sealed road pavement applications are generally referred to as unbound granular materials (Austroads 2009) or "soil aggregates" (Basford 1980). These materials are often used in their natural state but can also be processed of modified with soil fines to produce a better performing material (Basford 1980).

The common non-standard materials which are used extensively through Queensland by QTMR for unbound granular sealed road pavement applications and which were applied in development of this MAP are now briefly described.

1.3.1 WINTON SANDSTONE

This formation is typically a deep weathered sandstone profile; it is found in western Queensland as part of the Rolling Downs geological group. Considered as a type of white rock with sandstone origins, it has historically been used by QTMR for pavement materials west of Longreach including on the following roads:

- Landsborough Highway
- Thompson Developmental Road
- Kennedy Developmental Road
- Birdsville Developmental Road
- Diamantina Developmental Road and other local roads.

Winton Sandstone has also been used by QTMR as a pavement material north of the Flinders Highway as far as Cape York.

1.3.2 LOAMS

Loam is described as a sand material with a high proportion of silt and clay fines (Vanderstaay & Reeves 2000) with applications noted in the central west district of Queensland.

1.3.3 WHITE ROCK

White Rock is a general term which describes the pallid and mottled zone of the laterite profile associated with origins from weathered sandstone, limestone, shale or mudrocks. White rock has been most commonly used in south-western Queensland south of the Warrego Highway between Dalby and Charleville including roads to St George, Tara, and Cunnamulla, as well as local roads in the general area.

1.3.4 LATERITE GRAVELS

Laterite gravel is a general term associated with weathered surface ferrous rock used around Kingaroy and ironstone and ferricrete used north of Mareeba and Normanton.

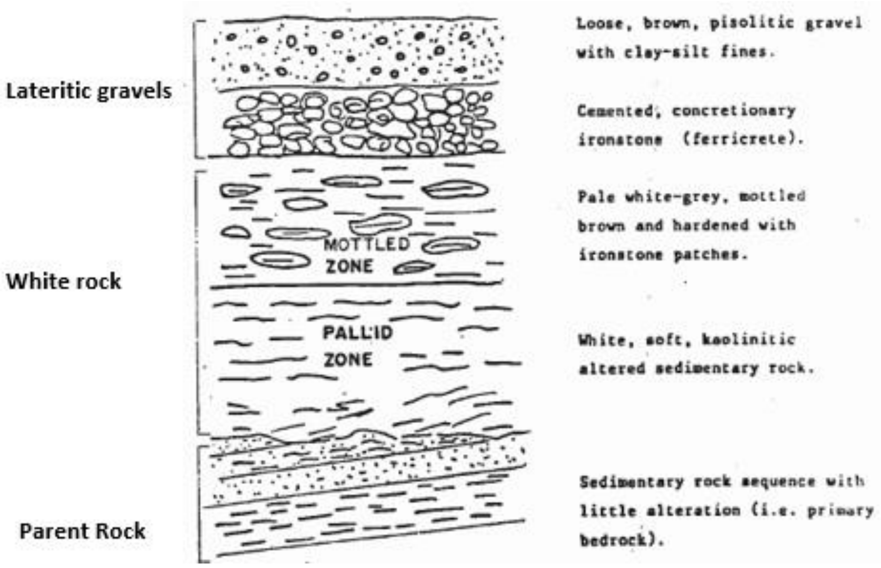
1.3.5 RIDGE GRAVELS AND ALLUVIAL GRAVELS

Ridge gravel deposits are formed on low topographic highs generally adjacent to major existing streams (for example, the Thompson River). These gravels were originally river/creek ("alluvial") gravels which, with climate change, became stranded on a higher level than the former water level. Historically, ridge gravels were the "non-standard" pavement material of choice, as they often met standard specification material requirements. These materials may have wider use in high-risk situations such as floodways and higher rainfall sections.

The "classic" topography for ridge gravels used in QTMR pavements has been between Longreach and Muttaburra, adjacent to the Thompson River. Ridge gravel and alluvial gravel deposits can often be found following a perusal of the geological maps and the identification of areas classed as "T" (Tertiary material) adjacent to an existing major stream.

With the exception of loam soils, which are typically found in sandplain regions, Figure 1.2 outlines the locations of the other non-standard materials mentioned within a typical laterite weathering profile.

Figure 1.2 Typical lateritic profile in south-western Queensland



2 PHASE 1: CONTEXT RISK

The first phase assesses the project *Context Risk*. It is a desktop study undertaken with the intention of completing all four phases of the assessment. It can also serve as a stand-alone pre-feasibility planning tool to assess the expected risk, and identify knowledge gaps within a specific project. The Context Risk is based on the interrelation of environmental, traffic loading, construction, and maintenance conditions.

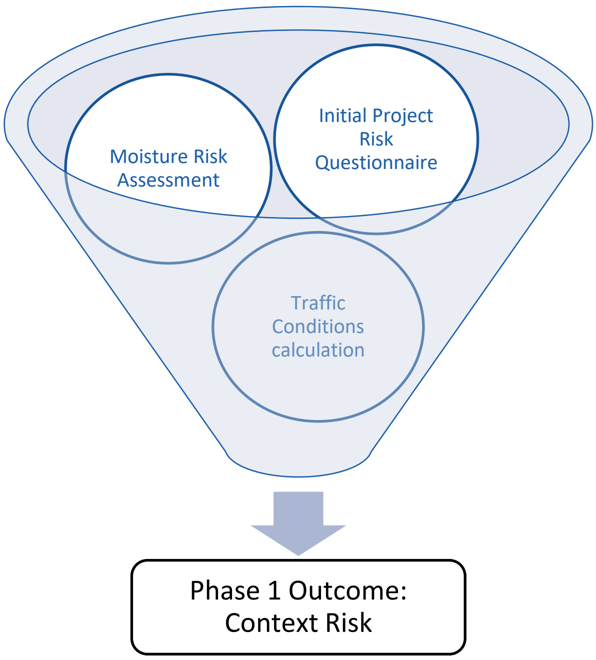
Operating conditions influencing performance characteristics include traffic loading magnitude and frequency, moisture availability, temperature, confining pressure, foundation support and employed construction practices (Bartley 1980; Metcalf 1983).

Fitness-for-purpose is defined by consideration of climate, hydrological regime, terrain, traffic, in addition to construction and maintenance standards (Cook et al. 2001).

A wide variety of non-standard materials have been successfully utilised in road pavement applications where the traffic and environment are understood and both factors are sufficiently accounted for in the design, construction and maintenance practices (Cook et al. 2001).

The Context Risk is determined via the combination of the Initial Project Risk Questionnaire, Moisture Risk and the Traffic Conditions Risk Assessment as shown in Figure 2.1.

Figure 2.1 Steps in determining Phase 1 output: Context Risk



2.1 INITIAL PROJECT RISK QUESTIONNAIRE

The Initial Project Risk Questionnaire is comprised of various risk items which relate to the following three key areas of pavement performance:

- moisture elimination
- construction considerations
- maintenance considerations.

Application of the questionnaire identifies the application as being a Low or High risk. If any of the risk items are assessed as a high risk, the initial (overall) project risk is considered high and risk mitigation solutions should be considered for inclusion in the project if it continues and uses this pavement material option.

2.1.1 MOISTURE ELIMINATION

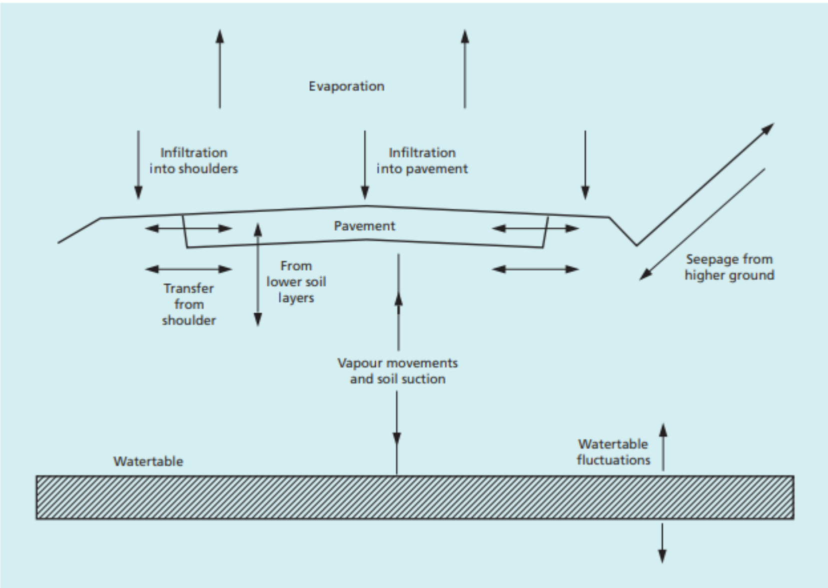
This part of the questionnaire allows the designer to understand how well the pavement will resist moisture ingress throughout its expected service life (see Table 2.1).

Non-standard materials require stable (dry) moisture environments where the potential for inundation is negligible (Metcalf 1983). Additionally, achieving satisfactory performance of non-standard materials is directly related to keeping the pavement structure as dry as possible (Martin, Drew, & Reeves 1989).

In road pavements carrying design traffic loadings of less than 5 x 10^5 ESAs (two directions) it was found that drainage is the most important parameter. Taking measures such as sealing shoulders, deepening and maintaining side drains, raising embankments, providing adequate crossfall or using other techniques to create a drier environment for the road pavement decreases usage risk (Robinson, Oppy, & Giummarra 1999; Pinard 2008).

Studies on pavements constructed with non-standard materials identified the most common failure mechanism as moisture ingress through unsealed shoulders and narrow shoulder widths (Kapitzke 1990; Morris 1972; Vlasic & Murphy 1971, Reeves 1992; Vuong et al. 1994; Tydd, 1998). The provision of a shoulder width of at least 1.0 m (QTMR 2015) is enough to reduce the risk of this type of failure and ensure ongoing performance.

Figure 2.2 Moisture movement in a road pavement



Source: Austroads 2019.

Table 2.1: Initial project risk questionnaire: moisture elimination

INITIAL PROJECT RISK QUESTIONNAIRE			
ITEM	RISK	RESPONSE	
		YES	NO
1.0	Has a drainage assessment been undertaken in accordance with the QTMR Road Planning Design Manual and QTMR Road Drainage Manual?	LOW	HIGH
1.1	Is the road geometry and location topography likely to protect the pavement from infiltration an inundation? Refer to WQ35 Section 6 for further details (QTMR 2014). Includes embankment height and batter slope.	LOW	HIGH
1.2	Will each of the road shoulders be sealed to a minimum width of 1.5 m?	LOW	SEE 1.2.1
1.2.1	If NO to 1.2, is the permeability of the base material likely to be LESS than 5 x 10^{-7} m/s once compacted to specification criteria?	LOW	HIGH

2.1.2 CONSTRUCTION CONSIDERATIONS

This part of the questionnaire allows the designer to identify construction considerations which may have a positive or negative impact on the expected performance of a pavement constructed with non-standard materials (see Table 2.2).

The key elements of construction practice used to maximise unbound granular material performance include (Bartley 1980):

- minimising segregation during handling and placement
- managing water contents
- ensuring the target density is achieved and compaction effort is uniformly applied
- minimising potential for moisture infiltration
- ensuring uniformity throughout the construction process.

In dry environments, the equilibrium moisture content ranges from 70 to 90% of optimum moisture content (OMC) at standard compaction (Robinson et al. 1999). Dry-back to 85% or 70% of the OMC is commonly recommended for sprayed seal and asphalt surfacings respectively (Cocks et al. 2015).

Marginal natural materials are highly dependent on soil suction and cohesive forces for the development of shear resistance. Even modest levels of moisture, approaching 60% degree of saturation, are enough to reduce confining forces sufficiently to cause distress and failure (McLennan 1988).

Low moisture contents result in high capillary suction, which has a positive influence on confining pressure, shear resistance and rigidity (Bartley 1980). Where relatively dry conditions prevail, high matric suction (cohesive) pressures are developed due to initial compaction, cyclic wetting and drying and trafficking (Pinard 2011).

African experience with the construction of pavements with non-standard materials “compaction to refusal” with the heaviest plant available is that this will often provide a substantial benefit in terms of increased pavement stiffness which correlates directly with longer pavement life (Pinard 2008). However, the density benefits of compaction to refusal need to be assessed against the risk of material breakdown; a closely monitored compaction trial is required as part of this assessment.

Table 2.2: Initial project risk questionnaire: construction considerations

INITIAL PROJECT RISK QUESTIONNAIRE			
ITEM	**RISK**	**RESPONSE**	
		YES	**NO**
1.3	Will strict control be implemented during construction to ensure excess moisture is minimised and satisfactory compaction ensured? That is, consideration for: – Correct material mixing, drying and placement methods – Scheduling of earthworks construction during dry months	LOW	HIGH

INITIAL PROJECT RISK QUESTIONNAIRE			
	– Selection and implementation of construction drainage, refer to WQ35 Section 4 for further details – Compaction to specification – Ample compaction verification – Sufficient dryback of pavement layers before placement of successive layers or sprayed bituminous treatment		

2.1.3 MAINTENANCE CONSIDERATIONS

This part of the questionnaire assesses whether timely maintenance will be undertaken to help protect against moisture infiltration through the surface and shoulder defects (Table 2.3).

Satisfactory performance can be achieved with non-standard materials when adequate, planned maintenance is carried out and structural overloading is prevented (Pinard 2011). QTMR has achieved satisfactory performance with non-standard materials when the pavement formation and seal were properly designed, constructed and maintained (Vuong et al. 2002).

The predominant path of moisture entry into the subgrade is through an unsealed shoulder and the paving materials (Kapitzke 1990). Regular surface resealing and shoulder maintenance will help maintain the optimum performance environment (Robinson et al. 1999).

Table 2.3: Initial project risk questionnaire: maintenance considerations

INITIAL PROJECT RISK QUESTIONNAIRE			
ITEM	RISK	RESPONSE	
		YES	NO
1.4	Is ongoing and timely routine maintenance of seals, shoulders and drainage likely to occur? – Free flowing, working drainage with no silt build up or erosion – No unsealed pavement cracks above medium severity – No encroaching grass and/or vegetation on shoulders – Allowances for timely future seal rejuvenation, enrichment or resealing	LOW	HIGH

2.2 MOISTURE RISK ASSESSMENT

The moisture risk is determined through a combination of the Initial Project Risk Questionnaire output and the probability of total rainfall exceeding 500 mm/year.

Non-standard materials require dry moisture environments where potential for inundation is negligible (Metcalf 1983). The primary factor in achieving satisfactory performance of non-standard materials is directly related to keeping the pavement structure as dry as possible (Martin et al. 1989).

Non-standard materials are typically utilised in pavement applications where annual rainfall is less than 500 mm (Martin et al. 1989; McLennan 1984). Otherwise, unbound granular materials conforming to standard specification should be used. This is mainly due to the difficulty in predicting the equilibrium moisture content in areas where the rainfall is greater than 650 mm per annum (NAASRA 1974). Being able to understand the equilibrium moisture is vital for ensuring the performance of non-standard materials (Tydd 1998).

The Rainfall Risk uses the probability of rainfall at a specific project location exceeding 500 mm annually. This probability is easily calculated using historic rainfall data available via the Bureau of Metrology (BOM) for the current climatological normal 30 year period between 1961 through to 1990 as defined by the World Meteorological Organisation (WMO).

Climatological normalities have long filled two major purposes. Firstly, they form a benchmark or reference against which conditions (especially current or recent conditions) can be assessed, and secondly, they are widely used as an indicator of the conditions likely to be experienced in a given location. (WMO 2007). The next climatological normal will come into use at the beginning of 2021 and will cover the years 1991 through to 2020.

A regression equation was developed using data from 21 weather stations throughout Queensland to predict the probability of exceeding 500 mm/year based on the distance from the 500 mm isohyet. The data set used to develop the regression equation is presented in Table 2.4 while the regression trend line is shown in Figure 2.3. This prediction equation may be used when sufficient historic data is unavailable.

Figure 2.3 Predicting probability of exceeding 500 mm/year by location – regression

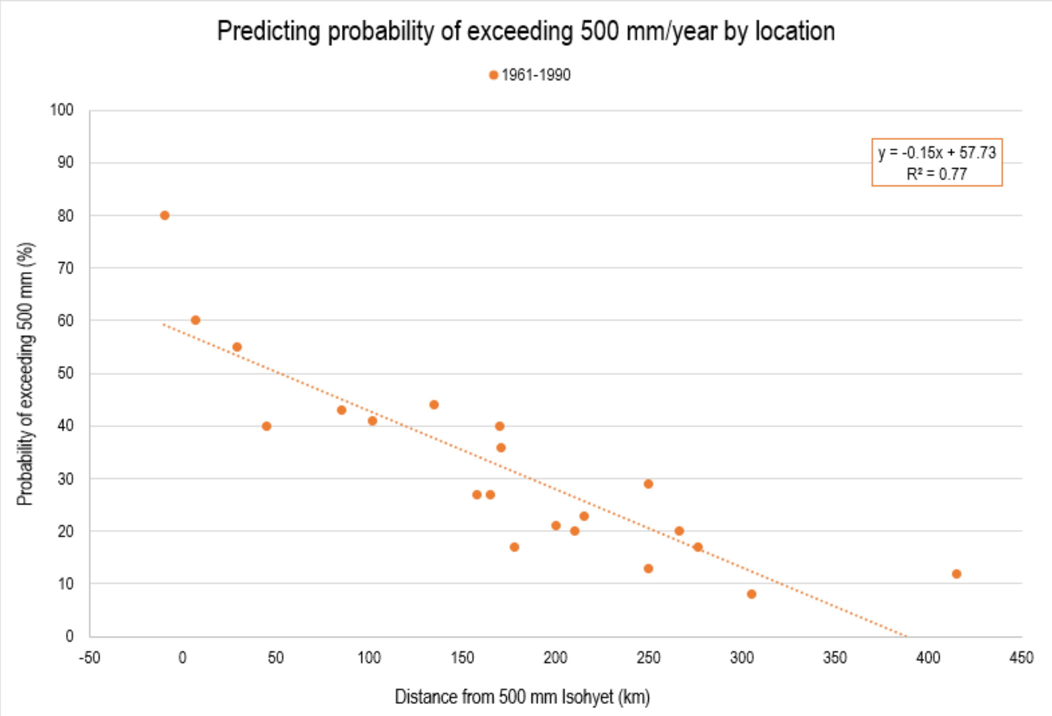


Table 2.4: Various Queensland weather station data

STATION NAME	BOM STATION ID	DISTANCE FROM 500 MM ISOHYET (KM)	1961-1990 PROBABILITY OF EXCEEDING 500 MM/YEAR (%)	1961-1990 MEDIAN ANNUAL RAINFALL (MM)
Boggabilla Post Office	53004	10	80	608
Morven Post Office	44050	7	60	542
Surbtion Station	36139	29	55	523
Merlin Station	30034	45	40	455
Barcaldine Post Office	36007	85	43	425
Granada Station	29022	102	41	395
Mount Morris	44052	135	44	479
Camoola Park	36013	158	27	424
Malboona	37030	165	27	378
Ambo Station	36002	170	40	358
Cloncurry	29008	171	36	391
Fernlee	44034	178	17	339
Camooweal	37010	200	21	362
Whitehill	36131	210	20	304
Cunnamulla	44026	215	23	382
Alni	37000	250	13	318

STATION NAME	BOM STATION ID	DISTANCE FROM 500 MM ISOHYET (KM)	1961-1990 PROBABILITY OF EXCEEDING 500 MM/YEAR (%)	1961-1990 MEDIAN ANNUAL RAINFALL (MM)
Bladensburg	37006	250	29	363
Elderslie	37046	266	20	315
Comongin North	45004	276	17	273
Barringun	48004	305	8	349
Boulia	38003	415	12	202
Source: Bureau of Meteorology (BOM), 2018.				

It was observed through this data set that probabilities of over 50% were often calculated at locations < 30 km from the 500 mm isohyet. These locations also had median annual rainfall above the literature-recommended limit of 500 mm/year. Once the distance from the Isohyet increased over 100 km, the probability dropped below 50% and the median annual rainfall also dropped below 500 mm/year (based on literature). Subsequently the probability dropped below 20% once the distance exceeded 250 km. The median annual rainfall is these areas were also typically below 350 mm/year.

The calculation of moisture risk probability and the moisture risk output matrix is shown in Table 2.5 and Table 2.6 respectively.

Table 2.5: Moisture risk probability calculation

MOISTURE RISK

The probability of rainfall at the project area exceeding 500 mm/year (X) can be determined using historic data sourced from http://www.bom.gov.au/climate/data/ as follows:

- Obtaining historic monthly rainfall data from the closest BOM weather station between the current standard statistics period of 1961-1990, and using the following equation:

$$\textbf{Probability (X)} = \frac{\textbf{Number of years total annual rainfall exceeded 500 mm}}{\textbf{Number of data years}} \times 100\%$$

When limited or no historical data is available then the approach may be used.

- Measuring the smallest distance in km (D) of the project location to the median annual 500 mm isohyet and using the following equation:

  Note: This method is not as reliable as obtaining historic rainfall data ($R^2 = 0.77$) and *should only be used when historic data is limited or unavailable.*

$$\textbf{Probability (X)} = 0.15D + 57.73$$

Table 2.6: Moisture Risk output matrix

MOISTURE RISK			
PROBABILITY (X) OF EXCEEDING 500 MM/YEAR	MOISTURE RISK		
X ≤ 20%	**L**	**L**	MOISTURE RISK
20% < X ≤ 50%	**L**	**M**	
X > 50%	**H**	**X**	
	LOW	HIGH	INITIAL PROJECT QUESTIONNAIRE RISK

2.3 TRAFFIC CONDITIONS CALCULATION

This part of the assessment requires calculation of the design traffic loading in ESAs/day, using two way annual average daily traffic (AADT), the per cent heavy vehicles, and an equivalency factor. A presumptive value for the equivalency factor can be found in Appendix E of Austroads 2019). The maximum 20-year design traffic loading identified in the literature and specified for use in this assessment procedure is 5×10^6 ESAs (Table 2.7).

Non-standard materials are typically utilised in pavement applications where the design traffic loading is less than 1×10^6 equivalent single axle (ESA) (Martin et al. 1989). They have been successfully used between 5×10^6 and 1×10^7

ESAs (Vuong et al. 1994; Martin et al. 1989; Martin 1992). Traffic volumes are often between 50 to 500 veh/day (two directions), with approximately 10-27% truck traffic (Eacott & Andrews 1977; Worrall, 1992).

The loads imposed by cars are negligible and therefore do not contribute to structural damage (Eacott & Andrews 1977). CULWAY loading analysis has shown that the most number of heavy vehicles typically using low-volume, regional pavements carry > 100 tonnes (class 12 heavy vehicles) (Worrall 1992). QTMR Technical Note 118: *Sealing of Unsealed Roads with Low Traffic* (QTMR 2015) classifies low traffic as a maximum two-way AADT of 300 veh/day and with up to 50 of these vehicles (17% HV) being Austroads Classes 3 – 12 vehicles (QTMR 2015).

Based on experience, a traffic risk table (Table 2.8) of HV/day was supplied by QTMR.

Table 2.7: Traffic conditions

TRAFFIC CONDITIONS (ESAS/DAY)
This assessment protocol is only applicable for lightly-trafficked roads with a 20-year design traffic loading of less than 5 x 10^6 ESAs as per **Item A.0**. HVs/day can be determined using the following Equation: **HV/day = (ESAs/day) / (ESAs/HV) = two way AADT x HV%** ESAs/HV may be taken from measured WIM data, QTMRTMR's Class-Specific Traffic Load Distribution spreadsheet tool (see: https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Pavement-design-supplement) or the presumptive WIM tables provided in Appendix E of the *Austroads Guide to Pavement Technology Part 2: Pavement Structural Design* Publication no: AGPT02-17, published: 29 November 2019).. What is the expected traffic loading in HV/day over the design period? ≤ 20 HV/day ☐ 50 < HV/day ≤ 100 ☐ 20 < HV/day ≤ 50 ☐ HV/day > 100 ☐

Table 2.8: Typical traffic risk and corresponding traffic risk levels for non-standards

RISK LEVEL	HV PER DAY
Very low	< 2
Low	2 – 20
Medium	20 – 25
High	25 – 50
Very high	50 – 100
Undesirable	> 100

2.4 OUTPUT OF PHASE 1 – CONTEXT RISK

The traffic conditions are combined with the results of the Moisture Risk assessment to provide the Context Risk (see Table 2.9).

As discussed previously, drainage and the exclusion of moisture from a pavement structure comprised of non-standard materials is the most important consideration to ensure ongoing performance. Therefore, there are more opportunities to obtain a "Low" Context Risk when the answers to the Initial Project Risk questionnaire have indicated favourable operating conditions and the Moisture Risk is low to medium.

The Context Risk will either be:

- Low – assigned "L".
- Medium – assigned "M".
- High – assigned "H".
- Undesirable – assigned "X".

When the Context Risk is rated as undesirable, the use of the material under the circumstances evaluated must be reconsidered .

Table 2.9: Context risk output matrix

CONTEXT RISK (PHASE 1 OUTPUT)					
MOISTURE RISK	CONTEXT RISK				CONTEXT RISK
HIGH RISK	**M**	**M**	**H**	**X**	
MEDIUM RISK	**L**	**M**	**H**	**X**	
LOW RISK	**L**	**L**	**M**	**H**	
	< 20	20 – 50	50 – 100	> 100	TRAFFIC CONDITIONS (HV/day)

Notes:

L – Low Context Risk

M – Medium Context Risk

H – High Context Risk

X – Undesirable project risk, reconsider use BEFORE moving to PHASE 2

20 year design traffic loading over 5 x 10^6 ESAs is not valid for use with this assessment as per Item A.0

Context Risk: LOW ☐ MEDIUM ☐ HIGH ☐ UNDESIRABLE ☐

3 PHASE 2: MATERIAL RISK AND APPLICATION EVALUATION

3.1 MATERIAL RISK

The Material Risk is dependent on the chosen material category (Winton Sandstone, Loams, Laterite Gravels, Ridge and Alluvial Gravels and White Rock). It uses basic material properties such a grading and plasticity characteristics. These properties have been identified through past research to provide a good indication of stability, permeability, workability, compatibility and subsequent expected performance of non-standard materials (Murphy & Grahame 1975).

This assessment provides the following material-dependent Material Risk output:

- Low Material Risk – assigned "1".
- Medium Material Risk – assigned "2".
- High Material Risk – assigned "3".
- Undesirable Material Risk – assigned "X".

If the Material Risk is Undesirable ("X"), blending to alter the material grading or plasticity must be undertaken before proceeding.

The Material Risk is used in conjunction with the Context Risk and the soil zone (reactive or non-reactive) to produce the Material Application in the next step as shown in Table 3.1.

Table 3.1: Material Risk evaluation risk matrices

MATERIAL RISK EVALUATION

2.0 Material Risk Matrix

Select the appropriate Material Risk Matrix based on the selected Material Type as per Item A.1

WINTON SANDSTONE

Fines Ratio	MATERIAL RISK		
< 0.30 or > 0.45	**X**	**H(3)**	MATERIAL RISK
≥ 0.30 and ≤ 0.45	**M(2)**	**L(1)**	
	< 100 or >900	≥ 100 and ≤ 900	**WLS**

LOAMS

Fines Ratio	MATERIAL RISK		
< 0.35 or > 0.55	**X**	**H(3)**	MATERIAL RISK
≥ 0.35 and ≤ 0.55	**M(2)**	**L(1)**	
	< 100 or >300	≥ 100 and ≤ 300	**WLS**

LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS

Fines Ratio	MATERIAL RISK		
< 0.30 or > 0.55	**X**	**H(3)**	MATERIAL RISK
≥ 0.30 and ≤ 0.55	**M(2)**	**L(1)**	
	< 30 or >200	≥ 30 and ≤ 200	**WLS**

WHITE ROCK

Fines Ratio	MATERIAL RISK		
< 0.30 or > 0.55	**X**	**H(3)**	MATERIAL RISK
≥ 0.30 and ≤ 0.55	**M(2)**	**L(1)**	
	< 90 or >280	≥ 90 and ≤ 280	**WLS**

Material Risk Category: LOW ☐ MEDIUM ☐ HIGH ☐

Notes:

– If the Material Risk is Undesirable ("X"), blending to alter the material grading or plasticity MUST be undertaken BEFORE proceeding to PHASE 3.

3.2 USE OF BASIC MATERIAL PROPERTIES

The fines ratio is a good indicator of the suitability of the overall grading, especially for non-standard road pavement materials which usually comprise a large proportion of finer materials as they are derived from the weathering process. The overall fines grading influences cohesive forces, soil suction, permeability, stability and durability (Kapitzke 1990), all which contribute directly to performance. Naturally-occurring, non-standard pavement materials are highly dependent on soil suction and cohesive forces for shear resistance (McLennan 1988).

Linear shrinkage, like the plasticity index, provides an indication of the plastic properties of the material in addition to its reactivity (volume change potential). The weighted linear shrinkage (WLS) is an index of the combined effect of these characteristics relative to the amount of the fines (Murphy & Grahame 1975). Linear shrinkage is often preferred over the plasticity test as it is easily obtainable in the field, easily repeatable and suitable for control testing (McLennan 1986; Vlasic & Murphy 1971).

Observations of field performance indicate pavement materials with low WLS values have a greater propensity for premature failure (Wijeyakulasuriya et al. 2004). The WLS is believed to be an indicator of the amount of cohesive fines in the material which in turn is believed to be a good performance indicator, with materials with adequate cohesive fines performing well (Kapitzke 2001). For this reason, there are minimum and maximum criteria for WLS.

In dry climates an excess of evaporation over rainfall exists, causing negative pore water pressure, or positive suction (Gourley, Newill & Schreiner 1993). This results in an attractive force between particles. The amount of soil suction developed within a material is dependent on pore size and moisture content. This also explains why natural materials often perform poorly at higher moisture contents (> 90% OMC), but better at lower levels (< 85% OMC).

3.2.1 WINTON SANDSTONE

Winton Sandstone that is suitable for use as a non-standard road pavement material is the decomposed top portion of sandstone deposits (Vlasic & Murphy 1972). These materials are highly susceptible to moisture, and also have the tendency to break down during construction. Therefore, the grading before construction is often not representative of that after construction (Vlasic & Murphy 1972).

Good performance is observed when rainfall is typically < 500 mm/year and the 20 year design traffic loading is less than 5 x 10^6 ESAs (Reeves 1992; Vuong et al. 1994, Martin 1992).

Similarly, the fines ratio is a good indicator of performance, as a higher fines ratio is associated with a lower permeability and therefore lower potential for moisture ingress. The typical value of the fines ratio of Winton sandstones is around 0.4 (Vanderstaay & Reeves 2000) with 25 to 60% passing the 0.075 mm sieve and 90-100 % passing the 0.425 mm sieve (Kapitzke & Carseldine 1989).

The plasticity index is considered to be an unreliable means of predicting the performance of Winton sandstone, with linear shrinkage identified as a better measure (Vlasic & Murphy 1971; Vuong et al. 1994). Linear shrinkage is often 4 to 10% and combined with the typical high 0.425 mm fraction, the typical WLS is also high (> 300).

3.2.2 LOAMS

Loam is described as a sand material with a high proportion of silt and clay fines (Vanderstaay & Reeves 2000). Extensive studies conducted in the central western district of Queensland on road pavements utilising loam material identified a strong connection between the fines ratio and performance (Kapitzke 1990).

Rainfall in the areas studied was typically 300 – 500 mm/year with evaporation rates of 3000 – 4000 mm/year. Traffic volumes were low, but loadings were heavy, with a design traffic loading of 1 x 10^5 to 3 x 10^6 ESAs (Kapitzke 1990).

Good performance was observed when the per cent passing the 0.075 mm sieve was greater than 20% and, more importantly ,the fines ratio was above 0.3 (Kapitzke 1990). The fines ratio was identified as the most crucial property in ensuring ongoing good performance of loam (Kapitzke 1990; Morris 1972). The linear shrinkage should also be above 1.5%, or WLS greater than 100 (Kapitzke 1990).

Further to this, in 1983 a specification for loam pavement materials was developed with a requirement that the fines ratio criteria be between 0.35 and 0.55, and a maximum WLS of 300 (Kapitzke 1990). When constructing on non-reactive soils, these criteria was still applicable; however, the fines could be slightly lower due to permeability not being as crucial (Kapitzke 1990).

3.2.3 LATERITE GRAVELS AND RIDGE/ALLUVIAL GRAVELS

This category covers several different types of materials including Laterite gravels such as ferricrete and ironstone in addition to ridge and alluvial gravels.

These materials have been used successfully in the past in areas with rainfall is less than 500 mm/year and traffic levels around 200 veh/day (two directions) (McLennan 1984). Generally, they comprise a matrix of granular, coarse particles surrounded by fine clay particles.

The fine material acts as a cohesive force and is a good indicator of expected performance (Kapitzke 2001). The presence of these plastic fines allows high suction forces to develop within the material which produces lower permeability (Hight, Toll & Grace 1988; Wijeyakulasuriya et al. 2004). These materials often have very low permeability with typical values between 1×10^{-7} to 1×10^{-8} m/s (Hight et al. 1988). Alluvial and ridge gravels with a low amount of cohesive fines have performed poorly in the past (Kapitzke 2001).

The plasticity characteristics of these fines, and the total content within the material matrix, determines the suction and ongoing performance. Materials with low WLS commonly have higher plastic strains and have failed prematurely in the past (Hight et al. 1988; Wijeyakulasuriya et Al. 2004; Bathurst 1998). Best performance has been observed when the WLS is from 20 to 140. A fines fraction between 5 and 20% has also performed satisfactorily (Kapitzke 2001; Hight et al. 1988).

Lateritic materials tend to have high suction forces which in turn produce a higher modulus. However, there is a rapid matric suction decrease with increased degree of saturation (Wijeyakulasuriya et al. 2004). For this reason, suction forces cannot be relied on to maintain pavement performance after heavy rainfall (Hight et al. 1988). At 85% OMC, typical matric suction levels are approximately 200 kPa and material moduli are between 450 to 550 MPa. At 100% OMC, matric suction drops to 50 kPa (Wijeyakulasuriya et al. 2004).

Changes in density have little effect on the matric suction which depends mostly on the clay fraction (Hight et al. 1988). To maximise the generation of suction forces within the material, it is best to compact at OMC and allow the material to dry back to the required value. Construction during or shortly after a very wet period is to be avoided (Kapitzke 2001).

3.2.4 WHITE ROCK

White rock generally applies to the pallid zone of a laterite profile developed on sedimentary rocks of tertiary age (Vanderstaay & Reeves 2000). It has the tendency to break down during construction and therefore the grading and plasticity before construction is often not representative of that after construction. The change in grading is advantageous for this material as the breakdown produces a well-graded, strong, impermeable product that has performed well in service (Bullen 2003). Studies of historic white rock pavements cite moisture ingress as the number one factor determining performance of these pavements (Tydd 1998).

Good performance is observed when rainfall is typically < 600 mm/year and the 20 year design traffic loading is less than 5×10^6 ESAs (Robinson et al. 1999; Waters & Donaghey 1987; Tydd 1998).

Linear shrinkage is often variable (4-10%) and combined with a typical 0.425 mm fraction of approximately 35% (Vanderstaay & Reeves 2000), the WLS is typically < 350. Linear shrinkage has been considered the main criterion for acceptance of a white rock material (Callaghan 1986) and when considered too high, 10 to 15% of sand can be added to reduce the WLS (Taylor 1987; Reeves 1989; Martin 1988). However, too much sand can have a detrimental effect on the strength so no more than 15% by total mass is recommended (Taylor 1987; Reeves 1989; Martin 1988).

A preliminary white rock specification was developed in 1982 based on materials that had been used in past road pavement applications. These specifications quoted a maximum linear shrinkage of 5% (Callaghan 1986). For sealed pavements with light to moderate traffic it was later specified that the WLS should be between 260 to 280 (Waters 1999).

Furthermore, the fines ratio should be between 0.30 to 0.55 to ensure low permeability and control stability of the fines fraction (Skinner 1989).

3.3 OUTPUT OF PHASE 2 – MATERIAL APPLICATION EVALUATION

The Material Application evaluation is determined by the:

- Context Risk
- Material Risk
- soil zone.

The material application evaluation is based on these factors and shown in Table 3.3.

The soil zone represents the anticipated subgrade reactivity in terms of the volumetric instability of expansive soils. Non-reactive soil zones are those defined as soils with low to medium expansive nature as shown in Table 3.2. Reactive soil zones are those defined as soils with high, very high and extreme expansive natures.

Table 3.2: Relationship between WPI, CBR (swell) and the expansive nature of non-standard materials

EXPANSIVE NATURE	WEIGHTED PLASTICITY INDEX	CBR SWELL (%)[1]
Extreme	> 4200	> 10.0
Very high	3200 – 4200	5.0 – 10.0
High	2200 – 3200	2.5 – 5.0
Moderate	1200 – 2200	0.5 – 2.5
Low	< 1200	< 0.5

Notes:

1. Swell at OMC, 95% to 98% MDD (standard compactive effort), four day soaked, and using a 4.5 kg surcharge

Source: Table 5.3.5 of QTMR (2018.)

Table 3.3: Material application evaluation table

MATERIAL APPLICATION EVALUATION					
2.1	Soil Zone	Non-reactive ☐	Reactive ☐		
2.2	Material Classification	Context Risk	Material Risk	Soil Zone	Application
		Low	Low	Non-reactive	NR1
			Medium		NR2
			High		NR3
		Medium	Low		NR4
			Medium		NR5
			High		NR6
		High	Low		NR7
			Medium		NR8
			High		NR9
		Low	Low	Reactive	R1
			Medium		R2
			High		R3
		Medium	Low		R4
			Medium		R5
			High		R6
		High	Low		R7
			Medium		R8
			High		R9

Application:__________

3.4 PHASE 3: SECONDARY MATERIAL ASSESSMENT REQUIREMENTS

Phase 3 is a test specification phase. It determines the tests, and test conditions, that need to be undertaken to obtain a Material Usage Risk for use in Phase 4. The Secondary Material Assessment Requirements are based on the Material Application determined in Phase 2 (Table 3.4).

Materials with lower moisture risk only require unsoaked California Bearing Ratio (CBR) testing to be undertaken. This is due to the expectation that these materials will not be used where in high moisture conditions are expected. All other materials, depending on the Material Type (White rock, Winton sandstone, etc.), will require a combination of unsoaked and soaked CBR, or soaked CBR and permeability testing.

Table 3.4: Secondary material assessment requirements based on phase 2 application

SECONDARY MATERIAL ASSESSMENT REQUIREMENTS	
3.1	Is the Material Application any of the following: ***NR1*** ***NR2*** ***NR3*** ***NR4***
3.1.1	*If **YES** to 3.1*, only **UNSOAKED** CBR testing is required. **See item 4.0 in Phase 4.** Notes: – All CBR testing should be undertaken in accordance with Test Method Q113A (QTMR 2017) and should be conducted at 100% MDD and 100% OMC, unless otherwise specified. – Other specific test methods are listed in ***ITEM B.0***
3.1.2	*If **NO** to 3.1*, **SOAKED** and **UNSOAKED** CBR testing is required, as well as **PERMEABILITY** testing, **See item 4.1 or 4.2 in Phase 4**. Notes: – All CBR testing should be undertaken in accordance with Test Method Q113A (QTMR 2017) and should be conducted at 100% MDD and 100% OMC unless otherwise specified. – Where a soaked CBR is specified, the soaking period shall be four days unless otherwise nominated in the design documents. – All permeability testing should be undertaken in accordance with Test Method AS1289.6.7.1 and should be conducted at 100% MDD and 100% OMC, unless otherwise specified. – Other specific test methods are listed in ***ITEM B.0***

4 PHASE 4: MATERIAL USAGE RISK

The Material Usage Risk is based on the results of the testing specified in Phase 3 in conjunction with material-specific Risk Matrices. There are three sets of Risk Matrices for use with different applications: low risk, medium risk and high risk applications. The Material Usage Risk Assessment for the three categories are shown in Table 4.1, Table 4.2 and Table 4.3 respectively.

Table 4.1: Material usage risk assessment – low risk applications

RISK MATRICES FOR APPLICATIONS NR1, NR2, NR3, NR4

4.0 For items following 3.1.1 and with the below applications, using test results as detailed in Section B.0, input into the risk matrices below to determine the Material Usage Risk.

This covers the following applications:

– NR1
– NR2
– NR3
– NR4

WINTON SANDSTONE		LOAMS	
Unsoaked CBR	**USAGE RISK**	**Unsoaked CBR**	**USAGE RISK**
≥ 25%	L	≥ 10%	L
< 25%	M	< 10%	M
LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS		**WHITE ROCK**	
Unsoaked CBR	**USAGE RISK**	**Unsoaked CBR**	**USAGE RISK**
≥ 25%	L	≥ 20%	L
< 25%	M	< 20%	M

Table 4.2: Material usage risk assessment – medium risk applications

RISK MATRICES FOR APPLICATIONS R1, R2, R3, NR5, NR6

4.1 For items following 3.1.2 and with the below applications, using test results as detailed in Section B.0, input into the risk matrices below to determine the Material Usage Risk.

This covers the following applications:

– R1
– R2
– R3
– NR5
– NR6

WINTON SANDSTONE				LOAMS			
Permeability	**USAGE RISK**			**Unsoaked CBR**	**USAGE RISK**		
> 5 x 10^{-7} m/s	H	M		≤ 10 %	H	M	
≤ 5 x 10^{-7} m/s	M	L		> 10 %	M	L	
	< 10 %	≥ 10 %	**Soaked CBR**		< 5 %	≥ 5 %	**Soaked CBR**
LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS				**WHITE ROCK**			
Permeability	**USAGE RISK**			**Permeability**	**USAGE RISK**		
> 5 x 10^{-7} m/s	H	M		> 5 x 10^{-7} m/s	H	M	
≤ 5 x 10^{-7} m/s	M	L		≤ 5 x 10^{-7} m/s	M	L	
	< 20 %	≥ 20 %	**Soaked CBR**		< 15 %	≥ 15%	**Soaked CBR**

Table 4.3: Material usage risk assessment – high risk applications

RISK MATRICES FOR APPLICATIONS R4, R5, R6, R7, NR7, NR8, NR9	
4.2	For items following 3.1.2 and with the below applications, using test results as detailed in Section B.0, input into the risk matrices below to determine the Material Usage Risk. This covers the following applications: – R4 – NR7 – R5 – NR8 – R6 – NR9 – R7 – R8

WINTON SANDSTONE

Permeability	USAGE RISK		
> 1 x 10^{-8} m/s	X	H	
≤ 1 x 10^{-8} m/s	H	M	
	< 15 %	≥ 15 %	Soaked CBR

LOAMS

Unsoaked CBR	USAGE RISK		
≤ 15 %	X	H	
> 15 %	H	M	
	< 5 %	≥ 5 %	Soaked CBR

LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS

Permeability	USAGE RISK		
> 1 x 10^{-8} m/s	X	H	
≤ 1 x 10^{-8} m/s	H	M	
	< 30 %	≥ 30 %	Soaked CBR

WHITE ROCK

Permeability	USAGE RISK		
> 1 x 10^{-8} m/s	X	H	
≤ 1 x 10^{-8} m/s	H	M	
	< 25 %	≥ 25 %	Soaked CBR

4.1 USE OF CALIFORNIAN BEARING RATIO AND PERMEABILITY

For basecourse applications, a minimum CBR of 40% should be achieved at 100% MDD (standard effort) and the design moisture content (DMC) (Martin et al. 1989; Kapitzke 1990).

There is also a need to control the permeability of the paving material (Kapitzke 1990). Low-permeability base materials minimise moisture penetration to underlying layers of a pavement therefore preventing moisture ingress and subsequent failure (Paige-Green 2003). Permeability of base materials should typically be lower than 5×10^{-7} m/s when compacted (Cocks et. al. 2015).

4.1.1 WINTON SANDSTONE

Similarly to loam material, there is a large increase in CBR when moisture is lower than 100% OMC. Unsoaked CBR values at 100% OMC are approximately 25% and increase above a CBR of 90% at 80% OMC (Vlasic & Murphy 1972). The measured in situ CBR values for sandstone pavements are typically > 30% at field moisture, while soaked CBR values are typically < 10%. Studies have shown that a decrease in moisture content of Winton sandstones subsequently increases cohesion and suction (Martin 1992). This in turn increases the performance of the material.

Aggregates with high plasticity are subject to reduced strength when wet, increased moisture susceptibility and poor workability (Cook et al. 2001). Ensuring low permeability of the base when using Winton sandstone has been identified as a major factor in obtaining good performance (Bullen 2003).

4.1.2 LOAMS

Unsoaked CBR values for loams are often quite low (< 10%) at moisture levels of 100 % of OMC but increase significantly (> 60%) at lower moisture contents which better represent operating moisture conditions (ARRB 1971; Morris 1972; Porter & Armstrong 1978). Soaked CBR values usually show similar increases as moisture decreases, with a CBR of > 40% CBR at moisture conditions closer to operating levels. (ARRB 1971; Porter & Armstrong 1978).

Higher CBR values have been achieved when using modified compaction methods at the same moisture contents of standard compaction-prepared samples (Porter & Armstrong, 1978). The OMC of the Loam material was often lower at modified compaction than at standard moisture by between 2%-5% (ARRB 1971; Porter & Armstrong 1978).

Based on observed performance, adequate soaked CBR values were considered to be >50% at operating moisture content (~80% OMC) (Kapitzke 1990). Typical unsoaked CBR values for loams throughout Queensland can be between 20% to 50% at 100% maximum dry density (MDD) and 100% OMC using standard compaction (Eacott & Andrews 1977).

4.1.3 LATERITE GRAVELS AND RIDGE/ALLUVIAL GRAVELS

Typical values of unsoaked CBR for Laterites at 100% OMC and compacted at standard effort are >30%, and soaked values < 20% (Thomas 1999). Similar to loam materials, these values both increase above CBR 100% when modified compaction is used. Furthermore, at standard compaction and lower moisture contents (~ 85% OMC) the CBR values increase above 80% (Thomas 1999).

Unlike other materials covered by this assessment, the soaked and unsoaked CBR values of laterite gravels are very similar, with the unsoaked values only slightly higher than soaked (Thomas 1999; Eades 1978) suggesting these materials are relatively moisture insensitive.

It is important with laterite gravels to ensure a low permeability, as this ensures adequate fines are present within the material to form suction forces that help performance (Kapitzke 2001; Hightet al. 1988; Wijeyakulasuriya et al. 2004).

4.1.4 WHITE ROCK

Again, there is a large increase in CBR when the moisture content is lower than 100% OMC (Martin 1988). Unsoaked values typically produce CBRs of > 60% at 80% OMC (Drew 1989). The typical in situ operating moisture contents in a White Rock pavement is between 60 to 75% OMC (Martin 1988).

Similarly to the findings for Winton Sandstone, ensuring low permeability in White Rock pavements has proved to promote good performance (Tydd 1998). Typical permeabilities at 100% OMC and 100% MDD (both using standard compaction) is less than 1×10^{-7} m/s (Tydd 1998). Permeability decreases when the material is compacted at moisture contents lower than 100% OMC (Tydd 1998).

5 RISK MANAGEMENT

The guidance provided can be used to mitigate the risks associates with using a material in the medium, high or undesirable usage risk categories. Typically, materials in the low usage risk category do not require additional controls; however, the guidance may be adopted as good practice in any case.

This risk control guidance may be applied to the material assessment procedure in the following ways:

5.1 RISK CONTROL GUIDANCE

The recommended guidance may be incorporated into the project design and contract documents/requirements, and the material assessment procedure redone to determine the revised material usage risk.

The Risk Control Guidance specific to each material type has been gathered from the reviewed literature. This guidance generally includes:

- general design and construction advice
- blending or screening of the material to improve grading and/or plasticity properties
- stabilisation to create a lightly-bound pavement material.

By adopting some or all of these recommendations, the Material Usage Risk given by the procedure may be reduced. Further details of the Risk Control Guidance is presented in Appendix A.6.1.

5.2 LOCAL EXPERIENCE

Local experience and conditions may justify the use of materials regardless of the outcomes of this assessment procedure.

Where local experience shows that material of a similar quality has performed satisfactorily in comparable conditions, the designer may elect to utilise those materials irrespective of the material usage risk determined from this procedure on the condition that the requirements/controls that were adopted for the local use cases are implemented on the current project.

6 DISTRIBUTION AND FEEDBACK

Feedback was sought from 27 QTMR pavement practitioners throughout Queensland on the suitability and applicability of the material assessment procedure for non-standards. The assessment procedure as presented in Appendix A was distributed through email, along with the contents of this report as the basis and justification for the assessment procedure. A questionnaire was also provided to enable targeted feedback of the assessment (Appendix B). No formal responses were received .

A meeting was also held at the Central West District (CWD) to obtain feedback on the assessment procedure. The outcome of this discussion was detailed in the questionnaire and responses submitted to ARRB. A summary of the feedback from the CWD about the use of non-standard materials included the following:

- The WQ35 specifications for base material are used for heavily-trafficked roads in the district:
  - The assessment procedure should be based around the WQ35 grading and plasticity requirements to determine risk rather than values from the literature.
- The use of ridge gravels is diminishing due to low source volumes and required permits:
  - Ridge gravels could be combined with laterite gravels as they are treated the same locally.
- CBR is not a common specification requirement/test:
  - Common properties for specification are grading a plasticity information. CWD also commented that the questionnaire could be clearer or could better describe what is being assessed.
- Permeability is not a common test.
- Experience has shown good performance of local materials when annual rainfall is below 500 mm/year.
- Moisture Risk could be less stringent:
  - Low < 50%
  - Medium 50-70%
  - High > 70%.
- Traffic Risk could be less stringent:
  - Low < 100 HV/day
  - Medium 100 – 300 HV/day
  - High > 300 HV/day.
- WLS and fines ratio are not a great indicator of risk or the performance of sandstones.
  - Use of experienced contractors when using sandstone is important.
- Further calibration of the assessment criteria is required.
- Distance to source and haulage also influence material decisions.

7 CONCLUSIONS

The purpose of the Material Assessment Procedure for non-standard unbound granular materials is to systemise and summarise QTMR's knowledge and experience to date with four common non-standard pavement materials used throughout the state for road pavements and within certain limitations.

Published documentation and data from QTMR's extensive literature library was used as the basis for various material property criteria included in the assessment procedure. These criteria included:

- rainfall and moisture effects on pavement performance
- traffic levels
- grading characteristics
- plasticity characteristics
- California Bearing Ratio characteristics
- permeability characteristics.

In addition to the extensive review of the literature, regional practitioner input was requested via a questionnaire. Feedback was received from one area (Central West District) which identified various areas for revision and further investigation within the assessment.

Given the outputs of the procedure were not able to be verified from feedback and the recent completion of Austroads research (project AAM6144 *Sustainable roads through fit-for-purpose use of available materials*), which investigated a similar material risk assessment procedure combined with whole of life cycle cost considerations, it has been decided that there will be no further development of the procedure included in this document.

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World Metrological Organization (WMO) 2007, *The Role of climatological normals in a changing climate*, WMO/TD No. 1377; WCDMP No. 61, Geneva.

Australian Standards

AS1289, *Methods of testing soils for engineering purposes. Method 6.7.1: soil strength and consolidation tests – determination of permeability of a soil – constant head method for a remoulded specimen*.

QTMR Specifications

MRTS05: *Unbound pavement (November 2019)*

MRTS07B: *In situ stabilised pavements using cement or cementitious blends (July 2019)*

MRTS07C Insitu Stabilised Pavements using Foamed Bitumen (July 2019)

MRTS10: *Plant-mixed lightly bound pavement (November 2019)*

QTMR Test Methods

QTMR Materials Testing Manual, edn 4, amendment 4, December 2017:

- Q101: *Preparation of disturbed samples*, March 2016.
- Q101E: *Pre-treatment, December* 2017.
- Q103A: *Particle size distribution of soil – wet sieving*, September 2017.
- Q104A: *Liquid limit of soil*, December 2017.
- Q106: *Linear shrinkage of soil*, March 2016.
- Q113A: *California Bearing Ratio of soil – standard*, December 2017.
- Q142A: *Dry density-moisture relationship of soils and crushed rock – standard*, September 2017.

QTMR Materials Testing Manual, Part 2: Application, July 2019

APPENDIX A MATERIAL ASSESSMENT PROCEDURE FOR NON-STANDARD MATERIALS

This Appendix presents the full preliminary material assessment for non-standard materials in the anticipated layout which was distributed for feedback.

A.1 USING THE ASSESSMENT

PROJECT SCREENING

A.0 This Material Assessment Procedure (MAP) typically assumes a 20 year design traffic loading less than 5 x 10^6 ESAs and the use of a sealed unbound granular pavement.

This MAP is based on, and calibrated against, past pavement performance observations and measurements on the state controlled road network of Queensland within certain limitations (use context).

Material Category

A.1 The common non-standard pavement materials that are covered by this MAP and have been used historically by QTMR are:

- “Winton Sandstones”: a specific term which covers the pallid and mottled zones of a weathered sandstone profile, typically found in the Winton region. Essentially a type of white rock with sandstone origins.
- “Loams”: a general term which covers clayey and silty sands.
- “White rock”: a general term which covers the pallid and mottled zone of the laterite profile. White Rock may have origins from weathered sandstone, limestone, shale or “mudrocks”.
- Laterite gravels: a general term which covers the top portion of the weathering profile and includes ferricrete and ironstone.
- “Ridge and Alluvial gravels”: river and creek gravels which often meet standard specification material requirements.

The assessment protocol **SHALL NOT** be used for other materials.

Test Methods

B.0 The following test methods shall be used in conjunction with the Material Assessment Procedure:

TEST METHOD	REFERENCE STANDARD	TEST FRACTION
Sample preparation	Q101	-
Pre-treatment	Q101E	-
Particle size distribution and fines ratio	Q103A	26.5 – 0.075 mm
Liquid limit	Q104A	< 0.425 mm
Linear shrinkage	Q106	< 0.425 mm
MDD & OMC (standard compaction)	Q142A	< 19.0 mm
Permeability	AS 1289.6.7.1	< 19.0 mm
Standard CBR	Q113A	< 19.0 mm

Test Method Notes:

- All CBR testing to be conducted at 100% standard maximum dry density (MDD) and 100% OMC (standard compaction)unless otherwise specified.
- Where a soaked CBR is specified, the soaking period shall be four days unless otherwise nominated in the design documents.
- All permeability testing should be conducted at 100% MDD and 100% OMC (standard compaction), unless otherwise specified.
- The pre-treatment requirements for testing of Winton sandstone are incorporated into the following test methods:
  - Q101 Sample preparation
  - Q101E Pre-treatment

PROJECT SCREENING
– The linear shrinkage testing for Winton Sandstone has been incorporated into the standard test methods: o Q106 – Linear shrinkage of a soil – Addition of sand to White Rock has historically been completed with a specialised testing suite by local (Western Downs) districts.

A.2 PHASE 1: CONTEXT RISK

INITIAL PROJECT RISK QUESTIONNAIRE			
ITEM	RISK	RISK RATING RESPONSE	
		YES	NO
1.0	Has a drainage assessment been undertaken in accordance with the Road Planning Design Manual and QTMR Road Drainage Manual?	LOW	HIGH
1.1	Is the road geometry and location topography likely to protect the pavement from infiltration and inundation? – Refer to WQ35 Section 6 for further details. – Includes embankment height and batter slope.	LOW	HIGH
1.2	Will both road shoulders be sealed to a minimum width of 1.5 m?	LOW	SEE 1.2.1
1.2.1	If NO to 1.2, is the permeability of the base material likely to be LESS than 5 x 10^{-7}m/s once compacted to specification criteria?	LOW	HIGH
1.3	Will strict control be implemented during construction to ensure excess moisture is minimised? That is, control of: – Correct material mixing, placement and dry back methods – Scheduling of earthworks construction during dry months – Selection and implementation of construction drainage o Refer to WQ35 and WQ35 Table 1.0 for further details – Compaction to specification – Ample compaction verification – Sufficient dryback of pavement layers before placement of successive layers or seal	LOW	HIGH
1.4	Is ongoing and timely maintenance of seals, shoulders and drainage likely to occur? For example to ensure: – Free flowing, working drainage with no silt build up or erosion. – No unsealed pavement cracks above medium severity. – No encroaching grass and/or vegetation on shoulders.	LOW	HIGH

INITAL PROJECT RISK: LOW ☐ HIGH ☐

Notes on assigning Initial Project Risk:

– If the answer to any of the above questions is HIGH, the Initial Project Risk output is also HIGH.

Moisture Risk

The Probability of rainfall at the project area exceeding 500 mm/year (X) can be determined using historic data sourced from http://www.bom.gov.au/climate/data/

Calculate the probability by obtaining historic monthly rainfall data from the closest Bureau of Metrology (BOM) weather station between the current standard statistics period of 1961-1990 and using the following Equation:

$$\textbf{Probability (X)} = \frac{\textbf{Number of years total annual rainfall exceeded 500 mm}}{\textbf{Number of data years}} \times 100\%$$

When limited or no historical data is available the following equation may be used.

Measuring the smallest distance in km (D) of the project location to the median annual 500 mm isohyet and using the following Equation to calculate the probability:

Note: This method is not as reliable as obtaining historic rainfall data (R^2= 0.77) and should only be used when historic data is limited or unavailable.

$$\textbf{Probability (X)} = 0.15D + 57.73$$

The Probability, X, obtained above is used in conjunction with the Initial Project Risk to determine the Moisture Risk using the risk matrix on the following page.

INITIAL PROJECT RISK QUESTIONNAIRE			
Moisture Risk (continued…)			
PROBABILITY (X) OF EXCEEDING 500 MM/YEAR			
X ≤ 20%	**L**	**L**	
20% ≤ X ≤ 50%	**L**	**M**	
X ≥ 50%	**H**	**X**	
	LOW	**HIGH**	INITIAL PROJECT RISK

L – Low Moisture Risk
M – Medium Moisture Risk
H – High Moisture Risk
X – Undesirable Moisture Risk– review Questionnaire BEFORE moving to PHASE 2.

MOISTURE RISK: LOW ☐ MEDIUM ☐ HIGH ☐ UNDESIRABLE ☐

Traffic Conditions Calculation (HV/day)

This assessment protocol is only applicable for lightly trafficked sealed unbound granular roads with a 20-year design traffic loading less than 5 x 10^6 ESAs as per Item A.0.

HV/day can be determined using the following Equation:

HV/day = (ESAs/day) / (ESAs/HV) = AADT (two-way) x HV%

- ESAs/HV may be taken from measured WIM data, QTMR's Class-Specific Traffic Load Distribution spreadsheet tool (see: https://www.tmr.qld.gov.au/business-industry/Technical-standards-publications/Pavement-design-supplement) or the presumptive WIM tables provided in Appendix E of the Austroads *Guide to Pavement Technology Part 2: Pavement Structural Design* Publication no: AGPT02-17, published: 29 November 2019).

What is the expected traffic level in HV/day?

≤ 20 HV/day ☐ 50 < HV/day ≤ 100 ☐

20 < HV/day ≤ 50 ☐ HV/day > 100 ☐

Context Risk (Phase 1 Output)					
MOISTURE RISK					
HIGH RISK	**M**	**H**	**X**	**X**	
MEDIUM RISK	**L**	**M**	**H**	**H**	
LOW RISK	**L**	**L**	**M**	**H**	
	< 20	**20 – 50**	**50 – 100**	**> 100**	TRAFFIC CONDITIONS (HV/day)

Notes:
L – Low Context Risk
M – Medium Context Risk
H – High Context Risk
X – Undesirable Context Risk – review proposed use BEFORE moving to PHASE 2.
Traffic levels exceeding 5 x 10^6 ESAs for 20-year design period are not recommended for use with this assessment as per Item A.0

Context Risk: LOW ☐ MEDIUM ☐ HIGH ☐ UNDESIRABLE ☐

Comments and notes:

A.3 PHASE 2: MATERIAL RISK AND APPLICATION EVALUATION

MATERIAL RISK EVALUATION

2.0 Material Risk Matrix

Select the appropriate Material Risk Matrix based on the selected Material Type as per ***Item A.1.***

WINTON SANDSTONE

Fines Ratio			
< 0.30 or > 0.45	**X**	**H**	
≥ 0.30 and ≤ 0.45	**H**	**M**	
	< 100 or >900	*≥ 100 and ≤ 900*	***WLS***

LOAMS

Fines Ratio			
< 0.35 or > 0.55	**X**	**H**	
≥ 0.35 and ≤ 0.55	**M**	**L**	
	< 100 or >300	*≥ 100 and ≤ 300*	***WLS***

LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS

Fines Ratio			
< 0.30 or > 0.55	**X**	**H**	
≥ 0.30 and ≤ 0.55	**M**	**L**	
	< 30 or >200	*≥ 30 and ≤ 200*	***WLS***

WHITE ROCK

Fines Ratio			
< 0.30 or > 0.55	**X**	**H**	
≥ 0.30 and ≤ 0.55	**M**	**L**	
	< 90 or >280	*≥ 90 and ≤ 280*	***WLS***

Material Risk Category: LOW ☐ MEDIUM ☐ HIGH ☐

Notes:

– If the Material Risk is Undesirable (“X”), blending to alter the material grading or plasticity **MUST** be undertaken **BEFORE** proceeding to *PHASE 3*.

Material Application Evaluation

2.1 Subgrade

Non-reactive (low to moderate expansive nature) ☐

Reactive (high, very high and extreme expansive ☐

2.2	**Context Risk**	**Material Risk**	**Subgrade**	**Application**
	Low	Low	Non- reactive	***NR1***
		Medium		***NR2***
		High		***NR3***
	Medium	Low		***NR4***
		Medium		***NR5***
		High		***NR6***
	High	Low		***NR7***
		Medium		***NR8***
		High		***NR9***
	Low	Low	Reactive	***R1***
		Medium		***R2***
		High		***R3***
	Medium	Low		***R4***
		Medium		***R5***
		High		***R6***
	High	Low		***R7***
		Medium		***R8***
		High		***R9***

Material Application:_______________

A.4 PHASE 3: SECONDARY MATERIAL ASSESSMENT REQUIREMENTS

SECONDARY MATERIAL ASSESSMENT REQUIREMENTS	
3.1	Is the Material Application any of the following: ***NR1*** ***NR2*** ***NR3*** ***NR4***
3.1.1	*If **YES** to 3.1*, only **UNSOAKED** CBR testing is required. **See item 4.0 in Phase 4.** Notes: – All CBR testing should be undertaken in accordance with Test Method Q113A and should be conducted at 100% MDD and 100% OMC (standard compaction). – Other specific test methods are listed in ***ITEM B.0***
3.1.2	*If **NO** to 3.1*, **SOAKED** and **UNSOAKED** CBR testing is required, as well as **PERMEABILITY** testing, S**ee item 4.1 or 4.2 in Phase 4.** Notes: – All CBR testing should be undertaken in accordance with Test Method Q113A and should be conducted at 100% MDD and 100% OMC unless otherwise specified. – Where a soaked CBR is specified, the soaking period shall be four days unless otherwise nominated in the design documents. – All Permeability testing should be undertaken in accordance with Test Method AS1289.6.7.1 and should be conducted at 100% MDD and 100% OMC (standard compaction), unless otherwise specified. – Other specific test methods are listed in ***ITEM B.0***

A.5 PHASE 4: MATERIAL USAGE RISK

MATERIAL USAGE RISK ASSESSMENT

To determine the Material Usage Risk, use the Risk Matrices presented in either **Item 4.0**, **Item 4.1** **OR** **Item 4.2** **DEPENDING ON THE MATERIAL APPLICATION**. Within each item there are specific Risk Matrices for each of the Material Categories as per **Item A.0**.

Risk Matrices for Applications NR1, NR2, NR3, NR4

4.0 For items following 3.1.1 and with the below applications, using test results as detailed in Section B.0, input into the risk matrices below to determine the Material Usage Risk.

This covers the following applications:

- NR1
- NR2
- NR3
- NR4

WINTON SANDSTONE

Unsoaked CBR	
≥ 25%	L
< 25%	M

LOAMS

Unsoaked CBR	
≥ 15%	L
< 15%	M

LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS

Unsoaked CBR	
≥ 25%	L
< 25%	M

WHITE ROCK

Unsoaked CBR	
≥ 20%	L
< 20%	M

Risk Matrices for Applications R1, R2, R3, NR5, NR6

4.1 For items following 3.1.2 and with the below applications, using test results as detailed in Section B.0, input into the risk matrices below to determine the Material Usage Risk.

This covers the following applications:

- R1
- R2
- R3
- NR5
- NR6

WINTON SANDSTONE

Permeability			
> 5 x 10^{-7} m/s	H	M	
≤ 5 x 10^{-7} m/s	M	L	
	< 10 %	≥ 10 %	Soaked CBR

LOAMS

Unsoaked CBR			
≤ 15%	H	M	
> 15%	M	L	
	< 10 %	≥ 10 %	Soaked CBR

LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS

Permeability			
> 5 x 10^{-7} m/s	H	M	
≤ 5 x 10^{-7} m/s	M	L	
	< 20 %	≥ 20 %	Soaked CBR

WHITE ROCK

Permeability			
> 5 x 10^{-7} m/s	H	M	
≤ 5 x 10^{-7} m/s	M	L	
	< 15 %	≥ 15%	Soaked CBR

MATERIAL USAGE RISK ASSESSMENT (CONTINUED)

Risk Matrices for Applications R4, R5, R6, R7, NR7, NR8, NR9

4.2 For items following 3.1.2 and with the below applications, using test results as detailed in Section B.0, input into the risk matrices below to determine the Material Usage Risk.

This covers the following applications:

- R4
- R5
- R6
- R7
- R8
- NR7
- NR8
- NR9

MATERIAL USAGE RISK ASSESSMENT (CONTINUED)							
WINTON SANDSTONE				***LOAMS***			
Permeability				Unsoaked CBR			
> 1 x 10^{-8} m/s	**X**	**H**		≤ 15 %	**X**	**H**	
≤ 1E-8 m/s	**H**	**M**		> 15 %	**H**	**M**	
	< 15%	≥ 15%	Soaked CBR		< 5%	≥ 5%	Soaked CBR
LATERITE GRAVELS and RIDGE/ALLUVIAL GRAVELS				***WHITE ROCK***			
Permeability				Permeability	USAGE RISK		USAGE RISK
> 1 x 10^{-8} m/s	**X**	**H**		> 1 x 10^{-8} m/s	**X**	**H**	
≤ 1 x 10^{-8} m/s	**H**	**M**		≤ 1 x 10^{-8} m/s	**H**	**M**	
	< 30%	≥ 30%	Soaked CBR		< 25%	≥ 25%	Soaked CBR

- L – Low Material Usage Risk
- M – Medium Material Usage Risk
- H – High Material Usage Risk
- X – Undesirable Material Usage Risk– MATERIAL NOT RECOMMENDED FOR USE WITHOUT STRICT CONTROL

Usage Risk Category: LOW ☐ MEDIUM ☐ HIGH ☐

A.6 RISK MANAGEMENT

The guidance provided in this section may be used to mitigate the risks associated with using a material in the medium, high or undesirable usage risk categories. Typically, materials in the low usage risk category do not require additional controls, however the following guidance may be adopted as good practice in any case.

A.6.1 RISK CONTROL GUIDANCE

The recommended guidance may be incorporated into the project design and the material assessment procedure rerun to determine a revised material usage risk (based on these risk controls being in place).

The table below details specific Risk Control Guidance which has been suggested in reviewed literature. This guidance generally includes:

- general design and construction advice
- blending or screening of the material to improve grading and/or plasticity properties
- stabilisation to create a lightly-bound pavement material.

By adopting some or all of these recommendations, the Material Usage Risk may be reduced.

RISK CONTROL GUIDANCE TABLES

GENERAL GUIDANCE APPLICABLE TO ALL MATERIALS

Material

- Understand project details and if the material complies with WQ35 guidelines
  - If non-compliant to WQ35, further investigation through the risk assessment should be undertaken
  - WQ compliant materials for high traffic roads
- Undertake adequate soil surveys and testing well in advance of construction
- Ensure adequate stockpile management and material testing as non-standard materials are inherently variable
- Screening or blending can be undertaken to overcome grading deficiencies and plasticity problems
- Permeability of final product should be checked

Design

- Ensure cross-sections will shed water especially in low lying areas and/or areas of high rainfall. Table drain design is important, including transverse and longitudinal aspects.

- Full width pavement construction is vital in ensuring shoulder stability and performance
- The bottom of the pavement should be above existing natural surfaces to ensure good drainage
- Ensure sealed shoulders at least 1.5 m wide are provided on each side with adequate seal width for the expected traffic

Construction

- Ensure the subgrade is at or near equilibrium moisture content before constructing overlying layers, especially in expansive soil zones
- Ensure correct dryback before placing seal

Procurement

- Use of sole invitee contracts with experience contractor if permitted/possible, especially for higher risk materials.

Table 1 – Typical permissable moisture contents

Zone	Typical 1 Moisture Content Range – % of Optimum Moisture Content (OMC) based on Standard Compaction	
	Before covering/sealing	Equilibrium (post-construction)
Base	< 70	35-50
Subbase	< 70	35-65
Embankment (top 300 mm above top of subgrade)	total layer: 60-85 upper 150 mm < 70	70-95
Embankment (> 300 mm below top of subgrade)		70-95

Source: WQ35 (Refer to WQ35 for further details).

- In areas of scarce water, priming short sections of pavement as they are completed
- Grid rolling to breakdown oversize stones often can improve quality but over working should be avoided
- Compaction trials should be undertaken to determine the number of passes to achieve the required degree of compaction
- The maximum depth of each lift layer should be related to the compaction equipment
- Ensure there is no ponding of water on any layer of the pavement during construction
- Ensure shoulders and pavement edges are compacted to the same degree as the rest of the pavement area

Maintenance and monitoring

- Ensure shoulder upkeep to prevent moisture ingress
  - includes vegetation/grass control and early intervention to correct edge defects (like edge break)
- Ensure seal upkeep to prevent moisture ingress
  - includes seal rejuvenation and early crack and pothole intervention and timely resealing
- Ensure adequate drainage adequacy to minimise effects of inundation
  - includes allowance for drainage inspections after heavy rainfall events to prevent pavement damage from blocked or deformed drainage systems
- Re-assess seal width adequacy once pavement has been trafficked, especially after seasonal high traffic periods or inundation.
- Monitor traffic levels throughout service life
- If inundated assess pavement (e.g. structural capacity) for carriage of heavy vehicles and implement restrictions as/if needed to minimise damage to pavement (e.g. deflection monitoring) regularly.

WINTON SANDSTONE

Material

- Potential source pits should be tested on a grid pattern of 25m x 25m
- Any areas of high shrinkage (LS > 8%) material should be avoided.
- Pulverisation of large clumps of sandstone is achieved by windrowing and grid rolling the material
  - Spread in layers of up to 200mm thickness and roll with a grid roller until the maximum clod size of 50mm is achieved, generally after four to five passes
  - Following the pulverisation process the material is wet mixed and allowed to cure overnight prior to cartage onto the road
- Compaction factor generally between 1.3 and 1.4 (i.e. approximately 130 m3 of dry loose sandstone will produce 100 m3 at 100% MDD (standard compaction)
- See general guidance for more details.

Design

- Pavement thickness should be no less than 200 mm
    - Note: Winton Sandstone can absorb excess bitumen in hot conditions – seal design and construction may need to take this into account.
- Meeting these requirements will reduce water penetration and moisture sensitivity and may increase the materials strength. The following measures should be considered especially if Usage Risk is MEDIUM or HIGH
    - Lime stabilisation may be considered in accordance with TMR Materials Testing Manual, Part 2: Application, Section 7.
    - The addition of cementitious binders can also be used to increase strength and reduce moisture sensitivity. For materials that are close to meeting MRTS05 *Unbound Pavements* requirements for standard materials, stabilisation should be completed in accordance with the following TMR documents:
        - MRTS10 Plant-Mixed Lightly Bound Pavements.
        - Materials Testing Manual, Part 2: Application
        - MRTS07B Insitu Stabilised Pavements using Cement or Cementitious Blends
        - MRTS07C Insitu Stabilised Pavements using Foamed Bitumen
- Full width base and subbase construction should be included as it has been shown to enhance performance.
- Flat batters are recommended for shoulders to prevent scour and erosion and minimum shoulder a pavement edge cracking.

<u>Construction</u>

- Typical density and OMC at 100% MDD (standard compaction):
    - o MDD = 1600 – 1750 kg/m3
    - o OMC = 17.5 – 21 %
- Limit mixing time during construction as material will breakdown and change materials properties
- Compaction of unbound material should be undertaken at a moisture content 2-3% below OMC of SMDD to produce optimum results
- A compaction trial should be undertaken to confirm the best compaction method
- Compaction of stabilised material should be undertaken at 90 – 105% OMC of MDD (standard compaction) to produce optimum results
- Typical compacted lift heights should be between 100 – 150 mm. Softer sandstones will require thicker lifts < 200 mm
- Bitumen priming of this material should be undertaken when base is 1 – 2% below equilibrium moisture to prevent cracking
- Heavy application or a double coat prime for seal is required to ensure adhesion and void filling – seal design and construction may need to take this into account.
- A double/double seal for waterproofing is also recommended <u>especially</u> if Usage Risk is ***MEDIUM*** or ***HIGH***
- Ensuring adequate dryback before sealing is crucial to performance
- See general guidance for more details

<u>Maintenance</u>

- Allowance should be made for ongoing seal maintenance with enrichments, rejuvenation or reseals, <u>especially</u> if Usage Risk is ***MEDIUM*** or ***HIGH***
- After rain seal edges are highly vulnerable to damage by scour and rutting and need to be protected / repaired
- See general guidance for more details

LOAMS

<u>Material</u>

- For optimum performance there needs to be a balance between permeability and strength (CBR) which can be controlled by grading and plastic properties.
    - Consider material blending if material has unsatisfactory grading or plasticity
- The existence of a gap between the 0.425 mm and 2.36 – 6.5 mm sieve (armchair grading) is not detrimental to performance.
- The existence of a flatter grading curve above the 0.425 mm sieve is not detrimental to performance.
- See general guidance for more details.

<u>Design</u>

- See general guidance for more details.

<u>Construction</u>

- Typical density and OMC at 100% MDD (standard compaction):

- MDD = 1700 – 1800 kg/m³
- OMC = 16%.

– Undertake compaction at a moisture content of ~2% below OMC. Too dry of OMC will effect permeability.
  - A compaction trial should be undertaken to confirm the best compaction method,

– See general guidance for more details.

Maintenance

– See general guidance for more details.

LATERITE GRAVELS

Material

– See general guidance for more details.

Design

– Consider higher embankments (> 300 mm) for improved moisture mitigation when using lateritic gravels especially if Usage Risk is ***MEDIUM*** or ***HIGH.***

– See general guidance for more details.

Construction and material

– Typical compaction:
  - 95% MDD achieved at 7% OMC

– Meeting these requirements will reduce water penetration and moisture sensitivity and may increase the materials strength. This should be considered especially if Usage Risk is ***MEDIUM*** or ***HIGH.***
  - Lime stabilisation may be considered in accordance with TN 151 *Testing of Materials for Lime Stabilisation*.
  - The addition of cementitious binders can also be used to increase strength and reduce moisture sensitivity. For materials that are close to meeting MRTS05 – *Unbound Pavements* – requirements for standard materials, stabilisation should be completed in accordance with:
    - MRTS10 – *Plant-Mixed Lightly Bound Pavements*.
    - MRTS07B Insitu Stabilised Pavements using Cement or Cementitious Blends
    - MRTS07C Insitu Stabilised Pavements using Foamed Bitumen
    - Materials Testing Manual, Part 2: Application

– Cure with moisture close to, but not above, OMC before compaction as there is a tendency to soften the clay if over wet.

– Best to compact at OMC and allow dryback to specified moisture level to encourage suction forces.

– Compaction at modified effort may produce a much higher CBR. However, this compaction must be trialled, and testing undertaken to assess whether there is excessive breakdown of materials or not.

– See general guidance for more details.

Maintenance

– See general guidance for more details.

RIDGE/ALLUVIAL GRAVELS

Material

– See general guidance for more details.

Design

– Consider higher embankments (> 300 mm) to mitigate moisture effects when using Ridge/Alluvial gravels especially if Usage Risk is MEDIUM or HIGH.

– See general guidance for more details.

Construction and material

– Typical compaction:
  - 100% MDD achieved at 6-7% MC.

– Meeting these requirements will reduce water penetration and moisture sensitivity and may increase the materials strength. This should be considered especially if Usage Risk is ***MEDIUM*** or ***HIGH:***
  - Lime stabilisation may be considered in accordance with TN 151 *Testing of Materials for Lime Stabilisation*.
  - The addition of cementitious binders can also be used to increase strength and reduce moisture sensitivity. For materials that are close to meeting MRTS05 – *Unbound Pavements* – requirements for standard materials, stabilisation should be completed in accordance with:

RISK CONTROL GUIDANCE TABLES
▪ MRTS10 – Plant-Mixed Lightly Bound Pavements. ▪ MRTS07B Insitu Stabilised Pavements using Cement or Cementitious Blends ▪ MRTS07C Insitu Stabilised Pavements using Foamed Bitumen ▪ Materials Testing Manual, Part 2: Application – See Laterite Gravels and general guidance for more details. **<u>Maintenance</u>** – See general guidance for more details.
WHITE ROCK
<u>Design</u> – Addition of 10 – 15% sand has historically been used to modify grading and decrease plasticity properties of White Rock. However the addition of too much sand will decrease CBR and increase permeability. Secondary testing shall be undertaken on the blended material. – See general guidance for more details. **<u>Construction and material</u>** – Typical density and OMC at 100% MDD (standard compaction): ○ MDD = 1700 – 1900 kg/m^3 ○ OMC = 11 – 17%. – Control winning procedures and limit mixing time during construction as it causes material breakdown and leads to a changes in material properties. – A critical indicator for selection of material for base/sub-base is based upon its ease of excavation and stockpiling: ○ In higher traffic situations, a 250 kW (DS) dozer should not produce more than 150 m^3 per hour. This ensures that the material is not too soft. ○ For lower traffic situations a front end loader should be capable of winning satisfactory material. – This material should be placed for compaction at a moisture content ~4% below OMC. This will increase CBR and decrease permeability. – Use of grid rollers and rock busters to reduce oversize is practiced. – See general guidance for more details. **<u>Maintenance</u>** – See general guidance for more details.

A.6.2 LOCAL EXPERIENCE

Local experience and conditions may justify the use of materials regardless of the outcomes of this assessment procedure.

Where local experience shows that material of a similar quality have performed satisfactorily in comparable conditions, the designer may elect to utilise those materials irrespective of the material usage risk determined from this procedure.

APPENDIX B FEEDBACK QUESTIONNAIRE

B.1 PURPOSE

The purpose of this feedback questionnaire is to incorporate feedback from experienced practitioners in reviewing the draft version of the Material Assessment Procedure for non-standard pavement materials, along with details covering the development of the Assessment Procedure and justification of each Phase (see attached Project Summary Report).

To date, the Material Assessment Procedure has been developed from a desktop review including proceedings from regional Queensland QTMR symposiums, Queensland Roads journal content, Western Queensland best practice research, local specifications, and various academic papers exploring the performance of constructed and trafficked non-standard pavements throughout Queensland.

The following questionnaire refers to the documents contained in the Project Summary Report. All feedback is gratefully received as in-field experience and local knowledge is critical to understanding and using these materials successfully.

B.2 USING THE ASSESSMENT

PROJECT SCREENING	
ITEM	**QUESTION**
Item A.0	Is a 20 year design traffic loading less than 5 x 10^6 ESAs typical of pavements which would consider using non-standard material? If not, what is a closer traffic level in your experience with non-standard pavement materials?
Item A.1	Are the materials covered by this Assessment Procedure relevant to future projects?
	Are the descriptions of the materials relevant for those who have little or no prior knowledge of them?
	Are there are ways of describing your local materials and what are they?
General item	Do you have any other comments regarding the ***Project Screening*** section of the Assessment?
TEST METHODS	
ITEM	**QUESTION**
Item B.0	Are there other testing standards that are often used/associated with non-standards? If so, please list.
General item	Do you have any other comments regarding the Test Methods information?

B.3 PHASE 1: CONTEXT RISK

INITIAL PROJECT RISK QUESTIONNAIRE	
ITEM	**QUESTION**
General item	Are the items (ITEMS 1.0 – 1.5) listed in the Initial Project Risk Questionnaire relevant?
	Is there other outstanding items that should be included in this questionnaire that relate to project context and help ensure ongoing performance of non-standards?
	If yes, compared to those already listed, what is the importance/priority of this item?
	Are the external references to external QTMR documentation (WQ guidelines, etc.) typical for these types of projects, or are other references required?
	Is obtaining an Initial Project Risk from the Questionnaire self-explanatory with the direction provided?
	Do you have any other comments regarding the Initial Project Risk Questionnaire?

MOISTURE RISK	
General item	In local experience, is good performance of non-standards often observed when annual rainfall is less than 500 mm?
	If no, what would be considered a more appropriate level of rainfall to base the Moisture Risk around.
	Is the method for determining the Probability of exceeding 500 mm annual rainfall from historic BOM data self-explanatory from the guidance given, or should an example be included?
	Is the Probability prediction equation based on BOM data (for feasibility study purposes only) a useful inclusion? Or should only one method be presented?
Risk Matrix	Are the risk levels in the Moisture Risk matrix appropriate for the respective Initial Project Risk levels? If not, what should be changed?
General item	Do you have any other comments regarding the Moisture Risk?
TRAFFIC CONDITIONS CALCULATION (ESAS/DAY)	
General item	Are the assumptions used to calculate the equivalency factor (ESA/day) justified? i.e. it has been assumed that the heavy vehicles are fully loaded for 50% of the year and unloaded for the remainder. Taking the worst-case scenario of Class 12 making up the full HV count, the equivalency factor becomes 5.1 ESAs/day (see Appendix Section A.4.3 for further details).
	Is the ability to use the Austroads presumptive WIM tables as an alternative method to calculate the equivalency factor a useful inclusion for the type of projects this Assessment Procedure will typically cover?
Risk Matrix	Does the Context Risk (Phase 1 output) matrix produce appropriate/expected risk levels for each combination of Traffic Conditions and Moisture Risk Conditions? Or should these risk levels be altered.
General item	Do you have any other comments regarding the Traffic Conditions and/or the Context Risk output matrix?

B.4 PHASE 2: MATERIAL RISK AND APPLICATION EVALUATION

MATERIAL RISK EVALUATION	
ITEM	**QUESTION**
Risk Matrices (Item 2.0)	Is the use of fines ratio and weighted linear shrinkage (WLS) as the key decision values for the Material Risk appropriate from local experience?
	If not, which property/properties would are considered more appropriate and why?
	Are the trigger values for fines ratio and WLS appropriate for the material types from local experience?
	If not, what values are considered more appropriate and why?
Risk Matrices (Item 2.0)	Do the material specific Material Risk output matrix produce appropriate/expected risk levels for each combination of fines ratio and WLS? Or should these risk levels be altered.
General Item	Are there other local practices used to mitigate material risk and if so please describe (for example, material type and practice such as stabilization)
	Do you have any other comments regarding the Material Risk Evaluation?
MATERIAL APPLICATION EVALUATION	
Item 2.1	Is the inclusion of the Soil Zone (i.e. reactive or non-reactive) in determining the Material Application relevant, or should the Soil Zone be considered elsewhere, if at all?
Item 2.2	Is the method for determining a Material Application clear?
General Item	Do you have any other comments regarding Material Application?

B.5 PHASE 3: SECONDARY MATERIAL ASSESSMENT REQUIREMENTS

SECONDARY MATERIAL ASSESSMENT REQUIREMENTS	
General Item	Is this Phase of the assessment clear?
Items 3.1.1/3.1.2	Are the test conditions specified for the Secondary Material Requirements those that are normal to the projects that would typically use this Assessment? If not, what would be more appropriate?
General Item	Do you have any other comments regarding the Secondary Material Assessment Requirements?

B.6 PHASE 4: MATERIAL USAGE RISK AND RISK CONTROL GUIDANCE

MATERIAL USAGE RISK	
General Item	Is it clear which Material Usage Risk Matrix should be used for each Material Subtype? i.e. Either Item 4.0, Item 4.1, or Item 4.2?
Item 4.0	Is the Secondary Assessment for Low risk Material Subtypes (Item 4.0) too simple by only considering the unsoaked CBR? If yes, what else could be considered in this Item.
	For Item 4.0, is local experience that the unsoaked CBR values for each material appropriate for the assigned risk levels? Please keep in mind that these are values at 100% MDD and 100% OMC and are expected to be much lower than those at operating conditions closer to 70% OMC.
Risk Matrix (Item 4.1)	From local experience, are the values of Permeability, Soaked CBR and Unsoaked CBR applicable to the materials?
	From local experience, is the Usage Risk produced by the Permeability and Soaked CBR combination or the Unsoaked CBR and Soaked CBR combination applicable?
Risk Matrix (Item 4.2)	From local experience, are the values of Permeability, Soaked CBR and Unsoaked CBR applicable to the materials?
	From local experience, is the Usage Risk produced by the Permeability and Soaked CBR combination or the Unsoaked CBR and Soaked CBR combination applicable?
General Item	Do you have any other comments regarding the Secondary Material Assessment Requirements?
RISK CONTROL GUIDANCE	
From local experience, are there other ways of reducing risk/ increasing performance of each non-standard pavement material? This includes material handling/sourcing, in addition to design, construction and maintenance considerations.	
GENERAL GUIDANCE APPLICABLE TO ALL MATERIALS	
WINTON SANDSTONE	
LOAMS	
LATERITE GRAVELS	
RIDGE/ALLUVIAL GRAVELS	

B.7 OTHER

OTHER FEEDBACK
Do you have any further comments on the Material Assessment Procedure that was not addressed in the above questionnaire?