Queensland Government
Department of Main Roads
Road System & Engineering

MATERIAL SOURCES IN WESTERN QUEENSLAND

WQ33

Contact: Lex Vanderstaay Phone: (07) 4931 1657 / Ian Reeves Phone: (07) 3834 3089

1 Introduction

This note describes the mode of formation, likely occurrence, and characteristics of road making materials which may be used for road construction in Western Queensland. This note should be read in conjunction with the other Technical Notes in the WQ series, particularly the notes on "Geology and Geomorphology" (WQ31) and "Soils" (WQ32). The details of the full series of notes can be found in the "Preface to the WQ Series of Technical Notes". This current note does not cover one of the most critical materials - water.

The aim of this note is to highlight the existence of a range of potential materials and, in the broadest terms to indicate their potential occurrence. In all cases detailed prospecting will be required to locate sources, followed by testing to confirm their quality.

CDs accompany the Geology and Geomorphology and Soils technical notes. These CDs contain digital mapping and data which has been interfaced with the Department's GIS systems (MapInfo). These CDs should be used when attempting to gain further details on the distribution of the various material sources described in this note.

2 Road Making Materials Standards

In the QDMR unbound pavements specification MRS11.05, various classes of material are defined i.e. Types 1, 2, 3 or 4 materials. A further class of materials has been defined, based on performance studies, in the WQ series of technical notes. These materials are termed WQ materials, and may, but need not, be MRS 11.05 Type 2, or 3 materials.

WQ materials, when used in conjunction with the specified cross section and in the western environment, have been found to show superior performance over some MRS 11.05 materials. The use of WQ materials outside Western Queensland or in cross sections other than those defined in the relevant WQ Technical Notes must be regarded as problematic.

3 Source Assessment

Source certification is mandatory for the supply of MRS 11.05 Type 1, or Subtypes 2.1 to 2.4 or 3.1 to 3.4 materials. The procedures required to obtain source certification are detailed in MR Engineering Policy EP108. Source certification is not required for sources of other material types, but Source Assessment (SA) is mandated for sources of all Type 4 materials.

SA should be considered as being mandated for all WQ sources. All SAs should follow the principles outlined in EP108. For WQ sources the SA should, as well as meeting the requirements of EP108, define "pit rules" for the source. Pit rules are practical guidelines to be used by plant operators during winning operations to allow determination of which material is suitable and which is not.

4 Classification of Sources

Thirteen broad classes of Western Queensland material sources can be defined, based largely on their mode of formation. Each of these potential sources is described in detail below. The following table summarises the classification of the various sources in terms of likelihood of meeting various specifications. In many cases, blending two materials may result in an acceptable material being produced, although individually the component sources may not produce acceptable materials.

Probability of Meeting Materials Specifications			
Material	**Aggregates**	**MRS11.05 Types 1,2,3**	**WQ Material**
Ancient Rocks	High	High	Moderate
Tertiary Basalt	High	High	Moderate
Sandstone	Nil	Very Low	Moderate
Mudrock	Nil	Very Low	Moderate
Soft Limestone	Nil	Very Low	Moderate
White Rock	Low	Moderate	Moderate
Duricrust	Moderate	Moderate	Moderate
Ridge Gravels	Moderate	Moderate	High
Alluvial Gravels	Moderate	Moderate	High
Loams	Nil	Low	Moderate
Gidgee	High	As an additive	
Black Soil	Nil	Nil	Low
Mine Waste	Moderate	High	Moderate

Maps showing the distribution of some of the various sources are appended to this note.

5 Ancient Rocks

General

These materials are confined to the pre-Cambrian, Cambrian and Ordovician rocks outcropping in a triangular area extending southwest and northwest from Cloncurry to the Northern Territory border, and in an area centered on Georgetown, as shown on Map 1. They occur as a wide range of geological units. These rocks contain a full range of lithologies from igneous to sedimentary and metamorphic types and require conventional crushing to produce MRS11.05 Types 1 and 2 materials. Quarries in these locations can expect to be able to produce aggregates as well as gravel.

Quarry Selection

In this terrain some quarries already exist, while others may be established in greenfield sites. In both cases, source assessments should be undertaken in accordance with EP108.

Pit Processing

Standard quarrying procedures are required.

Properties

Rock properties should be expected to comply with the relevant requirements of the MRS 11.05 specification.

6 Tertiary Basalt

General

Tertiary basalts have been traditional sources of road making materials, aggregates and railway ballast in various areas of the south and north west. Suitable source rocks outcrop in the Ambi, Tambo and Roma areas, and north of the Flinders Highway between Hughenden and Richmond, as shown on Map 1. Such basalts are also relatively common in areas east of the study area, including the Darling Downs, Central Highlands and Burdekin area. Although some volcanics have been individually named, all these units may be broadly grouped into the geological unit "tertiary basalts."

Quarry Selection

In this terrain some quarries already exist, while others may be established in greenfield sites. In both cases source assessments should be undertaken on accordance with EP108.

Quarry Processing

Standard quarrying procedures are required.

Properties

Rock properties should be expected to comply with the relevant requirements of the MRS 11.05 specification.

7 Sandstone

General

This material is a yellow to fawn, weathered, very low strength, labile sandstone of Cretaceous age, composed of sand-size grains of weathered ancient rocks and clay balls. This material is also known as "Winton Sandstone". It bears no resemblance to the sandstone which is used as a building stone.

Sandstone is found within the outcrop area of a number of geological units of the Rolling Downs Group (RDG) of Cretaceous age. It is most common in the outcrop area of the Winton, Mackunda and Wallumbilla Formations. The term "Winton Sandstone" should not be confused with the geological unit Winton Formation which forms part of the RDG. This formation is the most common unit for the occurrence of sandstone. The typical mode of occurrence is as a series of gently dipping sandstone beds, sub-cropping under a 1m to 2m thick layer of black soil. The thickness of the sandstone units does not generally exceed 3m, and is underlain by more clayey and shaley beds. Although the various geological formations outcrop over a huge area, careful selection of suitable sandstone deposits is required. Pits are generally of limited extent. The distribution of sandstone is shown on Map 1 as "Sandstone and Mudrock".

Pit Selection

Extensive prospecting for suitable pits, generally using a backhoe is required. Pits are often located on the middle to upper flanks of the gently undulating terrain characteristic of the areas underlain by the RDG. Pits are generally selected on the basis of least thickness of overlying black soil (usually < 1.5m), while the suitability of the sandstone is generally assessed on the basis of linear shrinkage. Pits are generally located within 3km of the road.

Pit Processing

Pit processing generally involves stripping the surface black soil, often using scrapers, then ripping the sandstone. Care must be exercised during winning to ensure that the pit is not deepened excessively and only the sandstone beds are actually won. Sandstone readily breaks down to a loam, hence it is critical not to excessively work this material during winning or placing.

Properties

The following table lists the typical properties of sandstone. Modified testing procedures should be used when testing this material as it has been found that several test properties change significantly, depending on the degree of working of the material during testing. Hence modified test procedures, involving the use of standard mixing times, have been developed for use during the testing of these materials. These modified procedures should be strictly followed in all cases.

Properties of Sandstone	
Test	**Typical value**
Grading	
% 2.36mm	100
% 0.425mm	90
% 0.075	40
Fines Ratio (0.075 / 0.425)	0.4
Liquid Limit (%)	40
Plastic Index	15
Linear Shrinkage (%)	7
MDD (t/m^3)	1.7
OMC 100% std. (%)	20
CBR (Unsoaked)	20

History of Use

Extensive use of this material has been made in the Central Western District, including on the Landsborough Highway, and various State strategic roads and local roads. Research on the performance of the material in the Longreach - Winton section is documented in Martin et al. (1988) and Martin et al. (1992).

8 Mudrock

General

This material is a yellow, clayey, weathered low strength labile shale / siltstone / mudstone. It is found within the outcrop area of the RDG of Cretaceous age i.e. the same areas as sandstone. The typical mode of occurrence is as a series of gently dipping beds, subcropping under a 1m to 2m thick layer of black soil. The insitu thickness of these materials may exceed 10m. This material has been used as an alternative to sandstone in some areas where suitable sandstone deposits could not be located. The distribution of mudrock is shown on Map 1.

Pit Selection

Extensive prospecting for suitable pits is not generally undertaken. Pits are generally located on

the middle to upper flanks of the gently undulating terrain characteristic of the RDG. Pits are generally selected on the basis of least thickness of overlying black soil, and the linear shrinkage of the material. Pits are generally located adjacent to the road.

Pit Processing

Pit processing generally involves stripping of the surface black soil, often using scrapers, then ripping the mudrock. Generally less care is required in the selection of materials in mudrock pits than that exercised during the winning of sandstone.

Properties

The following table lists typical properties of mudrock. Modified testing procedures should be used when testing this material as it has been found that several test properties change significantly during testing, depending on the degree of working of the material.

Properties of Mudrocks	
Test	**Typical value**
Grading	
% 9.5mm	80
% 2.36mm	81
% 0.425mm	60
% 0.075	20
Fines Ratio (0.075 / 0.425)	0.3
Linear Shrinkage (%)	8

History of Use

Use of this material has been made in the Central Western and Cloncurry District, particularly on the Hughenden - Winton road. It has also been used as a running course on various unsealed roads, particularly the Windorah - Birdsville - Bedourie area.

9 Soft Limestone

General

This material is a weathered, low-strength, impure shaley limestone of Cretaceous age. It bears no resemblance to older high purity limestones which occur elsewhere in Queensland, from which MRS11.05 Type 1 materials can generally be produced.

Soft limestone is found within the outcrop area of the Toolebuc Limestone which forms part of the RDG. The geological unit is thin, typically less than 20m thick, however the actual limestone material may constitute only less than 2m.

The unit outcrops in two broad arcs, one from Barcaldine - Aramac - Hughenden - Julia Creek, with the other from south of Burketown to Min Min. The typical mode of occurrence is a 1m to 2m thick bed of soft limestone, underlain by mudrock and overlain by 1m to 2m of black soil. Although the unit outcrops over a large area, careful selection of suitable limestone is required. Pits are generally of limited extent. The material is known by a range of names including Toolebuc Limestone, Kopi, and St Elmo's Limestone. The distribution of soft limestone is shown on Map 1.

Pit Selection

Extensive prospecting for suitable pits is required generally using a backhoe. This unit has a charisteristic air photo pattern which simplifies the selection of sites requiring detailed prospecting. Pits are generally selected on the basis of thickness of limestone, quality of the limestone based on linear shrinkage, and thickness of overlying black soil. Pits may be located some distance from the road and cartage of this material to a job site is not unusual.

Pit Processing

Pit processing generally involves stripping the surface black soil, often using scrapers, then ripping the limestone. Care must be exercised during winning to ensure that only low shrinkage limestone largely uncontaminated by underlying mudrocks or overlying black soil, is won. In some areas the limestone is of sufficient strength to enable it to be used as a pitching stone.

Properties

The following table lists the typical properties of Toolebuc Limestone.

Properties of Toolebuc Limestone	
Test	**Typical value**
Grading	
% 2.36mm	40
% 0.425mm	30
% 0.075	20
Fines Ratio (0.075 / 0.425)	0.7
Liquid Limit (%)	30
Plastic Index	20
Linear Shrinkage (%)	8
MDD (t/m³)	2.0
OMC 100% std. (%)	10
CBR (unsoaked)	20

History of Use

This material has been used with varying degrees of success on the Flinders Highway in the Julia Creek area, and successfully on various roads in the Aramac area. Failures with this material have occurred where inadequate in-pit selection processes have been applied. Careful in-pit selection is critical to the successful use of this material.

10 White Rock

General

White rock is a generic term, initially used in areas in the western Darling Downs to describe a predominately white coloured (but not exclusively) relatively soft, sedimentary rock material. The term white rock is now generally applied to the pallid zone of a laterite profile developed on sedimentary rocks generally of Tertiary age.

White rock occurs over extensive areas of Western Queensland where sedimentary rocks of Tertiary age outcrop. They extend from the Darling Downs in the southeast to the far southwest and northwards into Cloncurry District. The term has now also been applied to the pallid zone materials developed on Cretaceous rocks. In some cases the quality of white rock is such that it may be successfully processed into MRS11.05 grade materials. The distribution of potential white rock sources is shown on Map 2 as Duricrust.

Pit Selection

This material tends to outcrop on relatively low ridges, the remnants of once much higher structures. It can also be found on the flanks of mesas which are still capped by duricrust materials. Suitable pits are generally determined on the basis of linear shrinkage of the material and the effort required to excavate material from the pits. Pits may be located some distance from the road and cartage of this material to a job site is not unusual.

Pit Processing

Typically, suitable white rock is material which can be excavated at a rate of not greater than 150m³ per hour using a Cat D8 dozer or equivalent. Pit processing generally involves removal of the lower strength material, i.e. that material which can be excavated at a rate greater than the minimum rate. In some cases white rock has been crushed to produce MRS11.05 Type 2 material, but this is not the norm. Following ripping in the pit, the material is carted to the road bed and grid rolled to break down any grossly oversize material. Material is not generally screened in pit as this process would remove the higher strength material from the source. Where individual boulders are not successfully broken up during grid rolling these are manually removed from the road bed and placed adjacent to the road. The occurrence of such white boulders along the road following construction is one of the characteristics of some white rock jobs.

Properties

The following table lists the typical properties of a white rock. It must be noted that white rocks with a wide range of properties have been successfully used in various areas with properties well beyond those quoted.

Properties of White Rock	
Test	**Typical value**
Grading	
% 2.36mm	50
% 0.425mm	35
% 0.075	15
Fines Ratio (0.0 75 / 0.425)	0.4
Liquid Limit (%)	30
Plastic Index	12
Linear Shrinkage (%)	6
MDD (t/m³)	1.7
CBR (unsoaked)	30

History of Use

Extensive use of this material has been made in the Warwick, Roma, and Barcaldine Districts, see Basford (1987) and Basford (1988).

11 Duricrusts

General

Duricrust is a term applied to the hard cap material developed during the lateritisation. This cap was formed insitu on then existing outcrops of rocks - in the west, typically sedimentary rocks of Tertiary and to a lesser extent Cretaceous age. This material may overlie areas of white rock, hence the distribution of Duricrust shown on Map 2 is also applicable to white rock.

Pits are generally less than 4m deep and particularly shallow pits may cover a wide area. In a number of cases duricrust materials have been successfully processed to MRS 11.05 Type 2 material.

Pit Selection

Extensive prospecting for suitable pits is required to locate sites which contain adequate reserves of suitable material. Often the sources are located in relatively inaccessible sites, e.g. the top of mesas. This source may be the original source for the coarse silcrete boulders discussed under the heading gidgee.

Pit Processing

Pit processing generally involves stripping the surface and then processing the source material, usually involving some crushing. Care must be exercised during winning to ensure that the pit is not deepened excessively and only the duricrust material is actually won. Below the duricrust highly plastic clays are not uncommon.

Properties

The following table lists the properties of a typical duricrust product.

Properties of Duricrust	
Test	**Typical value**
Grading	
% 9.5mm	66
% 2.36mm	25
% 0.425mm	15
% 0.075	10
Fines Ratio (0.0 75 / 0.425))	0.7
Linear Shrinkage (%)	3

History of Use

Extensive use of this material has been made, particularly on the Landsborough Highway between Ayrshire and McKinlay, where MRS 11.05 Type 2 materials were produced via a crushing process.

12 Ridge Gravels

General

These materials are ancient gravels similar to the alluvial gravels, but occurring as distinct ridge deposits parallel to major drainage systems. e.g. Diamantina and Thompson rivers. The material tends to be a mixed gravel / sand / clay deposit. This class is also known as Lateritic gravel, as some ridge gravels have suffered lateritization.

Pit Selection

Pits selection may be difficult, however deposits can often be located due to subtle differences in their vegetation cover. Such differences include variation both in vegetation type (i.e. species diversity) and/or vegetation density. Pits are generally located on high areas adjacent to major drainage systems. Extensive pitting must be undertaken to delineate the exact

location of the deposit. Often deposits are complex lenticular bodies and cut off by more recent (but still ancient) deposits. The deposits are often overlain by up to 2m of surface soils. In some cases the gravels have been extensively ferruginised and the deposits could be considered as being ferricrete. Where the deposits are calcified they may be termed a calcrete. These deposits may be suitable for the production of MRS11.05 Type 2 or 3 materials as well as WQ materials, provided suitable processing is undertaken.

Pit Processing

Pits are generally worked by stripping the overburden, followed by extracting the gravel. Care must be exercised to ensure only suitable material is won, particularly considering the highly variable nature of these deposits. Where deposits contain appreciable proportions of oversize material, it is far preferable to crush this oversize material and incorporate the crushed product into the mix rather than simply remove the oversize.

Properties

A wide range of properties occurs with these materials. In terms of gradings, these gravels generally have an "arm chair" grading, i.e. are deficient in the sand size (2.36mm to 0.425mm) fractions. The existence of this type of grading may not necessarily be detrimental, provided the material can still meet the WQ requirements.

History of Use

Extensive use has been made of these materials, however in some areas their use has diminished due to their apparent unavailability against availability of other materials. Often statements are made that a particular deposit is worked out. Such reports may reflect a lack of investigation into the actual level of reserves remaining in a deposit.

13 Alluvial Gravels

General

These materials are ancient gravels similar to the ridge gravels, but now occur adjacent to major stream channels, but without the characteristic ridge of the ridge gravels. Pit selection is difficult, however they can often be located due to subtle differences in their vegetation cover. Such changes include both changes in vegetation type (i.e. species diversity) and /or vegetation density. The material tends to be a mixed gravel / sand / clay deposit. The distribution of alluvium is shown on Map 3.

Pit Selection

Pits selection may be difficult. Potential pit sites may be located using aerial photographs or ground surveys as there are typical differences in vegetation cover (either species diversity or density). Extensive pitting must be undertaken to delineate the exact location and extent of the deposit. Often deposits are complex lenticular bodies and cut off by more recent alluvial deposits. The deposits are often overlain by up to 2m of surface soils. In some cases the gravels have been ferrugenised. These deposits may be suitable for the production of MRS11.05 Type 2 or 3 materials as well as WQ materials provided suitable processing is undertaken.

Pit Processing

Pits are generally worked by stripping the overburden followed by extracting the gravel. Care must be exercised to ensure only suitable material is won, particularly considering the highly variable nature of these deposits.

Properties

A wide range of properties occurs with these materials. In terms of gradings these gravels generally have an "arm chair" grading, i.e. are deficient in the sand-size fractions between 2.36mm and 0.425mm. The existence of this type of grading may not necessarily be detrimental, provided the material can still meet the WQ requirements.

History of Use

Use of these materials is less extensive than for the ridge gravels, largely due to the difficulty in locating deposits. As with the ridge gravels, statements are often made to the effect that a particular deposit is worked out. Such reports may reflect a lack of

investigation into the actual level of reserves remaining in a deposit

14 Loams

General

This material generally occurs as the remnants of ancient or current dune deposits. They are essentially mixes of siliceous sands and clays. They may also occur as significant deposits associated with ridge gravels. The distribution of loams is shown on Map 2.

Pit Selection

Location of loam deposits is relatively simple as they form prominent linear ridges, however extensive testing is required to ensure that the loam is of suitable quality. Non-plastic loams have almost invariably been found not to perform satisfactorily as they tend to be single-sized and lack cohesion. They should be avoided unless mixed with other materials. Extensive prospecting for suitable pits is often required. Pits are generally selected on the basis of availability of suitable plastic loam, pits are often located some distance from jobs.

Pit Processing

Pit processing generally consists of some surface stripping to remove vegetation and/or non-plastic material. Pits are of limited depth, with the pit floor generally consisting of plastic clay.

Properties

The following table lists the typical properties of a good quality western loam.

Properties of Loams	
Test	**Typical value**
Grading	
% 2.36mm	100
% 0.425mm	60
% 0.075	25
Fines Ratio (0.0 75 / 0.425)	0.4
Linear Shrinkage (%)	4

History of Use

Extensive use of this material has been made in the Central Western District, particularly in the area bound by Tambo - Blackall - Isisford - Emmet. These materials have also been extensively used in a mix with other sources to adjust properties to the desired levels.

15 Gidgee

General

This material occurs in two forms, either as a surface mono layer of ferruginous gravel up to 50mm, or as a mono layer of siliceous (silcrete) cobbles typically less than 400mm diameter. Its use as a road making material is generally restricted as a source of rock for the manufacture of screenings and gabion rock. More recently, use is being made of crushed gidgee to provide the stone content of a loam / gidgee mix to produce a MRS11.05 Type 2 or 3, or a WQ material.

In some areas, accumulations of silcrete cobbles have been located. In these cases the cobbles may represent the remains of a duricrust layer long since removed by erosion.

Pit Selection

Gidgee is found in an number of sites in the west, typically in the area of black soil (see Technical Note WQ32). It occurs as a surface layer, often identifiable by the presence of scalds (areas totally devoid of vegetation). The location of the silcrete accumulations is generally related to their intimate association with existing duricrust mesa structures or the remains of such structures, combined with a characteristic assemblage of vegetation.

Pit Processing

Pits are generally not developed as such, rather areas are harvested with a grader. This laborious harvesting technique combined with the extremely high strength of the stone renders the cost of processing gidgee very high. Generally processing this material is no longer undertaken, except for areas with thick accumulations.

16 Black Soil

General

For further information on black soil reference should also be made to WQ32. Black soil, either in a stabilised or unstabilised form, has been used for both sealed and unsealed construction in some areas, generally on a trial basis. Black soil is an extremely moisture-susceptible material. Its use should be restricted to the lightest trafficked roads. When used, it is imperative that moisture control measures are effective. The distribution of black soil is shown on Map 2.

Pit Selection

No pit selection is generally undertaken with material being won adjacent to the construction.

Properties

The following table lists the typical properties of an alluvial black soil.

Properties of (Alluvial) Black Soils	
Test	**Typical value**
Grading	
% 2.36mm	100%
% 0.425mm	85%
% 0.075	75%
Fines Ratio (0.0 75 / 0.425)	0.9
Liquid Limit (%)	50
Plastic Index	30
Linear Shrinkage (%)	15

History of Use

Black soil has been extensively used in New South Wales where, perhaps due to the less seasonal rainfall, its use has been successful. New South Wales experience has been largely with alluvial black soils (see WQ32), however some trials using residual black soil have been undertaken on lightly trafficked roads in Barcaldine District.

17 Mine Wastes

General

Mine waste materials, particularly those derived from heap leach activities, can be valuable material sources. Particular care must be exercised in planning for the use of these materials. Environmental and OH&S concerns and permits may be required due to the possible heavy metal and/or processing chemicals content (notably cyanide).

Pit Processing

Often some blending is required to achieve acceptable materials.

Properties

Often rock properties are somewhat lower than those required by the MRS 11.05. However in drier western conditions this may not present a significant problem.

History of Use

Such materials have been very successfully used in most mineral-rich areas of the State.

18 General Comments

The majority of the materials described herein may be classified as non-traditional materials. They generally require specific practices during winning, processing, laying, and sealing. When use of a particular material is being considered, it is imperative that previous experience with the material is analysed. The rule generally applicable to all these materials is their susceptibility to poor performance if they are overworked. Generally it is preferable not to hydra-screen these materials to remove oversize, rather the oversize should be crushed and the crushed material incorporated into the mix. Such crushing may be achieved by conventional crushers, or via in-pavement processes such as using swing hammer type processing or grid rolling. Such processing may initially appear unjustifiable on economic grounds. It has been found that crushing to a nominal maximum particle size, rather than a specified grading, can be undertaken at a similar cost to hydra-screening if over 25% rejects are produced.

19 Author

This note was written by A.G.B. Vanderstaay Regional Advisor Technical Services (Central Queensland).

20 References

Basford, G. 1987: *The Use of Marginal Materials Progress Report No 1*, Unpublished report R1624, Main Roads Materials Branch, Brisbane.

Basford, G. 1988: *The Use of Marginal Materials Progress Report No 2*, Unpublished report R1640, Main Roads Materials Branch, Brisbane.

Bathurst, R. 1999: *The Performance of Lateritic Gravels*. Workshop on Low Volume Roads. Roma, 1999, Main Roads, Brisbane.

Callaghan, P. 1999: *White Rock*. Workshop on Low Volume Roads. Roma, 1999, Main Roads, Brisbane.

Martin, J.M., Waters, T. & Vanderstaay, A.G.B. 1988: *Report on Winton Sandstone Project*. Unpublished report R1653. Main Roads Materials Branch, Brisbane.

Martin, J.M., Baran E. & Worrall, J. 1992: *Design, Construction and Maintenance of Pavements using Winton Sandstone*. Unpublished report R1825, Main Roads Materials Branch, Brisbane.

Queensland Department of Main Roads 1999: *Engineering Policy EP108 Quarry Assessment and Certification*. The Dept., Brisbane.

Robinson, P., Oppy, T. & Giummarra G. 1999: *Pavement Materials in Road Building: Guidelines for Better Use of Local Materials*. ARRB Transport Research. Melbourne.

Vanderstaay A.G.B. 1999: *A Review of Non-standard Materials (notably Winton Sandstone, Toolebuc Limestone and White Rock)*. Workshop on Low Volume Roads. Roma, 1999, Main Roads, Brisbane.

20 Appendices

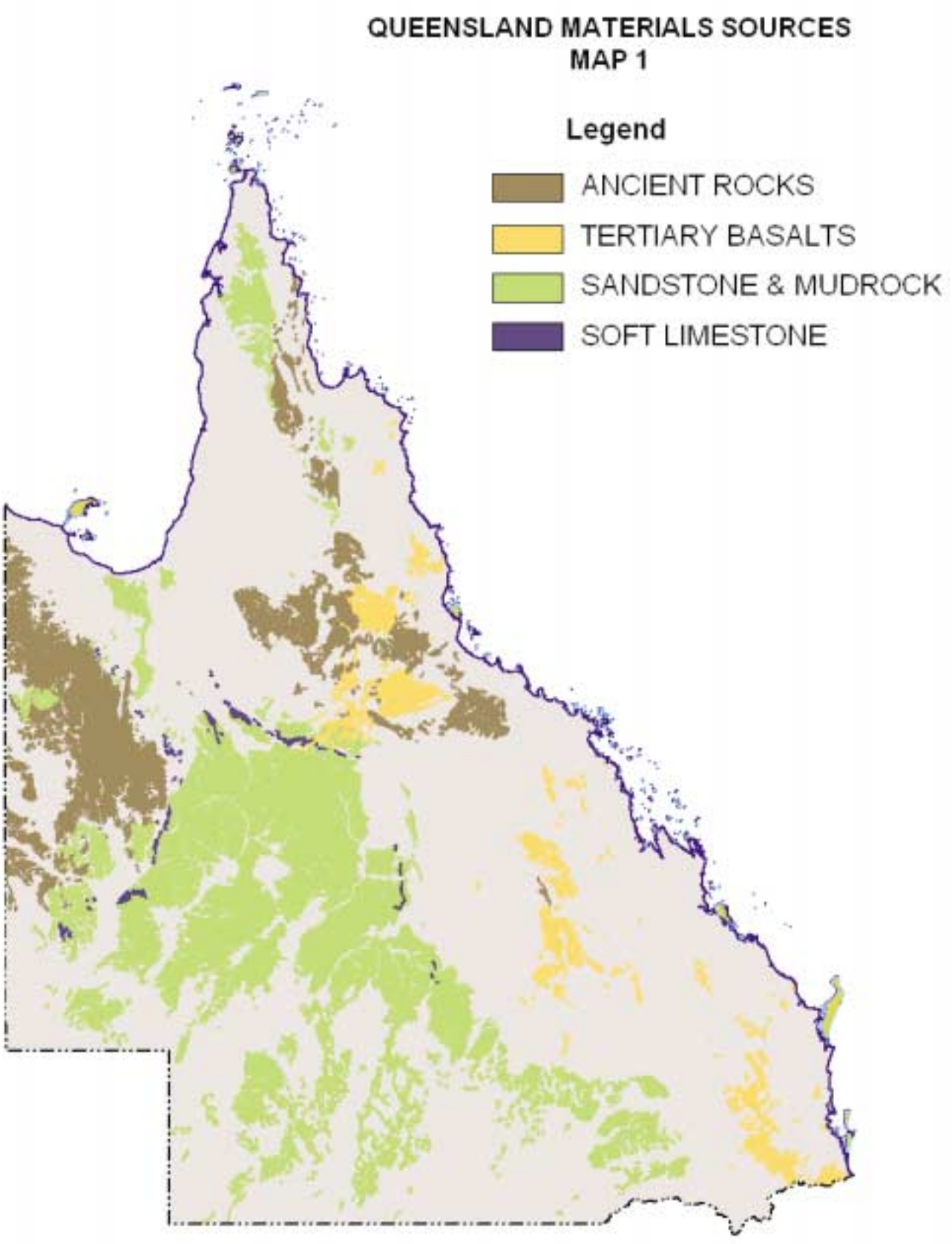
The maps appended to this note show the approximate distribution of the various sources. When perusing these maps, it must be remembered that the marked areas represent areas where the nominated sources *could* occur, based on geological, geomorphological or soil occurrences, rather than defining actual materials deposits. The location of actual pits can be established only following detailed prospecting.

The following maps are appended:-

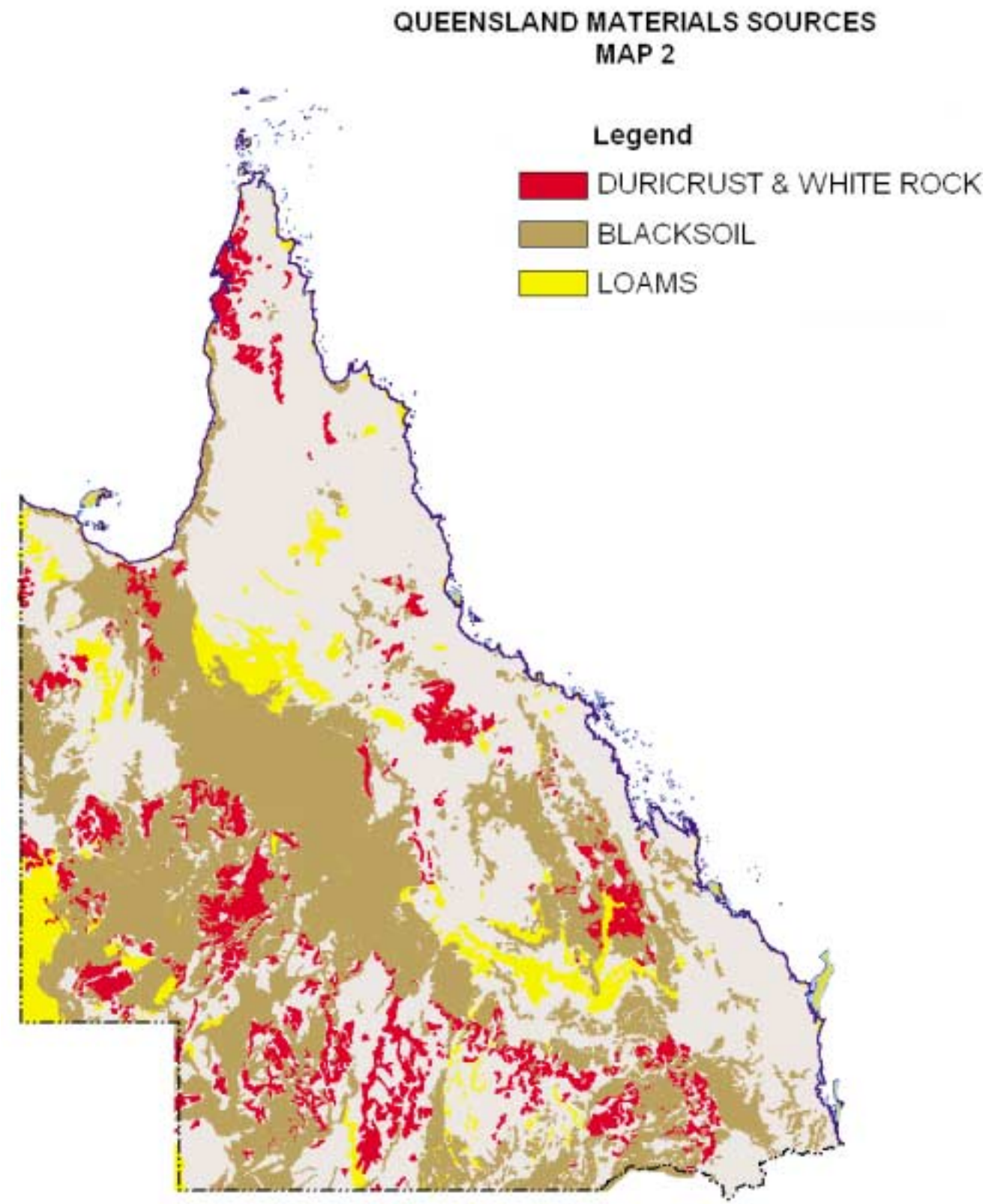
Queensland Material Sources Map 1: Ancient Rocks, Tertiary Basalts, Sandstone and Mudrock, Soft Limestone.

Queensland Material Sources Map 2: Duricrust and White Rock, Black Soil, Loams.

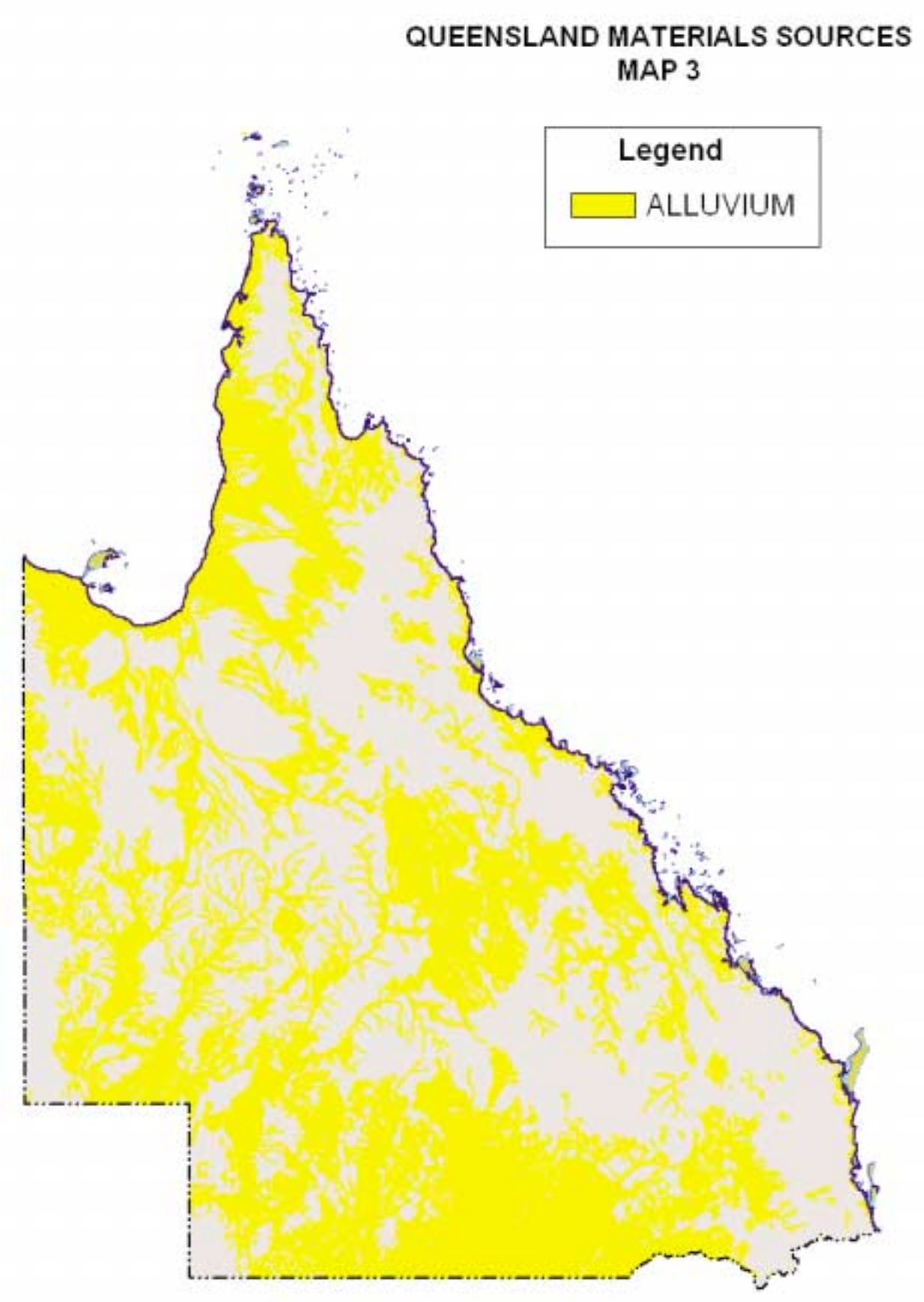
Queensland Material Sources Map 3: Alluvium.



Queensland Material Sources Map 1: Ancient Rocks, Tertiary Basalts, Sandstone and Mudrock, Soft Limestone



Queensland Material Sources Map 2: Duricrust and White Rock, Black Soil, Loams



Queensland Material Sources Map 3: Alluvium