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ANNUAL SUMMARY REPORT

P94 – Optimising the Use of Recycled Materials in Queensland for Unbound and Stabilised Products Year 1 (2018/2019)

ARRB Project No.:	PRP18038
Author/s:	Lincoln Latter, Alireza Mohammadinia and Andrew Beecroft
Prepared for:	Queensland Department of Transport and Main Roads

27/04/2020

FINAL

AN INITIATIVE BY:
arrb Queensland Government

SUMMARY

The increased utilisation of recycled materials in road construction has become a priority for TMR, not just because of the significant environmental benefits that it can deliver, but for the potential to save money without compromising performance. In the case of substituting quarried materials with recycled materials for unbound and stabilised layers, uptake has been relatively low compared to the large quantities of construction and demolition (C&D) waste that is presently being recycled across all industries.

This report focused on the current Australian state road agency requirements regarding the usage of recycled products in road construction to identify potential quick wins to deliver an immediate increase in the use of recycled materials in Queensland. Furthermore, the various environmental considerations for recycled products were explored, including identification, thresholds, limits and procedures for recycled materials in road construction.

The findings of this report can be summarised as follows:

- The use of recycled crushed concrete as road base and subbase in Australia is widely accepted.
- While product usage and specification limits vary across jurisdictions, the literature identified that in terms of performance, recycled crushed concrete is suitable for base and subbase applications.
- In general, state road agencies have strong alignment between specifications for traditional quarried materials and recycled materials.
- Recycled materials such as crushed brick, reclaimed asphalt pavement and crushed glass have been widely used in Australia and may have scope for allowing increased percentages in Queensland pavements.
- With regard to environmental considerations, there is general alignment across Australia in the testing and threshold values allowed.

The report proposes a series of recommendations moving into the second year of research, most notably to:

- make several changes to the allowable limits for recycled materials and help promote the increased use of recycled materials and improve flexibility of recycled material suppliers
- investigate the potential for better alignment or merging of the standalone specification for recycled material blends (MRTS35) with the conventional unbound granular specification MRTS05
- introduce a supplier registration system, similar to the TMR Quarry Registration System (QRS), – in an attempt to minimise the perception that alternative materials may be of inferior quality
- explore the relative performance of recycled material samples obtained from Queensland suppliers through a program of laboratory testing.

A preliminary laboratory testing program has been developed in advance for Year 2, which will help inform the final project outcomes and recommendations for implementation into TMR practice.

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1 INTRODUCTION

1.1 BACKGROUND

There is a global focus on reducing the reliance on finite resources including virgin quarry materials. Using recycled materials produced from processing construction and demolition (C&D) waste into unbound and stabilised granular pavements is a sustainable and economical alternative to conventional quarry materials. However, this is only the case where the engineering properties and performance of these recycled materials still satisfies the requirements of the relevant road construction specifications. Availability of these materials is also in important factor as for a specific project, haulage can significantly offset the recycled material cost compared to quarry materials which might be more readily available.

The use of recycled materials as unbound and stabilised granular pavement materials has traditionally been relatively low in Queensland, despite the Queensland Department of Transport and Main Roads (TMR) permitting the use of recycled materials through the MRTS35 *Recycled Materials for Pavements* specification (2018d). It is important to note that TMR are not currently considering to mandating the use of recycled materials.

1.2 OBJECTIVE AND APPROACH

The general objective of this project is to identify how the use of recycled materials can be optimised on TMR projects to achieve cost, sustainability and long-term performance benefits. To help facilitate the increased use of recycled materials in unbound pavements, a significant review of MRTS35 was undertaken. A particular focus was a review of the permissible uses as unbound pavement materials to facilitate the increased use of these materials where appropriate.

This report outlines the first year of a multi-year project where the primary objective of Year 1 was to review the use of recycled materials nationally and to identify 'quick wins' that could help facilitate the immediate increased use of recycled materials in unbound and stabilised granular materials in Queensland. The approach undertaken may be summarised as follows:

- defining the waste streams for Australia at the national level, and for Queensland at the state level to provide the context and outline of the potential barriers to implementation – Section 2.
- reviewing the existing practice for each of the Australian state road agencies with regard to the specifications and permissible uses of recycled materials in unbound and bound pavements – Section 3.
- reviewing and documenting the environmental requirements of using recycled materials in Australia-wide pavement applications – Section 4.
- summarising the findings based on the project outcomes, recommending any changes to current TMR practice and outlining the scope for Year 2 of this project – Section 5.

2 CONSTRUCTION AND DEMOLITION (C&D) WASTE

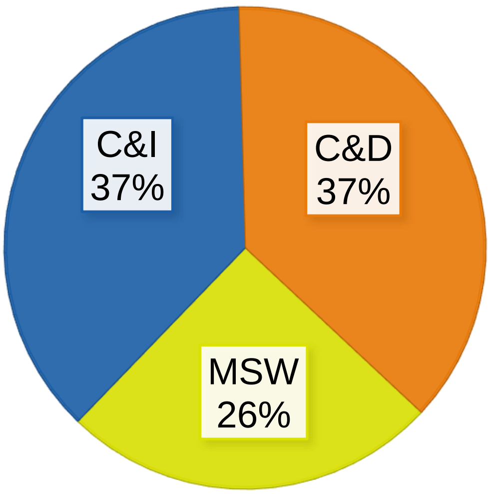
2.1 C&D WASTE GENERATION AND RECYCLING

2.1.1 C&D WASTE IN AUSTRALIA

According to the Australian National Waste Report 2018 (Pickin et al. 2018), 54.6 million tonnes (Mt) of 'core waste' was generated in Australia during 2016-17. This was comprised of three primary waste streams, represented in Figure 2.1, showing that C&D waste accounted for about 37% of all the waste produced in Australia in 2016-17:

- Municipal solid waste (MSW) – 13.8 Mt:
  - primarily collected from households and councils through kerbside waste and recycling collections
  - includes biodegradable material, recyclable materials (bottles, paper, cardboard, aluminium cans) and a wide range of non-degradable material (paint, appliances, furniture, lighting)
- Construction and demolition (C&D) waste – 20.4 Mt:
  - waste produced by demolition and building activities, such as road and rail construction and maintenance and the excavation of land associated with construction activities
  - includes concrete and bricks, asphalt, metals, timber, plastics, plasterboard, rocks and excavation stone and soil/sand
- Commercial and industrial (C&I) waste – 20.4 Mt:
  - produced by institutions and businesses, including schools, restaurants, offices, retail and wholesale businesses and industries including manufacturing
  - includes metals, glass, food organics, cardboard, paper, timber, soft plastics and manufacturing wastes such as bio solids, fly ash and slags, liquid wastes and agricultural and mining wastes.

Figure 2.1 Percentage of components of core waste in Australia (2016-17)



Source: Pickin et al. (2018).

Table 2.1 shows the changes in waste generation (in different categories) in Australia over a period of 11 years. It is important to note that this table shows quantities including and excluding ash, which is generated mostly by coal fired power stations and managed on the generating site outside the main waste management system. It is important to note that decreases including ash may reflect a general decline in coal-fired power generation in Australia of approximately 14% over this period, thus decreasing ash generation and impacting the changes. While all the other types of waste experienced a noticeable decline, C&D waste generation increased by 2% per person.

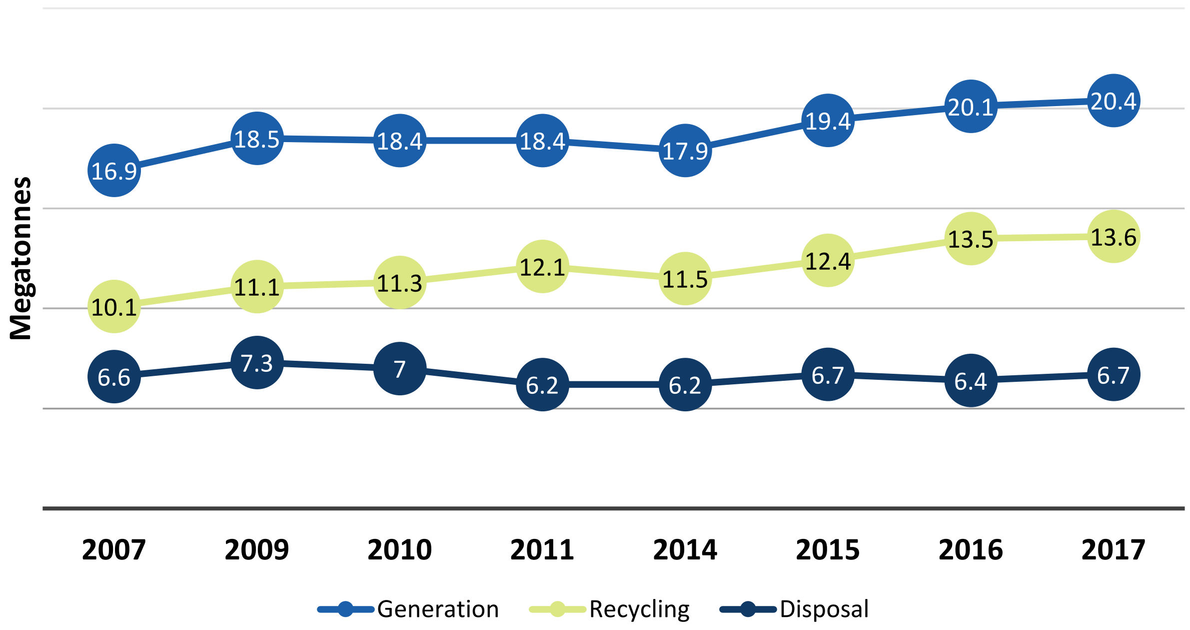
Table 2.1: Changes in the quantity of waste per person generated in Australia from 2006-07 to 2016-17

Total waste	Total excl. ash	MSW	C&I	C&I exc. ash	C&D
–10%	–5%	–10%	–17%	–8%	2%

Source: Pickin et al. (2018).

The quantities of generated, disposed and recycled C&D waste in Australia from 2007 to 2017 are shown in Figure 2.2. Over this period, the generation of C&D waste increased by 20.7%, however, the rate of disposal only increased by 1.5%, which may indicate that there is a growing stockpile of C&D waste material yet to be utilised. As shown in Figure 2.2 there is a slight increasing trend in Australia towards the recycling of C&D aggregates and reducing the disposal of these materials into landfill between 2007 and 2017.

Figure 2.2 Trends in generation, recycling and disposal of C&D waste in Australia



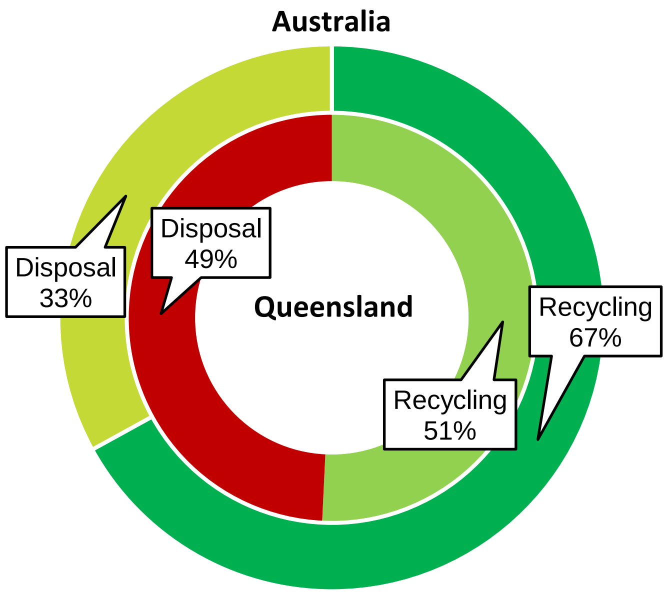
Source: Pickin et al. (2018).

2.1.2 C&D WASTE IN QUEENSLAND

The Queensland Government published a report titled, *Recycling and Waste in Queensland 2017* (Queensland Government 2018 presenting information regarding the generation and recycling of C&D waste in Queensland in 2016-17. Based on this report, approximately 4.4 Mt of C&D waste was generated in 2016–17 in Queensland. However, only 50.9% of this was recycled. A comparison between C&D recycling and disposal in Queensland and Australia in 2016-17 is presented in Figure 2.3. The recycling rate of Queensland is about 16% less than that of Australia.

It should be noted that in this report, the term 'recovered' was defined as, recovered in Queensland which means the material was either fully recovered by the reporting entity or was sent to another (non-reporting) operator in Queensland for further processing (Queensland Government 2018). It is possible that materials last tracked to a Queensland site were subsequently sent interstate or overseas. This suggests that the actual amount of recovered C&D waste may be less than the reported amounts.

Figure 2.3 C&D waste recycling and disposal in Queensland and Australia in 2016-17



Source: Pickin et al. (2018); Queensland Government (2018).

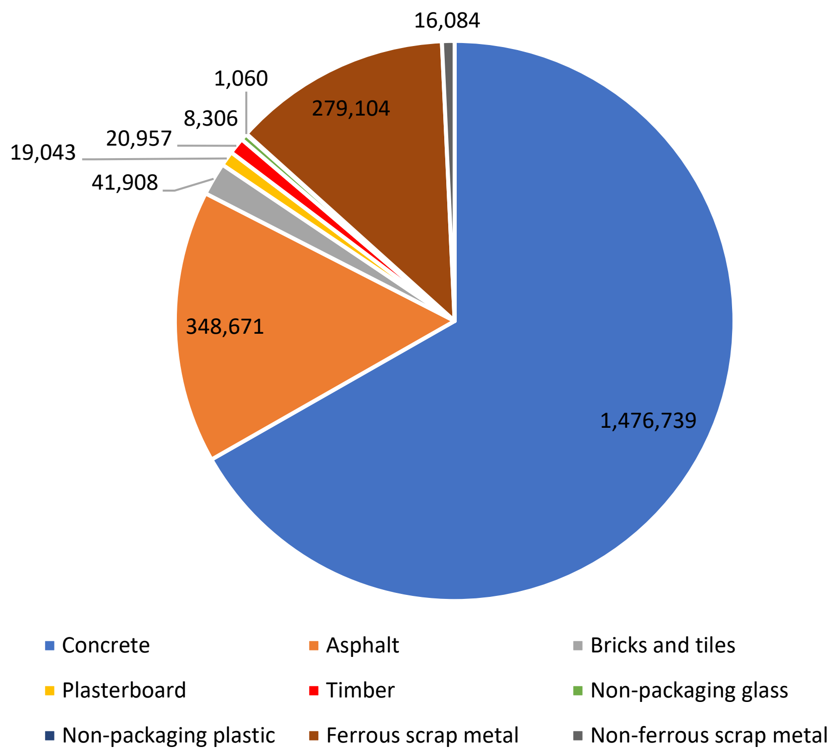
Concrete was the main type of recycled C&D waste material generated in Queensland in 2016-17, followed by asphalt as summarised in Table 2.2 and depicted in Figure 2.4. The quantity of asphalt recovered experienced a substantial increase from 2016 in Queensland, while the quantity of brick and tiles recovered halved during the same period. Recently there have been significant efforts by TMR to help facilitate the increased use of reclaimed asphalt pavement (RAP) in new asphalt production.

Table 2.2: The amount of recovery of C&D waste in Queensland in 2016–17

Material	Quantity recovered or sent for recovery in Queensland (tonnes)	Change from 2016 to 2017
Concrete	1 476 739	12.0%
Asphalt	348 671	133.1%
Bricks and tiles	41 908	-50.1%
Plasterboard	19 043	–
Timber	20 957	–
Non-packaging glass	8 306	–
Non-packaging plastic	1 060	–
Ferrous scrap metal	279 104	–
Non-ferrous scrap metal	16 084	–
TOTAL	2 211 872	–

Source: Queensland Government (2018).

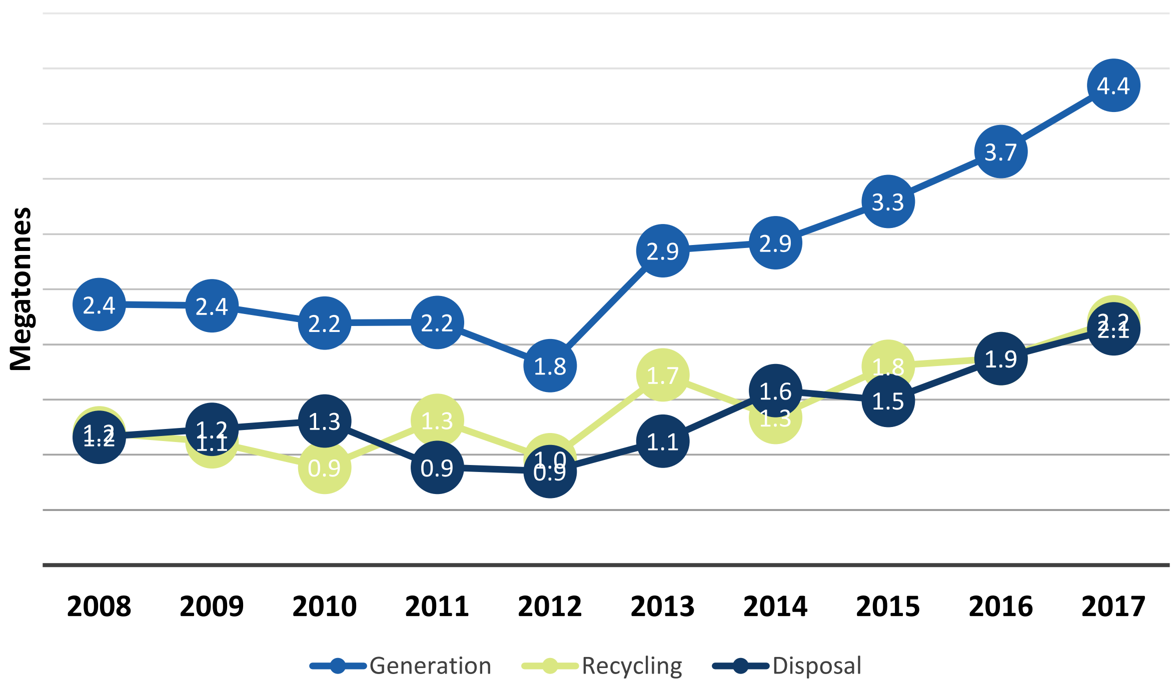
Figure 2.4 Recovery of C&D waste in Queensland (2016–17) (tonnes)



Source: Queensland Government (2018).

Figure 2.5 illustrates the quantity of the C&D waste which was generated, recycled and disposed of in Queensland from 2008 to 2017. This shows that over the 10-year period the rate of recycling has remained at approximately 50% of the waste generated.

Figure 2.5 Trends in generation, recycling and disposal of C&D waste in Queensland from 2008 to 2017

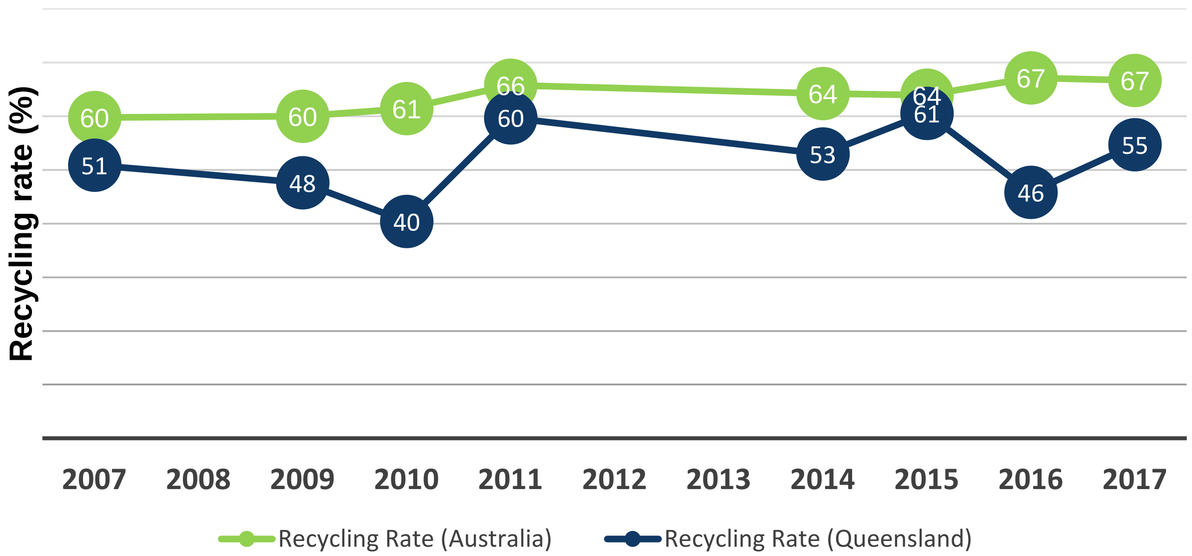


Source: Queensland Government (2018).

The C&D waste recovery rate of Queensland is compared with the national recovery rate in Figure 2.6. The fluctuating recovery rate of C&D material in Queensland is noticeable compared to the gradual increase in C&D waste recovery nationally.

Based on the *Australian National Waste Report* (Pickin et al. 2018), Queensland targeted the ambitious recycling rate of 80% by 2024, which further signifies the importance of conducting more studies on the opportunities for recycling C&D waste in Queensland.

Figure 2.6 Recovery rate of C&D waste in Queensland and Australia 2007–2017



Source: Queensland Government (2018).

2.2 C&D WASTE MATERIALS SUITABLE FOR PAVEMENT CONSTRUCTION

This project will primarily focus on reviewing the most commonly available C&D materials suitable for pavement construction, based on the materials most commonly recycled in the manufacture of unbound granular basecourses and subbases outlined in the Austroads *Guide to Pavement Technology Part 4E: Recycled Materials* (Austroads 2009). This includes, recycled crushed concrete (RCC), recycled crushed brick (RCB), recycled crushed glass (RCG), reclaimed asphalt pavement (RAP) and industrial by-products such as slag and fly ash.

2.2.1 RECYCLED CRUSHED CONCRETE (RCC)

As shown in Table 2.2, concrete made the most significant contribution to the C&D waste in Queensland during the 2016–17 financial year by approximately four times the next largest contributor, asphalt. RCC is generally considered to be a strong and durable construction material, with the original aggregate typically being sourced from high quality quarry materials (often of a higher standard than would be used for granular pavement materials). One of the primary perceived barriers for the use of RCC in pavements is the presence of excess or non-hydrated cementitious materials which may have a minor 're-binding' effect after crushing.

2.2.2 RECYCLED CRUSHED BRICK (RCB)

The particle size distribution of RCB makes it suitable for use in pavement construction. However, due to the comparatively lower aggregate crushing value of RCB compared to RCC (and virgin rock), as well as brick only comprising a small portion in the C&D waste stream, it is generally used as a relatively small constituent of blends with quarried rock or RCC. RCB was the third largest portion of C&D waste (that is suitable for use as a pavement material) in Queensland 2016–17, comprising approximately 2% of the total quantity recovered or sent for recovery, as shown in Table 2.2.

2.2.3 RECYCLED CRUSHED GLASS (RCG)

Glass cullet is a mixture of coloured glass particles that typically comes from the municipal waste stream which can be recycled back into new food and beverage containers made from glass, however this requires glass to be colour sorted and contaminant free (Disfani 2011). An increase in co-mingled recycling and crushing systems has subsequently led to an increase in fine, unprocessed glass cullet of different colours, creating a resource that is currently under-utilised in Australia (Leek & Huband 2010).

Although approaches such as container refund schemes are being used to help recycle glass bottles in high-value recycling activities, this approach has not yet significantly changed the fate of glass sourced from kerbside collections. In addition, there are large existing stockpiles of mixed colour crushed glass that are yet to be utilised.

Further research into the use of recycled glass in pavement materials is currently being undertaken under NACoE project P76 *The Use of Recycled Glass in Roads.* As such, this report will consider the use of glass by other state road agencies but will not specifically focus on implementing higher percentages of recycled glass in unbound or stabilised pavement materials.

2.2.4 RECLAIMED ASPHALT PAVEMENT (RAP)

Asphalt was ranked second in terms of recycling C&D waste in Queensland in 2016–17, as shown in Table 2.2. A significant quantity of RAP is reused in new asphalt production, with ongoing work underway throughout Australia to increase the amount of RAP that can be allowed in these applications.

The reuse of RAP in asphalt is considered to be a high value recycling opportunity as both the amount of new aggregate and bitumen needed for mixes can be reduced leading to significant economic and sustainability benefits. Many practitioners believe that the majority of the RAP that is currently available and will become available in the future can be reused in new asphalt mixes. The remaining RAP material (that is too dirty or too variable) can be used in other applications such as granular pavement or fill materials. In certain circumstances, the reuse of higher quality RAP directly onsite may also have economic or sustainability benefits where fill material would otherwise need to be imported from offsite.

As with RCC, RAP aggregates are generally considered to be a strong and durable construction material, with the constituents typically being sourced from high quality quarry materials. RAP materials also tend to re-bind, however unlike cementitious stabilised materials they are less prone to cracking in-service.

2.2.5 INDUSTRIAL BY-PRODUCTS

Aside from the recycled granular materials that can be utilised for sustainable construction of unbound pavements, industrial by-products such as blast-furnace slag (BFS) and fly ash can be incorporated in certain proportions in modified and stabilised base layers with minimal carbon footprint and economic advantages compared to conventional alternatives such as lime and Portland cement.

It is important to note that both BFS and fly ash may be used as binder additives to concrete and stabilised material blends and as this project is focussed on incorporating recycled materials as aggregates, binder applications will not be considered in this report. Furthermore, as there is no current producer of slag in Queensland, applications incorporating this by-product are imported from Japan, China or Thailand (TMR 2015).

2.3 BARRIERS TO THE USE OF RECYCLED MATERIALS

2.3.1 PERCEPTIONS

The use of recycled materials in Queensland's unbound granular and stabilised granular pavement materials has traditionally been relatively low, despite TMR permitting the use of recycled materials through MRTS35

Recycled Materials for Pavements (TMR 2018d). The limited uptake of these materials may be attributed to factors including:

- a perception that recycled materials are inferior to virgin materials
- limited technical knowledge regarding the allowable proportion of recycled materials and the long-term performance of these materials in certain pavement layers
- the limited number of suppliers (compared to quarry sources) of these materials, located mainly in South-East Queensland
- recycled materials are specified and procured in a different manner to quarry products, which can become an administrative barrier to their use.

This report shows that the recycled materials are widely accepted in unbound and stabilised pavement materials throughout Australia. While the report has not specifically focussed on the performance of pavement constructed from recycled materials, it is apparent that when used in the allowable applications these materials perform satisfactorily.

In Queensland, the use of recycled materials in granular pavement layers may be restricted to some degree by MRTS35 being a supplementary specification. While this specification is linked to the parent technical specifications including MRTS05 (TMR 2018a), there may be scenarios where the use of recycled materials is considered too difficult from a contractual perspective. To address this, the option of merging the recycled material requirements into the parent specifications should be explored.

At present, TMR maintains a Quarry Registration System (QRS) and recycled material suppliers do not have such a registration scheme. Anecdotal evidence suggests that this has been a limiting factor for suppliers when attempting to win work, with an unwillingness to take on a supplier that is not registered under the TMR QRS.

While preparing this report it was noted that VicRoads maintains a system of registration for all crushed rock mixes, which includes registration for recycled materials.

2.3.2 WORKPLACE HEALTH AND SAFETY

Occupation health and safety (OHS) risks are primarily related to contamination of C&D waste with asbestos. However, this type of material is no longer permitted to be used in building products, so the greatest potential for asbestos contamination comes from demolition and renovation works, not new construction. Generally, most of the agencies follow a similar procedure in identifying and dealing with asbestos in recycled materials (visual inspection). The general procedure and requirements regarding the inspection of asbestos are outlined below (Worksafe Victoria 2007; WA Department of Health 2009; Safework NSW 2010; NSW EPA 2018):

1. Identifying the source of C&D waste. This plays an important role in determining the risk of presence of asbestos in C&D waste.
2. Identifying the components of the load. As a general guide, asbestos may be found in items like cement sheet, vinyl tiles, bitumen sheet, caulking, gaskets and expansion joint material. Generally, a competent person is required to inspect the loads (NSW EPA 2018).
3. The construction date of the site. As a general guide, buildings and structures constructed before 1990 may have been built using asbestos-containing materials.
4. Checking and inspecting incoming materials before stockpiling or processing, to minimise the risk of asbestos contamination in recovered materials.
5. Rejecting loads, to avoid accepting and recycling asbestos-containing materials.
6. Spreading and turning the material can help the visual processing.

Typically, the engineering specifications used by each road agency specify that asbestos shall not be incorporated into the pavement material.

3 NATIONAL USE OF RECYCLED MATERIALS IN PAVEMENTS

The incorporation of recycled materials in unbound and bound pavement layers is well established in some parts of Australia, especially in metropolitan centres where a continuous supply of recycled materials is available. The usage management and permissibility of using recycled materials in unbound and bound pavement layers varies between jurisdictions. National specifications and documents reviewed are summarised in Table 3.1.

Table 3.1: National documents reviewed

Jurisdiction	Documents reviewed
Austroads	Guide to Pavement Technology 4E: Recycled Materials (Austroads 2009)
Queensland	MRTS05 *Unbound Pavements* (TMR 2018a) MRTS08 *Plant Mixed Heavily Bound Pavements* (TMR 2018b) MRTS10 *Plant Mixed Lightly Bound Pavements* (TMR 2018c) MRTS35 *Recycled Materials for Pavements* (TMR 2018d) Supplement to '*Part 2: Pavement Structural Design*' of the Austroads *Guide to Pavement Technology* (TMR 2018e)
New South Wales	QA Specification 3051 *Granular Pavement Base and Subbase Materials* (RMS 2018a) Roads and Maritime Supplement to Austroads *Guide to Pavement Technology Part 2: Pavement Structural Design* (RMS 2018b)
South Australia	Part R15 *Supply of Pavement Materials* (DPTI 2017a) Part R15 – Attachment A *Pavement Material Specification* (DPTI 2017b) Supplement to the Austroads *Guide to Pavement Technology Part 2: Pavement Structural Design* (DPTI 2018)
Victoria	Section 820 *Crushed Concrete for Pavement Subbase and Light Duty Base* (VicRoads 2011) Code of Practice RC 500.02 *Registration of Crushed Rock Mixes* (VicRoads 2017) Code of Practice RC 500.22 *Selection and Design of Pavements and Surfacings* (VicRoads 2018) Technical Note 107 *Use of Recycled Materials in Road Pavements* (VicRoads 2019)
Western Australia	Specification 302 *Earthworks* (MRWA 2019) Specification 501 *Pavements* (MRWA 2018)

Documentation from the Northern Territory Department of Infrastructure, Planning and Logistics (DIPL) makes no reference to the usage of recycled materials (except for recycled crushed glass as a drainage bedding material) in roadworks (DIPL 2017). As such, this was not included in the review. Additionally, the Department of State Growth Tasmania has aligned their specifications with VicRoads, and thus, these were not separately reviewed. The Australian Capital Territory (ACT) Government has adopted the relevant specifications of the NSW Roads and Maritime Services (RMS) in many areas of road infrastructure and management. The required properties of recycled materials to be used as pavement materials were in accordance with RMS specifications and practice and were not further reviewed.

3.1 AUSTROADS

The Austroads *Guide to Pavement Technology Part 4E: Recycled Materials* (Austroads 2009) contains limited guidance on the specification, manufacture and application of various recycled products for unbound granular basecourse and subbase. The information is primarily limited to a review (of now superseded) state road agency specifications for recycled materials and definitions of the most common materials suitable for pavements. As outlined in Section 2.2, this includes RCC, RCB, RCG, RAP and industrial by-products.

3.2 QUEENSLAND DEPARTMENT OF TRANSPORT AND MAIN ROADS (TMR)

The Queensland Department of Transport and Main Roads (TMR) manages the use of recycled materials through specification MRTS35 *Recycled Material Blends for Pavements* (TMR 2018d). This specification outlines requirements and permissible uses of recycled material blends for the construction, rehabilitation and maintenance of road pavements. Conventional unbound materials are specified in MRTS05 *Unbound Pavements* (TMR 2018a) whereas bound materials are covered in MRTS08 *Plant Mixed Heavily Bound Pavements* (TMR 2018b) and MRTS10 *Plant Mixed Lightly Bound Pavements* (TMR 2018c). Incorporating both conventional and recycled materials in pavement designs is outlined in the TMR *Supplement to 'Part 2: Pavement Structural Design' of the Austroads Guide to Pavement Technology* (TMR 2018e).

3.2.1 UNBOUND PAVEMENT

In accordance with MRTS35 (TMR 2018d), recycled materials may be used in unbound pavement construction when the following requirements are met:

- in carparks, sub-base and lower unbound pavement layers with no additional restrictions
- for 'District Roads' where the recycled material is below an asphalt layer:
  - where the average daily equivalent standard axles (ESA) in the design lane is less than 100 in the year of opening, the surfacing shall be of dense graded and/or stone mastic asphalt with a thickness at least 25 mm.
  - where the average daily ESA in the design lane is greater than or equal to 100 in the year of opening, a minimum combined thickness of 100 mm surfacing with dense graded and/or stone mastic asphalt is required.
- for 'National Network Roads', 'State Strategic Roads' or 'Regional Roads' where the recycled material is below an asphalt layer, a minimum combined thickness of 100 mm surfacing with dense graded and/or stone mastic asphalt is required.

Recycled material blends are not permissible for use in pavement layers directly in contact with traffic (e.g. unsealed pavements or unsealed shoulders), any permanent base layers immediately below a permanent sprayed seal surfacing, or any base layer below a permanent sprayed seal surfacing that is to be trafficked with a speed limit exceeding 60 km/h.

Generally, RCC is the primary constituent in recycled material blends where other recycled material limits such as RAP, RCB and RCG, vary with material type, as summarised in Table 3.2 with the required particle size distribution (PSD) presented in Table 3.3. Notably, the TMR limits recycled material blends to a nominal particle size of 20 mm and specifies different gradings to the typical 'C' grading used by conventional materials in accordance with MRTS05 (TMR 2018a).

Table 3.2: TMR limits of constituents in recycled material blends

Recycled material type	Equivalent MRTS05 subtype	Maximum limit of each constituent (% by mass of mix)				
		Quarry material	RCC	RAP	RCB	RCG
RM001	2.1	100	100	0	0	0
RM002	2.2	100	100	15	0	0
RM003	2.3	100	100	15	15	0
RM004	2.4	100	100	15	15	0
RM005	2.5	100	100	15	45	5
RM006	2.6	100	100	15	45	5

Source: TMR (2018d).

Table 3.3: TMR grading limits for recycled materials

Sieve size (mm)	% Passing by mass		
	RM001 and RM002	RM003 and RM004	RM005 and RM006
26.5	100	100	100
19	95-100	95-100	84-100
13.2	78-92	75-95	69-95
9.5	63-83	60-90	56-90
4.75	44-64	42-76	37-77
2.36	30-48	28-60	23-63
0.425	13-21	10-28	8-30
0.075	5-11	3-11	2-14

Source: Adapted from TMR (2018d).

In general, the requirements for coarse aggregates consist of fragments that are clean, sound, hard, durable, and angular. The material shall be free from clay and other aggregations of fine material, laminated particles, soil, organic matter and any other deleterious material as summarised in Table 3.4. Table 3.5 lists the property requirements of recycled materials against conventional materials for unbound pavements.

Table 3.4: TMR limits of foreign materials in recycled material blends

Constituents of foreign material type	Test method	Recycled material blend	Maximum percent in mix (% by mass)
Brick	Q477	RM001, RM002	1.0
Asphalt		RM001	1.0
Metal, ceramics and slag (other than blast furnace slag)		All	3.0
Plaster, clay lumps and other friable material		All	1.0
Rubber, plastic, bitumen not part of asphalt, paper, cloth, paint, wood and other vegetable matter		All	0.2
Free lime	RMS T134	All	0.6

Source: Adapted from TMR (2018d).

Table 3.5: Comparison of TMR conventional and recycled material property requirements

Property	RM001	2.1	RM002	2.2	RM003	2.3	RM004	2.4	RM005	2.5	RM006	3.5
Liquid limit (%), max	35	25	35	25	35	28	35	35	40	40	40	40
Linear shrinkage (%), max	3.5	3.5	3.5	3.5	4.5	4.5	6.5	6.5	7.5	7.5	7.5	7.5
Weighted linear shrinkage (%), max	85	85	85	85	110	110	195	195	–	–	–	–
Wet strength (kN), min	85	115-135	85	100-115	70	35-45	70	70-85	–	–		–
Wet/dry strength variation (%), max	35	35-40	40	35-40	45	35-45	45	35-45	45	–	45	–
Degradation factor, min	–	40-50	–	40-50	–	30-40	–	30-40	–	–	–	–
Flakiness index (%), max	35	35	35	35	40	40	40	40	40	–	40	–
CBR soaked (%), min	80	80	60	60	45	45	35	35	15	15	–	–
CBR, unsoaked (%), min	–	–	–	–	–	–	–	–	–	–	15	15
UCS at 7 days (MPa), max	0.7	–	0.7	–	0.7	–	0.7	–	0.7	–	0.7	–

Source: Adapted from TMR (2018a) and TMR (2018d).

3.2.2 BOUND PAVEMENT

In accordance with MRTS08 *Plant-mixed Heavily Bound (Cemented) Pavements* (TMR 2018b) and MRTS07B *Insitu Stabilised Pavements using Cement or Cementitious Blends,* only RM001 materials can be used for Category 1 and Category 2 bound layers for both base and subbase applications that adhere to the following requirements:

- permanent pavements:
  - basecourses – when the average daily ESA in the design lane in the year of opening is less than 100
  - subbasecourses
  - subgrade treatments.
- temporary pavements (≤ 2 year design life): for all the layers.

MRTS10 *Plant-mixed Lightly Bound Pavements* (TMR 2018c) permits RM001, RM002 and RM003 materials for use in lightly bound improved layers. Additionally, MRTS07C *Insitu Stabilised Pavements using Foamed Bitumen* and *MRTS09 Plant-Mixed Pavement Layers Stabilised Using Foamed Bitumen* permits only RM001 material. The requirements for these materials are outlined in Table 3.2 to Table 3.5.

3.3 ROADS AND MARITIME SERVICES (RMS)

In New South Wales, the Roads and Maritime Services (RMS) manages the use of conventional and recycled materials in both unbound, modified and bound pavement layers through Quality Assurance (QA) Specification 3051 *Granular Pavement Base and Subbase Materials* (RMS 2018a).

3.3.1 UNBOUND PAVEMENT

RMS has three primary classifications for the unbound materials; densely graded base (DGB), densely graded subbase (DGS) and material to be bound (MB). The property requirements for these materials vary based on nominal aggregate size and design traffic category. These traffic categories are expressed in ESAs as follows:

- A: ≥ 10^7 ESAs.
- B: $4x10^6$ – 10^7 ESAs.
- C: 10^6 – $4x10^6$ ESAs.
- D: < 10^6 ESAs.

Generally, RCC and slag may be used in all categories of base and subbase materials with the limits on the use of recycled and manufactured materials as constituent materials outlined in Table 3.6. These materials are permitted under the following:

- For unbound or modified base layers with a design traffic exceeding $4x10^6$ ESAs:
  - RCC must be sourced from rigid pavements or structural concrete (concrete containing reinforcement).
  - RAP may only be obtained from profilings.
- The addition of fly ash or furnace bottom ash may not be acceptable if modification is to be carried out.

RMS grading requirements are consistent for both quarried materials and blends containing recycled material and manufactured materials, as summarised in Table 3.7, where the undesirable material limits for each application are presented in Table 3.8. The property requirements for both quarried materials and recycled material blends are presented in Table 3.9, showing that RMS permits recycled materials to have a higher maximum liquid limit whereas the other requirements are the same for quarried and recycled products.

Table 3.6: RMS limits on use of recycled and manufactured materials as constituent materials

Recycled material	Maximum limit of each constituent (% by mass of mix)	
	Unbound or modified base and subbase	Bound base and subbase
Slag	100	100
RCC	100	100
RCB	20	10
RAP	40	40
Fly ash	10	10
Furnace bottom ash (FBA)	10	10
RCG	10	10

Source: RMS (2018a).

Table 3.7: RMS grading limits on materials

Sieve size (mm)	% Passing by mass				
	Unbound base	Unbound or modified subbase		Bound base and subbase	
	Class 1 DGB, Class 2 DGB	DGS20	DGS40	MB20	MB40
53	–	–	100	–	–
37.5	–	–	95-100	–	100
26.5	100	100	75-95	100	–
19	95 - 100	95 – 100	64-90	95-100	–
13.2	78 – 92	70-90	–	70-90	55-80
9.5	63 – 83	58-80	42-78	60-80	30-55
4.75	44 – 64	43-65	27-64	–	–
2.36	33-49	30-55	20-50	30-50	20-40
0.425	14-23	10-30	10-23	10-25	8-25
0.075	7-14	4-17	4-12	4-12	3-10
0.0135	3-7	2-10	2-7	–	–

Source: Adapted from RMS (2018a).

Table 3.8: RMS limits of foreign materials in recycled and manufactured materials

Foreign materials	Test method	Traffic category	Maximum percent in mix (% by mass)	
			Base	Subbase
Metal, unprocessed glass, and ceramic material (excluding bricks)	RMS T276	• A: ≥ 10^7 • B: $4x10^6$ – 10^7 • C & D: < $4x10^6$	1% 1% 2%	2% 2% 3%
Plaster, clay lumps and other friable material		• A: ≥ 10^7 • B: $4x10^6$ – 10^7 • C & D: < $4x10^6$	0.1% 0.2% 0.5%	0.5% 0.5% 0.5%
Rubber, plastic, paper, cloth, paint, wood and other vegetable matter		• A: ≥ 10^7 • B: $4x10^6$ – 10^7 • C & D: < $4x10^6$	0.1% 0.1% 0.2%	0.2% 0.2% 0.2%
Tar (including coal tar)		All	0%	0%
Free lime	RMS T134	All	0.6%	0.6%

Source: Adapted from RMS (2018a).

Table 3.9: Comparison of RMS conventional and recycled material property requirements

Property	Unbound/modified base (recycled)	Unbound/modified base (natural/manufactured)	Unbound/modified subbase (recycled)	Unbound/modified subbase (natural/manufactured)	Bound base and subbase (all)
Liquid limit (%), max	27	20[2] (ESA ≥ 4x10^{6}) 23 (ESA < 4x10^{6})	27	23	–
Plasticity index (%)	2-6 (ESA ≥ 4x10^{6}) 2-6[1] (ESA < 4x10^{6})	2-6 (ESA ≥ 4x10^{6}) 2-6[1] (ESA < 4x10^{6})	0-10	0-10	0-2 (ESA ≥ 4x10^{6}) 0-6 (10^{6} ≥ ESA < 4x10^{6}) 0-10 (ESA < 10^{6})
Plastic limit (%), max	20	20	20	20	–
Wet strength (kN), min	100 (ESA ≥ 4x10^{6}) 70 (ESA < 4x10^{6})	100 (ESA ≥ 4x10^{6}) 70 (ESA < 4x10^{6})	70	70	70
Wet/dry strength variation (%), max	35	35	35 (ESA ≥ 4x10^{6}) 40 (ESA < 4x10^{6})	35 (ESA ≥ 4x10^{6}) 40 (ESA < 4x10^{6})	35
UCS at 7 days (MPa), max	1.0	1.0	–	–	–
Permeability (m/sec), max	5x10^{-8} (ESA ≥ 10^{7})	5x10^{-8} (ESA ≥ 10^{7})	–	–	–
Particle shape (%), max	35	35	35	35	35
Two or more fractured faces (%), min	85 (ESA ≥ 4x10^{6}) 75 (ESA < 4x10^{6})	85 (ESA ≥ 4x10^{6}) 75 (ESA < 4x10^{6})	75	75	75
Dry compressive strength (MPa), min	1.7	1.7	1.0	1.0	–
Acid soluble sulfate content (%), max	0.3	0.3	0.3	0.3	0.3

Property	Unbound/modified base (recycled)	Unbound/modified base (natural/manufactured)	Unbound/modified subbase (recycled)	Unbound/modified subbase (natural/manufactured)	Bound base and subbase (all)
Modified Texas triaxial compression (no.), max	2.2 ($10^6 \geq$ ESA < $4x10^6$) 2.5 (ESA < 10^6)	2.2 ($10^6 \geq$ ESA < $4x10^6$) 2.5 (ESA < 10^6)	3.2 (ESA < $4x10^6$)	3.2 (ESA < $4x10^6$)	2.2 (ESA $\geq 10^7$) 2.5 ($4x10^6 \geq$ ESA < 10^7) 3.0 (ESA $4x10^6$)

1. *Only applicable when specified for unbound material for use in base that is constructed under traffic and is to be spray sealed.*
2. *May be increased to 23% for non-plastic crushed rock, provided that the value determined is not influenced by the presence of adverse constituents (e.g. mica).*

Source: adapted from RMS (2018a).

3.3.2 BOUND PAVEMENT

Similar to unbound pavements, QA 3051 (RMS 2018a) permits up to 100% slag and 100% RCC to be used in materials to be bound where bound pavements are only permitted to contain up to 10% RCB compared to 20% RCB by mass in unbound or modified materials, as outlined in Table 3.6 Undesirable constituent limits are summarised in Table 3.8. The PSD for base and subbase material to be bound is presented in Table 3.7 and the property requirements are in accordance with Table 3.9.

3.4 DEPARTMENT OF PLANNING, TRANSPORT AND INFRASTRUCTURE (DPTI)

The South Australian Department of Planning, Transport and Infrastructure (DPTI) specifies the requirements for the supply and delivery of materials to be used in pavements in Specification R15 *Supply of Pavement Materials* (DPTI 2017a) and Specification R15 – Attachment A *Pavement Material Specification* (DPTI 2017b). The *Supplement to the Austroads Guide to Pavement Technology Part 2: Pavement Structural Design* (DPTI 2018) is also used in conjunction with the material specifications to provide specific guidance on recycled material permissible uses.

3.4.1 UNBOUND PAVEMENT

DPTI permits the use of recycled materials through both grading-based (GB) and performance-based (PB) specifications for Class 1, Class 2 and Class 3 materials in accordance with R15 – Attachment A (DPTI 2017b), where the required properties and permissible usages vary based on nominal aggregate size and design traffic category. The requirements for the use of recycled materials in accordance with DPTI (2018) include:

- not permitted in Class 1 heavily trafficked heavy duty (≥ $1x10^7$ ESAs) unbound granular basecourse
- permitted in Class 1 base, Class 2 upper subbase, Class 2 lower subbase and Class 2 working platforms for heavily (≥ $5x10^6$ ESA) and moderately trafficked roads ($1x10^5$ – $5x10^6$ ESAs)
- permitted in Class 2 base and Class 3 lower subbase for lightly trafficked roads (< $1x10^5$ ESAs)
- permissible applications vary with recycled material gradings and properties.

DPTI permits recycled material blends to be comprised of quarried material, RCC or any combination of both with a maximum constituent of RCB, crushed tiles or RAP limited to 20% by mass regardless of the application. Furthermore, Specification R15 (DPTI 2017a) permits blast furnace slag (BFS) to be used in lieu of quarried materials if the material blend complies with all the requirements of R15 – Attachment A (DPTI 2017b), with the exception of Class 1 heavy duty material blends which do not permit recycled material, as summarised in Table 3.10. The PSD of materials shall comply with the requirements of Table 3.11, where it is noted that DPTI permits recycled materials to be used in mixes with a nominal size of up to 40 mm.

Table 3.10: DPTI limits on the use of recycled materials as constituents

Material class	Source	Maximum limit of each constituent (% by mass of mix)					
		Quarry material	RCC	BFS	RCB	Crushed tiles	RAP
Class 1 heavy duty (GB)	Quarried	100	0	0	0	0	0
Class 1 (GB)	Quarried	100	0	100	0	0	0
Class 1 (PB)	Quarried	100	0	0	0	0	0
Class 1 (GB/PB)	Recycled	100	100	100	20	20	20
Class 2 (GB/PB)	Quarried	100	0	100	0	0	0
Class 2 (GB/PB)	Recycled	100	100	100	20	20	20

Material class	Source	Maximum limit of each constituent (% by mass of mix)					
		Quarry material	RCC	BFS	RCB	Crushed tiles	RAP
Class 3 (GB)	Quarried	100	0	100	0	0	0
Class 3 (GB)	Recycled	100	100	100	20	20	20

Source: Adapted from DPTI (2017a), DPTI (2017b) & DPTI (2018).

Table 3.11: DPTI grading limit for quarried and recycled materials

Sieve size (mm)	% Passing by mass											
	Unbound base					Unbound upper subbase or lower subbase[1]					Unbound lower subbase[2]	
	Class 1 (PB)		Class 1 (GB)			Class 2 (PB)		Class 2 (GB)			Class 3 (GB)	
	Nominal size (mm)											
	20	30	20	30	40	20	30	20	30	40	20	40
53	–	–	–	–	100	–	–	–	–	100	–	100
37.5	–	100	–	100	95-100	–	100	–	100	90-100	–	90-100
26.5	100	–	100	95-100	79-91	100	90-100	100	90-100	74-96	100	–
19	95-100	80-95	95-100	79-93	65-83	90-100	80-95	90-100	77-95	62-86	90-100	60-85
13.2	–	–	77-93	–	–	–	–	74-96	–	–	–	–
9.5	65-85	50-75	63-83	53-73	44-64	–	–	61-85	51-75	42-66	–	–
4.75	–	–	44-64	36-56	29-49	–	–	42-66	35-57	28-50	40-65	25-50
2.36	30-50	25-45	29-49	25-43	20-38	30-60	25-55	28-50	24-44	20-39	–	–
0.425	–	–	13-23	10-21	8-18	–	–	11-27	9-22	8-21	–	–
0.075	5-15	5-15	5-11	4-10	3-9	5-20	5-20	4-14	4-12	3-11	5-15	3-11

1. *Permitted in base for lightly trafficked (< $1x10^5$ ESAs) roads.*
2. *Permitted in lightly trafficked (< $1x10^5$ ESAs) roads.*

Source: Adapted from DPTI (2017b).

Generally, RCC and BFS may be used instead of Class 1, Class 2 and Class 3 quarried materials where the limits of foreign materials are consistent with each class of material (both quarried and recycled) as shown in Table 3.12. Notably, there is no difference in the limits for PSD, PI, LL, LS and Los Angeles Abrasion value of quarried and recycled materials, summarised in Table 3.13.

Table 3.12: DPTI limits of foreign materials in recycled material blends

Foreign materials	Test method	Maximum percent in mix (% by mass)		
		Class 1	Class 2	Class 3
Metal, unprocessed glass, and ceramic material (excluding bricks)	RMS T276	–	–	–
Plaster, clay lumps and other friable material		1.0	1.0	1.0
Rubber, plastic, paper, cloth, paint, wood and other vegetable matter		0.5	0.5	0.5
Bitumen content	AS/NZS 2891.3.3	1.0	1.0	1.0

Source: Adapted from DPTI (2017b).

Table 3.13: DPTI material property requirements for quarried and recycled materials

Property	Unbound base		Unbound upper subbase or lower subbase1		Unbound lower subbase2
	Class 1 (PB)	Class 1 (GB)	Class 2 (PB)	Class 2 (GB)	Class 3 (GB)
Liquid limit (%), max	25	25	30	28	35
Plasticity index (%)	1-6	1-6	1-10	1-8	0-15
Linear shrinkage (%), max	3	3	5	4	8
Resilient modulus (MPa), min	300	–	250	–	–
Deformation, max	10^{-8}	–	10^{-7}	–	–
LA abrasion grading 'A'	–	N/A (20 & 30 mm) 30 (40 mm)	–	N/A (20 & 30 mm) 45 (40 mm)	N/A (20 mm) 45 (40 mm)
LA abrasion grading 'B'	Contractor nom.	30 (20 & 30 mm) N/A (40 mm)	Contractor nom.	45 (20 & 30 mm) N/A (40 mm)	45 (20 mm) N/A (40 mm)
Triaxial compression cohesion (kPa), max	150	–	250	–	–
Triaxial compression friction angle (°), min	45	–	40	–	–

1. *Permitted in base for lightly trafficked (< $1x10^5$ ESAs) roads.*
2. *Permitted in lightly trafficked (< $1x10^5$ ESAs) roads.*

Source: Adapted from DPTI (2017b).

3.4.2 BOUND PAVEMENT

In accordance with DPTI (2018) Class 1 and Class 2 materials up to 40 mm nominal aggregate size GB quarried materials may be used in bound pavement applications, conforming to the same requirements outlined in Table 3.10 to Table 3.13. DPTI (2018) also notes that recycled materials in accordance with Part R15 (DPTI 2017a) may be used instead of quarried materials for bound pavements with prior approval. However, no additional information regarding approvals is provided in the DPTI documents reviewed.

3.5 VICROADS

In Victoria, the use of recycled materials in pavements is managed through the VicRoads Code of Practice RC 500.02 *Registration of Crushed Rock Mixes* (VicRoads 2017) and Code of Practice RC 500.22 *Selection and Design of Pavements and Surfacings* (VicRoads 2018). General guidance and a summary of practice is presented in Technical Note 107 *Use of Recycled Materials in Road Pavements* (VicRoads 2019).

3.5.1 UNBOUND PAVEMENT

VicRoads permits recycled materials to be used in Class 2, Class 3 and Class 4 unbound granular material, although with varying permissible limits. In accordance with VicRoads (2017) and VicRoads (2018), the four material classes may be used for the following applications:

- Class 1 materials are used for base layers in heavy duty (design traffic ≥ $7x10^6$ ESAs) unbound flexible pavements.
- Class 2 materials may be used for unbound basecourse layers.
- Class 3 materials may be used for upper subbase layers in heavy duty (design traffic ≥ $7x10^6$ ESAs) unbound flexible pavements, the basecourse for lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements or bound subbase for deep strength asphalt pavements.
- Class 4 materials may be used for lower subbase layers in heavy duty (design traffic ≥ $7x10^6$ ESAs) unbound flexible pavements or as a subbase for other types of pavements.

Generally, RCC is allowed to be supplemented for conventional crushed rock in Class 2, Class 3 and Class 4 materials while Class 1 materials do not permit the supplementation of RCC and all four classes allow RCB, RCG and RAP. The allowable limits of each constituent material for each of the four material classes are summarised in Table 3.14. Notably, the PSD (Table 3.15), foreign material limit (Table 3.16) and property requirements (Table 3.17) for each of the four material classes are not altered with or without the inclusion of recycled materials. Further, the VicRoads grading limits specify separate gradings for unbound base and unbound upper subbase layers based on LAV where recycled materials will typically have an LAV ≥ 26. VicRoads do not specify a foreign material limit for Class 1 materials.

Table 3.14: VicRoads limits on the use of recycled materials as constituents

Material class	Maximum limit of each constituent (% by mass of mix)				
	Quarry material	RCC	RCB[1]	RCG[1]	RAP[1]
Class 1	100	0	Not specified (5)	Not specified (5)	Not specified (5)
Class 2	100	10[1]	Not specified (10[2])	Not specified (10[2])	Not specified (10[2])
Class 3	100	100	Not specified (15)	Not specified (15)	Not specified (15)
Class 4	100	100	Not specified (50)	Not specified (50)	20
Cement treated (utilising Class 3)	100	100	Not specified (15[3])	Not specified (15[3])	0

1. *VicRoads classifies recycled material (including RCB, RCG and RAP) other than RCC to be supplementary materials and individual limits are not generally specified (i.e. Class 1 materials may contain up to 5% supplementary materials in the total mix).*
2. *Contents greater than 10% permitted for lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*
3. *Permitted for use in lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*

Source: Adapted from VicRoads (2011; 2019).

Table 3.15: VicRoads grading limits for quarried and recycled materials

Grading sieve size (mm)	Unbound base		Unbound upper subbase[1,2]				Unbound lower subbase[1,3]				
	Class 1[1] and Class 2		Class 3				Class 4				
	(LAV ≤ 25)	(LAV ≥ 26)	(LAV ≤ 25)		(LAV ≥ 26)						
	Nominal size (mm)										
	20	20	20	40	20	40	14	20	25	30	40
53.0	–	–	–	100	–	100	–	–	–	–	100
37.5	–	–	–	95-100	–	95-100	–	–	100	100	–
26.5	100	100	100	75-95	100	75-95	–	100	–	–	–
19.0	95-100	95-100	95-100	64-90	95-100	64-90	100	–	–	–	64-90
13.2	78-92	78-92	75-95	–	75-95	–	–	–	–	–	–
9.5	63-83	63-83	60-90	42-78	60-90	42-78	–	–	54-75	48-70	–
4.75	44-64	44-64	42-76	28-64	42-76	28-64	54-75	42-76	–	–	–

Grading sieve size (mm)	Unbound base		Unbound upper subbase[1,2]				Unbound lower subbase[1,3]				
	Class 1[1] and Class 2		Class 3				Class 4				
	(LAV ≤ 25)	(LAV ≥ 26)	(LAV ≤ 25)		(LAV ≥ 26)						
	Nominal size (mm)										
	20	20	20	40	20	40	14	20	25	30	40
2.36	30-48	29-48	28-60	20-50	28-60	20-50	–	–	–	–	–
0.425	14-22	13-21	14-28	10-23	10-28	7-23	15-32	10-28	10-26	9-24	7-23
0.075	7-11	5-9	6-13	6-12	2-10	2-9	6-17	2-14	2-13	2-12	2-12

1. *For heavy duty pavements (≥ 7×10^6 ESAs).*
2. *Permitted for use in basecourse of lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*
3. *Subbase for pavements with design traffic < 7×10^6 ESAs.*

Source: Adapted from VicRoads (2017) and VicRoads (2018).

Table 3.16: VicRoads limits of foreign materials by class

Foreign materials	Test method	Maximum percent in mix (% by mass)		
		Class 2	Class 3	Class 4
Metal, unprocessed glass, and ceramic material (excluding bricks)	RMS T276	2.0	3.0	5.0
Plaster, clay lumps and other friable material		0.5	1.0	3.0
Rubber, plastic, paper, cloth, paint, wood and other vegetable matter		0.1	0.2	0.5

Source: Adapted from VicRoads (2017).

Table 3.17: VicRoads material property requirements for quarried and recycled materials

Property	Unbound base		Unbound upper subbase[1,2]	Unbound lower subbase[1,3]
	Class 1[1]	Class 2	Class 3	Class 4
Liquid limit (%), max	30	30	35	40
Plasticity index (%)	2-6	0-6	0-10	0-20
Flakiness index (%), max	35	35	–	–
CBR, soaked (%), min	N/A	100	80	20
Marginal and unsound rock (%), max	10	10	20	–
Unsound rock (%), max	5	7	10	–

1. *For heavy duty pavements (≥ 7×10^6 ESAs).*
2. *Permitted for use in basecourse of lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*
3. *Subbase for pavements with design traffic < 7×10^6 ESAs.*

Source: Adapted from VicRoads (2017) and VicRoads (2018).

3.5.2 BOUND PAVEMENT

Class 3 materials may be used as a bound subbase for deep strength asphalt pavements provided the material complies with the requirements outlined in Table 3.15 and Table 3.17. As summarised in Table 3.14, the Class 3 material may be comprised of quarried or RCC up to a limit of 100% by mass and up to 15% RCB and RCG by mass are only permitted if the bound subbase is lightly trafficked (< 3500 AADT and less than 10% heavy vehicles).

3.6 MAIN ROADS WESTERN AUSTRALIA (MRWA)

MRWA guidance on the usage and management of recycled material in both unbound and bound pavement layers is comparatively limited compared to the other state road agencies reviewed. Specification 501 *Pavement* (MRWA 2018) does permit the use of RCC as a subbase below full depth asphalt (FDA) pavements although limited by the following:

- The RCC subbase material specification is not contained within Specification 501 and must be requested from the MRWA Materials Engineering Branch.
- It is generally only used in Alliance contracts, where the risk of contamination is jointly managed.

Personal conversations with MRWA personnel indicate this limit to the use of RCC was added based on previous experience with RCC containing asbestos. Furthermore, MRWA is currently undergoing a review of Specification 501 and aims to include an updated section on recycled material usage for publication in 2020. It is important to note that Specification 302 *Earthworks* (MRWA 2019) permits the use of glass cullet in pavement embankments but does not specify any recycled material use in unbound or bound pavement layers.

3.7 COMPARISON OF AUSTRALIAN PRACTICE

This section presents a comparison of TMR practice to the other state road agencies. As it is difficult to directly compare terminology across jurisdictions, three categories of unbound and bound pavement are used; base layer, upper subbase layer and lower subbase layer. Exceptions to these definitions are noted where applicable. Material classifications in accordance with each state road agency may be found in the appropriate part of Section 3.2 to Section 3.6. This allows for a generalised comparison across the three categories for each of the unbound and bound pavement layers.

Table 3.18 summarises the permitted recycled materials and their permissible uses for unbound granular pavements and bound pavements across each state road agency, while Table 3.19 presents a comparison of the percentage of allowable recycled materials permitted in each pavement layer as well as the limits on foreign materials. Table 3.20 and Table 3.21 compare the 20 mm nominal size gradings for unbound and bound pavements respectively, by the state road agencies, and the other nominal sized gradings for each road agency may be found in Section 3.2 to Section 3.6. Comparisons of the unbound base and unbound upper subbase material gradings between the state road agencies is presented in Figure 3.1 and Figure 3.2, respectively. Comparisons of the required material properties of blends containing recycled materials are presented in Table 3.22.

General observations from the comparison between current TMR requirements and other Australian state road agencies include:

- The use of recycled materials is widely accepted in unbound and stabilised pavement materials throughout Australia.
- Generally, the state road agency specifications indicate that recycled materials are suitable for use in both unbound and bound base and subbase applications.
- RMS, DPTI and VicRoads have combined or have closely aligned their specifications for traditional quarried materials and recycled materials. TMR is the only state road agency reviewed that has a separate specification for recycled materials.
- The grading requirements for recycled materials are consistent between each of the state road agencies reviewed. However, TMR is the only state road agency that specifies different material grading requirements for recycled and conventional materials.
- The property requirements for recycled materials are generally consistent between each of the state road agencies, although TMR and VicRoads permit the highest permissible liquid limits.
- Other than MRWA that does not permit recycled materials to be used outside of subbases below FDA pavements, TMR has the most stringent permissible use requirements on recycled materials in unbound

and bound basecourses. RMS, DPTI and VicRoads generally permit their use except for under heavily trafficked pavements (≥ $4x10^6$ ESAs).

- The permissible percentage of RCB ranges from 0% - 20% in unbound base applications and up to 45% in lower subbase applications.
- The permissible percentage of RAP ranges from 15% - 40% in unbound base applications and up to 40% in lower subbase applications.
- The permissible percentage of RCG ranges from 0% - 10% in unbound base applications and up to 15% in lower subbase applications.
- Recycled material constituents permitted outside Queensland include slag, fly ash, FBA and crushed tiles.
- Foreign material limits are similar between the state road agencies reviewed, where it is notable that DPTI does limit the proportion of high-density foreign materials such as metal, ceramics and slags.

Table 3.18: Comparison of state road agency permitted recycled materials and their permissible uses in unbound and bound pavement layers

Criteria	TMR	RMS	DPTI	VicRoads	MRWA
Materials permitted	• RCC • RCB • RCG • RAP	• RCC • Slag • RCB • RCG • RAP • Fly ash • FBA	• RCC • Blast furnace slag – must not be granulated or ground • RCB • Crushed tiles • RAP	• RCC • RCB • RCG • RAP	• RCC • RCG • RAP
Permissible uses	• Permitted in unbound basecourse if: – covered by a DGA or SMA layer at least 25 mm thick if average daily ESA < 100, or 100 mm thick if average daily ESA >100. • Not permitted in unsealed pavements. • Not permitted in base of sprayed seals with design speed >60 km/h. • Not permitted in base of sprayed seals >3 months traffic. • Permitted in bound basecourse if average daily ESA in the design lane is <100.	• For unbound or modified base layers with a design traffic exceeding 4×10^6 ESAs: – RCC must be sourced from rigid pavements or structural concrete (concrete containing reinforcement). – RAP may only be obtained from profilings. • The addition of fly ash or furnace bottom ash may not be acceptable if modification is to be carried out.	• Not permitted in heavily trafficked heavy duty (≥ 1×10^7 ESAs) unbound granular basecourse. • Permitted in base, upper subbase, lower subbase, working platforms for heavily (≥ 5×10^6 ESA) and moderately trafficked roads (1×10^5 – 5×10^6 ESAs). • Permitted in base for lightly trafficked roads (< 1×10^5 ESAs). • Permissible applications vary with recycled material gradings and properties.	• RCC is not permitted in the basecourse of pavements with a design traffic exceeding 7×10^6 ESAs. • Unbound light duty (< 3500 AADT and < 10% heavy vehicles) basecourse comprised of recycled materials must be directly beneath a bituminous surfacing.	• RCC is only permitted in the subbase below FDA pavements. • Crushed glass is only permitted in embankments. • RAP is only permitted in subbase applications.

Table 3.19: Comparison of state road agency permitted recycled and foreign materials by mass

Road agency	Application	Max allowable contents by mass (%)								Foreign material limits by mass (%)				
		RCC	BFS	RAP	RCB	RCG	FA	FBA	Tiles	High density	Low density	Organic	Free lime	Other
TMR	Unbound base (RM001)	100	–	0	0	0	–	–	–	3	1	0.2	0.6	• 1% RCB. • 1% asphalt.
	Light duty unbound base (RM002)	100	–	15	0	0	–	–	–	3	1	0.2	0.6	• 1% RCB.
	Upper subbase (RM003/RM004)	100	–	15	15	0	–	–	–	3	1	0.2	0.6	• N/A.
	Lower subbase (RM005/RM006)	100	–	15	45	5	–	–	–	3	1	0.2	0.6	• N/A.
	Bound base and subbase (RM001)	100	–	15	0	0	–	–	–	3	1	0.2	0.6	• 1% RCB. • 1% asphalt.
RMS	Unbound base (Class 1/Class 2 DGB)	100	100	40	20	10	10	10	–	1 (ESA ≥ 4x10^{6}) 2 (ESA < 4x10^{6})	0.1 (ESA ≥ 10^{7}) 0.2 (4x10^{6} ≥ ESA < 10^{7}) 0.3 (ESA < 4x10^{6})	0.1 (ESA ≥ 4x10^{6}) 0.2 (ESA < 4x10^{6})	0.6 (all ESA)	• 0% tar (all).
	Unbound subbase (DGS20, DGS40)	100	100	40	20	10	10	10	–	2 (ESA ≥ 4x10^{6}) 3 (ESA < 4x10^{6})	0.5 (all ESA)	0.2 (all ESA)	0.6 (all ESA)	• 0% tar (all).
	Bound base (MB20, MB40	100	100	40	10	10	10	10	–	1 (ESA ≥ 4x10^{6}) 2 (ESA < 4x10^{6})	0.1 (ESA ≥ 10^{7}) 0.2 (4x10^{6} ≥ ESA < 10^{7}) 0.3 (ESA < 4x10^{6})	0.1 (ESA ≥ 4x10^{6}) 0.2 (ESA < 4x10^{6})	0.6 (all ESA)	• 0% tar (all).
	Bound subbase (MB20, MB40)	100	100	40	10	10	10	10	–	2 (ESA ≥ 4x10^{6}) 3 (ESA < 4x10^{6})	0.5 (all ESA)	0.2 (all ESA)	0.6 (all ESA)	• 0% tar (all).

Road agency	Application	Max allowable contents by mass (%)								Foreign material limits by mass (%)				
		RCC	BFS	RAP	RCB	RCG	FA	FBA	Tiles	High density	Low density	Organic	Free lime	Other
DPTI	Unbound base (Class 1) and subbase (Class 2, Class 3)	100	100	20	20	–	–	–	20	–	1%	0.5%	–	• 1% bitumen content.
	Bound base and subbase (Class 1, Class 2)	N/S	N/S	N/S	N/S	–	–	–	N/S	–	1%	0.5%	–	• 1% bitumen content.
VicRoads	Unbound base (Class 1) (Class 2)	0[1,2] 10[1,3]	–	5[1,2] 10[1,3]	5[1,2] 10[1,3]	5[1,2] 10[1,3]	–	–	–	2	0.5	0.1	–	• N/A.
	Upper subbase (Class 3)	100	–	15[1]	15[1]	15[1]	–	–	–	3	1	0.2	–	• N/A.
	Lower subbase (Class 4)	100	–	20	50[1]	50[1]	–	–	–	5	3	0.5	–	• N/A.
	Bound base (Not specified)	–	–	–	–	–	–	–	–	–	–	–	–	• N/A.
	Bound subbase (Class 3)	100	–	–	15[3]	15[3]	–	–	–	5	3	0.5	–	• N/A.
MRWA	Unbound base	N/S	–	N/S	–	N/S	–	–	–	–	–	–	–	• N/A.
	Unbound subbase	N/S	–	N/S	–	N/S	–	–	–	–	–	–	–	• N/A.
	Bound base and subbase	N/S	–	N/S	–	N/S	–	–	–	–	–	–	–	• N/A.

1. *VicRoads classifies recycled material (including RCB, RCG and RAP) other than RCC to be supplementary materials and individual limits are not generally specified (i.e. Class 1 may contain up to 5% supplementary materials in the total mix).*
2. *Permitted for Class 1 materials (design traffic > 7x10^6 ESAs).*
3. *Contents greater than 10% permitted for lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*
4. *Permitted for use in basecourse of lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*

Note: N/S = limit not specified.

Table 3.20: Comparison of state road agency recycled material gradings for unbound pavement layers with a nominal aggregate size of 20 mm

Grading sieve size (mm)	TMR			RMS		DPTI			VicRoads		
	Unbound base (RM001/ RM002)	Unbound upper subbase (RM003/ RM004)	Unbound lower subbase (RM005/ RM006)	Unbound base (Class 1/ Class 2 DGB)	Unbound subbase (DGS20)	Unbound base GB (PB) (Class 1)	Unbound upper and lower subbase GB (PB)[1] (Class 2)	Unbound lower subbase[2] (Class 3)	Unbound base[3,4] (Class 1/ Class 2)	Unbound upper subbase[3,4,5] (Class 3)	Unbound lower subbase[3,6] (Class 4)
26.5	100	100	100	100	100	100 (100)	100	100	100	100	100
19	95-100	95-100	84-100	95-100	95-100	95-100 (95-100)	90-100 (90-100)	90-100	95-100	95-100	–
13.2	78-92	75-95	69-95	78-92	70-90	77-93	74-96	–	78-92	75-95	–
9.5	63-83	60-90	56-90	63-83	58-80	63-83 (65-85)	61-85	–	63-83	60-90	–
4.75	44-64	42-76	37-77	44-64	43-65	44-64	42-66	40-65	44-64	42-76	42-76
2.36	30-48	28-60	23-63	33-49	30-55	29-49 (30-50)	28-50 (30-60)	–	29-48	28-60	–
0.425	13-21	10-28	8-30	14-23	10-30	13-23	11-27	–	13-21	10-28	10-28
0.075	5-11	3-11	2-14	7-14	4-17	5-11 (5-15)	4-14 (5-20)	5-15	5-9	2-10	2-14
0.0135	–	–	–	3-7	2-10	–	–	–	–	–	–

1. *Permitted for use in unbound basecourses of pavements carrying less than $1x10^6$ ESAs.*
2. *Permitted for use in unbound lower subbase of pavements carrying less than $1x10^6$ ESAs.*
3. *For pavements carrying ≥ $7x10^6$ ESAs.*
4. *Los Angeles Value ≥ 26.*
5. *Permitted for use in basecourse of lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*
6. *Subbase for pavements with design traffic < $7x10^6$ ESAs.*

Note: GB = grading based, PB = performance based.

Figure 3.1 Comparison of state road agency unbound base material gradings

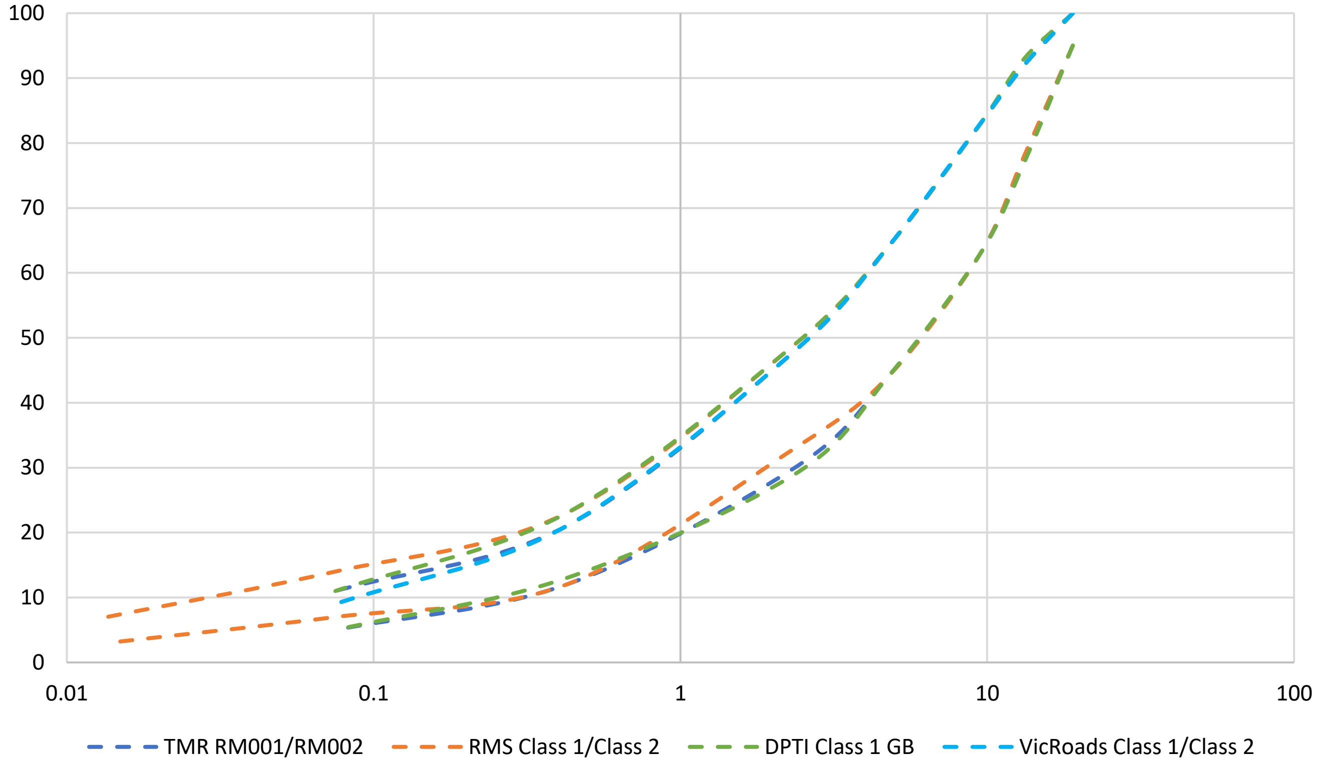


Figure 3.2 Comparison of state road agency unbound upper subbase material gradings

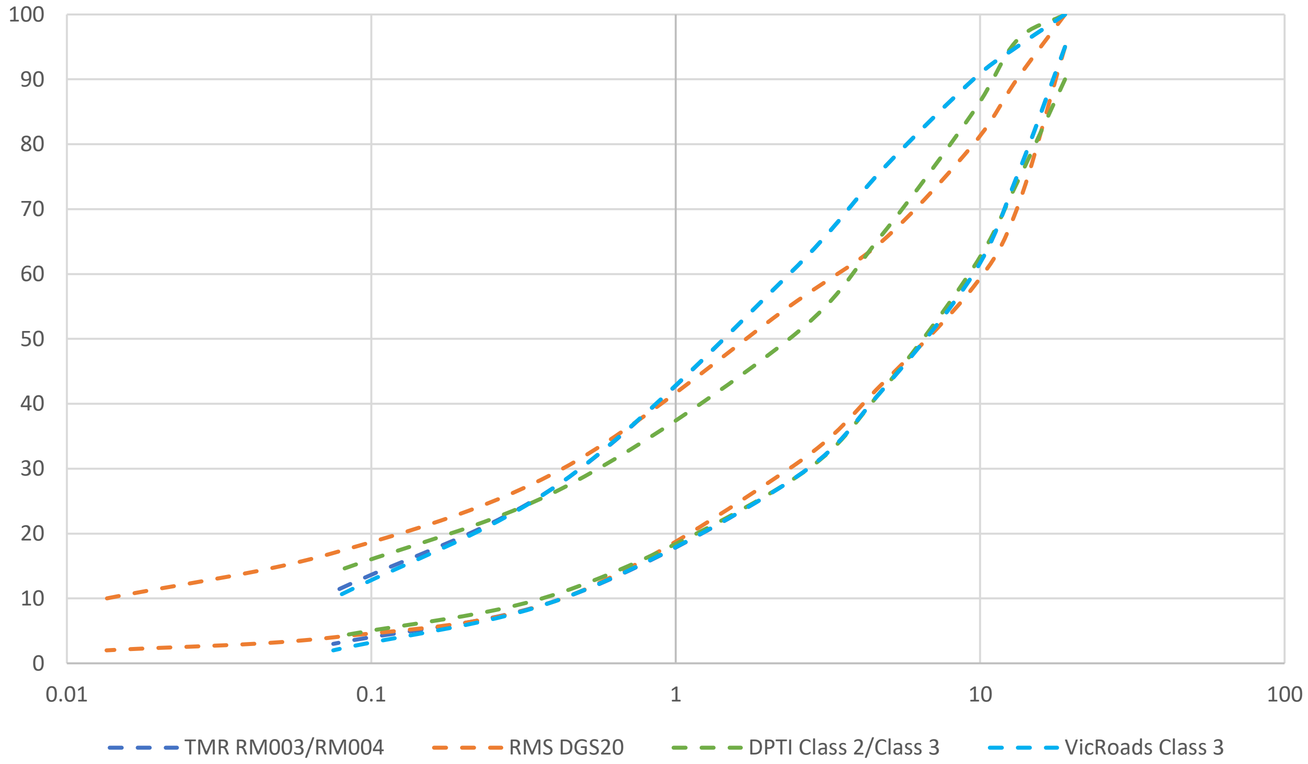


Table 3.21: Comparison of state road agency recycled material gradings for bound pavement layers with a nominal aggregate size of 20 mm

Grading sieve size (mm)	TMR	RMS	DPTI[1]		VicRoads
	Bound base and subbase	Bound base and subbase	Bound base and subbase – Class 1 GB (PB)	Bound base and subbase – Class 2 GB (PB)	Bound subbase[2]
26.5	100	100	100 (100)	100	100
19	95-100	95-100	95-100 (95-100)	90-100 (90-100)	95-100
13.2	78-92	70-90	77-93	74-96	75-95
9.5	63-83	60-80	63-83 (65-85)	61-85	60-90
4.75	44-64	–	44-64	42-66	42-76
2.36	30-48	30-50	29-49 (30-50)	28-50 (30-60)	28-60
0.425	13-21	10-25	13-23	11-27	10-28
0.075	5-11	4-12	5-11 (5-15)	4-14 (5-20)	2-10
0.0135	–	–	–	–	–

1. *GB = grading based, PB = performance based.*
2. *Los Angeles Value ≥ 26.*

Table 3.22: Comparison of state road agency recycled material property requirements

Property	TMR				RMS			DPTI				VicRoads			
	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound base and subbase	Unbound/ modified base	Unbound/ modified subbase	Bound base and subbase	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound base and subbase	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound subbase
Liquid limit (%), max	35	35	40	35	27	27	–	25 (Class 1 GB & PB) 28 (Class 2 GB)[1] 30 (Class 2 PB)[1]	28 (Class 2 GB) 30 (Class 2 PB)	28 (Class 2 GB) 30 (Class 2 PB) 35 (Class 3 GB)[1]	28 (Class 2 GB) 30 (Class 2 PB)	30 (Class 1 & 2) 35 (Class 3)[2]	35	40	35
Linear shrinkage (%), max	3.5	4.5 (RM003) 6.5 (RM004)	7.5	3.5	–	–	–	3 (Class 1 GB & PB) 4 (Class 2 GB)[1] 5 (Class 2 PB)[1]	4 (Class 2 GB) 5 (Class 2 PB)	4 (Class 2 GB) 5 (Class 2 PB) 8 (Class 3 GB)[1]	4 (Class 2 GB) 5 (Class 2 PB)	–	–	–	–
Weighted linear shrinkage, max	85	110 (RM003) 195 (RM004)	–	85	–	–	–	–	–	–	–	–	–	–	–
Plasticity index (%)	–	–	–	–	2-6 (ESA ≥ 4x10^6) 2-6 (ESA < 4x10^6)	0-10	0-2 (ESA ≥ 4x10^6) 0-6 (10^6 ≥ ESA < 4x10^6) 0-10 (ESA < 10^6)	1-6 (Class 1 GB & PB) 1-8 (Class 2 GB)[1] 1-10 (Class 2 PB)[1]	1-8 (Class 2 GB) 1-10 (Class 2 PB)	1-8 (Class 2 GB) 1-10 (Class 2 PB) 15 (Class 3 GB)[1]	1-8 (Class 2 GB) 1-10 (Class 2 PB)	2-6 (Class 1) 0-6 (Class 2) 0-10 (Class 3)[2]	0-10	0-20	0-10
Plastic limit (%), max	–	–	–	–	20	20	–	–	–	–	–	–	–	–	–
Wet strength (kN), min	85	70	–	85	100 (ESA ≥ 4x10^6) 70 (ESA < 4x10^6)	70	70	–	–	–	–	–	–	–	–
Wet/dry strength variation (%), max	35 (RM001) 40 (RM002)	45	45	35 (RM001)	35	35 (ESA ≥ 4x10^6) 40 (ESA < 4x10^6)	35	–	–	–	–	–	–	–	–
Degradation factor, min	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Flakiness index (%), max	35	40	40	35	–	–	–	–	–	–	–	35	–	–	–
CBR, soaked (%), min	80 (RM001) 60 (RM002)	45 (RM003) 35 (RM004)	15 (RM005)	80 (RM001)	–	–	–	–	–	–	–	N/A (Class 1) 100 (Class 2) 80 (Class 3)[2]	80	20	80
CBR, unsoaked (%), min	–	–	15 (RM006)	–	–	–	–	–	–	–	–	–	–	–	–
UCS at 7 days (MPa), max	0.7	0.7	0.7	0.7	1.0	–	–	–	–	–	–	–	–	–	–
Permeability (m/sec), max	–	–	–	–	5x10^{-8} (ESA ≥ 10^7)	–	–	–	–	–	–	–	–	–	–

Property	TMR				RMS			DPTI				VicRoads			
	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound base and subbase	Unbound/ modified base	Unbound/ modified subbase	Bound base and subbase	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound base and subbase	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound subbase
Particle shape (%), max	–	–	–	–	35	35	35	–	–	–	–	–	–	–	–
Two or more fractured faces (%), min	–	–	–	–	85 (ESA ≥ $4x10^6$) 75 (ESA < $4x10^6$)	75	75	–	–	–	–	–	–	–	–
Dry compressive strength (MPa), min	–	–	–	–	1.7	1.0	–	–	–	–	–	–	–	–	–
Acid soluble sulfate content (%), max	–	–	–	–	0.3	0.3	0.3	–	–	–	–	–	–	–	–
Modified Texas triaxial compression (no.), max	–	–	–	–	2.2 (10^6 ≥ ESA < $4x10^6$) 2.5 (ESA < 10^6)	3.2 (ESA < $4x10^6$)	2.2 (ESA ≥ 10^7) 2.5 ($4x10^6$ ≥ ESA < 10^7) 3.0 (ESA < $4x10^6$)	–	–	–	–	–	–	–	–
Resilient modulus (MPa), min	–	–	–	–	–	–	–	300 (Class 1 PB) 250 (Class 2 PB)[1]	250 (Class 2 PB)	250 (Class 2 PB)	250 (Class 2 PB)	–	–	–	–
Deformation, max	–	–	–	–	–	–	–	10^{-8} (Class 1 PB) 10^{-7} (Class 2 PB)[1]	10^{-7} (Class 2 PB)	10^{-7} (Class 2 PB)	10^{-7} (Class 2 PB)	–	–	–	–
LA abrasion grading 'A'	–	–	–	–	–	–	–	N/A (Class 1 GB – size 20 & 30 mm) N/A (Class 2 GB – size 20 & 30 mm)[1] 45 (Class 2 GB – size 40 mm)[1]	N/A (Class 2 GB – size 20 & 30 mm) 45 (Class 2 GB – size 40 mm)	N/A (Class 2 GB – size 20 & 30 mm) 45 (Class 2 GB – size 40 mm) N/A (Class 3 GB – size 20 mm)[1] 45 (Class 3 GB – size 40 mm)[1]	N/A (GB – size 20 & 30 mm) 45 (Class 2 GB – size 40 mm)	–	–	–	–
LA abrasion grading 'B'	–	–	–	–	–	–	–	30 (Class 1 GB – size 20 & 30 mm) Contractor nominated (Class 1 & 2 PB) 45 (Class 2 GB – size 20 & 30 mm)[1] N/A (Class 2 GB – size 40 mm)[1]	45 (Class 2 GB – size 20 & 30 mm) N/A (Class 2 GB – size 40 mm) Contractor nominated (Class 2 PB)	45 (Class 2 GB – size 20 & 30 mm) N/A (Class 2 GB – size 40 mm) Contractor nominated (Class 2 PB) 45 (Class 3 GB – size 20 mm)[1] N/A (Class 3 GB – size 40 mm)[1]	45 (Class 2 GB – size 20 & 30 mm) N/A (Class 2 GB – size 40 mm) Contractor nominated (Class 2 PB)	–	–	–	–
Triaxial compression cohesion (kPa), max	–	–	–	–	–	–	–	150 (Class 1 PB) 250 (Class 2 PB)[1]	250 (Class 2 PB)	250 (Class 2 PB)	250 (Class 2 PB)	–	–	–	–

Property	TMR				RMS			DPTI				VicRoads			
	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound base and subbase	Unbound/ modified base	Unbound/ modified subbase	Bound base and subbase	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound base and subbase	Unbound base	Unbound upper subbase	Unbound lower subbase	Bound subbase
Triaxial compression friction angle (°), min	–	–	–	–	–	–	–	45 (Class 1 PB) 40 (Class 2 PB)[1]	40 (Class 2 PB)	40 (Class 2 PB)	40 (Class 2 PB)	–	–	–	–
Marginal and unsound rock (%), max	–	–	–	–	–	–	–	–	–	–	–	10 (Class 1 & 2) (20 Class 3)[2]	20	–	20
Unsound rock (%), max	–	–	–	–	–	–	–	–	–	–	–	5 (Class 1) 7 (Class 2) 10 (Class 3)[2]	10	–	10

1. *Permitted for pavements carrying less than 1x10^6 ESAs.*
2. *Permitted for lightly trafficked (< 3500 AADT and less than 10% heavy vehicles) pavements.*

Note: GB = grading based, PB = performance based.

4 ENVIRONMENTAL ASPECTS OF RECYCLED MATERIALS

4.1 NATIONAL ENVIRONMENT PROTECTION MEASURE

The National Environment Protection Council (NEPC) was established under the *National Environment Protection Council Act 1994*, as well as mirror legislation in state jurisdictions with two primary functions, to (NEPC n.d.):

- develop National Environment Protection Measures (NEPMs) – a set of national objectives designed to assist in protecting or managing aspects of the environment
- assess and report on the implementation and effectiveness of NEPMs in participating jurisdictions.

Requirements applicable to the use of recycled materials are described in Schedule B1: *Guideline on Investigation Levels for Soil and Groundwater* (NEPC 2011a) in relation to investigation levels for soil, soil gas and groundwater in the assessment of site contamination. Additionally, Schedule B7: *Guideline on Health-based Investigation Levels* (NEPC 2011b) provides further guidance in relation to health-based investigation levels in the assessment of site contamination. Sampling requirements for contaminated sites is outlined in Schedule B2: *Guideline on Site Characterisation* (NEPC 2011c).

4.1.1 SAMPLING REQUIREMENTS

Schedule B2 (NEPC 2011c) outlines the following procedure for assessing the health and environmental risks associated with site contamination:

1. Conduct a preliminary site investigation (including a desktop study) to identify the site characteristics (site location, heritage considerations, site layout etc.) and a site inspection to determine potential contaminants of concerns and identify areas of potential contamination.
2. Sampling may be undertaken using a variety of methods and equipment depending on the depth of the desired sample, type of sample required (disturbed or undisturbed), the contaminant type (volatile or non-volatile) and the soil type. Most commonly used are test pits, trenching or drilling of shallow bore holes in accordance with AS 4482.1.
3. Sample analysis shall be undertaken using the appropriate methodologies for each potential contaminant in laboratories accredited by the National Association of Testing Authorities (NATA) or an equivalent government-endorsed provider of accreditation for laboratories.

4.1.2 RECOMMENDED THRESHOLDS

The NEPC utilises health investigation levels (HILs), defined as the concentration of a contaminant above which further appropriate investigation and evaluation will be required (NEPC 2011b). It is important to note that levels in excess of the HILs do not imply unacceptability or that a significant health risk is likely to be present while levels under the HILs similarly, do not imply no health risks. These values were developed to estimate the risk of potential human exposure to contaminants and were derived by comparing estimated exposures with toxicity criteria using a quantitative modelling process as outlined in Schedule B7 (NEPC 2011b). For a site to be considered suitable for an intended land use, the following statistical analysis must be included:

- The 95% upper confidence limit (UCL) of the arithmetic mean concentration of the contaminant is less than the relevant HIL value.
- No individual sample concentration exceeds 250% of the HIL value.
- The standard deviation of the sample concentrations does not exceed 50% of the HIL value.
- A sufficient number of samples have been collected using a spatially representative sampling design (as outlined in Schedule B2).

The HILs requirements are categorised under four land-use categories, where the potential human exposure limits vary according to level of risk associated with each category. The simplified limits for soil contaminants with the least amount of adverse health risks due to exposure are presented Table 4.1. The detailed soil contamination requirements for all applications are detailed in Appendix A.1.

Table 4.1: Health-based investigation levels for soil contaminants

Attributes	Investigation level
Metals and inorganics (mg/kg dry weight)	
Arsenic	100
Beryllium	70
Boron	5 000
Cadmium	20
Chromium	100
Cobalt	100
Copper	7 000
Cyanide	250
Lead	300
Manganese	3 000
Methyl mercury	7
Mercury	200
Nickel	400
Selenium	200
Zinc	8 000
Polycyclic aromatic hydrocarbons (PAHs)	
Benzo(a)pyreneTEQ	3
PAHs	300
Phenols	
Phenol	3 000
Pentachlorophenol	100
Cresols	400
Other	
Asbestos more than 0.01% (w/w)	Not present

Source: NEPC (2011b).

4.2 QUEENSLAND DEPARTMENT OF ENVIRONMENT AND SCIENCE

The Queensland Department of Environment and Science (QDES) currently promotes resource recovery opportunities to enable waste to be viewed as a valuable resource through the use of an end of waste (EOW) framework under Chapter 8 and Chapter 8A of the *Waste Reduction and Recycling Act 2011* (QDES 2020a). This enables waste to be used as a resource if the QDES considers that it meets specified quality criteria for its specific use, specifying outcomes that need to be achieved in order for a waste to be deemed a resource. It is important to note that legally, without an EOW code, the material is still considered a waste and thus, waste management regulations still apply meaning that the use of a recycled material without an EOW code could be legally classified as landfilling.

Current published documentation regarding the use of recycled materials specific to road applications is included for coal combustion products (fly ash), concrete (washout and returned concrete), foundry sand and end-of-life tyres. An EOW code for railway ballast and ferronickel slag has been proposed with drafts developed (QDES 2020a). Completion of the draft is pending updates based on public consultation. The code is intended to address requirements regarding the use of these materials for various purposes, including in engineering fill, road base, sub road base and drainage layers. A review of current EOW codes indicates that across the codes there are inconsistent sampling requirements and contaminant thresholds.

Additionally, QDES identifies and manages the risks associated with waste management activities through Environmentally Relevant Activity (ERA) Regulations (QDES 2020b). These are generally related to the regulation of waste processing activities for suppliers of recycled materials, where the requirements vary by supplier and waste classification.

4.2.1 WASTE CLASSIFICATION AND SAMPLING

The *Environmental Protection Regulation 2019* (Qld) includes a risk-based waste classification framework, where regulated waste is classified as:

- Category 1 regulated waste (highest risk)
- Category 2 regulated waste (moderate risk)
- Not-regulated waste / general waste (lowest risk).

Regulated waste is classified as a waste that is commercial or industrial waste and contains a contaminant listed in Schedule 9, Part 1 of the *Environmental Protection Regulation 2019* (Qld). Categorisation of regulated waste into Category 1 or Category 2 is based on whether:

- The waste contaminants are categorised at Category 1 or 2.
- The concentrations of the contaminants are above Schedule 9 Part 2 categorisation thresholds for solid tested waste.

Regulation of the testing regime for waste is provided in section 46-48 of the *Environmental Protection Regulation 2019* (Qld) as summarised:

1. A sample of commercial or industrial waste must be tested for each relevant attribute and substance.
2. The results of the test are current for the waste from the date of the report for up to 3 months or unless an authorised person requests a retest of the waste. Test results for waste generated by an activity continue to be current test results for further waste generated by the same activity until a change of activity or a change in the waste generated by the activity.

4.2.2 RECOMMENDED THRESHOLDS

General waste is classified as material that does not contain asbestos, has a pH of 6.5 – 9.0 and is below the thresholds provided in the *Environmental Protection Regulation 2019* (Qld) Schedule 9, Part 3, Division 2, *Non-regulated thresholds for tested waste* as summarised in Table 4.2 and detailed in Appendix A.2.

Table 4.2: Non-regulated thresholds for tested waste

Attributes	Solid waste threshold
Arsenic	300
Beryllium	90
Boron	20 000
Cadmium	90
Chromium	300
Copper	220
Cyanide	240
Lead	300
Mercury	80
Nickel	1 200
Selenium	700
Zinc	400
Benzo(a)pyreneTEQ	3
PAHs	300
Phenol	40 000

Attributes	Solid waste threshold
Cresols	4 000

Source: Environmental Protection Regulation 2019 (Qld).

4.3 NSW ENVIRONMENT PROTECTION AUTHORITY

The NSW Environment Protection Authority *Recovered Aggregate Order 2014* (NSW EPA 2014a) provides requirements for the supply of recovered aggregate for application to land as a road making material, or in building, landscaping or construction works. Recovered aggregates in this orderare defined as materials consisting of concrete, brick, ceramics, natural rock and asphalt processed into an engineered material. The requirements of this order do not apply to refractory bricks or associated refractory materials, nor asphalt that contains coal tar.

4.3.1 SAMPLING REQUIREMENTS

On or before supplying recycled aggregates, the supplier must:

1. Provide a written sampling plan which includes the method of sample preparation and storage procedures for the recycled aggregates.
2. Undertake sampling and testing of the recycled aggregates as presented below. The sampling must be carried out in accordance with the written sampling plan and Australian Standard 1141.3.1-2012 M*ethods for sampling and testing aggregates: sampling – aggregates* (or equivalent).
3. Analysis must be undertaken by analytical laboratories accredited by NATA (or equivalent).

The processor must undertake the following sampling, where the recovered aggregates are generated continuously:

1. Characterising the recovered aggregates by collecting 20 samples of the waste and testing each sample for the chemicals and other attributes listed in Table 4.3. Each composite sample must be taken from a batch, truckload or stockpile that has not been previously sampled for the purposes of characterisation. Characterisation must be conducted for recovered aggregate generated and processed every year following the commencement of the continuous process.
2. Routine sampling of the recovered aggregate by collecting either 5 composite samples from every 4 000 tonnes (or part thereof) processed or 5 composite samples every 3 months (whichever is the lesser); and testing each sample for the chemicals and other attributes listed in Table 4.3 other than those listed as 'not required'. Each composite sample must be taken from a batch, truckload or stockpile that has not been previously sampled for the purposes of routine sampling. However, if characterisation sampling occurs at the same frequency as routine sampling, any sample collected and tested for the purposes of characterisation under clause 1 may be treated as a sample collected and tested for the purposes of routine sampling under clause 2.

Where the recovered aggregate is not generated as part of a continuous process, the processor must undertake one-off sampling of a batch, truckload or stockpile of the recovered aggregate, by collecting 10 samples from every 4 000 tonnes (or part thereof) processed and testing each sample for the chemicals and other attributes listed in Table 4.3. The test results for each composite sample must be validated as compliant with the maximum average concentration or other value, as well as the absolute maximum concentration or other value listed in Table 4.3 prior to the supply of the recovered aggregate.

4.3.2 RECOMMENDED THRESHOLDS

Table 4.3 presents the allowable amount of concentration for recovered aggregates. The processor is not allowed to produce recycled aggregates if (NSW EPA 2014a):

1. The concentration or other value of that attribute of any sample collected and tested (as part of the characterisation, or the routine or one-off sampling) exceeds the absolute maximum concentration or other value listed in Table 4.3.

2. The average concentration or other value of that attribute from the characterisation or one-off sampling of the recovered aggregate (based on the arithmetic mean) exceeds the maximum average concentration or other value listed in Table 4.3.
3. The average concentration or other value of that attribute from the routine sampling of the recovered aggregate (based on the arithmetic mean) exceeds the maximum average concentration or other value listed in Table 4.3.

Table 4.3: Chemical and other materials requirements of recovered aggregates

Chemicals and other attributes	Test method	Maximum average concentration for characterisation	Maximum average concentration for routine testing	Absolute maximum concentration
		(mg/kg 'dry weight' unless otherwise specified)		
1. Mercury	Analysis using USEPA SW-846 Method 7471B Mercury in solid or semisolid waste (manual cold vapour technique), or an equivalent analytical method with a detection limit < 20% of the stated maximum average concentration in Column 2 (i.e. < 0.1 mg/kg dry weight)	0.5	Not required	1
2. Cadmium	Sample preparation by digesting using USEPA SW-846 Method 3051A Microwave assisted acid digestion of sediments, sludges, soils, and oils. Analysis using USEPA SW-846 Method 6010C Inductively coupled plasma - atomic emission spectrometry, or an equivalent analytical method with a detection limit < 10% of stated maximum concentration in Column 2 (i.e. 1 mg/kg dry weight for lead).	0.5	0.5	1.5
3. Lead		75	75	150
4. Arsenic		20	Not required	40
5. Chromium (total)		60	60	120
6. Copper		60	60	150
7. Nickel		40	Not required	80
8. Zinc		200	200	350
9. Electrical conductivity	Sample preparation by mixing 1 part recovered aggregate with 5 parts distilled water. Analysis using Method 104 (Electrical conductivity) in Schedule B (3): Guideline on Laboratory Analysis of Potentially Contaminated Soils, National Environment Protection (Assessment of Site Contamination) Measure 1999 (or an equivalent analytical method)	1.5 dS/m	1.5 dS/m	3 dS/m
10. Metal	NSW Roads & Traffic Authority Test Method T276 Foreign Materials Content of Recycled Crushed Aggregate (or an equivalent method), for the materials listed in 10 - 12 of Column 1	1%	1%	2%
11. Plaster		0.25%	0.25%	0.50%
12. Rubber, plastic, paper, cloth, paint, wood and other vegetable matter		0.20%	0.20%	0.30%

Source: NSW EPA (2014a).

4.3.3 OTHER TYPES OF RECYCLED MATERIALS

Recovered glass sand

The NSW EPA (2014b) *Recovered Glass Sand Order 2014* presents the requirements of recovered glass sand (i.e. RCG) that has been processed to produce a 'sand-like' glass material with the maximum PSD of generally less than 5 mm, and that contains at least 98% recovered glass.

The sampling requirements of this type of recycled material are the same as recovered aggregates which are presented in Section 4.3.1. The only difference is in the allowable value (maximum average concentration for characterisation, routine testing and absolute maximum concentration) of chemical and other materials which are allowed to be present in recovered glass. These are given in Table 4.4. However, indications of the source of allowable concentrations and why they differ to recovered aggregates are not stated. It should be noted that the testing methods of chemical components of the recovered sand glass are the same as recovered aggregates (Table 4.4).

Table 4.4: Chemical and other materials requirements of recovered glass sand

Chemicals and other attributes	Test method	Maximum average concentration for characterisation	Maximum average concentration for routine testing	Absolute maximum concentration
		Units in mg/kg 'dry weight' unless otherwise stated		
1. Mercury	Analysis using USEPA SW-846 Method 7471B	0.5	Not required	1.0
2. Cadmium	USEPA SW-846 Method 3051A, USEPA SW-846 Method 6010C, or an equivalent analytical method.	0.5	0.5	1.5
3. Lead		50	50	100
4. Arsenic		10	Not required	20
5. Chromium (total)		20	Not required	40
6. Copper		40	Not required	120
7. Molybdenum		5	Not required	10
8. Nickel		10	Not required	20
9. Zinc		100	100	300
10. Total organic carbon	Method 105 (Organic Carbon) and using a 2 gram sample in Schedule B (3): Guideline on Laboratory Analysis of Potentially Contaminated Soils, National Environment Protection (Assessment of Site Contamination) Measure 1999 (or an equivalent analytical method)	1.0%	Not required	2.0%
11. Electrical conductivity	Method 104 (Electrical conductivity) in Schedule B (3): Guideline on Laboratory Analysis of Potentially Contaminated Soils, National Environment Protection (Assessment of Site Contamination) Measure 1999 (or an equivalent analytical method)	1 dS/m	1 dS/m	2 dS/m
12. Metal	NSW Roads & Traffic Authority Test Method T276 (or an equivalent method)	0.25%	0.25%	0.50%
13. Plaster		0.25%	0.25%	0.50%
14. Rubber, plastic, paper, cloth, paint, wood and other vegetable matter		0.30%	0.30%	0.50%

Source: NSW EPA (2014b).

Reclaimed asphalt pavement

The *Reclaimed Asphalt Pavement Order 2014* (NSW EPA 2014c) defines these materials as an asphalt matrix which was previously used as an engineering material and which must not contain a detectable quantity of coal tar or asbestos. The general requirements of RAP are presented below:

1. The processor must implement procedures to minimise the potential to receive or process reclaimed asphalt pavement containing asbestos.
2. The processor must implement procedures to minimise the potential to receive or process reclaimed asphalt pavement in which the asphalt matrix contains detectable quantities of coal tar.

The procedure for both clause 1 and 2 must formally be documented and the records of compliance must be kept for a period of six years.

4.4 ENVIRONMENT PROTECTION AUTHORITY VICTORIA

EPA Victoria regulates the use of recycled materials under the *Environment Protection (Industrial Waste Resource) Regulations 2009* (Vic). Notably, the Regulations encourage industry to utilise industrial waste as a resource through exempting material from categorisation where a secondary, beneficial reuse is established. Industrial Waste Resource Guidelines (IWRG) have been developed to consolidate waste publications under the Regulations. The two relevant IWRG include *Soil Hazard Categorisation and Management* (Victoria EPA 2009a) and *Solid Industrial Waste Hazard Categorisation and Management* (Victoria EPA 2009b). These documents contain guidance on waste characterisation, sampling and analysis and specific contaminant recommended thresholds. It is important to note that in July 2020 the *Environment Protection Amendment Act 2018* (Vic) will come into effect and this may change the way in which EPA Victoria regulates recycled materials.

4.4.1 SAMPLING REQUIREMENTS

EPA Victoria (2009b) recommends the following procedure to sample and analyse the waste stream:

1. Wastes must be sampled, collected, preserved and analysed as specified in Industrial Waste Resource Guide *Sampling and Analysis of Waters, Wastewater, Soils and Waste* (Victoria EPA 2009c).
2. Sampling must be representative of the waste and account for variability in the waste composition. For solid wastes, the guide recommends sampling in accordance with AS 1141.3.
3. Samples must be submitted to an analytical laboratory accredited by the NATA to undertake the analyses. Total concentrations of contaminants may be tested in accordance with USEPA SW-846 (similar to those specified by NSW EPA in Section 4.3).

For determining the leachate concentrations of waste, two buffer solutions (one slightly acidic and one alkaline) must be used in accordance with AS 4439.2 and AS 4439.3 using class 3b leaching fluids (Victoria EPA 2009b).

4.4.2 RECOMMENDED THRESHOLDS

EPA Victoria documents for soil hazard categorisation (Victoria EPA 2009a) and solid industrial waste hazard categorisation (Victoria EPA 2009b) have relatively complex requirements in comparison to the NSW EPA. This involves categorising waste firstly, into one of four categories, which will determine management options available for that material. The simplified upper threshold limits for an industrial waste (the lowest hazard category), enabling the wastes to remain unregulated are outlined in Table 4.5, showing the Total Concentration (TC) and Australian Standard Leaching Protocol (ASLP) for solid industrial waste which can be used for C&D waste. This is compared to the threshold limits for soil-based fill materials (does not include C&D waste), below which soils are classified as clean fill (EPA Vic 2009a). Material exceeding the fill material upper limits but below the industrial waste upper limits may require treatment to reduce or control the hazard before disposal to a licensed facility, varying with the waste TC (EPA Victoria 2009a).

EPA Victoria (2009b) recommends the following analytical process in determining the hazard category of waste:

1. Initially, TC should be determined for a range of contaminant constituents and if, the TC values are less than the values mentioned in Table 4.5 as maximum TC for fill material, the waste is categorised as clean fill material and leachability testing is not required.
2. In all other situations, ASLP must be measured to determine the hazard category. This will inform the management options for the waste. Solid wastes categorised as industrial waste are not regulated and may be used as solid inert materials, although this still requires licensing by the Victorian EPA.

After the initial testing for classification purposes, the required frequency for re-testing of these properties is not specified. It is important to note that the contaminant thresholds for both fill materials and industrial wastes have been simplified in Table 4.5. The requirements for soils and solid wastes include additional requirements which may be found in *Soil Hazard Categorisation and Management* (EPA Victoria 2009a) and *Solid Industrial Waste Hazard Categorisation and Management* (EPA Victoria 2009b), and summarised in Appendix A.3.

Table 4.5: TC and ASLP thresholds for fill and solid industrial waste materials

Contaminant concentration thresholds	Fill material upper limits[1]		Industrial waste upper limits[2]	
	ASLP (mg/L)	TC (mg/kg)	ASLP (mg/L)	TC (mg/kg)
Arsenic	–	20	0.35	500
Barium	–	–	35	6,250
Beryllium	–	–	0.5	100
Boron	–	–	15	15,000
Cadmium	–	3	0.1	100
Chromium (VI)	–	1	2.5	500
Copper	–	100	100	5,000
Lead	–	300	0.5	1,500
Mercury	–	1	0.05	75
Molybdenum	–	40	2.5	1,000
Nickel	–	60	1	3,000
Selenium6	–	10	0.5	50
Silver6	–	10	5	180
Tributyltin oxide	–		0.05	2.5
Zinc	–	200	150	35,000

1. *Adapted from Victoria EPA (2009a).*
2. *Adapted from Victoria EPA (2009b).*

4.5 ENVIRONMENT PROTECTION AUTHORITY OF SOUTH AUSTRALIA

The South Australian EPA *Standard for the Production and Use of Waste Derived Fill* (SA EPA 2013), describes the information and processes required by the SA EPA to support the beneficial reuse of a range of wastes recovered for use as fill material.

4.5.1 WASTE CLASSIFICATION AND SAMPLING

Waste derived fill is defined as follows (SA EPA 2013):

- waste soil – waste soil consists of soil, clay, rock, sand or other natural mineralogical matter and must not contain other wastes
- C&D wastes – includes clean CRC, CRB and ceramics
- mineralogically based homogeneous industrial residues – includes secondary materials from processing C&I waste.

The sampling program should be based on standardised, scientifically valid procedures and methodologies taking into account waste volume, heterogeneity and knowledge of the activity and level of consistency of the process from which the waste is produced (SA EPA 2013). The waste sampling is in accordance with NEPM, as outlined in Section 4.1.1 and Victorian EPA as summarised in Section 4.4.1.

The number of samples to be collected should be determined on a case-by-case basis, based on investigation of the site history or the process producing the waste as applicable, combined with visual inspection to determine the homogeneity of the soil or waste being characterised. General requirements include:

- For waste soil a minimum sampling rate of one sample per 250 m^3 with a minimum of five samples is required.
- A minimum of one internal-laboratory field duplicate and one external-laboratory field duplicate per 20 primary samples is recommended.

Leachate analysis shall be undertaken in accordance with AS 4439.2 and AS 4439.3 and leaching fluids chosen shall be specific for the receiving environment proposed. This shall include comparison of the current pH and redox potential of the receiving environment.

4.5.2 RECOMMENDED THRESHOLDS

Regarding the C&D waste, the following points are outlined (SA EPA 2013):

- C&D waste received at recycling facilities must not be contaminated (above levels outlined in Table 4.6).
- Soils with known or likely contamination must not be received.
- C&D waste may include aggregate, crushed bricks and concrete, recycled bitumen, and inert soils and must not contain other wastes.
- All foreign materials and prohibited wastes must, as far as possible, be removed from the C&D waste at the beginning of the process or preferably prior to receipt.
- Any fines resulting from the processing may require further processing to again remove any foreign materials.

Table 4.6 presents the maximum concentrations of chemical substances to meet waste fill criteria, including C&D waste. In addition to the chemical limitations in Table 4.6, the material may contain bitumen but must not include asbestos or other wastes. The maximum allowable chemical concentration specified by the SA EPA are similar to the NSW EPA requirements for recovered aggregates, as outlined in Table 4.3.

Table 4.6: Chemical and other materials requirements of waste fill materials

Chemical substance	Maximum total dry weight chemical concentrations (mg/kg)	Chemical substance	Maximum total dry weight chemical concentrations (mg/kg)
Aldrin/Dieldrin (total)	2	Ethylbenzene	3.1
Arsenic	20	Heptachlor	2
Barium	300	Lead	300
Benzene	1	Manganese	500
Benzo(a)pyrene	1	Mercury	1
Beryllium	20	Nickel	60
Cadmium	3	Petroleum hydrocarbons TPH C6-C9 (total)	65
Chlordane	2	Petroleum hydrocarbons TPH >C9	1000
Chromium (III)	400	Phenolic compounds (total)	0.5

Chemical substance	Maximum total dry weight chemical concentrations (mg/kg)	Chemical substance	Maximum total dry weight chemical concentrations (mg/kg)
Chromium (VI)	1	Polycyclic aromatic hydrocarbons (PAH) (total)	5
Cobalt	170	Polychlorinated biphenyls (PCBs)	2
Copper	60	Toluene	1.4
Cyanides (total)	500	Xylene (total)	14
Dichlorodiphenyltri chloroethane (DDT)	2	Zinc	200

Source: SA EPA (2013).

The SA EPA (2013) recommends waste derived fill and components should be regularly and thoroughly tested to gain confidence in the consistency of composition. The requirements for ongoing assessment are to be determined based on the consistency in the initial test results and the processes involved in production.

4.6 WASTE AUTHORITY OF WESTERN AUSTRALIA

The Waste Authority of Western Australia has recently published a *Roads to Reuse Product Specification – Recycled Road Base and Recycled Drainage Rock* (Waste Authority WA 2018). This project is in cooperation with MRWA to reuse construction and demolition waste in roadworks.

The report states that generally, C&D waste may include other contaminations including pesticides, asbestos and heavy metals, depending on the source of the waste. Visual inspection or inspecting the odours of the waste may be used for identifying some types of these contaminations (like asbestos). However, chemical contaminants may not always be identifiable through visual inspections or odour checks.

Two general types of application of recycled materials are provided in this report (Waste Authority WA 2018):

1. Recycled road base: As subbase or basecourse in road and pavement construction and other hardstand areas such as footpaths and car parks for urban residential, public open space and commercial and industrial land uses only.
2. Recycled drainage rock: As pipe bedding in underground projects for urban residential, public open space and commercial and industrial land uses only. It can also be used as drainage rock in civil drainage infrastructure.

4.6.1 ACCEPTANCE PROCEDURE

In order to determine the feasibility of reusing the C&D waste in road base or drainage rock, Waste Authority WA (2018) provides the following general procedures.

Pre-acceptance procedure

Prior to accepting this waste to be reused in road base or recycled drainage rock, as much information as possible should be obtained by the producer regarding the following points:

- the source site of the waste
- the current and previous application/s of the source site
- age of any structure and building (can be an indicator of asbestos risk)
- whether the source site is a contaminated site
- any known contamination of the source site or waste
- types of the material contained in the load.

The producer must focus on not allowing any asbestos to enter the site of recycling.

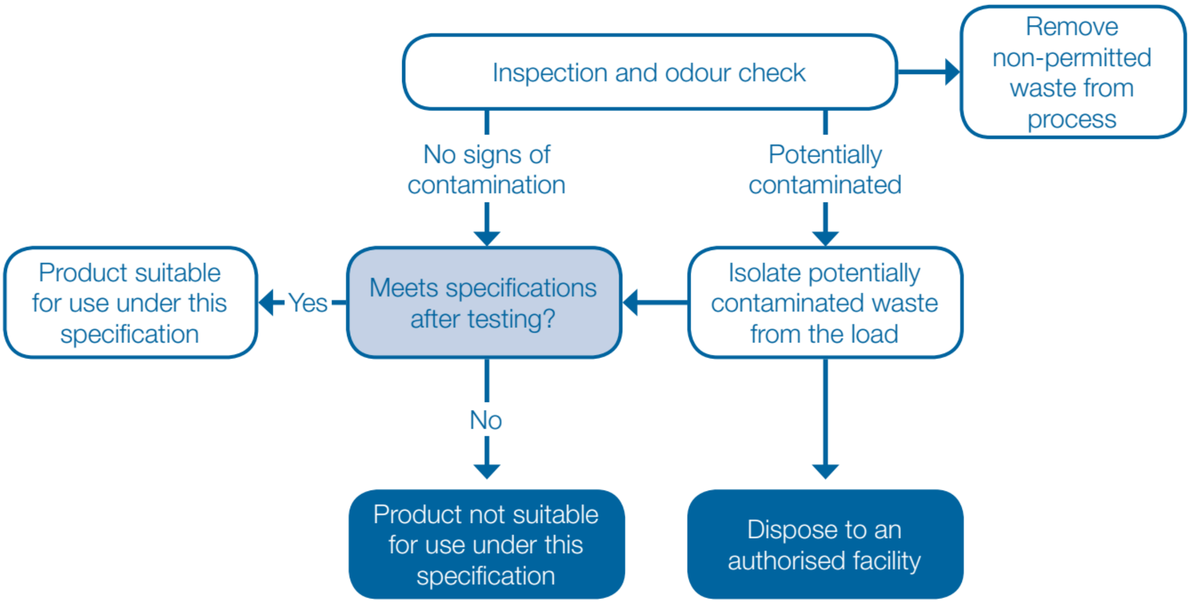
Acceptance procedure

These procedures should be conducted on the waste arriving at the recycling facilities. Figure 4.1 illustrates the acceptance procedure of C&D waste to be used as road base or drainage rock. In order to identify the contaminants, the following points should be inspected (Waste Authority WA 2018):

- discolouration of the waste
- the presence of hydrocarbon staining
- the presence of asbestos containing materials
- the presence of odours that would indicate that acid sulphate soil or other contaminants are present in the waste
- the presence of non-permitted waste.

In order to help manage the asbestos risk, it is advised that the loads should be dampened.

Figure 4.1 Acceptance procedure of C&D waste after pre-acceptance



Source: Waste Authority WA (2018).

Waste processing controls

After dealing with the C&D waste at the previous stage (acceptance procedure), continuous inspections and odour checks should be undertaken at all stages of the production. It is generally recommended that the size of each stockpile does not exceed 4 000 tonnes (approximately 2 900 m^3) for better sampling and testing of the materials.

4.6.2 SAMPLING REQUIREMENTS

To ensure that recycled road base and recycled drainage rock have been produced to the required product specification, it is necessary for product testing to be undertaken by producers as summarised in Table 4.7.

Table 4.7: Product sampling of C&D waste for road base and drainage rock

Sampling	Description
Sampling standards and personnel qualifications	In accordance with AS 1141.3.1 and shall be conducted by a trained person. Testing must be undertaken by a laboratory with NATA (or equivalent) accreditation.
Conveyor	Is the preferred sampling method, prior to stockpiling.

Sampling	Description
	Sampling at various intervals from a stopped conveyor belt. Samples should be collected at the frequency of one sample per 140 m^3 of material, or 20 samples per 4000 tonnes.
Stockpile sampling	Where conveyor sampling is not possible. Samples should be taken from various sections of the stockpile. Samples must be collected from stockpiles of recycled road base and recycled drainage rock at a rate of 20 samples per 4000 tonnes or seven samples per 1000 m^3 of material or parts thereof. For small stockpiles under 100 m^3, a minimum of three samples per stockpile is required. Additional samples must be taken where an inspection and/or odour check has identified evidence of potential contamination.
Reduced frequency routine sampling	If the producer consistently meets the product specification, they may be eligible for a reduced routine sampling rate of five samples per 4000 tonnes (or one sample per 600 m^3) of material.

Source: Waste Authority WA (2018).

4.6.3 RECOMMENDED THRESHOLDS

According to the Waste Authority WA (2018), recycled road base may consist only of concrete, bricks, tiles, ceramics, asphalt, natural rock, sand, recovered glass. Drainage rock should not contain concrete in order to achieve a pH level of 6 to 9.

Recycled road base or recycled drainage rock product must:

- meet the definition of recycled road base or recycled drainage rock respectively
- not exceed the limits, of road base or drainage rock not containing concrete listed in Table 4.8, and recycled road base containing concrete listed in Table 4.9 (once prescribed statistical analysis and interpretation have been applied)
- not contain any acid sulphate soils or copper chrome arsenate treated timber
- not contain more than one per cent by weight (combined) of other C&D wastes (other than concrete, bricks, tiles, ceramics, asphalt, natural rock, sand and recovered glass)
- concrete-containing products with pH > 9 should not be used within 100 metres of any wetland/watercourse or on land subject to flooding
- road base containing concrete, and with a pH greater than 9, may only be used when sealed with asphalt
- recycled road base should not be used on land used for the cultivation of food crops for human consumption.

The laboratory sample preparation method for determining the attributes presented in Table 4.8 and Table 4.9 is suggested as below (Waste Authority WA 2018):

- isolate suitably large subsamples representative of the bulk sample
- crush/pulverise each subsample sufficient to allow the sample to pass through a 2 mm sieve
- strong acid digest conducted (followed by analysis) as an estimate of total available metals (noting not 100%total digest).

Notably, the requirements for concrete-containing recycled road base product are similar to those summarised in Table 4.3, applied by the NSW EPA for recovered aggregates.

Table 4.8: Chemical and other requirements of non-concrete recycled road base and recycled drainage rock product (pH 6-9)

Attributes	Absolute limit
Metals (mg/kg dry weight)	
Arsenic	20
Cadmium	1
Total chromium	75

Attributes	Absolute limit
Copper	100
Lead	200
Mercury	1
Nickel	60
Zinc	200
Hydrocarbons (not required for road base sealed with asphalt) (mg/kg dry weight)	
Benzene	1
Toluene	50
Ethylbenzene	100
Xylene (total)	180
Total recoverable hydrocarbons (C6-C10)	100
Total recoverable hydrocarbons (C10-C36)	420
Polycyclic aromatic hydrocarbons (PAH)	40
Other	
pH	6 to 9 pH units
Asbestos	Visual inspection on acceptance (refer to Section 4.6.1)

Source: Waste Authority WA (2018).

Table 4.9: Chemical and other materials requirements of concrete-containing recycled road base product (pH > 9)

Attributes	Maximum average concentration	Absolute maximum concentration
Metals (mg/kg dry weight)		
Antimony	10	20
Arsenic	20	40
Cadmium	0.5	1.5
Total chromium	60	120
Copper	60	150
Lead	75	150
Mercury	0.5	1
Molybdenum	40	80
Nickel	40	80
Selenium	2	4
Vanadium	25	50
Zinc	200	350
Other		
pH	9 and above pH units	9 and above pH units
Asbestos	Visual inspection on acceptance (refer to Section 4.6.1)	

Source: Waste Authority WA (2018).

4.7 COMPARISON OF ENVIRONMENTAL REQUIREMENTS

This section presents a simplified comparison of current environmental practice of the national body NEPM, Queensland and selected Australian states regarding the reuse of waste and/or recycled materials. A summary of the sampling requirements is presented in Table 4.10 while Table 4.11 summarises the maximum concentration limits for the use of recycled materials, varying by state and application.

General observations from the comparison between the national, Queensland and other Australian state agency requirements include:

- Sampling is generally in accordance with AS 1141.3.1, except for the NEPM and Queensland documents reviewed which did not specify a method. Similarly, sample analysis must be undertaken using NATA accredited laboratories, although not explicitly stated by the Queensland legislation.
- Frequency of testing varies between states. Notably, WA has two separate frequencies for materials sampled from a conveyor belt and materials sampled from a stockpile.
- Leachate testing was only specified in Victoria and SA, both in accordance with AS 4439.2 and AS 4439.3.
- Generally, although the applications vary between agency, the contaminants to be tested and their maximum concentration limits are relatively similar.

Table 4.10: Summary of sampling requirements between national and state agencies reviewed

Criteria	NEPM	Qld	NSW	Vic	SA	WA
Sampling	• Conduct preliminary site investigation and site inspection to identify potential contaminants. • Material sampling in accordance with AS 4482.1. • Analysis undertaken in laboratories with NATA (or equivalent) accreditation.	• Sample of commercial or industrial waste tested for each relevant attribute and substance.	• Supplier must provide sampling plan. • Undertake sampling in accordance with AS 1141.3.1. • Collecting 20 samples of the waste from a batch, truckload or stockpile and testing. • Analysis undertaken in laboratories with NATA (or equivalent) accreditation.	• Wastes sampled, collected, preserved and analysed in accordance with Victoria EPA (2009c). • Sampling must be representative of waste composition in accordance with AS 1141.3. • Analysis undertaken in laboratories with NATA (or equivalent) accreditation.	• Wastes sampled, collected, preserved and analysed in accordance with Victoria EPA (2009c). • Sampling must be representative of waste composition in accordance with AS 1141.3. • Analysis undertaken in laboratories with NATA (or equivalent) accreditation.	• Undertake sampling and testing in accordance with AS 1141.3.1. • Sampling from conveyor or stockpile (if conveyor unavailable). • Analysis undertaken in laboratories with NATA (or equivalent) accreditation.
Frequency	• Not specified.	• Results are current for the waste for 3 months.	• Either 5 samples per 4000 tonnes or 5 samples every 3 months (whichever is lesser). • If recycled aggregates are not part of a continuous process, testing must occur for 10 samples per 4000 tonnes.	• Not specified.	• Not specified, based on consistency of initial results and the processes involved.	• Conveyor – 1 sample per 140 m^3 or 20 samples per 4000 tonnes. • Stockpile – 7 samples per 1000 m^3 or 20 samples per 4000 tonnes. • 3 samples for stockpiles less than 100 m^3. • Eligible to reduce frequency to 5 samples per 4000 tonnes or 1 sample per 600 m^3.
Leaching	• Not specified.	• Not specified.	• Not specified.	• Two buffer solutions in accordance with AS 4439.2 and AS 4439.3 using class 3b leaching fluids.	• In accordance with AS 4439.2 and AS 4439.3.	• Not specified.

Table 4.11: Summary of maximum concentration requirements for recycled/waste materials between national and state agencies reviewed

Attributes	Absolute limit					
	NEPM (soil)	Qld (waste)	NSW (aggregate)	Vic (fill material)	SA (fill material)	WA (recycled base)
Metals (mg/kg dry weight)						
Arsenic	100	300	40	20	20	20
Barium	–	–	–	–	300	–
Beryllium	70	90	–	–	20	–
Boron	5 000	20 000	–	–	–	–
Cadmium	20	90	1.5	3	3	1
Chromium (III)	100	300	120	–	400	75
Chromium (IV)	–	–	–	1	1	–
Cobalt	100	–	–	–	170	–
Copper	7 000	220	150	100	60	100
Cyanide	250	240	–	50	500	–
Lead	300	300	150	300	300	200
Manganese	3 000	–	–	–	500	–
Methyl mercury	7	–	–	–	–	–
Mercury	200	80	1.0	1.0	1.0	1.0
Molybdenum	–	–	–	40	–	–
Nickel	400	1 200	80	60	60	60
Selenium	200	700	–	10	–	–
Silver	–	–	–	10	–	–
Zinc	8 000	400	350	200	200	200
Hydrocarbons (mg/kg dry weight)						
Benzene	–	–	–	1	1	1
Benzene(a)pyreneTEQ	3	3	–	1	1	–
Toluene	–	–	–	–	1.4	50
Ethylbenzene	–	–	–	–	3.1	100
Xylene (total)	–	–	–	–	14	180
Total recoverable hydrocarbons (C6-C10)	–	–	–	7	–	100
Total recoverable hydrocarbons (C10-C36)	–	–	–	–	–	420
Polycyclic aromatic hydrocarbons (PAH)	300	300	–	20	5	40
Petroleum hydrocarbons TPH C6-C9 (total)	–	–	–	–	65	–
Petroleum hydrocarbons TPH >C9	–	–	–	–	1000	–

Attributes	Absolute limit					
	NEPM (soil)	Qld (waste)	NSW (aggregate)	Vic (fill material)	SA (fill material)	WA (recycled base)
Other						
Electrical conductivity	–	–	3 dS/m	–	–	–
pH	–	6.5 – 9.0	–	–	–	6.0 – 9.0
Asbestos	Not present	Not present	Not present	Not present	Not present	Not present
Metal	–	–	2.0%	–	–	–
Plaster	–	–	0.5%	–	–	–
Rubber, plastic, paper, cloth, paint, wood and other vegetable matter	–	–	0.3%	–	–	–

5 SUMMARY AND RECOMMENDATIONS

The requirements specified in MRTS35 were originally published in 2010, in close consultation with the recycling industry in Queensland. These requirements were largely based on Victorian and New South Wales practices at the time with modifications to suit Queensland conditions and experience. Since this time, the uptake of the use of recycled materials in unbound granular and stabilised pavements has been relatively limited due to a number of factors including:

- a perception that recycled materials are inferior to virgin materials
- limited technical knowledge regarding the allowable proportion of recycled materials and the long-term performance of these materials in certain pavement layers
- in Queensland there is currently only a limited number of suppliers (compared to quarry sources) of these materials, located mainly in South-East Queensland
- recycled materials are specified and procured in a different manner to quarry products, which can become an administrative barrier to their use.

The general objective of this project was to identify how the use of recycled materials can be optimised on TMR projects to achieve cost, sustainability and long-term performance benefits. This report has focused on the current Australian state road agency requirements regarding the use of recycled products in road construction to identify potential quick wins that could facilitate the immediate increased use of recycled materials in unbound and stabilised granular materials in Queensland.

From this report, the following key findings may be summarised:

- The use of recycled materials is widely accepted in unbound and stabilised pavement materials throughout Australia.
- While different agencies specify different limits, most of the publications identified have shown that in terms of performance; recycled materials are suitable for base and subbase applications.
- State road agencies outside Queensland, including RMS, DPTI and VicRoads have combined or have closely aligned their specifications for traditional quarried materials and recycled materials. This allows for a simplified process in specifying alternative materials in tenders and/or contracts.
- The grading requirements are similar between each of the state road agencies reviewed.
- The property requirements for recycled materials are generally consistent between each of the state road agencies, although TMR and VicRoads permit the highest permissible liquid limits.
- Of the jurisdictions that allow the use of recycled materials, other than MRWA that does not permit recycled materials to be used outside of subbases below FDA pavements, TMR has the most stringent permissible use requirements on recycled materials in unbound and bound basecourses. RMS, DPTI and VicRoads generally permit their use except for under pavements with a design traffic of greater than 4×10^6 ESAs.
- The recommended percentage of RCB, RAP and RCG differs between agencies and varies depending on the application of the material and the recycled material type but can be up to 50% in lower subbase applications.
- Recycled material constituents permitted outside Queensland include slag, fly ash, FBA and crushed tiles. It is important to note not all of these recycled materials may be suitable/available in Queensland.
- Foreign material limits are similar between the state road agencies reviewed.
- Most Australian agencies have similar environmental requirements for recycled materials.

5.1 YEAR 1 RECOMMENDATIONS

The following recommendations from year 1 of the project are proposed to achieve 'quick wins' in optimising the use of recycled materials in Queensland:

- Consider permitting the use of other recycled materials not currently permitted by TMR such as FBA.
- The allowable proportions of recycled materials specified in MRTS35 could be revised as shown in Table 5.1, where the red text in brackets represents the proposed new limit. Changes are based on aligning TMR limits more closely with RMS, DPTI and VicRoads.
- Based on this report, there are no recommended changes to TMR recycled material strength and durability property requirements at this stage.
- Revise the permissible use restrictions for recycled material in unbound granular layers, as shown in Table 5.2.

These constituent limits may be further reviewed following laboratory determination of recycled material properties, proposed for Year 2 of this project (Section 5.2). It is also envisaged that this laboratory testing will inform possible changes to TMR recycled property requirements, gradings and permissible uses.

It is also noted that VicRoads are currently undertaking testing to investigate the potential to increase the use or crushed brick and glass in recycled materials.

Table 5.1: TMR current and proposed limits for adoption

Recycled material type	Maximum limit of each constituent (% by mass of mix)				
	Quarry material	RCC	RAP	RCB	RCG
RM001	100 (100)	100 (100)	0 (0)	0 (0)	0 (0)
RM002	100 (100)	100 (100)	15 (15)	0 (20)	0 (10)
RM003	100 (100)	100 (100)	15 (20)	15 (20)	0 (10)
RM004	100 (100)	100 (100)	15 (20)	15 (20)	0 (10)
RM005	100 (100)	100 (100)	15 (20)	45 (45)	5 (20)
RM006 Remove from specification	100 N/A	100 N/A	15 N/A	45 N/A	5 N/A

Table 5.2: TMR proposed permissible uses for recycled material in unbound layers

Average daily traffic in design lane in year of opening (ESA)	Typical material type (MRTS05)[1,2,3] Median annual rainfall (mm)		
	≥ 800 mm / year	≥ 500 mm / year to < 800 mm / year	< 500 mm / year
Base			
≥ 1000 to < 3000	1 (HSG)[4]	1 (HSG)[4]	1 (HSG)[4]
≥ 500 to < 1000	2.1	2.1 or 3.1	3.1
≥ 100 to < 500	2.1	2.1 or 3.1	3.1
10 to < 100	2.1	2.1 or 3.1	3.1
< 10	2.2	2.2 or 3.2	3.2
Upper subbase			
≥ 1000 to < 3000	2.3	2.3 or 2.4	2.3, 2.4, 3.3 or 3.4
≥ 100 to < 1000	2.3	2.3, 2.4, 3.3 or 3.4	3.3 or 3.4
< 100	2.4	2.4 or 3.4	3.4
Lower subbase			
All	2.5	2.5 or 3.5	3.5

1. *Where material type alternatives are given, the first is the preferred and typically adopted option, with other materials listed in order of preference.*
2. *The requirements for Type 3 materials in MRTS05 Unbound Pavements do not include any minimum durability requirements, and therefore site specific moisture conditions should be carefully considered in addition to median rainfall.*
3. *The decision to use Type 1 (HSG) material is typically based on a project-specific assessment. Refer to Transport and Main Roads Technical Note TN171 Use of High Standard Granular (HSG) Bases in Heavy Duty Unbound Granular Pavements for further guidance.*
4. *A Type 2 material may be used in lieu of a Type 3 material of the same subtype.*

(shaded)	Recycled materials can be used

5.2 YEAR 2 SCOPE

The following scope is proposed for Year 2 of this project:

- Sample recycled materials from a number of suppliers in Queensland and undertake classification and performance testing to determine:
  - the compliance of these materials against the current and proposed specification limits
  - the likely performance of the materials using repeat load triaxial (RLT) and wheel tracker testing
- Undertake industry consultation to:
  - identify recycled material suppliers in Queensland
  - discuss the issues faced by these suppliers meeting the current and proposed specification
  - identify any other barriers to the use of recycled materials in Queensland
- Investigate the feasibility and possible benefits of improving recycled materials procurement by TMR, including:
  - the option of specifying recycled and virgin materials in the same specification (combining MRTS05 and MRTS35)
  - the option to establish a supplier registration requirement for recycled materials (similar to what is currently done for quarries).

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APPENDIX A CONTAMINANT LIMITS

A.1 NATIONAL ENVIRONMENTAL PROTECTION MEASURE

Table A.1: Summary of HILs for soil contaminants

Chemical	Health-Based Investigation Levels (mg/kg)			
	A	B	C[1]	D
Metals and inorganics				
arsenic[2]	100	500	300	3000
beryllium	70	100	100	500
boron	5000	40000	20000	300000
cadmium	20	140	100	800
chromium (VI)	100	500	240	3000
cobalt	100	600	300	4000
copper	7000	30000	20000	250000
lead[3]	300	1200	600	1500
manganese	3000	8000	9000	40000
methyl mercury[4]	10	30	14	200
mercury (inorganic)	200	600	400	4000
nickel	400	800	800	4000
selenium	200	1500	700	10000
zinc	8000	60000	30000	400000
cyanide (free)	250	400	350	2000
Polycyclic aromatic hydrocarbons (PAHs)				
benzo(a)pyrene TEF[5]	3	4	4	40
Total PAHs[6]	300	400	400	4000
Phenols				
phenol	3000	50000	45000	250000
pentachlorophenol	100	150	140	700
cresols	400	5500	4700	27000
Organochlorine pesticides				
DDT+DDE+DDD	260	700	400	4000
aldrin and dieldrin	7	10	9	50
chlordane	50	100	80	560
endosulfan	300	460	400	2000
endrin	10	20	20	100
heptachlor	7	10	9	50
HCB	10	20	15	85
methoxychlor	400	550	500	2700
mirex	10	20	20	100
toxaphene	20	35	30	170
Phenoxyacetic acid herbicides				
2,4,5-T	700	1000	900	5000
2,4-D	1000	2000	1400	9500
MCPA	700	1000	900	5000
MCPB	700	1000	900	5000
mecoprop	700	1000	900	5000
picloram	5000	8000	6500	37000
Other pesticides				
atrazine	360	550	500	3000
chlorpyrifos	170	400	300	2000
bifenthrin	600	900	750	4000
Other organics				
PCBs	1	2	2	8
PBDE flame retardants (Br1-Br9)	1	2	2	10

Notes:
1 - This scenario includes developed open space such as parks, playgrounds, playing fields and schools (e.g. ovals) and footpaths. This does not include undeveloped public open space which should be subject to a site-specific assessment, where appropriate.
2 - HIL for arsenic assumes 70% oral bioavailability. Site-specific bioavailability may be important and should be considered where appropriate
3 - HIL for lead based on blood lead models (IEUBK for HILs A, B and C & Adult Lead Model for HIL D) where 50% oral bioavailability has been considered. Site-specific bioavailability may be important and should be considered where appropriate.
4 - Assessment of methyl mercury should only occur where there is evidence of its potential source. Background intakes of fish may result in exceedance of the toxicity reference value without consideration of another source. In addition, the reliability and quality of sampling/analysis should be considered.
5 – HILs relevant to BaP and carcinogenic PAHs assessed on the basis of BaP TEF. Elevated levels of BaP in relatively immobile sources, such as bitumen fragments, do not represent a significant health risk.
6 – Total PAHs HILs relevant to the sum of all PAHs reported where carcinogenic PAHs meet the BaP TEF HILs and naphthalene meets the relevant HSL.

Source: NEPC (2011b).

A.2 QUEENSLAND DEPARTMENT OF ENVIRONMENT AND SCIENCE THRESHOLD

Table A.2: Attribute table thresholds

Attributes	Solid waste threshold
pH	6.5 – 9.0
Asbestos more than 0.01% (w/w)	Not present

Source: Environmental Protection Regulation 2019 (Qld).

Table A.3: Substance table thresholds

Attributes	Solid waste threshold (mg/kg)
Aldrin and dieldrin (total)	10
Antimony	9
Arsenic	300
Barium	4,500
Benzene	5
Benzo(a)pyrene	3
Beryllium	90
Boron	20,000
Cadmium	90
Carbon tetrachloride	2
Chlorobenzene	84
Chloroform	1
Chromium (hexavalent)	300
Copper	220
Cresol (total)	4,000
Cyanide	240
Dichlorobenzene (1,2-dichlorobenzene)	540
Dichlorobenzene (1,4-dichlorobenzene)	8
Dichloroethane (1,2-dichloroethane)	1
Dichloroethylene (1,1-dichloroethylene)	69
Dichloromethane (methylene chloride)	105
Dichlorophenoxyacetic acid (2,4-dichlorophenoxyacetic acid)	210
Dieldrin and aldrin (total)	10
Dinitrotoluene (2,4-dinitrotoluene)	5
Ethylbenzene	17
Fluoride	930
Lead	300
Mercury	80
Methyl ethyl ketone	8,100
Molybdenum	117
Nickel	1,200
Nitrobenzene	15
Organochlorine pesticides (total)	50
Organophosphate pesticides (total)	250
Per- and poly-fluoroalkyl substances (PFAS)	0
Persistent organic pollutant (other)	50

Attributes	Solid waste threshold (mg/kg)
Petroleum hydrocarbons (C6 to C9)	950
Petroleum hydrocarbons (C10 to C36)	5,300
Phenols (total)	40,000
Polychlorinated biphenyls (pcbs)	2
Polycyclic aromatic hydrocarbons (total)	300
Selenium	700
Styrene (vinyl benzene)	1,800
Silver	117
Tetrachloroethane (1,1,1,2-tetrachloroethane)	6
Tetrachloroethane (1,1,2,2-tetrachloroethane)	6
Tetrachloroethylene	24
Trichloroethane (1,1,1-trichloroethane)	2,430
Trichloroethane (1,1,2-trichloroethane)	0.45
Trichloroethylene	1
Trichlorophenol (2,4,5-trichlorophenol)	1,890
Trichlorophenol (2,4,6-trichlorophenol)	19
Toluene	1,470
Vanadium	117
Vinyl chloride	0.18
Xylenes (total)	174
Zinc	400

Source: Environmental Protection Regulation 2019 (Qld).

A.3 VICTORIA EPA HAZARD CATEGORISATION REQUIREMENTS

Table A.4: Soil hazard categorisation thresholds

Category	Fill Material upper limits (FILL MATERIAL)		Category C upper limits (CATEGORY C CONTAMINATED SOIL)		Category B upper limits (CATEGORY B CONTAMINATED SOIL)		CATEGORY A CONTAMINATED SOIL
Contaminant concentration thresholds (dry weight)		TC0	ASLP1[1]	TC1	ASLP2[1]	TC2	
Units		(mg/kg)	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	
Inorganic species	**Inorganic species**		**Inorganic species**		**Inorganic species**		
Arsenic		20	0.7	500	2.8	2,000	
Cadmium		3	0.2	100	0.8	400	
Chromium (VI)		1	5	500	20	2,000	
Copper		100	200	5,000	800	20,000	
Lead		300	1	1,500	4	6,000	
Mercury		1	0.1	75	0.4	300	
Molybdenum		40	5	1,000	20	4,000	
Nickel		60	2	3,000	8	12,000	
Tin		50	-	500	-	-	
Selenium		10	1	50	4	200	
Silver		10	10	180	40	720	
Zinc		200	300	35,000	1,200	140,000	
Anions	**Anions**		**Anions**		**Anions**		
Cyanide		50	8	2,500	32	10,000	
Fluoride		450	150	10,000	600	40,000	
Organic species	**Organic species**		**Organic species**		**Organic species**		
Phenols (halogenated)[2]		1	2	10	8	320	
Phenols (non-halogenated)[3]		60	14	560	56	2,200	
Monocyclic aromatic hydrocarbons[4]		7	-	70	-	240	
Benzene		1	0.1	4	0.4	16	
Polycyclic aromatic hydrocarbons[5]		20	-	100	-	400	
Benzo(a)pyrene		1	0.001	5	0.004	20	
C6-C9 petroleum hydrocarbons		100	-	650	-	2,600	
C10-C36 petroleum hydrocarbons		1,000	-	10,000	-	40,000	
Polychlorinated biphenyls[6]		2	see note 6		see note 6		
Chlorinated hydrocarbons[7]		1					
Hexachlorobutadiene			0.07	2.8	0.28	11	
Vinyl chloride			0.03	1.2	0.12	4.8	
Other chlorinated hydrocarbons[8]			-	10	-	50	
Pesticides	**Pesticides**		**Pesticides**		**Pesticides**		
Organochlorine pesticides[9]		1					
Aldrin + dieldrin			0.03	1.2	0.12	4.8	
DDT + DDD + DDE			2	50	-	50	
Chlordane			0.1	4	0.4	16	
Heptachlor			0.03	1.2	0.12	4.8	
Other organochlorine pesticides[10]			-	10	-	50	

Source: Victoria EPA (2009a).

Table A.5: Solid industrial waste hazard categorisation thresholds

Category		Industrial waste upper limits			Category C upper limits			Category B upper limits		
Contaminant concentration thresholds (dry weight)	INDUSTRIAL WASTE	ASLP0	TC0	CATEGORY C PRESCRIBED INDUSTRIAL WASTE	ASLP1[1]	TC1[2]	CATEGORY B PRESCRIBED INDUSTRIAL WASTE	ASLP2	TC2	CATEGORY A PRESCRIBED INDUSTRIAL WASTE
Units		(mg/L)	(mg/kg)		(mg/L)	(mg/kg)		(mg/L)	(mg/kg)	
Inorganic species		**Inorganic species**			**Inorganic species**			**Inorganic species**		
Antimony[3,8]		1	75		2	75		8	300	
Arsenic		0.35	500		0.7	500		2.8	2,000	
Barium[3]		35	6,250		70	6,250		280	25,000	
Beryllium[5]		0.5	100		1	100		4	400	
Boron		15	15,000		30	15,000		120	60,000	
Cadmium		0.1	100		0.2	100		0.8	400	
Chromium (VI)		2.5	500		5	500		20	2,000	
Copper		100	5,000		200	5,000		800	20,000	
Lead		0.5	1,500		1	1,500		4	6,000	
Mercury		0.05	75		0.1	75		0.4	300	
Molybdenum[6]		2.5	1,000		5	1,000		20	4,000	
Nickel		1	3,000		2	3,000		8	12,000	
Selenium[6]		0.5	50		1	50		4	200	
Silver[6]		5	180		10	180		40	720	
Tributyltin oxide[3]		0.05	2.5		0.1	2.5		0.4	10	
Zinc		150	35,000		300	35,000		1,200	140,000	
Anions		**Anions**			**Anions**			**Anions**		
Chloride		12,500	N/A		25,000	N/A		N/A	N/A	
Cyanide (amenable)[5]		1.75	1,250		3.5	1,250		14	5,000	
Cyanide (total)		4	2,500		8	2,500		32	10,000	
Fluoride[6]		75	10,000		150	10,000		600	40,000	
Iodide		5	N/A		10	N/A		40	N/A	
Nitrate		2,500	N/A		5,000	N/A		20,000	N/A	
Nitrite		150	N/A		300	N/A		1,200	N/A	
Organic species		**Organic species**			**Organic species**			**Organic species**		
Benzene		0.05	4		0.1	4		0.4	16	
Benzo(a)pyrene[7]		0.0005	5		0.001	5		0.004	20	
C6-C9 petroleum hydrocarbons[6]		N/A	325		N/A	650		N/A	2,600	
C10-C36 petroleum hydrocarbons[6]		N/A	5,000		N/A	10,000		N/A	40,000	
Carbon tetrachloride		0.15	12		0.3	12		1.2	48	

Source: Victoria EPA (2009b).

Table A.6: Solid industrial waste hazard categorisation thresholds – continued

Category	Industrial waste upper limits		Category C upper limits		Category B upper limits		
	INDUSTRIAL WASTE		CATEGORY C PRESCRIBED INDUSTRIAL WASTE		CATEGORY B PRESCRIBED INDUSTRIAL WASTE		CATEGORY A PRESCRIBED INDUSTRIAL WASTE
Contaminant concentration thresholds (dry weight)	ASLP0	TC0	ASLP1[1]	TC1[2]	ASLP2	TC2	
Units	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	
Chlorobenzene	15	1,200	30	1,200	120	4,800	
Chloroform[5]	3	240	6	240	24	960	
2 Chlorophenol	15	1,200	30	1,200	120	4,800	
Cresol (total)[5]	100	8,000	200	8,000	800	32,000	
Di (2 ethylhexyl) phthalate	0.5	40	1	40	4	160	
1,2-Dichlorobenzene	75	6,000	150	6,000	600	24,000	
1,4-Dichlorobenzene	2	160	4	160	16	640	
1,2-Dichloroethane	0.15	12	0.3	12	1.2	48	
1,1-Dichloroethene	1.5	120	3	120	12	480	
1-2-Dichloroethene	3	240	6	240	24	960	
Dichloromethane (methylene chloride)	0.2	16	0.4	16	1.6	64	
2,4-Dichlorophenol	10	800	20	800	80	3,200	
2,4-Dinitrotoluene[5]	0.065	5.2	0.13	5.2	0.52	21	
Ethylbenzene	15	1,200	30	1,200	120	4,800	
Ethylene diamine tetra acetic acid (EDTA)	12.5	1,000	25	1,000	100	4,000	
Formaldehyde	25	2,000	50	2,000	200	8,000	
Hexachlorobutadiene	0.035	2.8	0.07	2.8	0.28	11	
Methyl ethyl ketone[5]	100	8,000	200	8,000	800	32,000	
Nitrobenzene[5]	1	80	2	80	8	320	
PAHs (total)[7,10]	N/A	50	N/A	100	N/A	400	
Phenols (total, non-halogenated)[5,11]	7	560	14	560	56	2,200	
Polychlorinated biphenyls[4]	N/A	2		see note 4		see note 4	
Styrene	1.5	120	3	120	12	480	
1,1,1,2-Tetrachloroethane[5]	5	400	10	400	40	1,600	
1,1,2,2-Tetrachloroethane[5]	0.65	52	1.3	52	5.2	210	
Tetrachloroethene	2.5	200	5	200	20	800	
Toluene	40	3,200	80	3,200	320	12,800	
Trichlorobenzene (total)	1.5	120	3	120	12	480	
1,1,1-Trichloroethane[5]	15	1,200	30	1,200	120	4,800	
1,1,2-Trichloroethane[5]	0.6	48	1.2	48	4.8	190	
Trichloroethene[5]	0.25	20	0.5	20	2	80	
2,4,5-Trichlorophenol[5]	200	16,000	400	16,000	1600	64,000	

Source: Victoria EPA (2009b).

Table A.7: Solid industrial waste hazard categorisation thresholds – continued (2)

Category	Industrial waste upper limits		Category C upper limits		Category B upper limits		
Contaminant concentration thresholds (dry weight)	ASLP0	TC0	ASLP1[1]	TC1[2]	ASLP2	TC2	
Units	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	(mg/L)	(mg/kg)	
2,4,6-Trichlorophenol	1	80	2	80	8	320	
Vinyl chloride	0.015	1.2	0.03	1.2	0.12	4.8	
Xylenes (total)	30	2,400	60	2,400	240	9,600	
Pesticides	Pesticides		Pesticides		Pesticides		
Aldrin + dieldrin	0.015	1.2	0.03	1.2	0.12	4.8	
DDT + DDD + DDE[9]	1	50	2	50	N/A	50	
2,4-D	1.5	120	3	120	12	480	
Chlordane	0.05	4	0.1	4	0.4	16	
Heptachlor	0.015	1.2	0.03	1.2	0.12	4.8	

Source: Victoria EPA (2009b).