2021-011 Investigating the Suitability of WA Mine Waste for Infrastructure Related Projects

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Summary

Australian governments, transport agencies and industries have identified the need to reduce waste in landfills and improve the use of recyclable materials. These objectives align with worldwide attitudes towards waste and industry by-products, considering and managing waste as a valuable resource by implementing future sustainable solutions.

The commitment to using recycled materials and promoting a circular economy is being promoted through various initiatives across Western Australia (WA). To align with these strategies, Main Roads Western Australia (Main Roads) is seeking alternative materials for use in road infrastructure construction and maintenance that reduce the reliance on natural rock.

In WA, the mining industry is the largest sector of the economy within the state, generating a substantial amount of waste and industry by-products that are being underutilised. However, guidelines and a framework for determining the suitability of mine waste materials for use in road infrastructure applications previously did not exist in WA.

Already, numerous case studies across the state have demonstrated successful implementation of mine waste materials into road infrastructure projects. From these studies, experience has indicated that using mine waste materials saves time and cost by not requiring environmental impact assessments, permit applications, rehabilitation of the site plus ongoing monitoring and a provides large quantities of sustainable, readily available materials where traditional material may otherwise be scarce.

To establish consistency across road transport and traffic agencies, Main Roads is recommended to adopt a customised framework to assess mine waste materials for implementation in road infrastructure applications. The protocol developed through assessment of relevant research, specifications and standards, can be used to rigorously scrutinise materials and to provide administrative agencies with a deeper understanding of the associated risks and benefits in using mine waste materials.

By establishing consistency across road transport and traffic agencies, a uniform approach to material assessment can improve the body of knowledge to support the production of standards and specifications, leading to a greater uptake of mine waste materials in road applications in WA.

Acknowledgements

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1 Introduction

Australian governments, transport agencies, and industries have identified the need to reduce waste in landfills and improve the use of recyclable materials. This move towards considering and managing waste as a valuable resource by implementing future sustainable solutions aligns with worldwide attitudes towards waste and industry by-products.

In Western Australia, a commitment to using recycled materials and promoting the circular economy is being promoted through various initiatives such as:

- Western Australian State Sustainability Strategy 2003
- Western Australian Climate Change Policy
- Waste Avoidance and Resource Recovery Strategy 2030 (including Roads to Re-use)
- Western Australia's Plan for Plastics (reducing and avoiding single-use plastics), and
- Council of Australian Governments (COAG) bans the export of various waste categories.

To align with the state's strategies, Main Roads has established several initiatives to use recycled materials in road infrastructure projects. So far, Main Roads has achieved implementation of more than 3,200 tonnes of crumb rubber into state road network projects, with the following additional objectives:

- Commit to having 50% of metropolitan road projects using crumb rubber in open graded asphalt surfacing.
- Increase the quantity of reclaimed asphalt pavement (RAP) in an intermediate course asphalt mix design to at least 20–25%.
- Increase the use of crushed recycled concrete across the Main Roads network to be greater than 200,000 tonnes.

The assessment of relevant research, specifications and standards seeks to promote waste management in pavement construction. This work will inform the protocol used to rigorously scrutinise documentation considered to provide administrative agencies with a deeper understanding of the associated risks and benefits of using recyclable materials.

By establishing consistency across road transport and traffic agencies, a uniform approach to material assessment will improve the body of knowledge that can accelerate the production of standards and specifications, leading to a greater uptake of recyclable materials.

In Western Australia (WA), the mining industry is the largest economy within the state, generating a substantial amount of waste and industry by-products that are being underutilised. Mine waste is currently one of the most generated by-products in the world. It comes from the extraction and processing of mineral resources and includes topsoil overburden, waste rock, tailings and industry by-products. Expressly, tailings and industry by-products represent the materials left over after extracting the valuable minerals and contains residues.

Globally, mine wastes are produced at an estimated 20–25 billion tonnes per year, of which 5 to 7 billion tonnes are mine tailings, and the rest are unprocessed waste rocks. WA is the mineral resources export hub of Australia. The sector produces more than 50 minerals from about 1,000 mines across WA. Main Roads is seeking alternative materials for use in road infrastructure construction and maintenance that reduce the reliance on natural materials. However, currently, guidelines and a framework for determining the suitability of using mine waste as alternative materials for use in road infrastructure applications do not exist.

1.1 Objectives

This project aimed to develop a framework that will guide the assessment of mine wastes and industry by-products generated from WA's mining industry for suitability as potential alternative materials for road construction.

1.2 Methodology

An initial literature review investigated if and how wastes and by-products resulting from mining operations have reusable applications, specifically in transport infrastructure applications. National and international practices were examined.

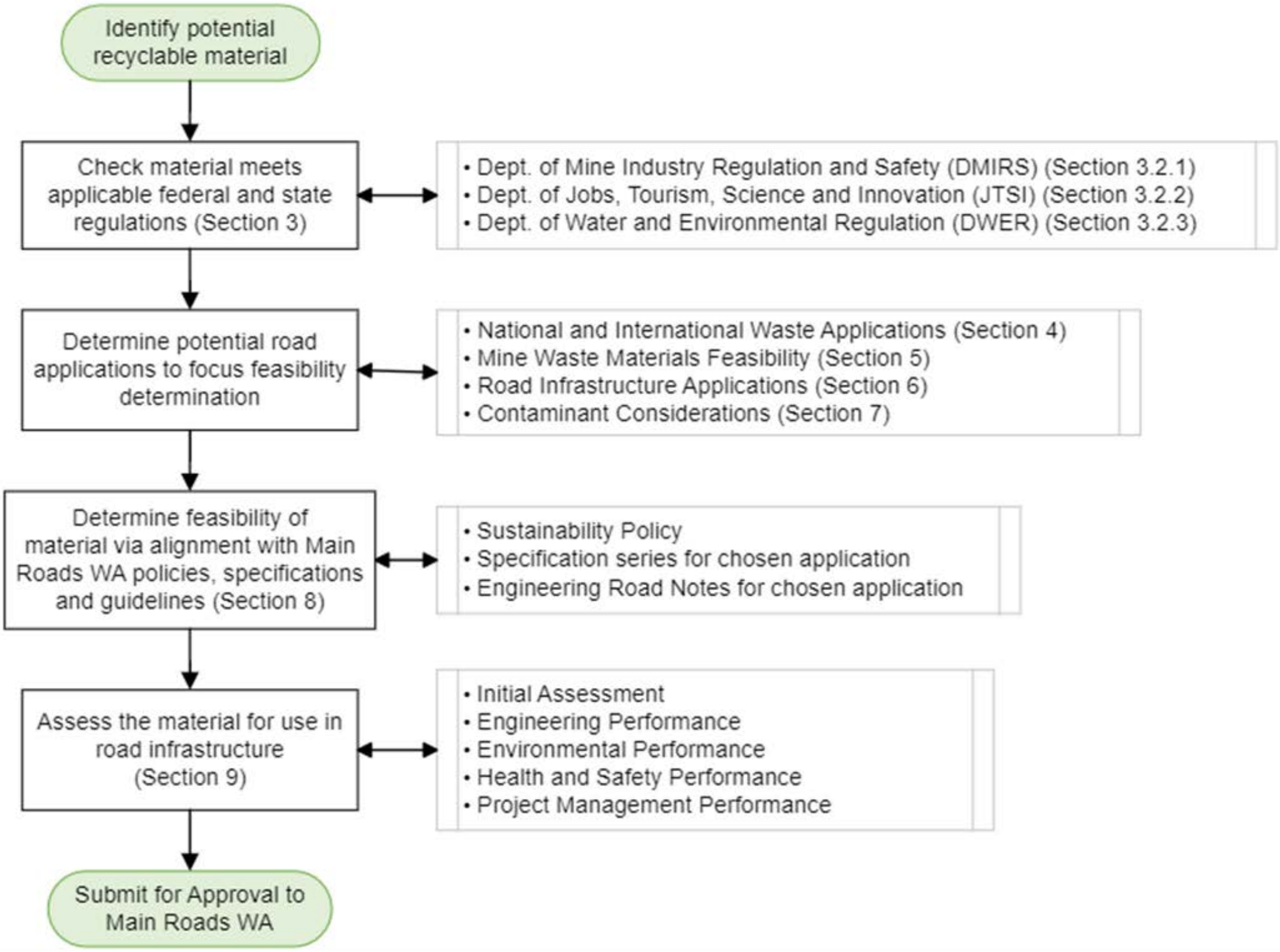
The project then considered industry assessment methods that classify the various types of mining waste and by-products produced and evaluate the waste material suitability in relation to the potential use in transport infrastructure applications.

A framework was selected and customised to provide a standardised approach for assessing candidate materials and promoting those with potential for use in transport infrastructure applications in WA.

1.3 Report Structure

Section 2 defines sustainability and the circular economy, providing context for the remaining sections outlined in Figure 1.1. Section 3 outlines current initiatives from federal and state government to support circular the economy. Section 4 goes on to identify applications of waste both domestically and internationally before section 5 follows with an explanation of mine waste feasibility. Section 6 will identify relevant road infrastructure applications followed by section 7 which explores the contaminant considerations. The report culminates in a proposed framework for assessing mine waste materials in section 9.

Figure 1.1: Project overview for WARRIPs Mine Waste Project



2 Sustainability and Economy

2.1 Sustainability

Sustainability is typically defined as meeting our current society's demands without compromising future generations' needs. Generally, sustainability considers the environment, society and economy as equal and interconnected elements. The sustainability description for each of these elements is described as follows:

- **Environment:** Ecological sustainability is when environmental stability is maintained and global environmental services and systems are in equilibrium. Preservation of natural resources does not compromise societal needs or the requirements of an ecosystem to function. Furthermore, the ecosystem is capable of replenishing resources when harvested successfully.
- **Social:** Social sustainability is about identifying and managing business impacts, both positive and negative, on people and their communities while accessing a required resource. Each community should have equal access to resources that do not impede another for survival. Furthermore, these activities should not disadvantage future generations when searching for secure sources of livelihood.
- **Economic**: Economic stability and economic sustainability is supporting long-term economic growth without causing an imbalance between social and environmental elements.

Focusing solely on economic development while disregarding the management of natural resources (environment) is likely to contribute to an ecological collapse and, consequently, an economic collapse preventing future generations' access to said resource. However, prioritising environmental conservation over economic development will also result in economic discourse. Thus, a collaboration between government, private industry and society is required to positively influence the operational direction of our economy from a linear model into a sustainable circular model referred to as a circular economy.

2.2 Circular Economy

According to the CSIRO (Pickin et al. 2020), the circular economy concept contains the following phases:

- **Avoidance**: avoid using a material with low recyclability or one that is potentially harmful during disposal; design for modularity and materials optimisation.
- **Design:** design for longevity and adaptability and consider opportunities for the product as a service (e.g. renting public lighting) and supplier take-back schemes (return materials at the end of their life cycle). Consider the disassembly of materials and potential economic and technical constraints for re-use.
- **Consumption**: extend the operational life of a material or asset to reduce the frequency of material consumption. Material is considered more valuable as an operating asset than it is as a recovered material.
- **Collection:** organise material collection and stockpiling of recycled construction and demolition (C&D) waste or reclaimed asphalt pavements (RAP) to reduce sorting costs and improve material quality.
- **Sorting:** effectively sort materials (e.g. C&D waste, RAP) and remove impurities to improve consistency and performance.
- **Recycling:** convert primary materials into secondary materials ready to be remanufactured.
- **Remanufacture**: produce a commodity item from recycled material for value-added applications.
- **Disposal**: eliminate material from the circular economic process, which results in waste disposal to landfills or energy recovery.

This concept creates a closed-loop system and aims to minimise resource inputs, waste, pollution, and carbon emissions while improving the longevity of products, materials, equipment and infrastructure (European Parliament 2015) as shown in Figure 2.1.

Figure 2.1: The concept of a circular economy

Source: Pickin et al. (2020).

The design-based implementation of the 3 principles of this model – eliminating waste and pollution, circulating products and materials, and the regeneration of nature – is required to achieve the circular economy aims.

Materials deemed as waste should be considered as input for other processes through waste valorisation. Re-using or recycling waste materials in innovative and alternative applications, such as a replacement for a natural resource material in infrastructure applications, develops the circular economy strategy as an industrial economy that is restorative or regenerative by value and design (European Parliament 2015).

3 Circular Economy Supporting Policies

Transport and infrastructure ministers have been requested to respond to significant shifts in domestic and international waste policy changes within their portfolios. Agencies across all government levels have increasingly updated their policies and guidance for using and procuring recycled materials to respond to these challenges.

3.1 Federal

Australia's National Waste Policy identified avoiding waste, improving resource recovery and increasing the use of recycled material and products as critical in Australia's shift toward a circular economy. A plan was developed to present targets and actions for implementing Australia's National Waste Policy. It outlines actions to:

- prioritise the development of national standards and specifications or adopt appropriate international standards and specifications for using recycled content in a broad range of capital works projects, prioritising road, and rail
- determine the use of recycled content in road construction to establish a baseline and allow reporting on actions to increase recycled content use significantly.

The *Australian Federal Recycling and Waste Reduction Act 2020* is supported by commitments from state governments to help address key issues with onshore processing and provides an impetus to drive local demand and use of recycled materials such as in infrastructure to support the move towards a circular economy.

Policy changes and initiatives have been designed to enhance the uptake of recycled materials across all levels of government. Refer to Appendix A.1 for the policy changes and initiatives.

3.2 State Government

WA's *Waste Avoidance and Resource Recovery Strategy 2030* (Waste Authority of WA 2019) outlines the state's strategy for becoming a sustainable, low waste circular economy where human health and the environment are protected from the impacts of waste. The strategy is defined by 3 objectives (Figure 3.1) and has set targets that underpin them. The objectives are:

1. to avoid waste
2. to recover more value and resources from waste
3. to protect the environment.

In the context of WA's sustainability strategy, mine waste materials are an undervalued and untapped resource with great potential to benefit the community as part of these objectives.

Figure 3.1: WA's waste avoidance and resource recovery objectives

Source: Waste Authority of WA (2019).

WA State Government Departments are tasked to implement and regulate this strategy.

A brief overview of each department's role and responsibilities is given below. For more information on each department's roles that are applicable to this report, please refer to **Error! Reference source not found.**.

3.2.1 Department of Mine, Industry Regulation and Safety (DMIRS)

The Department of Mines, Industry Regulation and Safety (DMIRS) ensures the responsible development of WA's mineral, petroleum, and geothermal resources. This includes regulating the industry to ensure environmental compliance and implementing best practice environmental management. The department's Resource and Environmental Compliance Division assesses WA's mineral, petroleum, and geothermal exploration and development applications. Refer to Appendix A.2 for the relevant legislation, policies and regulations governing WA's mining industry.

3.2.2 Department of Jobs, Tourism, Science and Innovation (JTSI)

Substantial investments in WA's resources sector contribute to continued economic growth. In many cases, proponents commit to these significant projects based on an agreement specifying terms and conditions with the WA Government for the development of the resource. These terms and conditions are contained within what is known as State Agreements, which are ratified by Acts of Parliament.

A State Agreement is a legal agreement between the WA Government and a proponent of a major project within the boundaries of WA. A State Agreement details the rights, obligations, terms and conditions for the development of the specific project, and the agreement is administered by the Department of Jobs, Tourism, Science and Innovation on behalf of the WA Government.

In State Agreements, significant responsibility is put on companies for infrastructure development, both industrial and social.

3.2.3 Department of Water and Environmental Regulation (DWER)

The Department of Water and Environmental Regulation (DWER) supports WA's community, economy, and environment by managing and regulating the state's environment and water resources.

Many waste reform projects to support the objectives of the *Waste Avoidance and Resource Recovery Strategy 2030* (Waste Authority of WA 2019) have been undertaken by the department including:

- amendments to the *Waste Avoidance and Resource Recovery* (WARR Act) and *Waste Avoidance and Resource Recovery Regulations 2008* (WARR Regulations) to require record keeping and reporting of waste and recycling data from local governments, waste recyclers and licensees of major regional landfills
- establishing the Waste Authority under the WARR Act to administer funds raised from the levy paid on all waste generated in the metropolitan area that is disposed to landfill and to advise the Minister on waste policy and provide the general promotion of waste management
- Western Australia's Container Deposit Scheme – *Containers for Change*
- a review of the *Environmental Protection (Controlled Waste) Regulations 2004*
- a review of the uncontaminated fill thresholds in Table 6 of the *Landfill Waste Classification and Waste Definitions 1996 (as amended 2018)*
- proposed amendments to the *WARR Levy Regulations* to require the use of weighbridges for Category 63, 64 and 65 landfill premises to calculate leviable waste
- the development of a legislative framework for waste derived materials.

DWER also recently consulted on amendments to the *Environmental Protection Act 1986 (EP Act)* to modernise this Act, to protect human health and the environment, and ensure sustainable development can occur for the benefit of all Western Australians.

As part of the administration of Part V Division 3 of the EP Act, DWER is included in the licensing of prescribed premises. Several prescribed premises categories in the *Environmental Protection Regulations 1987* (EP Regulations) are defined by reference to activities involving waste occurring on the premises. There are also a few provisions in the EP Act that make it an offence to do certain things with waste such as discharging of acid, animal waste, pesticides, etc.

DWER administers the WARR Act and the WARR Levy Regulations. EP Regulations require a levy payment for waste disposed of to landfill. This levy applies to the following categories of a prescribed premises in the EP regulations (See Appendix A.5):

- 63 Class I inert landfill site
- 64 Class II or III putrescible landfill site
- 65 Class IV secure landfill site.

Therefore, the assessment of whether a certain material is classified as waste is important in the application of these Acts and regulations. For DWER's definitions of waste as per the EP Act and WARR Act, please refer to Appendix A.3.

Landfill Waste Classification and Waste Definitions 1996

DWER's document *Landfill Waste Classification and Waste Definitions 1996 (as amended 2019)* (DWER 2019) provides guidance and criteria for determining the classification of wastes for acceptance to landfills that are licensed or registered in WA under Part V Division 3 of the EP Act. WA landfills are classified according to the type of materials permitted for disposal:

- Class I – Inert Landfill
- Class II and III – Putrescible Landfill
- Class IV – Secure Landfill
- Class V – Intractable Landfill.

The definitions of these classifications can be found in Appendix B.1.

To ensure waste materials are sent to appropriate facilities, DWER outlines a strict process for waste classification as defined in Appendix A.4.

Refer to Appendix B.5 for the associated tables that detail DWER's contaminant threshold values and guidelines used in the interpretation of the above process.

4 National and International Waste Applications

This section highlights the national and international application of mine waste and other recycled materials' use in road infrastructure applications.

4.1 Australia

National and local road agencies, together with the road construction industry, have a long history of incorporating recycled materials into road infrastructure. Concrete and masonry, fly ash, recycled asphalt, and rubber have been successfully incorporated into various aspects of road infrastructure projects and are complementary to natural materials (Austroads 2009).

The use of mine waste materials for road infrastructure applications is not the current practice of the Northern Territory, South Australia, New South Wales, Tasmania and Victoria.

4.2 Western Australia

In April 2018, the state government passed legislation encouraging the use of recycled materials in road construction projects. This was achieved by permitting the use of uncontaminated or excess site-won fill in road construction without having to pay a waste levy. Prior to this, the procedure to define and assess waste for contaminates as outlined in *Landfill Waste Classification and Waste Definitions 1996* (DWER 2019) was required prior to use.

Since then, numerous applications (outlined in Appendix C.1) of mining by-products into road infrastructure have been assessed, and some have been implemented (Main Roads 2021).

Main Roads also permits the use of other materials such as RAP, crumb rubber, recycled construction and demolition waste called crushed recycled concrete (CRC), blast-furnace slag, fly ash, recycled sand and crushed recycled glass in specific applications.

The Waste Authority, DWER and Main Roads collaborated on the Roads to Re-use (RtR) program, which encourages state government organisations, local governments, regional councils and the private sector to use recycled construction and demolition waste in civil applications, such as road construction. The program focused on developing a RtR product specification, product testing scheme and independent auditing regime. A pilot project was delivered using the RtR product specification and Main Roads' pilot project specification 501.92 (Waste Authority of WA 2020).

4.3 United States of America (USA)

In the USA, 19 states have successfully implemented mine waste materials into their road infrastructure construction for several years. Mine tailings and waste rock stemming from gold, iron and lead-zinc ore bodies were implemented as aggregate in asphalt paving, channel protection, and granular base courses. The US Department of Transport (2016) has utilised coarse coal refuse (~100 mm to 2 mm diameter) in the construction of highway embankments as well as blended with fly ash for stabilised road base installations. Additional detail on US waste material applications can be found in Appendix C.2.

4.4 Europe

Countries in the European Union, particularly Sweden, the Netherlands and Denmark are progressive with implementing waste materials into road construction projects.

Sweden’s government outlines specifications for using residual products such as slag in road construction (Appendix C.3).

In Denmark, the use of recyclables in road construction is actively promoted through initiatives such as supporting research investigations and demonstrations, tax policies on waste disposal, and issuing recommendations, guidance, and requirements for recycling (Appendix C.3).

In the Netherlands, a market philosophy for promoting the concept of using recycled materials in sustainable highway construction has been embraced and is integrated into policies, economic tools, regulations and other factors needed for increased recycling and the use of recyclables for sustainable road construction.

5 Mine Waste Materials Feasibility

5.1 Types of Mine Waste

Mine waste is a collective term that includes materials and by-products generated from excavating and extracting ore from its native rock. Many different types of materials are mine waste, including:

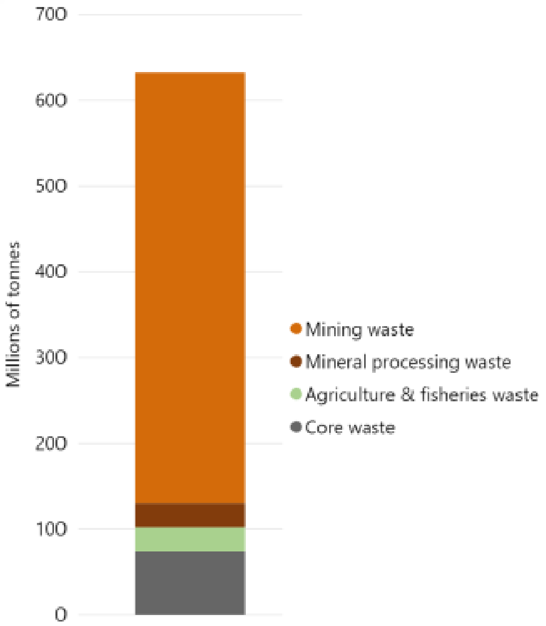
- overburden
- waste rock
- tailings
- sludge
- slag
- fly ash.

Definitions of these materials are contained in Appendix D.1.

Australia's *National Waste Report 2020* documented the first comprehensive estimate quantifying mine waste generated in the country. Waste generated from this industry is classified as Primary Production Waste Materials which is quantified under the Commercial and Industry (C&I) waste stream. The estimated total mine waste generated in 2018–19 was 502 Mt (dry weight) (Figure 5.1 and Figure 5.2). Approximately 83% of mine waste (dry weight) was processed tailings material, while 17% was used as infill for mining voids and pits (Pickin et al. 2020).

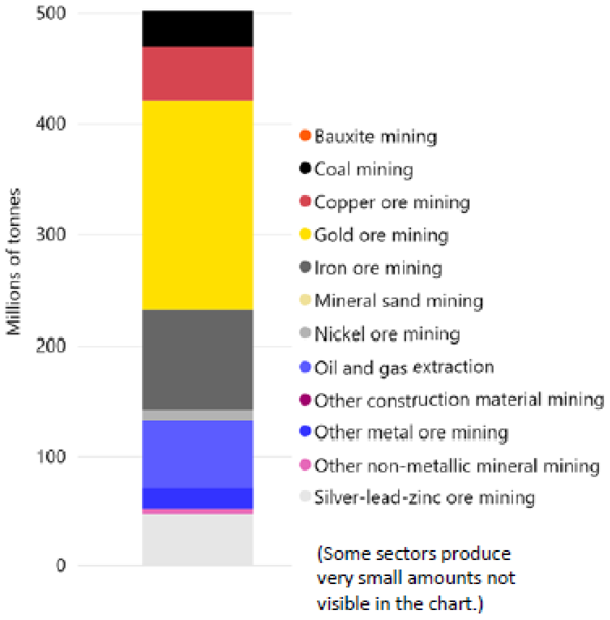
Mine waste production was estimated by combining data reported in the National Pollutant Inventory (NPI) and public annual audit compliance reports from mine sites in WA. The NPI is a database of emissions and transfers of 93 toxic substances, including those found in tailings. The mining sector matched these against the waste quantities stated in the audit compliance reports to derive an average ‘factor’ that could be applied to the national NPI data to scale up the NPI substance transfers to total waste.

Figure 5.1: Waste generation (all measured materials) by stream, Australia (2018–19)



Source: Pickin et al. (2020).

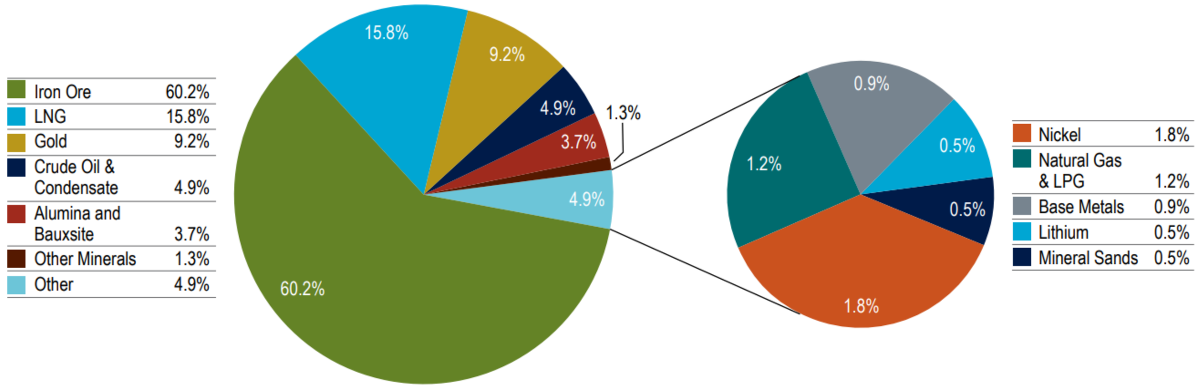
Figure 5.2: Estimated mining waste by sector, Australia (2018–19)



Source: Pickin et al. (2020).

The WA resource sector is dominated by the mining industry, which accounted for approximately 78% ($134 billion) of the state's economic value in 2019–20 (Department of Mines, Industry Regulation and Safety 2021a). Across the state there are more than 1,000 mineral deposits encompassing around 55 different mineral commodities. The largest mined commodities (excluding petroleum products) include iron ore (836 Mt), gold (212 t) and alumina and bauxites (15.8 Mt) (Department of Mines, Industry Regulation and Safety 2021b) as shown in Figure 5.3. Currently, there are 123 predominantly higher value and export-orientated mining projects that are active.

Figure 5.3: FY2019–20 mineral and petroleum summary (total $172 billion)



Source: DMIRS (2021b).

5.2 Storage and Rehabilitation of Mine Waste

As a condition of tenements, mining companies are required to store all waste generated from mining activities within mine tenements, and this typically includes placing these materials in specialised storage facilities, infilling exhausted mine pits or creating above-ground waste landforms. Furthermore, all disturbed land must undergo rehabilitation as part of a mine closure strategy.

The approved mine closure strategy rehabilitates and closes waste landforms in a manner to make them physically safe to humans and animals, geotechnically stable, geochemically non-polluting and non-contaminating, capable of sustaining an agreed post-mining land use, and without unacceptable liability to the state. The content of successful rehabilitation and closure strategies are outlined in Appendix D.2.

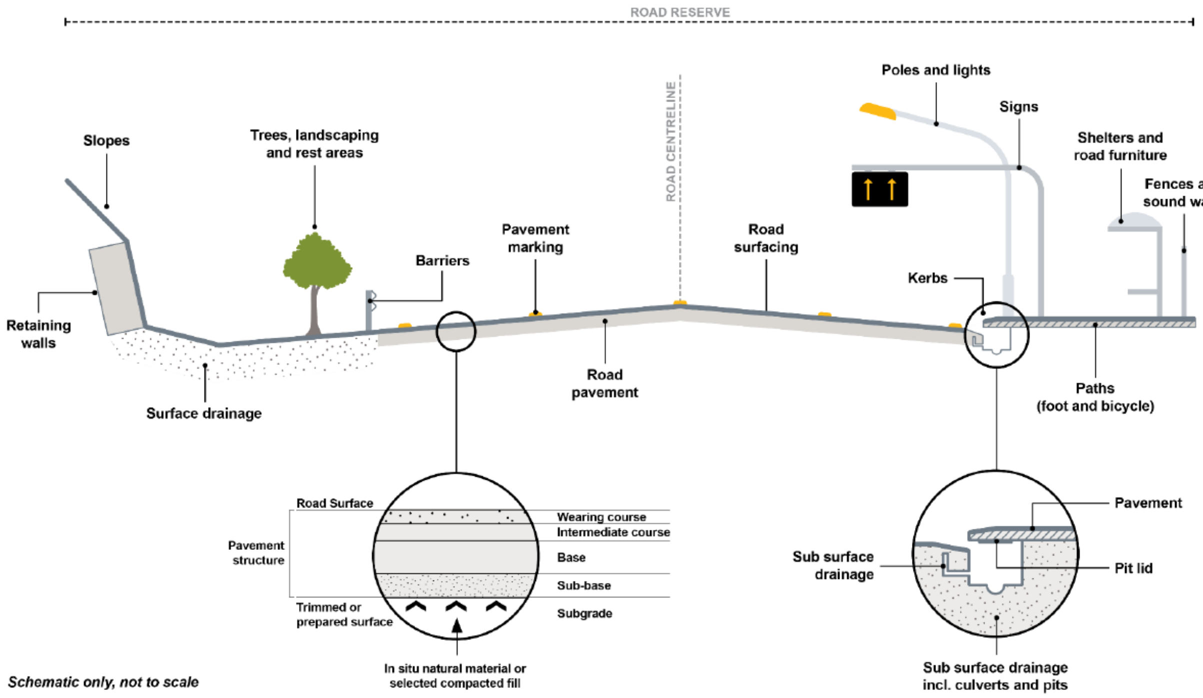
5.3 Royalties

Section 5.2 elaborated on the requirements for mine closure plans and storage and rehabilitation of waste. It is important to note that using mine waste materials for any application, other than that outlined in the mine closure plan, will require not only an update and review of the mine closure plan, but the mine waste materials removed from the tenement will also be subject to the payment of royalties (Appendix A.2). Royalties are due on any mineral obtained from the tenement, regardless of the value. This additional administrative and financial burden on mining tenement holders may hamper the use of mine waste materials.

6 Road Infrastructure Applications

This section defines a flexible road pavement system, describes the typical material used to construct it and provides an overview of the state road network and construction material consumption. However, road pavements are only one infrastructure element within the road reserve, with many other infrastructure elements also primed for the use of mine waste materials (e.g. retaining walls, drainage backfill, paths, etc.) (Figure 6.1).

Figure 6.1: Road infrastructure within a road reserve



Source: Austroads (2022).

6.1 Flexible Road Pavements

The basic function of a road pavement is to support the traffic loading with acceptable ride quality and without undue deterioration over the period for which it is designed. To do this, the pavement must sufficiently attenuate the traffic-induced stresses in all pavement layers and the subgrade, to prevent significant pavement distress. This is normally achieved by a structure consisting of several layers of differing quality material, with the highest quality materials in the upper portion of the pavement, where load induced stresses are higher, and lesser quality materials in lower layers where stresses have reduced (Austroads 2008). Refer to Appendix E.1 for additional technical information on flexible pavements.

6.2 Granular Materials

Unbound granular materials typically comprise of natural occurring gravel or crushed rock sourced from quarried material. The requirements of an unbound granular material are generally as follows:

- sufficient strength to withstand the applied traffic and environmental stresses
- sufficient hardness to withstand applied loads without inducing particle breakdown
- ability to be placed and compacted to meet specification requirements
- durable and do not degrade or disintegrate significantly over the life of the pavement
- quality that is fit-for-purpose (Austroads 2008).

Information on the requirements related to engineering properties for granular material used on the road network is outlined in Main Roads' Specification 302: *Earthworks* (Main Roads 2020) and Specification 501: *Pavements* (Main Roads 2022a). Appendix E.2 lists typical engineering properties specified in Main Roads' specifications. The material requirements vary between gravels and crushed rocks and between regions within the state.

6.3 State Road Network

WA's vast road network includes more than 18,400 km of highways and main roads and approximately 170,000 km of secondary and local roads spread across 2.5 million km^2. Due to the large size, the state is divided into 8 unique regions (Table 6.1). Table 6.2 lists the construction material consumed by Main Roads in building and maintaining the road network.

Table 6.1: Main Roads road network summary

Region	Population (000)	Area covered (000 km^2)	State roads length (km)
Metropolitan	1,943	5	882
South West	285	29	1,758
Great Southern	62	49	1,609
Wheatbelt	74	157	3,476
Kalgoorlie – Esperance	55	941	2,202
Mid West – Gascoyne	63	421	3,624
Pilbara	61	506	2,734
Kimberley	36	419	2,243
TOTAL	2,579	2,527	18,528

Source: Main Roads (2018).

Table 6.2: Main Roads material consumption in FY 2019–20

Material type	Tonnes consumed
Gravel	2,408,500
Crushed rock	895,000
Sand	175,700
Limestone	148,300
Recycled road base	57,200
Recycled crushed glass	56,000
Stabilised backfill	33,200
Recycled sand	13,900
Asphalt or profiling	13,400

Source: Main Roads (2022b).

Due to the state's vast road network and material demand, the ability to use mine waste materials for infrastructure development and maintenance will be a balance between the economic benefits of protecting natural materials within 10 km of the construction location vs the economic cost to transport mine waste material a further distance. Other impacts that can affect the economic value of using mine waste materials include:

- pick-up or delivery
- fuel consumption
- labour costs
- insurance
- delays due to weather events, accidents, etc.

6.4 Main Roads' Mine Waste Material Initiatives

6.4.1 Accessing Mine Waste Material

As outlined in Section 4.2, Main Roads have capitalised on mine waste material across WA. There appear to be more advantages to working with relatively new mines or mines in the closing phase when obtaining access and agreement to use mine waste material. Rehabilitated and historic mine waste material should be avoided. Historic mine waste may not have been processed with the current environmental controls (Lovell & Zelencic 2021). The process Main Roads have followed to secure mine waste material is outlined in Appendix E.3.

Upon advice from Department of Mines, Industry Regulation and Safety (DMIRS), Main Roads ensures that the following is addressed during negotiations with the mine operators:

- material removed is not designated material stockpiled to assist in the closure of the mine operation
- road building material will be stockpiled in a safe, stable and non-polluting manner on the mining tenement until it is ready to be used
- material provided will be captured within subsequent updates of the tenement holder's mine closure plan.

Although tenement holders were willing to provide mine waste materials at no cost, DMIRS indicated that royalties are due under Section 109(1)(a). Even when the cost of hauling material from commercial suppliers are compared to the cost of royalties, tens of millions of dollars can be saved.

6.4.2 Utilisation within the Road Pavement

Main Roads have focused on utilising overburden and waste rock, with tailings and industry by-products requiring further investigation and consideration. Overburden and waste rock have been targeted due to their being natural, untreated and generally free from contaminants. Depending on the ore type and processing requirements, tailings and industry by-products generally contain contaminants as remnants from their chemical processing.

A mine waste material's engineering properties are compared to Main Roads' Specification 302 and Specification 501 to establish if they satisfy the existing requirements. Where other material is available on the project but not satisfying the specified requirements, blending the mine waste material with other available material is explored to achieve the specified requirements.

Mine waste materials have been used as embankment fill, subbase, crushed rock basecourse and, in one instance, sealing aggregate.

Using mine waste material within the pavement structure mitigates any potential low-level contaminants still remaining within the mine waste material. These pavements are typically sealed with a wearing coarse asphalt or bituminous surfacing seal, which significantly reduces moisture movement throughout the structure. Placing a material layer over road distances constructed with mine waste reduces the potential of any contaminates leaching to a low-risk level by dilution of their initial concentrations.

Using mine waste in road pavements also lends itself to re-use, should the road require upgrading or future rehabilitation.

6.4.3 Misuse

There are concerns about the misuse of recycled materials incorporated in road construction. Roads should not be viewed as alternative avenues for waste disposal; instead, a material's suitability for re-use should add value and maintain (or enhance) existing performance. Recycled waste materials should have equivalent or better performance characteristics than conventional materials and should not pose an unacceptable risk to the environment, safety or human health. Additionally, materials used in road surfaces and pavements that include recycled materials should also be re-usable/'re-recyclable'. A life cycle assessment should consider the potential environmental and health impacts during the asset's construction, operation and decommissioning.

Roads are subject to environmental impacts and loads, so including inappropriate quality or performance materials can lead to premature failures. Premature failures increase life cycle costs and can offset the environmental benefits of using recycled materials. Therefore, all materials must deliver the required serviceability, functionality, durability and resilient performance to meet the long-term transport outcomes without premature degradation and costly remediation.

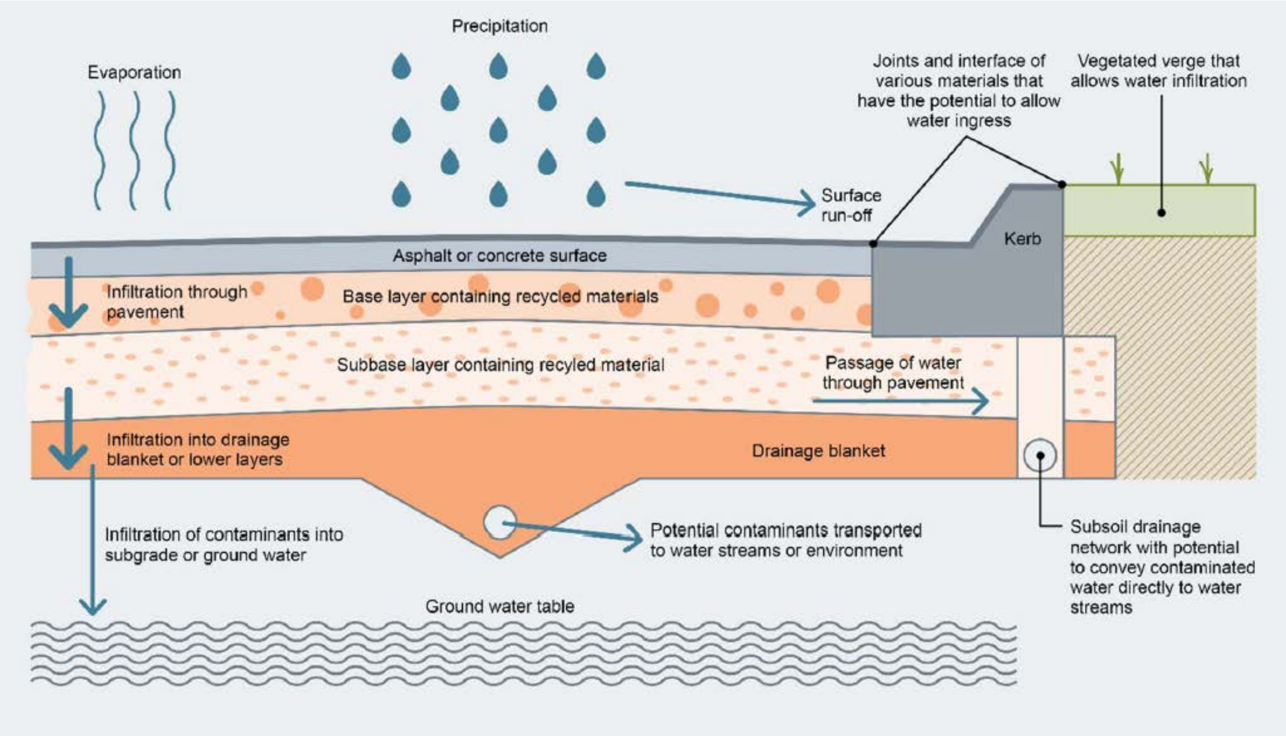
7 Contaminant Considerations

Waste landforms are designed and constructed to ensure that hazardous or challenging materials are appropriately encapsulated within the dump, including:

- those with acid metalliferous drainage potential
- those with high salinity
- those that are highly dispersive
- any other potentially polluting leachate.

Figure 7.1 shows a typical urban road section in WA and demonstrates water-related mechanisms that may allow contaminates to leach into the surrounding environment. Each recycled material should be assessed for its likelihood to leach undesirable, regulated or prohibited contaminates into the environment, and the impact associated with any such leaching.

Figure 7.1: Illustrated interactions between water mechanisms and road pavement cross-section



Source: Adapted from Austroads (2022) and Main Roads supplement to Austroads Guide to Road Design Part 3 (Main Roads 2022c).

Extreme precaution must be taken when considering tailings and by-products generated from the processing of sulfidic ores. Residual sulphides in the waste can generate acid waters upon oxidation that can result in the release of residual heavy metals into surface and ground water resources.

7.1 Acid Metalliferous Drainage (AMD)

AMD is a specific type of wastewater that stems from sulfidic ore bodies. Upon exposure to the environment, certain rock and soil types have the potential to become acidic through oxidation of pyrite and other sulphides that may be released into the surrounding environment. Due to mineralogy and other environmental factors (especially climate), the potential for AMD formation is exceedingly variable from site to site.

A discharge of acid wastewater into water bodies can have deleterious environmental impacts upon the biota and ecological balance. Furthermore, resources (e.g. drinking water supplies, irrigation systems) downstream from mining sites can be threatened by AMD (Department of Mines and Petroleum (DMP) 2009).

In terms of acid-forming capacity, mine waste materials are classified as either non-acid forming (NAF) or potentially acid forming (PAF). The acid neutralising capacity (ANC) and the maximum potential acidity (MPA) are used to determine NAF and PAF. Criteria distinguishing NAF from PAF vary; however, the standard PAF criteria used at mining operations is:

- NAF: ANC/MPA* ratio ≥ 2.
- PAF: ANC/MPA ratio < 2.

Where MPA (maximum potential acidity) is calculated from (Total percentage H_2SO_4) x 30.6 and is expressed in kg H_2SO_4/tonne.

A major source of acidity from iron ore operations in WA is the oxidation of exposed pyritic shale. This is either directly a source of environmental contaminants of potential concern or indirectly an initiator for the mobilisation of metals.

7.2 Heavy Metal Mobility

Heavy metals and metalloids (metal oxyanions) are distributed throughout mine waste in various geochemical forms, nominally water-soluble, exchangeable, carbonate associated, Fe–Mn oxide-associated, oxidisable (associated with organic matter and/or sulphide minerals) and residual forms. Mobilised metal ions or metalloid oxyanions may be either sorbed or deposited as secondary minerals. However, factors influencing the remobilisation of these sorbed/precipitated minerals are poorly understood. This is particularly true for rock samples taken from either un-weathered (fresh) rock or below the water table.

The toxicity and mobility of heavy metals and metalloids depend not only on total concentrations, but also on their specific chemical and mineral forms, their binding state, the geochemical properties, environmental factors and properties of the receiving environment unconsolidated natural material that could include contaminants.

These potential contaminants include cadmium, lead and mercury and metalloids, metal containing oxyanions (e.g. selenium, arsenic, chromium, etc.) released from rocks with acid neutralising capacity. Many of these ions mobilised at acidic pH may also be soluble at circum-neutral and alkaline pH.

Similarly, most silicates and some carbonate minerals weather more slowly than sulphides and, depending on the mineralogy and availability of minerals within the rock and environmental factors, the onset of AMD may be delayed in the field compared to the laboratory. It has been suggested that unless the rocks are high in sulphur, have low buffering capacity and/or are highly reactive, kinetic leaching tests should be run over 2 to 3 years.

7.3 Investigations to Identify Contaminants

Investigations are used to classify materials and identify the presence of sulphides before use of the material is required. If sulphides are present, their nature, quantity and distribution must be defined to inform preventative or mitigation measures (e.g. selective handling, burial or isolation) (DMP 2009).

Investigations comprise the following:

- **Desktop assessment** (i.e. geology, hydrology, bore logs)
- **Sampling:** Samples will characterise the type and volume of rock materials and account for material variability throughout the period of the mine's life exposed to the environment. Low sulphate and alkaline materials must be identified and quantified. Sand or mineral sand mines are assessed and managed by

the Acid Sulphate Soils (ASS) guidelines developed by the Department of Environment and Conservation.

- **Laboratory analysis:** Geochemical testing is performed on mine waste samples to determine the current and potential long-term geochemical characteristics of the waste material. Basic screening tests to assess the acid-forming capacity of mine waste materials are:
  - pH
  - electrical-conductivity (EC)
  - acid-base accounting (ABA)
  - multi-element composition
  - mineralogy.

  Acid-base accounting (ABA) identifies the risk of acidic and/or metalliferous water discharging into the environment. ABA is a preliminary suite of static tests used to evaluate the balance between acid generation processes and acid neutralising processes at a single point in time. This evaluation is based on the calculation of acid production from sulphur content, preferably the non-sulphate sulphur (i.e. sulphide sulphur) and the acid neutralisation capacity (ANC) of the rock. Values derived from ABA are the maximum potential acidity (MPA) and ANC. The ABA calculation includes quantifying total sulphur and sulphate sulphur content.

  Kinetic tests (i.e. column tests) attempt to mimic natural oxidation reactions of the field settings. They measure sulphide reactivity and weathering behaviour, including oxidation rate and metal leaching. These tests are primarily used to predict the onset of AMD, but more recently they Have been used to predict the impact on ground and surface water quality. These tests typically use a larger sample volume and require a much longer completion time (from 26 week to > 104 weeks depending on the rock type) than static tests.

- **Management plan:** Strategies available to prevent or mitigate the impact of AMD include avoidance of disturbance, dry covers, underwater storage, neutralisation and collection and treatment. Each strategy targets a different aspect of AMD using other mechanisms or processes and varies in effectiveness. However, avoiding the disturbance of a PAF material is always the preferred option. PAF materials are inert, provided no exposure to oxygen and water occurs. When PAF material is disturbed, mitigation strategies to minimise AMD requires the control of oxygen diffusion, water infiltration and neutralisation of existing and potential acidity. Mitigation strategies are dry cover systems, water cover systems and neutralisation.

  The dry cover system is a common AMD prevention and control technique. This system minimises the influx of water and provides an oxygen barrier. Also, it should resist erosion and support vegetation. For example, a low permeability layer, typically achieved through compaction of local borrow material, is placed directly on the underlying waste. The objective is to provide a hydraulic barrier to the percolation of water. A non-compacted layer must overlay the compacted layer to establish a sustainable vegetation cover and reduce the net percolation. Additional design objectives for dry cover systems placed on reactive tailings and waste rock may consider oxygen consumption (organic cover materials) and reaction-inhibiting materials (e.g. limestone).

7.4 Advanced Testing Options

Australian standard leaching protocol (ASLP) is used to assess the leaching potential of wastes, sediments and contaminated soils including processed mine waste (e.g. tailings). These tests help to inform mine site closure planning, waste storage and long-term management. The ASLP is derived from the USEPA Method 1311-Toxicity Characteristic Leachate Procedure (TLCP) with the primary difference being the maximum particle size of the test material is to be 2.4 mm for ASLP and 9.5 mm for TLCP.

Sequential leach testing (alternative) can rapidly predict the likely order of species mobilisation and the extent of extraction of metal ions and metalloids that would be leached from waste rock material in non-acid environments (a process known as neutral metalliferous drainage) by leaching samples with a sequence of increasingly aggressive solvents to:

- elucidate the chemical speciation of elements in soils and rocks

- characterise municipal wastes, soil, sediments, and mineral processing wastes
- characterise waste rocks associated with the mining of base metals.

Early identification of these metal/rock type risk factors can be used to support the EIA process and inform subsequent longer-term kinetic leaching studies to:

- validate predictions
- better understand potential risks
- better inform mining operation risk management strategies, including mine waste storage options and ultimately mine site closure.

Leaching Environmental Assessment Framework (LEAF)

The Leaching Environmental Assessment Framework (LEAF) is a collection of data management tools, leaching tests and methods developed to assess the environmental impact of using waste-derived materials and by-products in the environment.

LEAF combines geochemical modelling and laboratory-based tests to help understand how these products will behave in the environment in the long-term and can lead to more informed decisions regarding how best to manage industrial waste and use of by-products.

The LEAF tools can be applied to a wide range of waste-derived materials and by-products from a range of industrial processes, including water treatment and mineral processing residues.

Recommended leaching tests include:

- LEAF 1313 (USA EPA SW-846 Method 1313)
  - Liquid-Solid Partitioning as a Function of Extract pH using a Parallel Batch Extraction Procedure
- LEAF 1314 (USA EPA SW-846 Method 1314)
  - Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio (L/S) using an Up-flow Percolation Column Procedure
- LEAF 1315 (USA EPA SW-846 Method 1315)
  - Mass Transfer Rates in Monolithic and Compacted Granular Materials using a Semi-dynamic Tank Leaching Procedure
- LEAF 1316 (USA EPA SW-846 Method 1316)
  - Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio using a Parallel Batch Extraction Procedure.

8 Main Roads WA

8.1 Sustainability Policy

Main Roads is an agency in the Department of Transport that is responsible for the state's road network (Main Roads 2022a).

Main Roads is committed to developing a transport network that meets social, economic and environmental needs. Following the publication of the agency's strategic direction 'Keeping WA Moving' in 2015, Main Roads published its 'Sustainability Policy' in 2016. This policy outlines Main Roads' intent and objectives to deliver sustainable transport and is reviewed every 2 years.

Behind the intent of this policy are 6 key aspects that were developed in line with stakeholders within the Transport Portfolio, and each aspect aligns with an objective in the 'Sustainability Policy':

- Sustainable Transport
- Climate Change
- Environmental Footprint
- Behaviour
- Governance & Performance
- Funding and Financing.

8.2 Specifications

Main Roads' sustainability considerations are reiterated throughout specifications, with sustainability clauses incorporated to outline the sustainability hierarchy. For example, Specification 501: *Pavements* (Main Roads 2022a) outlines the requirements for pavement material management through the following:

- **Reduce** – materials are sourced from pits or quarries of natural materials that are finite, and waste shall be reduced to a minimum.
- **Re-use** – redundant pavement materials should be recovered, re-used, or recycled for the highest-level practical use. Repurposed materials shall be processed to produce a homogenous material and meet the specified requirements for either a subbase or basecourse.
- **Recycle** – manufactured materials sourced from Construction & Demolition (C&D) waste can be recycled for pavement construction uses. Recycled materials shall be processed to produce a homogenous material by a DWER licensed recycling premise.

8.3 Engineering Road Notes

Austroads Guides inform the design, construction, maintenance and operation of the road network in Australia and New Zealand (Austroads 2022). Each state publishes supplement documents to the Guides, which adapt the Guides to the particular conditions within the state. Main Roads' supplement documents are called Engineering Road Notes (ERN). ERN 9 outlines the procedure for the design of road pavements. Other ERNs are available on Main Roads' website (mainroads.wa.gov.au) under the Technical Library.

9 Proposed Framework for Assessing Mine Waste in WA

9.1 Austroads AGPT04E Guidelines

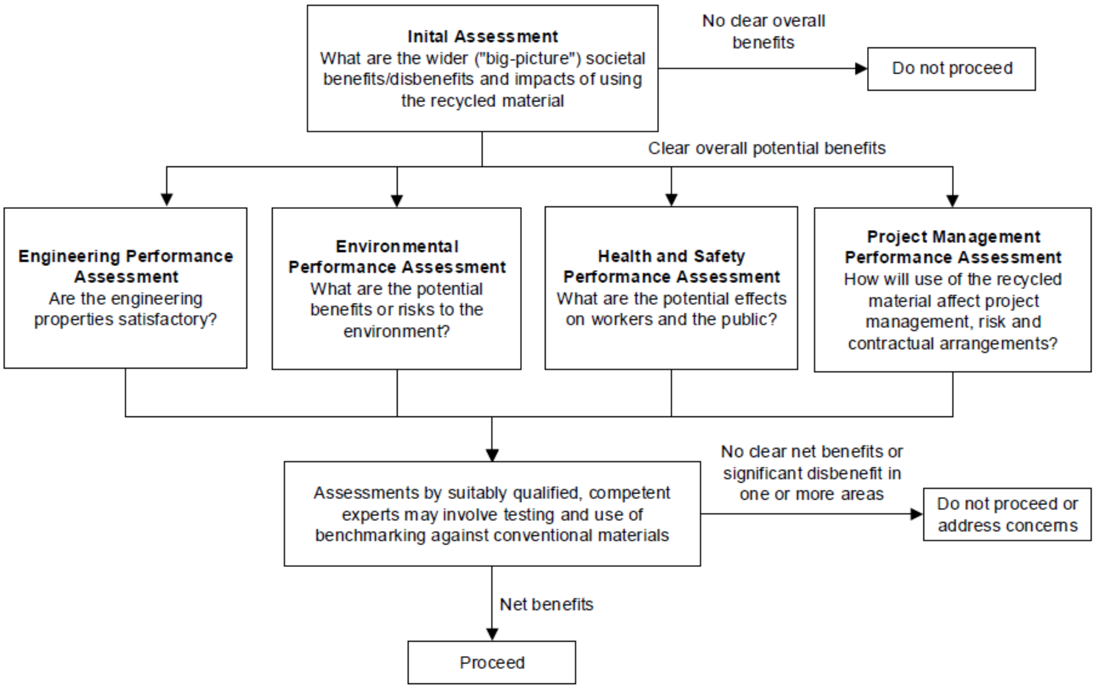
Austroads' 2022 updated *Guide to Pavement Technology Part 4E: Recycled Materials* (AGPT04E) presents the latest information on recycled materials pertaining to products manufactured from recycling various wastes accepted through registered recycling and reprocessing facilities (Austroads 2022).

The guide deals with the specification, manufacture and application of various products for use in road infrastructure applications derived from:

- C&D waste from the building industry
- RAP from pavement maintenance and rehabilitation activities
- recycled rubber from end-of-life tyres (crumb rubber)
- industrial slag from manufacturing processes
- fly ash from coal fired power generation
- recycled plastics from various sources
- recycled glass from various waste glass sources.

A high-level framework to assess recycled materials for their suitability in road infrastructure applications is presented as a flowchart (Figure 9.1) examining various project aspects including engineering, environmental, health and safety and project management factors.

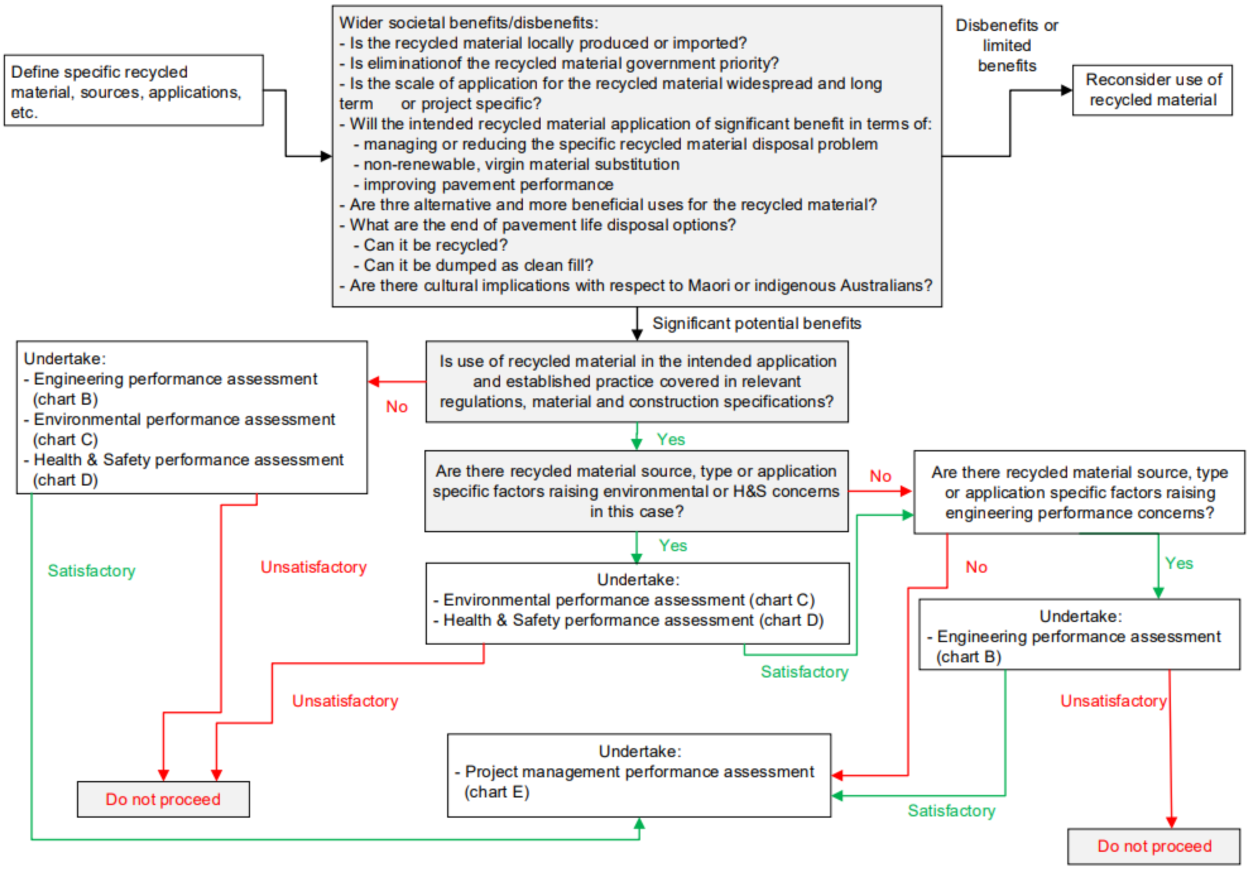
Figure 9.1: Austroads recycled material assessment framework overview



Source: Austroads (2022).

The Austroads (2022) framework starts with an initial assessment, which is elaborated into further assessment if using the recycled material appears to have significant benefits (Figure 9.2).

Figure 9.2: Initial assessment framework



Source: Austroads (2022).

9.2 Main Roads Framework for Assessing Mine Waste

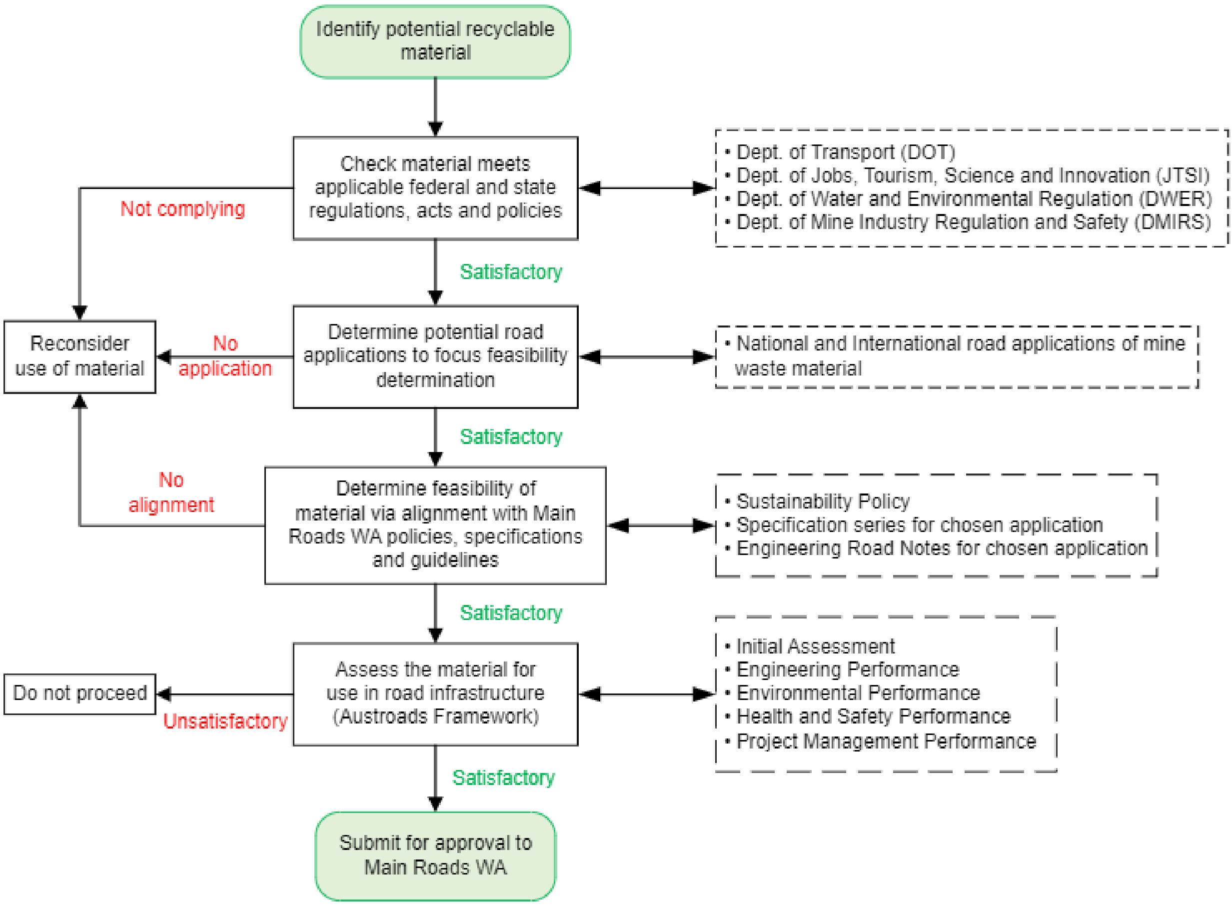
Main Roads proposes a framework for assessing mine waste that aligns with Austroads (2022) and is summarised in Figure 9.3.

Those considering the use of mine waste as an alternative to natural resources for specific projects should be responsible for leading the investigation into the potential benefits, engineering, environmental, health & safety and project management performance assessments as defined in the framework.

If Main Roads was considering using mine waste as a resource for a specific project (example presented in Section 6.4), the onus lies with Main Roads to demonstrate that these materials are suitable through leading the assessment process as per the Austroads (2022) framework. Furthermore, Main Roads will determine suitability throughout the various stages of assessment using the Main Roads Consequence and Likelihood Table contained in Appendix F as an internal risk assessment to the framework.

When a mining company is looking for offsets for their mine waste material, they are responsible for leading the potential benefits, engineering, environmental, health, safety and project management performance assessments with support from relevant subject matter experts.

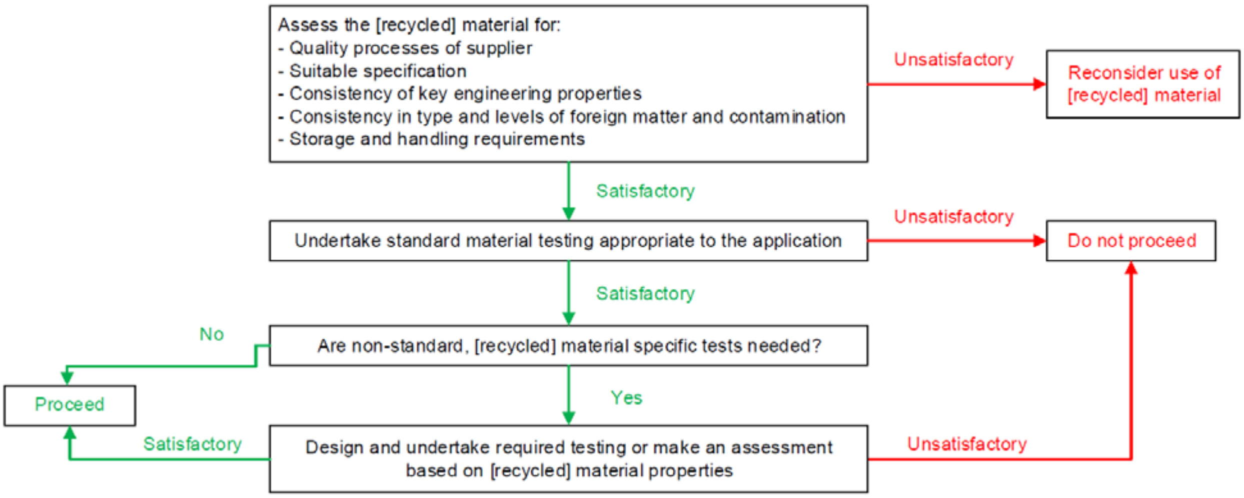
Figure 9.3: Main Roads proposed framework for assessing mine waste materials



Source: Adapted from Austroads (2022).

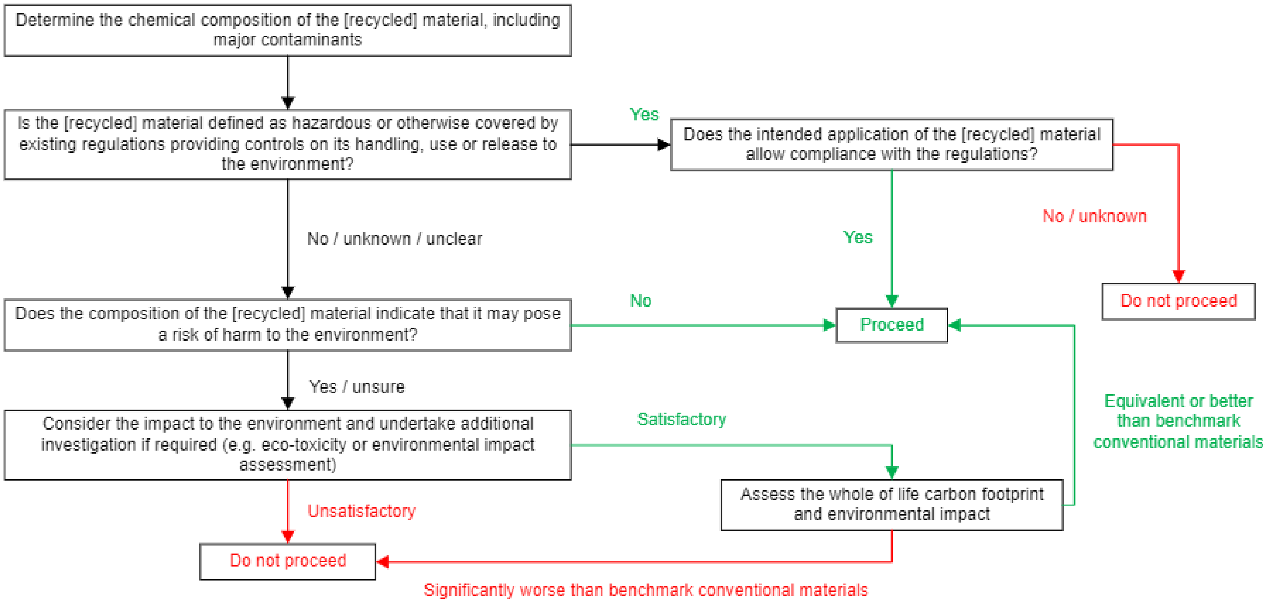
Figure 9.4 to Figure 9.7 are Austroads (2022) charts B to E, to be used as indicated in the framework above. Details on what these assessments could contain is outlined in Austroads (2022) and not repeated in this report.

Figure 9.4: Engineering performance assessment



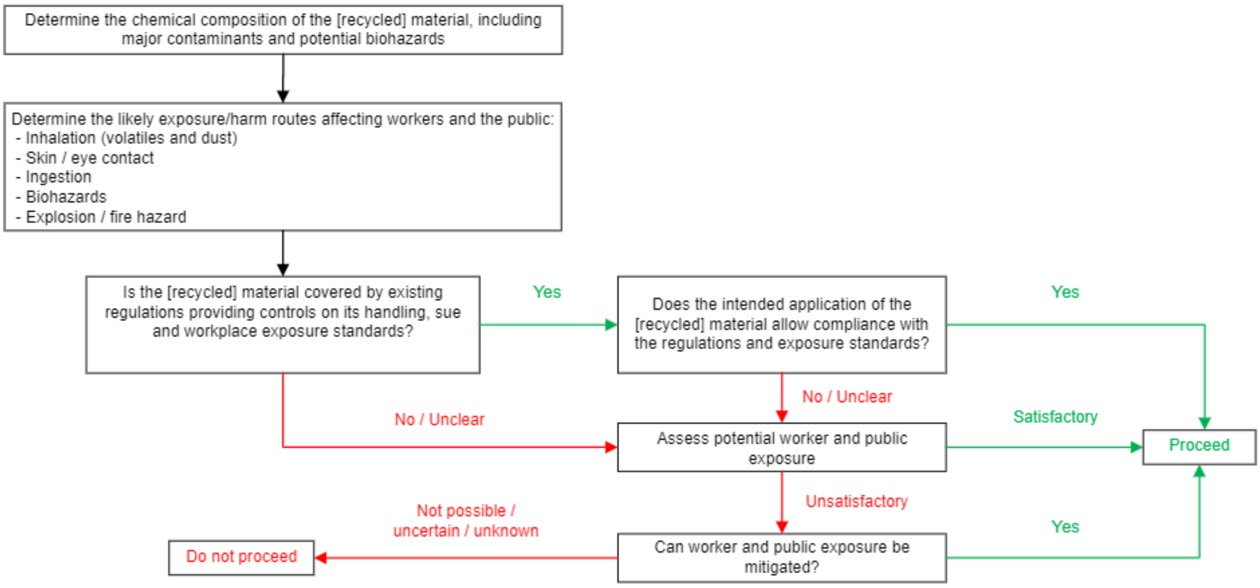
Source: Austroads (2022).

Figure 9.5: Environmental performance assessment



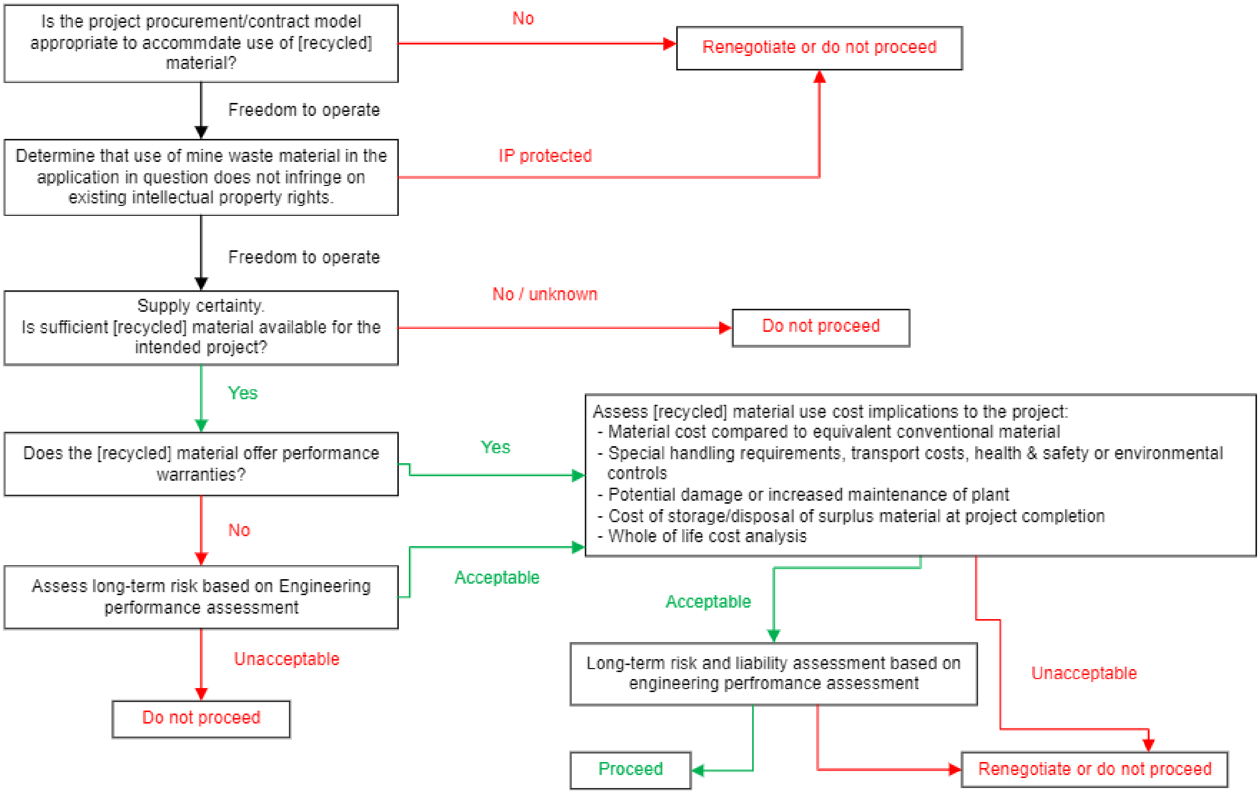
Source: Austroads (2022).

Figure 9.6: Health and safety performance assessment



Source: Austroads (2022).

Figure 9.7: Project management performance assessment



Source: Austroads (2022).

10 Recommendations to Main Roads (Commercial in Confidence)

On the basis of this investigation, the following recommendations are made for mine waste assessments to be considered for their implementation in road infrastructure applications:

- Guidelines and a framework for determining the suitability of mine waste materials for use in road infrastructure applications are needed in WA.
- Endorse a protocol and assessment framework to rigorously scrutinise materials and to provide Main Roads with a deeper understanding of the associated risks and benefits in using mine waste materials.
- Disseminate information contained within this report internally and provide interested companies with the guidelines for mine waste they wish to be assessed and considered for use in road infrastructure.
- Publish a redacted report to the WARRIP website for easy access and third-party hosting of guidelines.
- Regularly revisit and update report as new regulations are adopted.
- Ensure that all processes and considerations outlined above have been undertaken prior to providing a full assessment to Main Roads for consideration.

11 Conclusions

The commitment to using recycled materials and promoting a circular economy is being promoted through various initiatives across WA. To align with these strategies, Main Roads is seeking alternative materials for use in road infrastructure construction and maintenance that reduce the reliance on natural materials.

Mining generates a substantial amount of potential usable waste, with associated cost and time saving and other potential by-products. This report serves as a guideline and contains a framework for determining the suitability of mine waste materials for use in road infrastructure applications previously did not exist in WA.

This assessment method provides a consistent approach to material assessment in WA and will provide a pathway for improving the body of knowledge of approved mine waste materials, leading to a greater uptake of mine waste materials in road applications in WA. By thoroughly considering the types of mine waste materials that can be utilised, the potential applications in road infrastructure and the contaminants that could be released into the environment, the uptake of waste material will become a cost effective process that contributes greatly to the sustainability of our country.

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Test Methods

SW-846 Test Method 1311, Toxicity Characteristic Leaching Procedure.

SW-846 Test Method 1313, Liquid-Solid Partitioning as a Function of Extract pH using a Parallel Batch Extraction Procedure.

SW-846 Test Method 1314, Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio (L/S) using an Up-flow Percolation Column Procedure.

SW-846 Test Method 1315, Mass Transfer Rates in Monolithic and Compacted Granular Materials using a Semi-dynamic Tank Leaching Procedure.

SW-846 Test Method 1316, Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio using a Parallel Batch Extraction Procedure.

Appendix A Circular Economy Regulation

A.1 Federal Policies and Initiatives Designed to Increase Uptake of Recycled Materials

Federal policies supporting the *Australian Federal Recycling and Waste Reduction Act's* commitments include:

- the Sustainable Procurement Guide in 2020 which will enable Commonwealth agencies to better consider sustainable and recyclable materials in their procurement practices (Australian Government 2020).
- the updated Commonwealth Procurement Rules in 2020, which require the consideration of non-financial benefits and costs of the procurement, including environmental sustainability and whole-of-life costs (Department of Finance 2020).

A.2 Department of Mine, Industry Regulation and Safety (DMIRS)

A.2.1 Legislation and Compliance

The *Mining Act 1978* outlines the laws related to mining for incidental and other purposes. Tenement holders must comply with specific conditions and covenants imposed on mining tenements which involves submitting to the statutory requirements of the specific mining tenement.

Additional acts and regulations that also inform conditions and covenants of mining tenements are:

- *Mining Regulations 1981*
- *Environmental Protection Act 1986*
- *Environmental Protection Regulations 2004*
- *Mines Safety and Inspection Act 1994*
- *Mines Safety and Inspection Regulations 1995.*

A.2.2 Mining Proposals and Mine Closure Plans

The *Mining Act 1978* specifies that all companies looking to mine a tenement must submit a mining proposal detailing the proposed mining operation or a change to a mining operation. These proposals must include a mine closure plan that outlines strategies for mine waste management, such as:

- confirming whether waste rock or tailings will be generated
- confirming whether the waste rock will be stockpiled as a permanent landform
- confirming whether waste rock and overburden will be backfilled into excavations or stockpiled as a permanent landform
- providing a description of any unsuitable materials in the waste rock, tailings, or material to be leached
- determining material characteristics to inform the following:
  - presence of fibrous materials
  - presence of radioactive materials
  - confirm materials' capability to generate acid and metalliferous drainage, including neutral drainage and saline drainage
  - presence of dispersive and erosive materials
- confirming whether a heap/vat leach is proposed and describe the heap/vat leach.

All landforms and disturbances related to mining activities must be rehabilitated into safe, stable and non-polluting landforms. The landforms must integrate into the surrounding landscape and support a self-sustaining, functional ecosystem or alternative agreed outcome to the satisfaction of DMIRS.

Standard tenement conditions imposed under the *Mining Act 1978* for approved mine closure plans include:

- All excavations will be backfilled and closed to ensure they are stable and safe.
- Pit wall subsidence or the zone of pit instability must not impact the final footprint of waste materials after rehabilitation.
- All waste materials, rubbish, plastic sample bags, abandoned equipment and temporary buildings will be removed from the mine before or at the termination of the operation.
- Watercourses disturbed by mining operations will be restored to the pre-disturbance conditions as practicable.
- Shafts will be covered, fenced, or otherwise made safe.
- All chemicals and hydrocarbons will be removed from the site before or at the termination of the operation.

For heap/vat leach facilities:

- Upon discontinuation of use of heap leach or vat leach facilities, the lessee is to appropriately flush each facility to ensure the absence of free cyanide within the facility.

A.2.3 Royalties

The *Mining Act 1978* addresses royalties in Section 109, with Section 109(1)(a) stating that '…royalties shall be paid in respect of minerals or any class of mineral, obtained from land that is subject to a mining lease or other mining tenement granted under this Act…'

WA's three-tiered royalty system applies royalty rates depending on the form the mineral is sold as (ore, concentrate or final form) and the extent to which it is processed. Specific rates are applied on a per tonne of production.

Mining Regulations 1981 specifies that royalty rates are applied to low-value construction and industrial materials. The two royalty rates applied to production between 1 July 2015 and 30 June 2025 are:

- Amount A: 73 cents per tonne
- Amount B: 117 cents per tonne.

A.3 DWER Waste Definitions

A.3.1 Definition of Waste

Section 3(1) of the EP Act and Section 3(1) of the WARR Act define **waste** to include matter:

- whether liquid, solid, gaseous, or radioactive and whether useful or useless, which is discharged to the environment; or
- prescribed to be waste.

While not exhaustive, this definition of waste in the EP Act and WARR Act also includes the standard dictionary definition.

As per the WA Courts, waste includes:

- 'anything left over or superfluous, as excess material, by-products etc., not of use for work in hand' (i.e. unwanted or excess material, viewed from the perspective of its source); and/or
- any matter whether useful or useless which is gotten rid of into the environment.

Further clarification on determining whether a material is waste from DWER (2018, p.2–4) stipulates the following:

Point of view of the source/producer

For the purposes of the licensing and waste levy regimes, whether material that is received at premises is waste or not must be assessed from the perspective of the person who is the source/producer of the material and not the receiver of the material.

Accordingly, the fact that the receiver of the material considers it useful (e.g. to fill their land) and economically valuable (e.g. as a substitute for purchased fill material) does not mean that the material is not waste.

If material is unwanted or excess to requirements, viewed from the perspective of its source/producer, the material is waste.

The source/producer of material that is excavated at one site and taken to another will be the owner of the material at its source. This will often be (but will not necessarily always be) the owner of the land from which the material is excavated.

Concept of being ‘unwanted’

Even if material is left over from, or a by-product of, a particular project and not wanted by its source/producer for that project, it may still be wanted by them for use for some other project (on the same site or a different site) or for sale to a third party.

Material wanted by its producer/source for use in some other project or for sale to another person is not considered to be waste.

Payments Relating to the materials

Whether or not a third party pays for material or is paid to receive material from its producer/source, is a relevant consideration in assessing whether the material is waste.

If the producer of material pays a third party to receive it and dispose of it for them, this indicates that the producer does not want the material and it is waste. However, if material is sold by a producer to a third party, this will generally indicate that the material is a valuable commodity wanted by the producer for sale.

Substantially transformed

Material that is waste at a certain point in time may stop being waste if it is re-used in certain ways, sufficiently processed, or is recycled.

It is recognised in categories 13, 39, 44, 61, 61A, 62 and 67A in Schedule 1 of the EP Regulations, in section 5(1) of the WARR Act and in regulation 5(1)(b) of the WARR Levy Regulations that waste may be transformed into something else through re-use, processing (including treatment), recycling or use in energy recovery.

However, the decisions of the courts in the Eclipse case confirmed that the use of waste as fill to be buried does not qualify as the "re-use" of waste within the meaning of the WARR Levy Regulations or WARR Act. Waste that is buried and used as fill is considered "waste disposed of to landfill" within the meaning of the Levy Regulations.

When assessing whether material is waste, or still waste, at any particular point in time it may be relevant to consider whether and how it has been transformed into a product or good and the extent of the transformation or conversion. A mere intent to convert waste into a product or good is not sufficient.

The fact that material has been subject to some degree of processing does not necessarily mean that it has become a product or ceased to be waste. For example, the courts have found that merely sorting waste to exclude some contaminants does not mean that the material is no longer waste.

Consideration of whether material that is waste at a particular point in time has been substantially or materially transformed and converted into a product or good so that it is no longer waste at a different point in time will depend on a number of factors, such as:

- the type of processes the waste has been subjected to;
- the degree or extent of the transformation of the material; whether the essential nature, form and/or utility of the material has been substantially or materially changed;

- whether any relevant specifications or standards (including environmental specifications and standards) have been met; and
- whether there is an economic demand for the material in its altered state.

A.4 DWER Process for Waste Classification

DWER's document *Landfill Waste Classification and Waste Definitions 1996 (as amended 2019) (*DWER, 2019) provides guidance and criteria for determining the classification of wastes for acceptance to landfills. To ensure waste materials are sent to appropriate facilities, DWER outlines the following process for waste classification:

1. **Ensure that an assessment is needed**: Waste assessments are evaluated under a broad classification of waste types: clean fill, uncontaminated fill, inert, putrescible, neutralised acid sulfate soil, etc.
2. **Assess the waste**: Evaluate waste source characteristics such as the presence and concentration of relevant contaminants.
3. **Compare contaminant levels to threshold criteria**: Compare the contaminant concentrations with the maximum contaminant threshold values and assign a classification for each contaminant.
4. **Determine Australian Standard Leaching Procedure (ASLP) leachate concentrations**: Should the classification in step 2 be unacceptable, or any contaminant concentration exceeds the relevant threshold values, determine the ASLP leachate concentrations for all relevant contaminants.
5. **Compare ASLP leachate concentrations with criteria**: Compare the contaminant ASLP concentrations and total concentrations with the ASLP and concentration limit (CL) values in (Appendix B.3). Use Appendix B.4 as a guide to interpret the data for each contaminant.
6. **Test the immobilised waste against the ASLP criteria in B.3**: If the classification in step 4 is unacceptable, apply some form of immobilisation to the waste, then, after further leachate testing, apply the ASLP criteria only, to determine the appropriate waste classification as set out in step 5.

Refer to Appendix B.2 for the associated tables that detail DWER's contaminant threshold values and guidelines used in the interpretation of the above process.

A.5 Description of Category 63 to 65 in EP Regulations

Table A.1: Description of Category 63 to 65 in EP Regulations

Category number	Description of category	Production or design capacity
63	Class I inert landfill site: premises (other than clean fill premises) on which waste of a type permitted for disposal for this category of prescribed premises, in accordance with the Landfill Waste Classification and Waste Definitions 1996, is accepted for burial.	500 tonnes or more per year
64	Class II or III putrescible landfill site: premises (other than clean fill premises) on which waste of a type permitted for disposal for this category of prescribed premises, in accordance with the Landfill Waste Classification and Waste Definitions 1996, is accepted for burial.	20 tonnes or more per year
65	Class IV secure landfill site: premises (other than clean fill premises) on which waste of a type permitted for disposal for this category of prescribed premises, in accordance with the Landfill Waste Classification and Waste Definitions 1996, is accepted for burial.	Not applicable

Appendix B Landfill Waste Classification and Definitions

B.1 Definitions

The following definitions are extracted from the *Landfill Waste Classifications and Waste Definitions 1996 (as amended 2019) (DWER, 2019).*

Acceptance criteria	The concentration and leachate criteria published in this document (these may be varied for individual landfills in accordance with specific licence conditions)
Biodegradable	Capable of being decomposed by the action of biological processes
Class I landfill	An unlined landfill designed to accept inert wastes for burial
Class II landfill	An unlined landfill designed to accept putrescible and inert wastes for burial
Class III landfill	A lined landfill, which may include leachate collection, designed to accept putrescible and inert wastes for burial
Class IV landfill	A double-lined landfill with leachate collection, designed to accept contaminated soils and sludges (including encapsulated wastes) for burial
Class V landfill	Intractable landfill site: premises on which waste (as determined by reference to the waste type set out in the document entitled 'Landfill Waste Classification and Waste Definitions 1996' published by the Chief Executive Officer and as amended from time to time) is accepted for burial
Clean fill	Raw excavated natural material such as clay, gravel, sand, soil or rock fines that: a. has been excavated or removed from the earth in areas that have not been subject to potentially contaminating land uses(1) including industrial, commercial, mining or intensive agricultural activities; and b. has not been processed except for the purposes of: i. achieving desired particle size distribution; and/or ii. removing naturally occurring organic materials such as roots; and c. does not contain any acid sulfate soil; and d. does not contain any other type of waste.
Construction and demolition waste (C&D waste)	Materials in the waste stream which arise from construction, refurbishment or demolition activities
Contaminant	A substance or object in contact or mixed with a material that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value
Contaminated soil	Soil that has a substance in it at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value
Controlled waste	Waste types listed in Schedule 1 of the *Environmental Protection (Controlled Waste) Regulations 2004*
Encapsulation	The process of enclosing a waste within a secure container such as to render it acceptable for long-term disposal
Hazardous waste	The component of the waste stream which by its characteristics poses a threat or risk to public health, safety or the environment (includes substances which are toxic, infectious, mutagenic, carcinogenic, teratogenic, explosive, flammable, corrosive, oxidising and radioactive)
Immobilisation	The process of fixing or locking up contaminants in a waste such as to render it suitable for long-term disposal
Inert waste type 1	Non-hazardous, non-biodegradable (half-life greater than 2 years) wastes containing contaminant concentrations less than Class I landfill acceptance criteria, but excluding paper and cardboard and materials that require treatment to render them inert (e.g. peat, acid sulfate soils)
Inert waste type 2	Waste consisting of stable non-biodegradable organic materials such as tyres and plastics which require special management to reduce the potential for fires
Inert waste type 3	Waste material from licensed secondary waste treatment plants, subject to appropriate assessment and approval of that waste and the specified inert landfill
Intractable waste	Waste whose toxicity or chemical or physical characteristics make it difficult to dispose of or treat safely, and is not suitable for disposal in Class I, II, III and IV landfill facilities
Leaching procedure	The procedures specified in AS 4439.3-1997 *Wastes, Sediments and Contaminated Soils: Preparation of Leachates: Bottle Leaching Procedures*

Neutralised acid sulfate soil	Neutralised acid sulfate soil treated in accordance with *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DER 2015) and *Treatment and Management of Soil and Water in Acid Sulfate Soil Landscapes* (DER 2015)
Poisons	Materials defined as poisons under the *Poisons Act 1964*
Practical quantitation limit	The lowest concentration that can be reproduced and measured in a laboratory in routine laboratory analyses irrespective of any interference caused by the presence of other substances, such as chemicals, during the analysis. The practical quantitation limit value of any analyte is significantly higher than its detection limit value
Radioactive	Capable of giving off radiant energy in the form of particles or rays, as in alpha, beta and gamma rays at levels exceeding standards defined by the Radiological Council of Western Australia
Re-use	Use of a product again for the same or a different purpose without further manufacture
Solid	A material that: a. has an angle of repose of greater than 5 degrees; and b. does not contain, or is not comprised of, any free liquids; and c. does not contain, or is not comprised of, any liquids that are capable of being released when the waste is transported; and d. does not become free flowing at or below 60 degrees Celsius or when it is transported; and e. is generally capable of being moved by a spade at normal temperatures (i.e. is spadable)
Spadable	A physical state of a material where the material behaves sufficiently like a solid (as described above) to be moved by a spade at normal outdoor temperatures
Special waste type 1	Waste which includes asbestos and asbestos cement products
Special waste type 2	Waste consisting of certain types of biomedical waste which are regarded as hazardous but which, with the use of specific management techniques, may be disposed of safely within specified classes of landfill
Special waste type 3	Solid waste, including soils and other solid wastes impacted by Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS)
Storage	Placement of material in one place for more than one day with the intention to relocate, re-use or dispose of the material within a time limit specified before commencement of such storage
Treatment	Physical, chemical or biological processing of a waste for disposal or re-use
Uncontaminated fill	a. Inert waste type 1 (excluding asphalt and biosolids) that meets the requirements set out in Table B.4, as determined by relevant sampling and testing carried out in accordance with the requirements set out in Table B.5; and b. Neutralised acid sulfate soil that meets the requirements for relevant metals, metalloids and sulfate set out in Table B.4, as determined by relevant sampling and testing carried out in accordance with the requirements of Table B.5.

1. Appendix B in the Assessment and management of contaminated sites guidelines (DER 2014)

B.2 Maximum Contaminant Threshold Values

Table B.1: Maximum Contaminant Threshold Values

Contaminant[1]	Max. values of total concentration for classification without the requirements to assess leachability[2,3]			
	CT1 (mg/kg) Class I	CT2 (mg/kg) Class II	CT3 (mg/kg) Class III	CT4 (mg/kg) Class IV
Metals and metalloids				
Arsenic	14	14	140	1,400
Beryllium	2	2	20	200
Cadmium	0.4	0.4	4	40
Chromium (Hexavalent)	10	10	100	1,000
Lead	2	2	20	200
Mercury	0.2	0.2	2	20
Molybdenum	10	10	100	1,000
Nickel	4	4	40	400

Contaminant[1]	Max. values of total concentration for classification without the requirements to assess leachability[2,3]			
	CT1 (mg/kg) Class I	CT2 (mg/kg) Class II	CT3 (mg/kg) Class III	CT4 (mg/kg) Class IV
Selenium	2	2	20	200
Silver	20	20	200	2,000
Other inorganic species				
Cyanide (amenable)[4]	7	7	70	700
Cyanide (total)	16	16	160	1,600
Fluoride	300	300	3,000	30,000
Non-chlorinated organics				
Benzene	0.2	0.2	2	20
Cresols (total)	400	400	4,000	40,000
2,4-D	0.02	0.02	0.2	2
Ethylbenzene	60	60	600	6,000
Petroleum hydrocarbons	N/A	N/A	N/A	N/A
Phenol (total, non-halogenated)	28.8	28.8	288	2,880
Polycyclic aromatic hydrocarbons (total)	N/A	N/A	N/A	N/A
Styrene (vinyl benzene)	6	6	60	600
Toluene	160	160	1,600	16,000
Xylenes (total)	120	120	1,200	12,000
Chlorinated organics[5]				
Organochlorine pesticides, polychlorinated biphenyls etc.	N/A	N/A	N/A	N/A
Other metals[6]	% by weight	% by weight	% by weight	% by weight
Aluminium, barium, boron, cobalt, copper, manganese, vanadium and zinc	5	5	10	20

1. For organic and inorganic chemical contaminants not listed in Table B.1 contact the DWER for assessment/disposal advice.
2. Contaminant Threshold (CT) values based on 2004 Australian Drinking Water Guidelines (20 x ASLP criteria – uncorrected for practical quantitation limit).
3. N/A means no Contaminant Threshold applicable; however, the criteria in Table B.2 apply.
4. Analysis for cyanide (amenable) is the established method to assess the potentially leachable cyanide. Other methods may be considered by the Department if it can be demonstrated that these methods yield the same information.
5. OCP scheduled wastes, polycyclic aromatic hydrocarbons and polychlorinated biphenyls are assessed by using concentration criteria (CL values – Table B.2). No leaching analysis is required.
6. For waste containing significant quantities of these metals, preference should be given to recovery and recycling rather than disposal.

B.3 ASLP Leachable Concentration and Concentration Limit Values

Table B.2: ASLP[1] Leachable Concentration and Concentration Limit (CL[2])Values

Contaminant	Class I		Class II		Class III		Class IV	
	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)
Metals								
Arsenic[3]	0.5	500	0.5	500	5	5,000	50	20,000
Beryllium[3,4]	0.1	100	0.1	100	1	1,000	10	4,000
Cadmium[3]	0.1	100	0.1	100	1	1,000	10	4,000
Chromium (hexavalent)	0.5	500	0.5	500	5	5,000	50	2,000
Lead	0.1	1,500	0.1	1,500	1	15,000	10	60,000
Mercury	0.01	75	0.01	75	0.1	750	1	3,000
Molybdenum[4,5]	0.5	1,000	0.5	1,000	5	10,000	50	40,000
Nickel	0.2	3,000	0.2	3,000	2	30,000	20	120,000
Selenium[3,5]	0.5	50	0.5	50	5	500	50	2,000
Silver[5]	1	180	1	180	10	1,800	100	7,200
Aluminium, barium, boron, cobalt, copper, manganese, vanadium and zinc	N/A	5% by weight	N/A	5% by weight	N/A	10% by weight	N/A	20% by weight
Other inorganic species								
Cyanide (amenable)[4]	0.35	1,250	0.35	1,250	3.5	12,500	35	50,000
Cyanide (total)	0.8	2,500	0.8	2,500	8	25,000	80	100,000
Fluoride[5]	15	10,000	15	10,000	150	100,000	1500	400,000
Non-chlorinated organics								
Benzene	0.01	18	0.01	18	0.1	180	1	720
Cresol (total)[4,5]	20	7,200	20	7,200	200	72,000	2,000	288,000
Ethylbenzene[5]	3	1080	3	1,080	30	10,800	300	N/A
C_6-C_9 petroleum hydrocarbons[6]	N/A	2,800	N/A	2,800	N/A	28,000	N/A	112,000

Contaminant	Class I		Class II		Class III		Class IV	
	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)	Leachable concentration ASLP1 (mg/L)	Concentration Limit CL1 (mg/kg)
>C_{16}-C_{35} petroleum hydrocarbons (aromatics)	N/A	450	N/A	450	N/A	4,500	N/A	18,000
> C_{16}-C_{35} petroleum hydrocarbons (aliphatics)	N/A	28,000	N/A	28,000	N/A	280,000	N/A	N/A
Phenols (total, non-chlorinated)	1.44	42,500	1.44	42,500	14.4	425,000	144	N/A
PAHs (total)	N/A	100	N/A	100	N/A	1,000	N/A	4,000
Benzo(a)pyrene	0.0001	5	0.0001	5	0.001	50	0.01	200
Styrene(5)	0.3	108	0.3	108	3	1,080	30	4,320
Toluene(5)	8	518	8	518	80	5,180	800	N/A
Xylenes (total)(5)	6	1,800	6	1,800	60	18,000	600	N/A
Chlorinated organics								
2,4-D(5)	0.3	360	0.3	360	3	1,440	30	5,760
OCP scheduled wastes(8)	N/A	50	N/A	50	N/A	50	N/A	50
Other solvents	N/A	50	N/A	50	N/A	500	N/A	2,000
Polychlorinated biphenyls(9)	N/A	50	N/A	50	N/A	50	N/A	50

1. ASLP values determined as follows: Class I = 10 x Australian Drinking Water Health Guideline (ADWG 2004) value; Class II = Class I; Class III = 10 x Class I; Class IV = 100 x Class I.
2. CL values determined as follows: Class I = National Environmental Protection Measure, Health Investigation Level F (NEPM HIL F) for commercial/industrial land; Class II = Class I; Class III = 10 x Class I; Class IV = 40 x Class I.
3. ASLP1 and ASLP2 values = practical quantitation limit instead of figure derived from ADWG (2004).
4. ASLP values derived from Waste Classification Guidelines Part 1 Classifying Waste (NSW Department of Environment and Climate Change 2008 revised 2009) (Class I = SCC1). This value may be divided by 10 to take into account the sandy WA coastal plain soils (Class I = SCC1).
5. CL values derived from Environmental Guidelines: Assessment, Classification & Management of Liquid & Non-liquid Wastes (NSW EPA 1999) (Class I = SCC1).
6. CL values = one tenth limit for C15- to C35 limits consistent with previous Landfill Waste Classifications and Waste Definitions 1996.
7. Applies to soil contaminated with organochlorine pesticides consistent with Organochlorine Pesticides Waste Management Plan (ANZECC 1999).
8. CL values consistent with Organochlorine Pesticides Waste Management Plan (ANZECC 1999). Note that waste containing < 50 mg/kg is not classified as scheduled wastes for the purposes of this plan.
9. CL values consistent with Polychlorinated Biphenyls Management Plan (ANZECC 1996).

N/A No applicable value, please contact the Department for clarification on a case-by-case basis.

Source: DWER (2019).

B.4 Summary of Criteria for Chemical Contaminants in Waste Classification

Table B.3: Summary of Criteria for Chemical Contaminants in Waste Classification

Landfill class	Acceptance criteria (1,2,3,4,5)	Comments
Inert (Class I)	1. Concentration ≤ CT1	ASLP test not required.
	2. ASLP ≤ ASLP1 and concentration > CT1, ≤ CL1	Leaching solution to be used is water.
	3. ASLP ≤ ASLP1 and concentration > CL1	After immobilisation(6).
Putrescible (Class II)	1. Concentration ≤ CT2	ASLP test not required.
	2. ASLP ≤ ASLP2 and concentration > CT2, ≤ CL2	ASLP required
	3. ASLP ≤ ASLP2 and concentration > CL2	After immobilisation(6).
Putrescible (Class III)	1. Concentration ≤ CT3	ASLP test not required.
	2. ASLP ≤ ASLP3 and concentration > CT3, ≤ CL3	ASLP required.
	3. ASLP ≤ ASLP3 and concentration > CL3	After immobilisation(6) or encapsulation.
Secure (Class IV)	1. Concentration ≤ CT4	ASLP test not required.
	2. ASLP ≤ ASLP4 and concentration > CT4, ≤ CL4	ASLP required. Leaching solution to be specified in site licence.
	3. ASLP ≤ ASLP4 and concentration > CL4	After immobilisation(6) or encapsulation.
Intractable (Class V)(7)	1. ASLP > ASLP4	Store or treat waste as appropriate.
	2. ASLP ≤ ASLP4 and concentration > CL4	Store or treat waste as appropriate.

1. The values CT1–4 refer to concentration threshold criteria specified in Table 3.
2. The values ASLP1–4 refer to leachability criteria (ASLP) specified in Table 4.
3. The values CL1–4 refer to the concentration limit (CL) values specified in Table 4.
4. The acceptance criteria specified in Tables 3 and 4 apply to each toxic contaminant present in the waste.
5. The ASLP and concentration values refer to the test values determined on the basis of sampling and analysis in accordance with approved sampling procedures (typically the mean of the sample distribution plus 1 standard deviation).
6. In certain cases, the Department will require specific conditions, such as the segregation of immobilised waste from all other types of waste in a monofill or amonocell, in order to achieve a greater margin of safety against possible failure of the immobilisation in the future.

Note: Disposal of wastes to the Mount Walton East Intractable Waste Facility is subject to approval by the Environmental Protection Authority.

Source: DWER (2019).

B.5 Maximum Concentrations (Thresholds) of Relevant Chemical Substances and Limits of Relevant Physical Attributes for Uncontaminated Fill

Table B.4: Maximum Concentrations (Thresholds) of Relevant Chemical Substances and Limits of Relevant Physical Attributes for Uncontaminated Fill

Parameter	Max. concentration[1], mg/kg, dry weight	Leaching test[1] ASLP, mg/L
Metals and metalloids		
Antimony	20	3
Arsenic	100	10
Barium	500	–
Beryllium	4	–
Cadmium	1	0.2
Chromium III	160	3
Chromium VI	1	1
Cobalt	50	1
Copper	50	2
Lead	300	3

Parameter	Max. concentration[1], mg/kg, dry weight	Leaching test[1] ASLP, mg/L
Manganese	500	500
Mercury (inorganic)	0.5	0.05
Molybdenum	10	50
Nickel	10	10
Selenium	1	5
Silver	20	0.05
Thallium	1	0.03
Tin (inorganic)	50	–
Uranium	25	0.5
Vanadium	130	–
Zinc	120	10
Other inorganics		
Asbestos[(2)]	102	–
Sulfate	2,500	–
Cyanides	5 complexed (weak acid dissociable) 1 free	5 as CN
Ammonia as N	–	350
Fluoride	400	120
Total nitrogen	–	2,000
Total phosphorus	–	200
Organic compounds		
Benzene	0.5	1
Toluene	85	25
Ethyl benzene	55	5
Xylene (total)	40	20 sum
Total recoverable hydrocarbons (C_6-C_{10})[(3,4)]	45	–
Total recoverable hydrocarbons (>C_{10}-C_{16})[(3)]	110	–
Total recoverable hydrocarbons (>C_{16}-C_{34})[(3)]	300	–
Total recoverable hydrocarbons (>C_{34}-C_{40})[(3)]	2,800	–
Naphthalene	3	15
Benzo[a]pyrene	1	0.01
Carcinogenic polycyclic aromatic hydrocarbons (PAHs) as B(a)P TEQ (8 species)	3	–
Total PAHs5 (16 species)	300	–
Phenol	1	50
Cresols	–	2 (sum)
PCBs	1	–
Pesticides		
Aldrin	–	0.001
Dieldrin	–	0.01
DDT+DDD+DDE	3	0.006 DDT 0.0005 DDE
Other pesticides	–	< ADWG6 and < WQG7
Physical attributes		
pH (pH units)8	5.5–8.5	–

1. Refer AS 4439 using reagent water. Both total concentration and leaching analyses are required to assess the quality of the fill material unless no value is included in Table B.4 (indicated by '-').

2. Restrictions apply to the sale and supply of any asbestos and asbestos cement material other than for disposal. The maximum concentration is based on the product specification for recycled products in the *Guidelines for managing asbestos at construction and demolition waste recycling facilities* (DEC 2012 and as updated from time to time). The concentration indicated is equivalent to 0.001% asbestos weight for weight as specified in the guideline. The inspection, sampling and testing of fill material must be completed by a person who is competent in assessing the fill in the manner indicated by the guideline.
3. Thresholds for total recoverable hydrocarbons are applicable to petrogenic hydrocarbons (such as from petrol, diesel, crude oil, etc.). Additional analytical methods, such as silica gel clean-up and chromatographic interpretation, may be applied to differentiate between petrogenic and biogenic hydrocarbon sources. Refer to Schedule B3 of National Environment Protection (Assessment of Site Contamination) Measure (ASC NEPM).
4. Threshold applies to 'F1' fraction, comprising total recoverable hydrocarbons (C6−C10) not including the sum of BTEX (benzene, toluene, ethylbenzene, xylenes). Refer to Schedule B1 of the ASC NEPM.
5. Carcinogenic PAHs (as B (a) P TEQ): is based on the 8 carcinogenic polycyclicaromatic hydrocarbons (PAHs) listed below and their potency relative to benzo (a)pyrene. The B(a)P toxicity equivalence quotient (TEQ) is calculated by multiplying the concentration of each carcinogenic PAH in the sample by its B(a)P Total Equivalent Factor (TEF), given below, and summing these products.

PAH species	TEF	PAH species	TEF
Benzo(a)anthracene	0.1	Benzo(g,h,i)perylene	0.01
Benzo(a)pyrene	1	Chrysene	0.01
Benzo(b+j)fluoranthene	0.1	Dibenz(a,h)anthracene	1
Benzo(k)fluoranthene	0.1	Indeno(1,2,3-c,d)pyrene	0.1

6. Australian Drinking Water Guidelines (2011 as updated). The relevant compounds to be tested should be guided by the source of the fill material (site history).
7. Default guideline values for toxicants as specified in Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2018 and as updated).
8. Waste acid sulfate soils can be treated/neutralised before comparison against the thresholds

Notes:

- General – all thresholds consider ecological and human toxicity.
- Waste acid sulfate soils can be treated/neutralised before comparison against the thresholds.

Source: DWER (2019).

B.6 Minimum Sampling and Testing Standards for Uncontaminated Fill

Table B.5: Minimum Sampling and Testing Standards for Uncontaminated Fill

Activity	Minimum requirements
Sampling	Method 3.1 or Method 3.2 in the Australian Standard 1141 *Methods for Sampling and Testing Aggregates*. Sampling of soil stockpiles should be consistent with the methodology described in Section 7.5 of Schedule B2 (Guideline on Site Characterisation) of the *National Environment Protection (Assessment of Site Contamination) Measure* (ASC NEPM). Depending on the source of the material being characterised, it may be possible to use relevant site characterisation data for in situ soils (such as in a detailed site investigation report) provided that this was carried out in accordance with the ASC NEPM and that, since sampling, the characterised material has not been subject to any potentially contaminating land uses including industrial, commercial, mining or intensive agricultural activities. Further information on characterisation of soils based on the 95% Upper Confidence Limit (average) [95%UCLavg] for the soil (including worked examples) is provided in *Industrial Waste Resource Guidelines (7), Sampling and Analysis; Soil Sampling*, (EPA Victoria 2010). http://www.epa.vic.gov.au/business-and-industry/guidelines/waste-guidance/industrial-waste-resource-guidelines.
Testing	The laboratory should hold National Association of Testing Authorities, Australia (NATA) accreditation for the testing undertaken. Analytical methods adopted should be consistent with those specified in Schedule B3 of the ASC NEPM. Substances to be tested should be determined based on land use history of the site of origin. Refer to Appendix B (Potentially contaminating industries, activities, and land uses) in the *Assessment and Management of Contaminated Sites* (DER 2014, and as updated from time to time). If no value for a potential contaminant is included in Table 6, and the substance is indicated for testing on consideration of the site history, then it is not appropriate to consider material from the site for classification as uncontaminated fill.

Source: DWER (2019).

Appendix C National & International Waste Applications

C.1 Identified Mine Waste Applications in WA

Table C.1: Identified Mine Waste Applications in WA

Region	Mine	Mineral	Waste type	Application
Kimberly	Savannah Nickel-Copper-Cobalt mine	Nickel	Waste rock	In 2016, waste rock was trialled in the basecourse of a section along the Great Northern Highway demonstrating sufficient performance. Potential applications include the basecourse for the Great Northern Highway (Stage 2) and in road infrastructure locations south of Warmun.
	Pacific Niugini Nicholson mine	Gold	Tailings	~50 km west of Halls Creek. Tested as potential sealing aggregate, subbase material or in rock spalls. Potential replacement for the Laura River quarry deposit.
	Rio Tinto Argyle Diamond mine	Diamond	Tailings	Main Roads investigating the applicability of diamond tailings in the road network. Currently collecting and testing samples.
Pilbara	Marandoo Rio Tinto Iron Ore Deposit	Iron	Waste rock	Tested waste rock landform materials that indicated suitability for road infrastructure applications. Widening work of the Paraburdoo-Tom Price Road served as the test case using 40,000 tonnes of waste rock as embankment fill. No further crushing or screening of the material was required.
	FMG CID Deposit	Iron	Waste rock	Potential source of basecourse quality material. Investigation to collect bucket samples and undertake a visual site inspection of the deposit.
	Novo Resources – Beaton's Creek	Gold	–	Investigation into trialling Beaton's Creek mine waste products as potential for it to be used as a subbase.
Goldfields	Austral Pacific ex Paris and HHH mines	–	–	Austral, DMIRS, and Golder Associates are investigating the suitability and re-use of this mine waste. Petrographic testing has come back positive. A trial crush is to be undertaken to assess whether crushing will generate fines with plasticity to improve the properties of the material. Potential material supplying projects in the Kalgoorlie – Norseman area.
Wheatbelt	Pithara Mine (decommissioned)	Gold	Tailings	Great Northern Highway – Pithara upgrade in 2018–2019 used waste material from the local decommissioned gold mine. Material was used as rock protection and blended with local gravel for basecourse material.
Mid-West Gascoyne	Plutonic Gold Mine	Gold	Overburden	Great Northern Highway pavement repairs used overburden materials. Potential source for basecourse or subbase materials for work along the Great Northern Highway.
Perth Peel	Alcoa Wagerup Mine	Bauxite	Alcoa red sand (ARS)	Trial section (2009) along the Greenland's road in Pinjarra used ARS with satisfactory performance and the road is still in good condition. ARS meets pavement requirements such as, rutting, roughness and deflection. Testing demonstrates that ARS can be used as a subbase material where 100 mm of gravel is applied.

Region	Mine	Mineral	Waste type	Application
Great Southern	Mt. Cattlin mine site	–	Waste rock, granite and basalt from rock and soil stockpiles	Crushed waste rock used as rock protection; embankment fill on the Philips River Bridge project. Crushed waste rock was used as a basecourse on pavement overlay works in the region.

Source: Main Roads (2021).

C.2 US Mine Waste Applications

Table C.2: Use of recycled materials in roads in the USA (M Mt)

Material	Production (M Mt)	Used (M Mt)	Applications
Blast furnace slag	14	12.6	Aggregate in concrete
Coal bottom ash	14.5	4.4	Asphalt aggregate, Granular base, etc.
Boiler slag	2.3	2.1	
Coal fly ash	53.5	14.6	Cement production, structural fills, etc.
Foundry sands	9 to 13.6	–	Most reclaimed and used in process
Cement kiln dust	12.9	8.3	Used on site; some as stabilizer, ~90 M Mt stockpiled
Limed kiln dust	1.8 to 13.6	–	
Mineral waste	1.6 biolion	N/A	34 states reported use in roads
Waste to energy (WTE) ash	8.0	Small amounts	Some in asphalt, most on landfill roads and landfill cover
Non-ferrous slags	8.1	Not available	Granular base, hot mix asphalt, etc.
Steel slag	Not available	7.0 to 7.5	Aggregate, granular base
RAP	41.0	33.0	Aggregate in hot and cold mix asphalt, asphalt cement binder, etc.
Reclaimed concrete	Not available	Not available	Aggregate for cement-treated or lean concrete; aggregate for flowable fill, etc.

Source: Federal Highway Administration (FHWA) (2005)

Non-ferrous slags (including copper, nickel, zinc and phosphorus) are approved to be used as either a fine or coarse aggregate in hot mix asphalt pavements. Phosphorus slag is being used in Florida in dense graded hot mix surface course mixes for asphalt pavements. This is because the slag creates better skid resistance on roads, which is optimal for Florida's tropical climate. Copper and nickel slags are routinely used as granular base aggregate substitutes in hot mix asphalt, rail ballasts, blended cements and embankment materials (FHWA 2016).

Taconite, a dense, low-grade iron ore rock mined in Minnesota, generates annually ~125 Mt of mine waste as tailings (25 Mt) and waste rock (100 Mt) when processed (Zanko et al. 2009). The suitability of taconite's mine waste materials for road construction applications has been investigated and extensively trialled. The toughness and durability of this mine waste as indicated from multiple tests such as the aggregate impact, crushing value, Los Angeles abrasion and Micro-deval abrasion demonstrate its suitability as an aggregate (Li et al. 2021). Other applications include:

- waste rock – coarse sized (> 15 cm), applications as rip rap and landscaping
- crushed rock – coarse (–15 cm) and adjusted to fit specifications, concrete or bituminous aggregate, road base and railroad ballast
- tailings – coarse (–10 mm), applications include concrete or bituminous aggregate, road base, road subbase, select granular, embankment fill and friction surfacing.

C.3 European Waste Material Applications

C.3.1 Denmark materials tax policies and waste management

In 1999, the taxes per metric tonne of material in addition to the operating and other costs associated with the facilities prices were as follows:

- using a cubic meter (m^3) of virgin materials = Dkr 5 (~US$0.65)
- landfilling = Dkr 375 (~US$49)
- incinerating waste to recover energy for heat and power = Dkr 280 (~US$36)
- incinerating waste for energy recovery for heat only = Dkr 330 (~US$43).

In 2013, 2.89 million tonnes of Construction and Demolition Waste (CDW) under Chapter 17 according to the List of Waste, excluding soil, were reported as received at the registered CDW management sites by the Danish Environmental Protection Agency (EPA) in Denmark. The amount of CDW in 2013 represents a 7 % increase compared to 2012 (2.69 million tonnes) (Deloitte 2015a).

Table C.3: Denmark's generation of construction and demolition waste

Waste Category	2011	2012	2013(4)
Non hazardous CDW			
• CDW from buildings	2.42	2.69	2.89
• Soil(1)	2.00	2.34	4.18
• Dredging Spoils(2)	0.004	0.0001	0.0001
Hazardous CDW(3)	0.76	0.54	0.99
Total CDW	5.19	5.57	8.06

Source: Deloitte (2015a)

1. Excluding soil classified as hazardous
2. Excluding dredging spoils classified as hazardous
3. Excluding waste class 17 06 06
4. Not yet official data at time of publication

C.3.2 Waste Management in Austria

In 2013, Austria reported 8.3 Mt of non-hazardous construction and demolition waste in its official statistics (Deloitte 2015b).

Table C.4: Austria's national performance of construction and demolition waste

Code (ÖNORM S 2100)	Description	Quantity generated in 2013 (million tons)
31409	Building debris (no construction site waste)	2.4
31410	Road rubble/bitumen and asphalt	0.8
31427	Concrete demolition waste	2.9
31467	Track ballast	0.2
54912	Bitumen, Asphalt	1.6
91203	Construction site waste (no building debris)	0.3
	Other	0.08
Total		8.3

Source: Deloitte (2015b)

C.3.3 Waste Management in Sweden

In 2012, 7.7 million tonnes of construction and demolition waste (CDW) were officially reported as generated in Sweden (Deloitte 2015c).

Table C.5: Construction and demolition waste management national performance in Sweden

Year	2010	2012
Generated CDW (Mtonnes)	1.22	1.31
Recycled CDW (Mtonnes)	0.12	0.81
Backfilled CDW (Mtonnes)	0.61	0.48
Landfilled CDW (Mtonnes)	0.021	0.015
Energy recovery if any (Mtonnes)	0.24	0.41
Unknown treatment (tonnes)	0.23	0.23
Recycling rate (%)	59.9	49.9

Source: Deloitte (2015c)

C.3.4 Waste Management in Bulgaria

In 2013, 1 543.9 ktons of Construction and Demolition Waste (CDW) were officially reported as generated in Bulgaria (Deloitte 2015d).

Table C.6: Construction and demolition waste management national performance in Bulgaria

Waste Category	Quantity generated in 2013 (ktons)
Soil	1 344.6
Non-hazardous CDW	198.5
Total non-hazardous waste	1543.1
Hazardous soils	0.4
Hazardous CDW	0.4
Total Hazardous waste	0.8
Total CDW including soils	1543.9

Source: Deloitte (2015d)

C.3.5 Waste Management in the United Kingdom (UK)

In 2012, 100.23 million tons of construction and demolition Waste was generated in the UK. (Deloitte 2016).

Table C.7: Construction and demolition waste management national performance in the UK

Waste Category	Quantity generated in 2012 (million tons)
Excavation waste	54.39
Non-hazardous construction and demolition waste	44.79
Hazardous construction and demolition waste	1.06
Total CDW	100.23

Source: Deloitte (2016)

Appendix D Mine Waste Materials

D.1 Types of Mine Waste & Definitions

- **Overburden** is the material overlying the ore body of interest for exploitation. During mining, overburden is cleared and stockpiled in an above-ground surface landform for subsequent usage during the reclamation phase. Generally, this material is inert and does not contain any economic mineralisation.
- **Waste rock** is a general term for any material that contains ore at a low concentration that is considered uneconomical from a mining point of view. For example, an iron ore mine will typically stockpile material as waste when the Fe-grade is less than 55%. This material is stockpiled in above-ground landforms within 4–5 km of the active open pit.
- **Tailings** is a material resulting from an ore concentration process that removes the uneconomical material within the ore through mechanical and chemical processing. Tailings comprise small-sized particles pumped as a slurry to specialised designed storage facilities. Solids settle out, leaving the slurry water to be collected. At closure, tailings evaporate and consolidate over some time before being reclaimed. The most common forms of tailings are slurry (most common disposal means), paste (reduced water content), dry stacking and co-disposal with coarse wastes.
- **Sludge** is a semi-solid liquid waste produced in the mining of coal, gold and diamond ore bodies. The washing process removes surrounding soil and rock impurities, creating a liquid waste material typically high in heavy metals such as copper, aluminium, nickel, manganese oxides, etc. Sludge disposal is performed through the construction of dams to store the liquid waste.
- **Slag** is a by-product of smelting ores and contains three categories: ferrous (a result of processing iron and steel), ferroalloy (a result of ferroalloy production) or non-ferrous/base metals (results from recovering non-ferrous materials like copper, nickel, zinc and phosphorus). Dumps store the coarse-grade aggregate materials where exposure to the effects of weather contribute to degradation. Suitable applications for this material include ballast, concrete, granular road base and as a supply for phosphate fertilizer as defined by The Encyclopedia Britannica website.
- **Fly ash** is a fine powder residue that results from coal combustion. This material is commonly used as a pozzolan in Portland cement concrete applications as it contains siliceous and aluminous materials that act as cement when mixed with water.

D.2 Successful Rehabilitation and Closure Strategies

A successful rehabilitation and closure strategy:

- identifies the issues to be managed through the mine closure process and the environmental closure risks
- informs the development of criteria or indicators for closure monitoring and performance
- informs the establishment of achievable closure outcomes and goals in a local and regional context
- establishes baseline conditions for closure monitoring programs
- provides an analysis of the baseline data that describes how the wider receiving environment, receptors and exposure pathways have been considered
- provides an analysis of the baseline data that identifies the knowledge gaps and the risk of not having that information
- details the methodology of analysing the baseline data.

Mine closure plans are reviewed regularly in line with changes to the approved mine plan, new information or improved rehabilitation techniques (Minerals Council of Australia 2018). The mine closure plan must provide information on the processes and methodologies undertaken to identify the closure risks and their potential environmental impacts post-mining, including a description of the risk assessment criteria and risk evaluation techniques. As part of this plan, an environmental closure risk assessment is conducted that addresses the following:

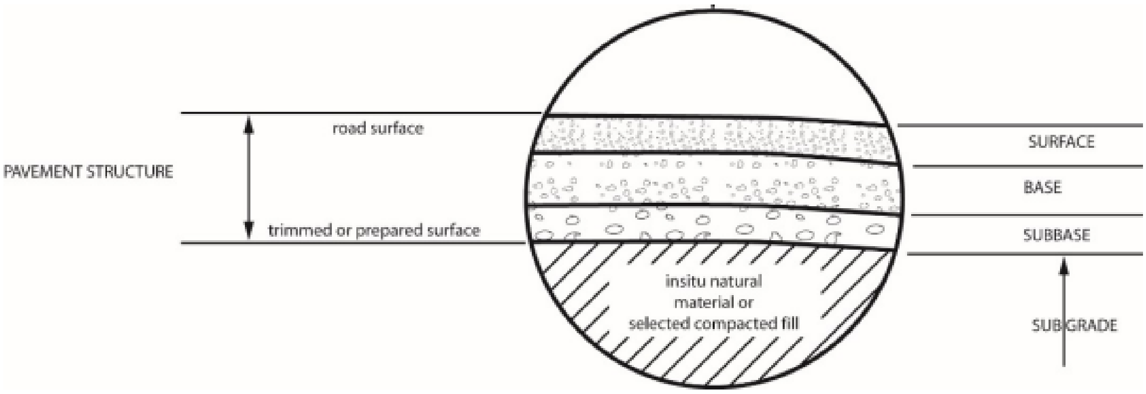
- identifies all the environmental closure risk pathways
- evaluates these risks to derive an inherent risk rating, prior to the application of treatments
- identifies appropriate risk treatments, using the hierarchy of control
- re-evaluates the risk pathways to derive a residual risk rating
- demonstrates that all residual risks are as low as reasonably practicable.

Appendix E Road Infrastructure Applications

E.1 Flexible Road Pavement Technical Information

Pavements are classified as either flexible (containing unbound granular and/or stabilised materials and/or asphalt) or rigid (concrete pavement with joints and/or steel reinforcement) (Austroads 2009).

Figure E.1:   Flexible pavement system



Source: Austroads (2009).

There are two primary structural layers of a flexible (unbound granular) pavement that distribute traffic loads as shown in Figure E.1:

1. **Base layer** consists of one or more layers of compacted granular materials usually constituting the uppermost structural element of a pavement on which the surfacing may be placed.
2. **Subbase layer** consists of one or more layers of compacted granular material laid on the subgrade and below the base layer, with the purpose to further reduce the intensity of the load transmitted to the subgrade, or to provide a working platform.

The subgrade is the trimmed or prepared portion of the formation on which the pavement is constructed and may comprise in situ or imported materials. In WA the subgrade is defined as the top 150 mm of an embankment fill.

The surfacing typically placed on the base layer consists of a thin (< 60 mm) asphalt wearing course or bituminous surfacing seal. Granular pavements with bituminous sprayed seal surfacings are the primary flexible pavement type used for light and moderately trafficked roads across regional Australia due to their low initial cost. For heavily trafficked regional roads, these pavements have been successfully used; however, their performance is subject to suitable materials, environments and construction and maintenance standards (Austroads 2009).

E.2 Requirements for Granular Materials

The material requirements vary between gravels, crushed rocks and also between regions within the state.

Typical engineering properties for which requirements are set include:

- particle size distribution
- Atterberg limits (liquid limit, plastic limit, plasticity index, linear shrinkage)
- maximum modified dry density and optimum moisture content
- California Bearing Ratio, soaked for 4 days
- Los Angeles abrasion value
- flakiness index
- maximum dry compressive strength
- wet/dry strength variation

- other specific material type requirements.

Any waste material earmarked for basecourse, subbase or embankment fill material should be evaluated against the criteria contained in Main Roads Specification 302 (Main Roads 2020) and Specification 501 (Main Roads 2022a).

E.3 Main Roads Process for Accessing Mine Waste Material

The process followed by Main Roads for accessing mine waste material typically involves the following:

- Contact the mine, typically the Mine Manager.
- Arrange a site visit to visually assess the material and location of the material on the tenement.
- Sample suitable mine waste material for laboratory testing of engineering properties (Main Roads Specification 302 and Specification 501).
- Commence negotiations if the material is deemed suitable based on laboratory testing.

Typical hurdles to this process include:

- Timing
  - time between first contact and gaining access to the mine
  - sampling and testing of the material could take several weeks
  - duration between contact, testing, negotiation, and delivery of the project.
- Mining operations
  - operations planned within the mining tenement may vary, moving from one location to the next
  - access to heterogeneous waste dumps as new material is added during operations
  - logistics to ensure safe interaction between automated vehicles on the active mine site and extracting the mine waste material.
- Decision/Commitment
  - making contact and negotiating with the correct person within the mine management structure that can make decisions.

Appendix F Main Roads WA Risk

Further to the Austroads framework assessment, suitability will be determined throughout the various stages of assessment using the Main Roads Consequence Table F.1 and Likelihood Table F.2 as risk assessment.

Table F.1: Main Roads consequence table

Level	Rank	Health & safety	Transport services	Financial	Reputation & trust (political, stakeholders and community)	Business operations	Environmental	Legal & compliance
1	INSIGNIFICANT	No treatment required	Service infrastructure receives minimal damage, minor rectification required. Service/s only temporarily unavailable or remain operational	Greater of:	Isolated local community or individual's issue-based concerns	Some insignificant delays to business activities	Low impact to isolated area	Guidance required for legal/compliance issues managed through routine procedures
			Minor impact to customers e.g. minor drop in patronage or minor congestion	Less than $100,000; or	Low profile media attention	Up to 5% variation in KPI or objective	Simple or no treatment required	Legal action unlikely
				Deviation from project budget within +5%			No lasting effect or significance	
2	MINOR	First aid treatment required	One or a number of services are unavailable or operating with restrictions but can be resumed within acceptable timeframes	Greater of:	Local community impacts and concerns	Minor delays to business activities	Contained low impact	Complex legal/ non-compliance issue to be addressed
			Short-term impact to customers e.g. short-term drop in patronage or isolated congestion	$100,000 to $1m; or	Occasional once off negative media attention	5% to 10% variation in KPI or objective	Standard treatment	Legal action and/or public liability claim possible
				Deviation from project budget between +6–10%	Trust issues raised		Minor local short-term residual effect	

Level	Rank	Health & safety	Transport services	Financial	Reputation & trust (political, stakeholders and community)	Business operations	Environmental	Legal & compliance
3	MODERATE	Medical treatment required or lost time injury	One or a number of services, including critical services, are unavailable for an extended length of time	Greater of:	Sectional community impacts and concerns publicly expressed	Some moderate delays to business activities	Uncontained impact, able to be rectified in short-medium term	Non-compliance/s with regulation and/ or probity infringements, which may result in some processes repeated.
			Moderate impact to customers e.g. complaints and moderate drop in patronage or moderate lever of short-term congestion	$1–10m; or	Increased negative media attention	10–25% variation in KPI or objective	Significant medium-term residual effect	Legal action probable
				Deviation from project budget between +10–20%	Loss of confidence and trust by community and stakeholders in agency processes and capability	One or more projects is significantly impaired		
					Ministerial concern			
4	MAJOR	Single fatality or major injuries or severe permanent disablement	A number of critical services are cancelled, with extensive rectification required before resumption of services	Greater of:	Considerable and prolonged community impact and dissatisfaction publicly expressed.	Major delays to activities	Extensive hazardous impact requiring long-term rectification.	Major non-compliance with regulation which may result in termination of a process or imposed penalties.
			Non-critical service infrastructure is not operational and cannot be rectified	$10–30m; or	Consistent negative media attention	25% to 50% variation in KPI or objective	Major medium-term residual effect	Legal action taken against agency and/or major public liability claim or potential class action
			Substantial impact to customers e.g. major drop in patronage or major level of congestion	Deviation from project budget between 20 and 30%	Criticism and loss of confidence/trust by community and stakeholders in agency processes and capability	One or more critical programs or projects cannot be delivered		
					Ministerial intervention			

Level	Rank	Health & safety	Transport services	Financial	Reputation & trust (political, stakeholders and community)	Business operations	Environmental	Legal & compliance
5	CATASTROPHIC	Multiple fatalities	Critical service infrastructure is not operational and cannot be rectified	Greater of:	Significant adverse community impacts and condemnation	Activities ceased.	Uncontained hazardous impact requiring major long-term treatment and monitoring	Major non-compliance with legislation and/or regulation which may result in criminal charges and/or loss of required accreditation
			Significant impact to customers e.g. sustained drop in patronage or sustained level of significant congestion	Greater than $30m; or	Extreme negative media attention	More than 50% variation in KPI or objective	Major long-term residual effect	Significant legal consequences/class action against agency
				Deviation from project budget > 30%	Consistent ongoing community loss of confidence and trust in agency capabilities and intentions	Multiple critical programs or projects cannot be delivered		
					Government intervention			

Source: Main Roads (2021).

Table F.2: Main Roads likelihood table

	Level	Rating	Description	Frequency
LIKELIHOOD RATING	**1**	**Rare**	The event may occur only in exceptional circumstances	Less than once every 50 years*
	2	**Unlikely**	The event could occur at some time	Once every 10 – 50 years
	3	**Possible**	The event might occur at some time	Once every 1 – 10 years
	4	**Likely**	The event will probably occur in most circumstances	More than once per year
	5	**Almost Certain**	The event is expected to occur in most circumstances	More than once per month

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