NSW Coal Mining Benchmarking Study: International Best Practice Measures to Prevent and/or Minimise Emissions of Particulate Matter from Coal Mining

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Executive Summary

There is growing community concern regarding both the health and amenity impacts associated with particle emissions from coal mining in NSW. Katestone Environmental was commissioned by OEH to conduct a review of coal mining activities in the Greater Metropolitan Region of NSW (GMR) to:

- Identify the major sources of particles from coal mines (i.e. TSP, PM_{10} and $PM_{2.5}$) and rank them in descending order of significance for offsite impacts.
- Identify current operational practices and emission controls for minimising particle emissions from coal mining. Visit a representative sample of operational open-cut coal mines in the Hunter Valley to assist in identifying current operational practices and emission controls.
- Research and identify international best practice to prevent and/or minimise particle emissions from all activities associated with coal mining including land rehabilitation.
- Evaluate the practicality of implementing best practice at coal mines in the GMR.

The objectives of the study were to:

- Review international best practice measures to prevent and/or minimise particle emissions from all activities associated with NSW coal mines, including land rehabilitation.
- Compare international best practice measures to prevent and/or minimise particle emissions with those currently used at NSW coal mines.
- Make recommendations regarding the adoption of international best practice measures that could be practicably implemented in NSW at existing and proposed coal mines.
- Estimate the likely reduction in particle emissions associated with adopting each international best practice measure at NSW coal mines.
- Estimate the costs associated with adopting each international best practice measure at NSW coal mines.

The conclusions and recommendations of the review of coal mining activities in the Greater Metropolitan Region of NSW (GMR) are summarised below.

The analysis of coal mining in the GMR indicates that:

- There are about 57 open-cut and underground coal mines in the GMR that produce more than 92% of total NSW production of coal. More than half of the mines are located in the Hunter Coalfield between Singleton and Muswellbrook and in the Newcastle Coalfield where the majority of NSW coal production occurs. Coal is also mined west of Sydney in the Western Coalfield in the regions surrounding the towns of Lithgow, Kandos, Rylstone, Mudgee and Ulan. There are a number of mines in the Southern Coalfield in the region surrounding Wollongong, reaching Appin to the north of Wollongong, Tahmoor to the northwest and Berrima to the west.

The existing issues associated with particulate matter emissions from coal mining are illustrated by the following:

- Ambient monitoring data collected at Muswellbrook, Singleton and Camberwell indicate that concentrations of particulate matter exceed the Ambient Air Quality NEPM standard for 24-hour average PM_{10} of 50 µg/m³ on a number of occasions per year.
- 331 complaints were received by OEH between 2007 and 2009 about air quality issues associated with coal mining. Approximately, 86% of complainants cited dust as a reason for the complaint. Sixty percent of the complaints came from residents in

Muswellbrook, Singleton and Camberwell. About 10% of complaints came from Wollar in the Western Coalfield.

- In 2009, the Department of Planning commissioned expert reports in relation to cumulative impacts on air quality and other issues in response to public concern over the potential impacts at Camberwell posed by existing and proposed future coal mining. In relation to best practice management of particulate matter emissions, the expert report concluded that there is a need to further improve operational management to ensure that human health is protected at Camberwell in the coming years.

The study has found the following in relation to international and Australian coal production:

- China is the world's largest coal producer with 44% of total world production. The United States (14%), India (8%) and Australia (6%) are the next highest coal producers. Four OECD countries are in the top ten coal producers. In addition to Australia and the United States, the others are Germany (2.6%) and Poland (1.9%).
- The Powder River basin (42%) in Wyoming and the Appalachian region of West Virginia (20%) produce the bulk of coal in the United States.
- The majority of Australian coal is black coal that is produced in Queensland (45%) and New South Wales (34%). The majority of the remainder is brown coal that is produced in Victoria (18%).
- Coal production in New South Wales comes from six coalfields. Four coalfields are located in the GMR and these produce 92% of New South Wales's coal. Namely, the Hunter Coalfield, Newcastle Coalfield, Southern Coalfield and Western Coalfield.
- Approximately 63% of coal produced in the GMR comes from open-cut mines and the remainder is produced by underground mines. Dragline and truck and shovel mining each represent about half of the open-cut production.
- New South Wales's coal production is expected to grow by 2% per year out to 2029-30. Coal production in New South Wales is projected to exceed 200 million tonnes per year by the end of this period. About 41% of the 91 million tonnes of new coal projects are expected to be in the Hunter Coalfield.

The study has found the following in relation to emissions from coal mining in the GMR:

- The 2003 emissions inventory found that coal mining was the largest emitter of particulate matter (as PM_{10}) in the GMR as a whole and in the Newcastle and Non-Urban Regions.
- The 2008 emissions inventory is currently being prepared. The contribution of coal mining to particulate emissions in the inventory is likely to maintain its prominence.
- OEH provided data from the 2008 emissions inventory for use in this study. Analysis of the 2008 emissions inventory data shows:
  - The largest source of PM_{10} from coal mining activities is haul trucks travelling on unpaved roads (40%), followed by wind erosion of overburden (27%), bulldozers (8%), blasting (6%) and trucks dumping overburden (4%).
  - The top three activities are found to produce 75% of PM_{10} emissions associated with GMR coal mines, whilst the top ten activities produce 97% of PM_{10} emissions.

A review of regulatory frameworks for air quality management around the world has jointly focused on countries with a high degree of economic development (OECD countries), the quantity of coal produced and level of environmental regulation adopted in the country. This review has found that:

- The regulatory regime in place in New South Wales is very transparent with a substantial amount of licence and approval information available on the websites of OEH and Department of Planning.

- Best practice is not strictly defined in the New South Wales legislation, but a form of best practice is implicit in Section 128 of the *Protection of the Environment Operations Act 1997* (POEO Act) that requires "...*the occupier of a premises to carry on any activity, or operate any plant, in or on the premises by such practicable means as may be necessary to prevent or minimise air pollution*." As distinct from other aspects of New South Wales legislation (e.g. the *Protection of the Environment Operations (Clean Air Regulation) 2002* (CAR) in relation to point source emissions), there is no legislation or guideline that might provide the regulator, community or coal mine with a detailed and practical interpretation of what Section 128 might mean for coal mining.
- In the United States and Canada, the legislation and project approvals provide specific and detailed expectations about controlling emissions of particulate matter from coal mining.
- The NSW approach is deliberately less prescriptive to allow the licensee to determine the optimal approach to achieving the ongoing minimisation. The less prescriptive approach means that conditions of development approval do not specifically state the commitments made during the Environmental Assessment, but include a statement that the project shall be carried out "generally in accordance with the Environmental Assessment." Additionally, the assumptions made in the Environmental Assessment can be optimistic with regard to a mine's ability to achieve an appropriate level of minimisation or lack specificity as to how the minimisation will be achieved in practice.
- No impact assessment criterion has been specified by OEH for 24-hour average TSP. The Canadian province of Alberta provides a 24-hour average TSP criterion of 100 µg/m³, which is the most stringent criterion of all jurisdictions considered in the review.
- The annual average TSP impact assessment criterion adopted by OEH is less stringent than the strictest limits adopted by other jurisdictions considered in the review. The Canadian provinces of Alberta, British Columbia and Ontario and the Government of Canada provide an annual average TSP criterion of 60 µg/m³, which is the most stringent criterion of all jurisdictions considered in the review.
- The 24-hour average PM_{10} impact assessment criterion adopted by OEH is consistent with the strictest limits adopted by other jurisdictions considered in the review.
- The annual average PM_{10} impact assessment criterion adopted by OEH is less stringent than the strictest limits adopted by other jurisdictions considered in the review. The World Health Organisation, California and Scotland provide annual average PM_{10} criteria that are equal to or less than 20 µg/m³, which are the most stringent criteria of all jurisdictions considered in the review.
- No impact assessment criteria have been specified by OEH for $PM_{2.5}$. Annual average and 24-hour average criteria have been specified by most jurisdictions considered in the review. The stated position of OEH is that there is currently an Ambient Air Quality NEPM process considering developing a standard for $PM_{2.5}$ in Australia and OEH is awaiting the outcome of this process prior to setting impact assessment criteria for $PM_{2.5}$.
- The impact assessment criteria for deposited dust adopted by OEH are consistent with the strictest limits adopted by other jurisdictions considered in the review.
- The differences between OEH's impact assessment criteria and the Department of Planning's land acquisition criteria, leaves a gap that is filled by the land acquisition process. The land acquisition process requires a person to be affected and for that affected party to make representations to the mine in order to trigger action.
- Emissions of particulate matter from coal mining are not captured under New South Wales Load Based Licensing scheme. In the United States coal mines that exceed a

specified threshold are subject to a load-based licensing fee that is charged based on the emission rate of particulate matter.

A detailed review of international techniques for controlling emissions of particulate matter from coal mining has been completed and best practice measures have been determined. The European and Victorian definitions of best practice have been central to the determination of best practice measures. Techniques adopted by GMR coal mines have been benchmarked against international best practice. Overall, coal mines in the GMR have adopted many elements of best practice. However, no mine has completely implemented best practice across the full range of activities. Additional efforts are applied to minimise emissions in adverse circumstances, but commensurate efforts may not be consistently applied at other times. Activities are commonly relocated to within the pit when conditions are conducive to the generation of particulate matter emissions but anecdotal evidence suggests that this may not always be effective and the literature suggests that pit retention may only provide a small (5% or less) reduction in emissions of PM_{10} and $PM_{2.5}$.

The following activity-specific conclusions have been reached:

- Haul roads: control measures include watering, grading, well-defined haul routes, speed limits to 40 km/hr and/or the use of suppressants. Approximately 89% of underground mines and 96% of open-cut mines use either fixed sprays or water carts to control emissions of particulate matter from haul roads. The majority of mines that were visited indicated that haul roads were watered on a consistent routine basis under normal weather conditions and that, under adverse conditions, visible particulate matter above the deck, wheels or tray of the haul trucks was used as a trigger for the application of additional watering. At a number of mines that were visited, haul truck drivers were instrumental in identifying problematic conditions and ensuring that water was applied to roads.

  However, the degree of diligence of watering activities could not be determined for each mine from the available information. Hence, the fact that watering is implemented may not mean that emissions are minimised as far as is practicable.

  Approximately 74% of underground mines and 64% of open-cut mines use speed restrictions to control emissions of particulate matter from unpaved haul roads.

  Best practice was found to be the application of suppressant on haul roads and application of water to control emissions from grading.

- Wind erosion of exposed materials and stockpiles: control measures include watering exposed areas, minimising areas of disturbance, progressive rehabilitation and use of suppressants. The majority (78%) of underground mines use watering to control emissions of particulate from cleared areas. At open-cut mines and combined underground and open-cut mines, watering (92%), limiting areas of disturbance (84%) and progressive rehabilitation (84%) are the major techniques that are used to minimise emissions associated with wind erosion.

  One mine in the GMR was found to use suppressant to control emissions from ROM stockpiles, whilst approximately 67% use water application.

  Best practice was found to be:
  - Use of water application or suppressants on coal stockpiles
  - Implementation of rehabilitation

- Bulldozing: best practice control measures include minimising the travel speed and distance travelled by bulldozers and the application of water to keep travel routes moist.

- Blasting: best practice control measures include delaying shot to avoid unfavourable weather conditions and minimising the area blasted. Most mines (91%) restrict blasting to times of favourable weather conditions.
- Drilling: best practice control measures include air extraction to a bag filter. No mines were found to use this practice. Approximately 58% of mines control emissions using water sprays, which are less effective than the use of fabric filtration, but still have a good level of effectiveness. Approximately, 62% use curtains to limit emissions.

- Draglines: there are seven open-cut mines that utilise draglines. Best practice control measures for draglines is minimising the drop height of materials to 5 metres and the suspension of operations in adverse conditions. Three GMR coal mines reported that drop heights were minimised to between 6 and 12 metres. Six metres has been taken to be equivalent to best practice.

- Loading and dumping overburden: current practices adopted to control emissions from loading and dumping overburden were found to be water application, minimisation of drop heights and suspension or modification of activities during adverse weather conditions. Best practice control measures were identified as minimising drop heights and or the application of water.

- Loading and dumping ROM coal: best practice control measures for minimising emissions from the ROM hopper is enclosure with air extraction to a fabric filter or other control device. No mines in the GMR adopt this approach. Three mines (13%) were found to utilise enclosure on three sides and water sprays. Most (83%) mines use water sprays activated by the movement of the truck.

- Monitoring, proactive and reactive management: Of the open-cut mines, 84% monitor meteorological conditions and 48% monitor using a TEOM or other continuous particulate monitoring technique. Forty eight percent modify or cease activities on dry or windy days based on consideration of monitoring data. At least three mines have continuous particulate matter monitoring data available in the control room with alarms to alert operators when trigger levels are being exceeded.

  A number of mines use a forecasting system and inversion tower data to predict the potential for strong inversions for scheduling blasts to avoid noise impacts. Three mines were identified that adopt similar proactive approaches for management of particulate matter emissions.

A particulate matter emission control metric has been developed to quantify the progress towards achieving best practice in GMR mines, which shows that:
- The Hunter and Newcastle coalfields have a similar level of particulate matter emissions control as an aggregate of all sources of emissions. Particulate matter emission control metrics of 63.2 and 67.0 out of 100 were estimated for these coalfields, respectively. The metrics indicate a moderate level of progress towards achieving best practice.
- Whilst lower combined metrics are evident in the Southern (46.5 out of 100) and Western (51.4 out of 100) coalfields, the relatively low contribution of these coalfields to the overall emissions into the GMR airshed mean that the combined GMR metric (62.8) is marginally lower than the Hunter and Newcastle coalfield metrics.

A cost benefit analysis has been conducted to estimate the cost to implement best practice control measures in GMR mines and the reduction in emissions of particulate matter that would be achieved by its implementation. The conclusions of this cost benefit analysis are as follows:

- Overall costs and benefits:
  - Significant reductions in emissions of particulate matter could be achieved through the application of best practice control measures that are both technically and economically feasible.
  - The cost of implementing best practice particulate emission controls in GMR coal mines was estimated to be $164M per year.
  - The application of best practice particulate emission controls was estimated to produce a 49% reduction in overall emissions of PM_{10}.
  - This reduction relies heavily on achieving a substantial increase in the area of land rehabilitated per year and the application of suppressant to haul roads.
  - Costs and benefits of the application of best practice control measures to different mine activities are based on generalised assumptions about mine activities, costs and effectiveness of those control measures. The actual cost and effectiveness will be dependent on site specific factors that need to be evaluated on a case-by-case basis.

- Haul roads:
  - The greatest reduction in emissions would be achieved by the application of suppressants to haul roads, which will reduce the current emissions by 21%. The cost for this is $59M per year.
  - A similar reduction in emissions could be achieved by the conversion of 50% of the haul roads to conveyors, which is estimated to cost $24M per year, and would reduce current emissions by 20%.
  - The most cost-effective control measure would be the replacement of the current fleet with larger-capacity vehicles, which is shown not to incur any additional costs, but instead produces a significant cost saving due to the reduction in the number of vehicles required to be purchased, as well as reduced operating costs. The use of larger haul trucks is estimated to reduce costs by $105M per year across GMR mines and to reduce overall emissions by 10%.

- Overburden emplacements:
  - Rehabilitation of 80% of the overburden emplacements will reduce the current emissions by 20% and is estimated to cost $20M per year.
  - Rehabilitation is a more cost-effective approach in minimising emissions than watering.

- Coal stockpiles:
  - The greatest reduction in emissions from coal stockpiles was achieved by the application of suppressants, which is expected to reduce the current emissions by 2.0% at an ongoing cost of $33M per year.
  - A more cost effective approach would be the application of Level 2 watering, estimated to reduce current emissions by 1.0% and is estimated to cost $8M per year

- Exposed areas:
  - Full rehabilitation of other exposed areas is estimated to reduce current emissions by almost 3%, and is estimated to reduce the costs of current control measures (namely watering) by approximately $4M.
  - Full or partial rehabilitation of the exposed areas is shown to reduce the

ongoing operational costs and the current emissions.

- Bulldozing:
    - Watering while bulldozing coal will reduce the current emissions by almost 2.0% of the current emissions and is estimated to cost over $53M per year.
    - Watering while bulldozing overburden will reduce the current emissions by less than 2% of the current emissions and is estimated to cost over $156M per year.

- Trucks dumping coal to the ROM hopper:
    - Enclosing the ROM hopper and the use of fabric filters is shown to reduce current PM_{10} emissions by less than 1% at a cost of $2M per year.

- Graders:
    - The application of level 2 watering to grading activities is estimated to reduce emissions by less than 1% at an estimated cost of $38M per year.

- Drilling:
    - The use of fabric filters on drill rigs is estimated to reduce emissions by less than 1.0% at a cost of $150,000 per year.
    - The cost of using the enclosure is significantly lower, estimated to cost $24,000 per year, and estimated to reduce emissions by less than 1.0%.

Based on the findings and conclusions of this study, the following steps may be considered to reduce emissions of particulate matter from coal mining activities.

- Provide a definition of best management practices (BMP) in the CAR that would be applied in instances where there is no standard of concentration defined under Section 128 of the POEO Act.

- Include opacity as an indicator of fugitive emissions of particulate matter and specify a limit for opacity with reference to limits defined in other jurisdictions. In the United States coal mining activities are required to minimise emissions to be less than a 20% opacity level. Such an approach could provide for a greater degree of management and control of emissions from haul roads and other emission sources, but would require training of mine and regulatory personnel to implement and enforce. Open-path opacity monitoring equipment could provide a technological solution to this.

- Consideration should be given to the development of a handbook, guideline or regulation that defines BMP for the control of particulate matter emissions from coal mining activities. The handbook could be initially developed from the findings of this study, but would be a dynamic document that is updated regularly based on experience, future innovation, community and stakeholder input. The document could:
    - Define appropriate emissions estimation techniques
    - Be referenced in conditions of approval and EPL conditions
    - Used as a tool for auditing
    - Used as a tool for developing management programs
    - Used as a resource for impact assessment studies
    - Define acceptable control factors for the development of emissions inventories required under the legislation. Alternative control factors or control measures that deviate from best practice could be acceptable based on review and approval using a process similar to the Chief Scientist process that is used to approve alternative sampling methods under the CAR.

- Incorporate coal mining into the load-based-licensing scheme. This could be used to drive the take up of more effective emission controls, but would require the development of the handbook described above. This may also motivate the development of more robust techniques for the quantification of particulate matter emissions from coal mining.

- Undertake a review of the currency, adequacy and effectiveness of existing TSP, PM_{10} and dust deposition criteria in avoiding adverse impacts on human health and amenity. Consider within this review whether $PM_{2.5}$ criteria should be adopted. Revise the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* accordingly.

- Develop a regional dispersion model for the Hunter Coalfield to assist the planning and development. The model would need to incorporate:
    - Existing activities and use mine plans to project future emissions. This may require ongoing provision of mine plans to an administrative body for incorporation into the model
    - Historical ambient air quality monitoring data
    - Historical surface meteorological measurements incorporated into a 3-dimensional meteorological model
    - Approved mining activities

  The model could be used to:
    - Provide an agreed and approved framework for the planning and approval of new coal mines or extension of existing mines
    - Forecast air quality to provide information and alerts to mine managers and to community about air quality.

- Require new coal mine developments (at EA stage) and existing coal mines to conduct site specific BMP determinations to identify the most technically and economically feasible options to reduce emissions. For new developments, the BMP determination should be transparently linked to the air quality impact assessment and detailed in the air quality management plan (AQMP), which should also accompany the EA. For existing premises, the BMP determination could be required through a pollution reduction program (PRP) and the outcomes implemented through EPL conditions.

1. Introduction

1.1 Study background

The NSW Office of Environment and Heritage (OEH) has commenced an environmental review that aims to benchmark the performance of the NSW coal mining industry against international best practice measures to prevent and/or minimise particle emissions.

There is growing community concern regarding both the health and amenity impacts associated with particle emissions from coal mining in the Greater Metropolitan Region (GMR) of NSW. Many recent scientific studies have confirmed that exposure to particles are associated with health risks.

Katestone Environmental was commissioned by OEH to conduct a review of coal mining activities in the GMR to:

- Identify the major sources of particles from coal mines (i.e. TSP, PM_{10} and $PM_{2.5}$) and rank them in descending order of significance for offsite impacts.
- Identify current operational practices and emission controls for minimising particle emissions from coal mining. Visit a representative sample of operational open-cut coal mines in the Hunter Valley to assist in identifying current operational practices and emission controls.
- Research and identify international best practice to prevent and/or minimise particle emissions from all activities associated with coal mining including land rehabilitation.
- Evaluate the practicality of implementing best practice at coal mines in the GMR.

The GMR measures 210 km (east-west) by 273 km (north-south) and includes the greater Sydney, Newcastle and Wollongong regions. The GMR covers a total area of 57,330 square kilometres. Approximately, 76% of the population of NSW resides within the GMR[1].

There are about 57 open-cut and underground coal mines in the GMR that are responsible for more than 92% of total NSW production of coal. More than half of the mines are located in the Hunter Coalfield between Singleton and Muswellbrook and in the Newcastle Coalfield and these produce the majority of NSW coal. Coal is also mined west of Sydney in the Western Coalfield in the regions surrounding the towns of Lithgow, Kandos, Rylstone, Mudgee and Ulan. There are a number of mines in the Southern Coalfield in the region surrounding Wollongong, reaching Appin to the north of Wollongong, Tahmoor to the northwest and Berrima to the west.

The air emissions inventory for the GMR[1] shows that the coal mining industry is the largest industrial emitter of:

- TSP in the GMR, emitting 88,606,091 kg of TSP per year, or 45.5% of anthropogenic emissions.
- PM_{10} in the GMR, emitting 32,109,349 kg of PM_{10} per year, or 42.7% of anthropogenic emissions.
- $PM_{2.5}$ in the GMR, emitting 6,887,798 kg of $PM_{2.5}$ per year, or 22.6% of anthropogenic emissions.

Particulate matter is the major air pollutant that is emitted from coal mining and processing activities. The majority of particulate matter emitted from coal mining consists of large particles generated from activities such as mechanical disturbance of rock and soil materials by bulldozing, blasting and trucks travelling on dirt roads. Particulate matter is also generated from wind erosion of stockpiles and bare ground. The majority of particulate matter generated by open-cut mining activities is derived from the dirt, rock and soil. The Coal Mines Emission Database (CMED) that was analysed for this study (Section 7.3) indicates that approximately 11% of particulate matter emitted from GMR mines is from coal handling and storage.

Particulate matter has the potential to cause nuisance impacts in surrounding communities due to soiling of surfaces such as clothes and buildings. Particulate matter in elevated concentrations also has the potential to cause adverse health effects. In sensitive individuals, or when high levels of fine particles are present, particulate matter may contribute to increased rates of respiratory illnesses and other symptoms.

In NSW, the most challenging region for management of particulate matter emissions from coal mining is in the Hunter Coalfield. The Hunter Coalfield produces almost 60% and 65% of all coal produced in NSW and GMR, respectively. It is from this region that OEH receives the most complaints about particulate matter from coal mining and significant expansion in coal mining is expected over the medium term.

Growth in coal production is expected in all NSW coalfields over the medium term and, with current emission controls, this could lead to higher ambient concentrations of particulate matter in populated areas such as Muswellbrook and Singleton and also in smaller towns such as Camberwell in the Hunter and Wollar in the Western Coalfields.

1.2 Study aims and objectives

This study has been prepared to address the aims and objectives specified in the Tender Document issued by OEH (Appendix A). OEH contracted Katestone Environmental to complete the review with the following broad objectives:

- Establish existing practices for minimising particle emissions from NSW coal mines and benchmark them against international best practice.
- Estimate the likely reduction in particle emissions and costs associated with adopting those international best practice measures.

The objectives of the study were to:

- Review international best practice measures to prevent and/or minimise particle emissions from all activities associated with NSW coal mines, including land rehabilitation.
- Compare international best practice measures to prevent and/or minimise particle emissions with those currently used at NSW coal mines.
- Make recommendations regarding the adoption of international best practice measures that could be practicably implemented in NSW at existing and proposed coal mines.
- Estimate the likely reduction in particle emissions associated with adopting each international best practice measure at NSW coal mines.
- Estimate the costs associated with adopting each international best practice measure at NSW coal mines.

1.3 Study methodology and document outline

The key elements of the study and structure of the report are as follows:

- **Amenity Impacts and Health Effects of Particulate Matter:** Definitions of particulate matter and a discussion of the potential for particulate matter to affect human health, amenity and the environment (Section 2).

- **Overview of Coal Mining Process and Techniques:** An overview of the coal mining process that introduces coal mining techniques, terminology and methods and describes coal mining processes that produce emissions of particulate matter (Section 3).

- **Air Quality Impacts in Mining Areas:** Various measures are considered such as complaints, ambient particulate measurements and non-compliance with environment protection licence conditions to provide a picture of the current issues associated with coal mining. The Camberwell Cumulative Impacts Review was also considered in this section to provide insight into the issues that exist in some mining communities and the sense that work needs to be done in various areas to improve the planning, assessment and regulation of coal mining activities to ensure that there is an ongoing minimisation of potential impacts (Section 4).

- **Identifying Major Coal Producers:** A review of World coal production by country, region and economic groupings was conducted to focus the international literature review on countries and regions that are most likely to have invested heavily in research and development of controls and regulatory regimes for management of particulate matter from coal mining (Section 5).

- **Coal Production in Australia:** A review of coal production in Australia was conducted to provide the local context and to identify the key coalfields in NSW. The method of coal mining was considered to determine whether this may have an important bearing on the potential for impact in different regions. Future trends in coal production are also considered, because in general terms increasing production whilst adopting the current approaches to particulate control will lead to increased emissions and potential impacts (Section 6).

- **Emissions Inventory Data for NSW Coal Mines:** Coal mining emissions in the GMR were quantified by OEH in the 2003 calendar year air emissions inventory. This data has been summarised to show the relative contribution of coal mining to particulate matter emissions in the GMR as a whole and to the Sydney, Newcastle, Wollongong and Non-Urban Regions within the GMR (Section 7).

- **Coal Mining Air Emissions Inventory for the GMR 2008:** OEH is currently preparing an emissions inventory for the 2008 calendar year. Coal mining data from this inventory was provided to Katestone Environmental for the benchmarking study. This information has been used to determine the relative contributions of specific aspects of the coal mining process to an individual mine's emissions and to overall emissions into the GMR airshed. Individual sources of particulate matter from coal mining activities have been ranked. This data has been used to focus the best practice literature review and review of current practices adopted by the coal mining industry in the GMR (Section 7.3).

- **Legislative Frameworks for Coal Mining:** The regulatory frameworks for the management of particulate matter emissions from coal mining in major coal producing countries have been researched and compared against current practice in NSW. Countries that are members of the Organisation for Economic Cooperation and Development (OECD) were the focus of this research, but consideration was also given to the frameworks adopted in non-member countries that are major coal producers. The concept of best practice is considered and the procedures used to plan, develop and regulate coal mining activities are discussed (Section 8).

- **International Techniques for Controlling Particulate Matter Emissions from Coal Mining:** International techniques for controlling particulate emissions from coal mining have been researched and best practice measures have been identified (Section 9).

- **NSW Techniques for Controlling Particulate Matter Emissions from Coal Mining:** Current techniques for controlling particulate matter emissions from coal mines in the GMR have been researched (Section 10) by considering:

    - Documents published by the coal mines such as: Annual Environment Management Reports (AEMR), Environmental Management Plans (EMP) and Environmental Management Systems (EMS).
    - Conditions of Approval and Environment Protection Licences (EPL).
    - Information sourced during site visits to thirteen mines in the Hunter and Newcastle coalfields.
    - An internet survey of GMR mines conducted in July-August 2010 and a follow-up survey conducted in February-March 2011.

- **Air Quality Management Tools:** The air quality management tools that are used to control emissions of particulate matter from coal mines and current practices adopted by coal mines in the GMR are detailed (Section 11).

  An Air Quality Management Plan (AQMP) is an essential part of controlling emissions of particulate matter. Measures to minimise the potential impact of fugitive particulate matter emissions must recognise all potential sources and have strategies in place to mitigate any unnecessary emissions and adverse impacts that the proposed activities may have on the health and amenity of the surrounding community. An AQMP should have both proactive and reactive components.

- **Estimated Costs of Controlling Particulate Matter Emissions from NSW Coal Mines:** A cost benefit analysis has been conducted to determine the cost of using best practice particulate emissions controls at GMR mines. The benefits, in terms of the reduction in emissions of particulate matter, have been determined along with the cost per tonne of particulate matter avoided (Section 12).

- **Conclusions and Recommendations:** Conclusions of the study and potential improvements to the management of particulate matter emissions from coal mines in the GMR are also presented (Section 13).

2. Amenity Impacts and Health Effects of Particulate Matter

This section provides definitions of particulate matter including the key metrics (TSP, PM_{10} and $PM_{2.5}$) that are used throughout the document. A discussion of the potential for particulate matter to affect human health, amenity and the environment is also provided.

2.1 Definitions of particulate matter

Particulate matter is a term used to define solid or liquid particles that may be suspended in the atmosphere. Particulate matter is a generic term that is commonly used interchangeably with other terms such as smoke, soot, haze and dust. The potential affect of particulate matter on the environment, human health and amenity depends on the size of the particles, the concentration of particulate matter in the atmosphere and rate of deposition. Concentration is the mass of particulate matter that is suspended per unit volume of air. Suspended particulate matter in ambient air is usually measured in micrograms per cubic metre ($\mu g/m^3$). Deposition is the mass of particulate matter that settles per unit surface area. Deposited particulate matter is usually measured in grams per square metre (g/m^2).

Particulate matter with an aerodynamic diameter greater than 10 micrometres (µm) tend to be associated with amenity impacts, while particulate matter less than 10 µm are associated with health impacts. For this reason, particulate matter is sub-divided into a number of metrics based on particle size. These metrics are total suspended particulates (TSP), PM_{10}, $PM_{2.5}$ and dust deposition rate:

- TSP refers to the total of all particles suspended in the air. When TSP is measured using a high volume air sampler, the maximum particle size has been found to be approximately 30 µm[2]. TSP was first used as a human health metric, but research has found a poor correlation between the concentration of TSP and health effects. TSP is now used as a metric of the potential for particulate matter to affect amenity.
- PM_{10} is a subset of TSP[2] and refers to particles suspended in the air with an aerodynamic diameter less than 10 µm.
- Coarse particulate matter[2] is a subset of TSP and PM_{10} and refers to particles suspended in the air with an aerodynamic diameter between 2.5 and 10 µm.
- $PM_{2.5}$ is a subset of TSP and PM_{10} and refers to particles suspended in the air with an aerodynamic diameter less than 2.5 µm. $PM_{2.5}$ is also called fine particulate matter[2].
- Dust deposition rate is the mass of particulate matter that collects on an area over a one month period. Dust deposition rate is used as a metric of the potential for particulate matter to affect amenity.

The atmospheric lifetimes of particles depends on the size of the particle with coarse particulate matter tending to deposit quickly and in relatively close proximity to its point of emissions, whilst fine particulate matter may remain suspended in the atmosphere for many days and travel many hundreds of kilometres. The atmospheric lifetimes of particles and potential travel distances based on the particle size are summarised in Table 1[3].

Table 1 Atmospheric lifetime and potential travel distance for particles of various size categories

Particle size	Description	Atmospheric lifetime	Travel distance
TSP	Total of all particles suspended in the atmosphere	Minutes to hours	Typically deposits within the proximate area downwind of the point of emissions
PM_{10}	A subset of TSP, including all particles smaller than 10 µm in diameter.	Days	Up to 100 kilometres or more
$PM_{2.5}$	A subset of the PM_{10} and TSP categories, including all particles smaller than 2.5 µm in diameter.	Days to weeks	Hundreds to thousands of kilometres

Figure 1[4] shows the sizes of particulate matter as $PM_{2.5}$ and PM_{10} relative to the average width of a human hair, which is 70 µm.

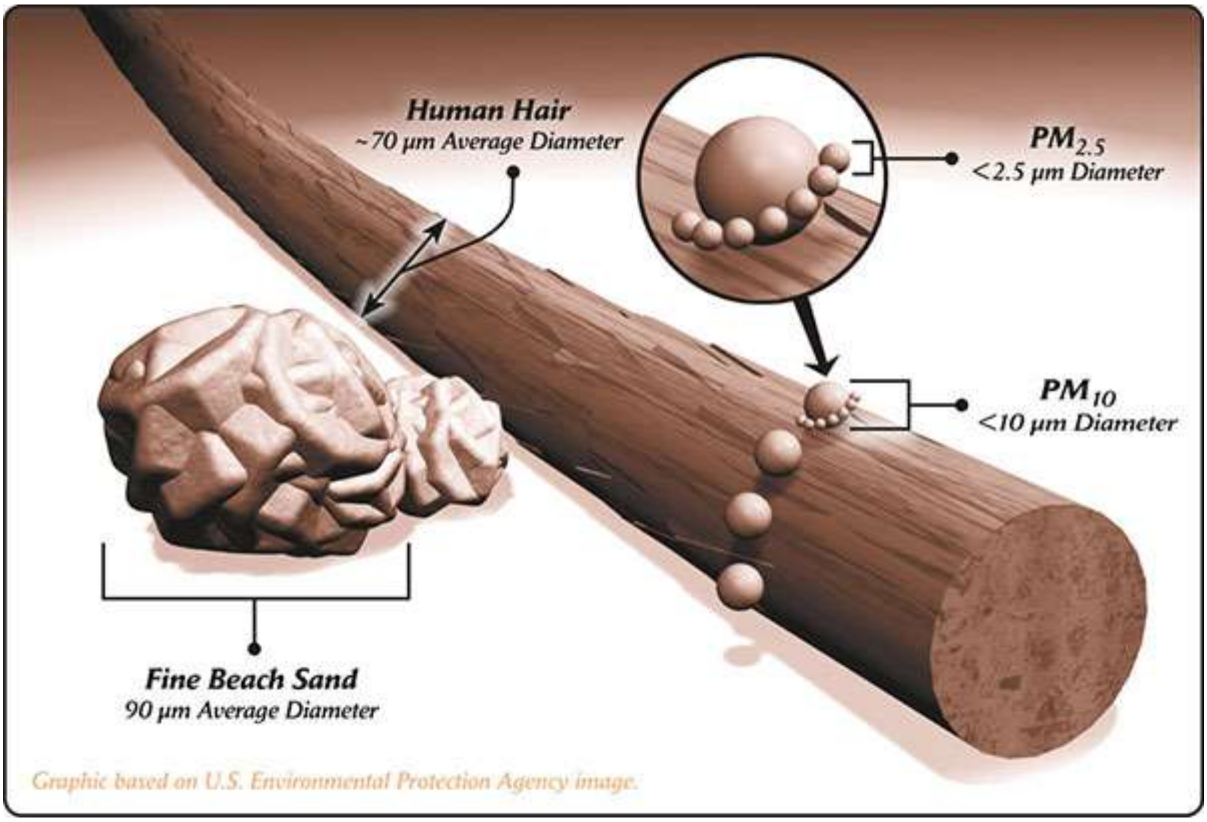

Figure 1 Sizes of particulate matter smaller than $PM_{2.5}$ and PM_{10} relative to the average width of a human hair

2.2 Amenity impacts of particulate matter

Amenity impacts can occur when levels of particulate matter become elevated[5]. The following impacts on amenity are commonly noted:

- Short-term reduction in visibility. For example, at a local scale particulate matter may pass across a road and temporarily affect a driver's ability to see oncoming traffic. At a regional scale, a visible plume of particulate matter may adversely affect the aesthetics of the environment such as scenic views.

- Build up of particulate matter on surfaces within homes resulting in the occupant needing to clean more frequently.
- Soiling of washing.
- Build up of particulate matter on the roofs of houses and, during rainfall, the flushing of the particulate matter into rainwater tanks potentially affecting quality of drinking water or tank capacity.

2.3 Health effects of particulate matter

The human body's respiratory system has a number of defence mechanisms to protect against the harmful effects of particulate matter[5]. Coarse particulate matter may be trapped in the mucus on the walls of the airways and can be removed by cilia, small hair-like structures that line the surface of the airways. The particulate matter is expelled from the body by coughing or is swallowed.

There is a demonstrated statistical association between health effects and the concentration of fine particulate matter. Recent studies Ono[6], Cowherd and Donaldson[7] and USEPA[8] indicate that in susceptible sub-populations, fine particulate matter from combustion related sources are markedly more detrimental to health than coarse particulate fractions ($PM_{10-2.5}$). There is data associating PM_{10} from a combustion origin with health effects but this fraction also contains $PM_{2.5}$[9] and, hence, the specific cause cannot be delineated.

Exposure to particulate matter can cause a variety of health effects[5]. For example, numerous studies link levels of fine particulate matter to increased hospital admissions and emergency room visits and even to death from heart or lung diseases. Both long (over years) and short term (hours or days) particle exposure have been linked to health problems.

There is clearly a fundamental distinction between particulate matter originating from the combustion of fuel and secondary chemical reactions, and mechanically generated crustal particulate matter. Where the former is generated for example by motor vehicles, power stations, and industrial activities and consists predominantly of fine particulate matter ($PM_{2.5}$). While the latter, originates from construction, mining, earth works, unpaved roads, agricultural activities and erosion and consists predominantly of coarse particulate matter (PM_{10}).

Ono[6], Cowherd and Donaldson[7] and USEPA[8] noted there are clear distinctions between:

- The character of the ambient mix of particles generally found in urban areas as compared to that found in rural areas.
- The nature of the evidence concerning health effects associated with thoracic coarse particles generally found in urban versus rural areas.

Further, the mix of particles typically found in areas with combustion sources such as industrial sites and urban areas contain a number of contaminants that are not commonly present, or not present to the same degree, in the mix of natural crustal particles. Particles of crustal origin, which are predominately in the coarse fraction, appear to be relatively non-toxic under most circumstances, compared to combustion-related particles.

NSW Health[5] considers that the following people may be more susceptible to the health effects of fine and coarse particles:

- Infants, children and adolescents.
- The elderly.
- People with respiratory conditions such as asthma, bronchitis and emphysema.

- People with heart disease.
- People with diabetes.

If health effects arise from exposure to particulate matter, the symptoms are likely to be[5]:

- Coughing.
- Wheezing or worsening of asthma.
- Increased need for medications (e.g. puffers, antibiotics).
- Increased breathlessness.
- Sneezing and sore eyes.

NSW Health reports[5] that recent research suggests that heart problems, such as angina and heart attacks may also be associated with coarse particle pollution.

Particulate matter is the major air pollutant that is emitted from coal mining and processing activities. The majority of particulate matter emitted from coal mining consists of large particles generated from activities such as mechanical disturbance of rock and soil materials by bulldozing, blasting and vehicles on dirt roads. Particulate matter is also generated from wind erosion of stockpiles and bare ground.

Section 8.7 presents a comparison of ambient air quality standards for particulate matter including total suspended particulate (TSP), PM_{10}, $PM_{2.5}$ and deposited dust that are promulgated in various national and state/provincial jurisdictions in Table 52 to Table 60.

3. Overview of Coal Mining Process and Techniques

This section presents an overview of the coal mining process for underground, open-cut and highwall mining. Coal mining techniques have been described including, terminology and methods used to access the coal and extract it from the ground. Coal mining activities that produce emissions of particulate matter have been identified.

Figure 2 is a schematic[10] that describes the open-cut and underground coal mining and washing processes.

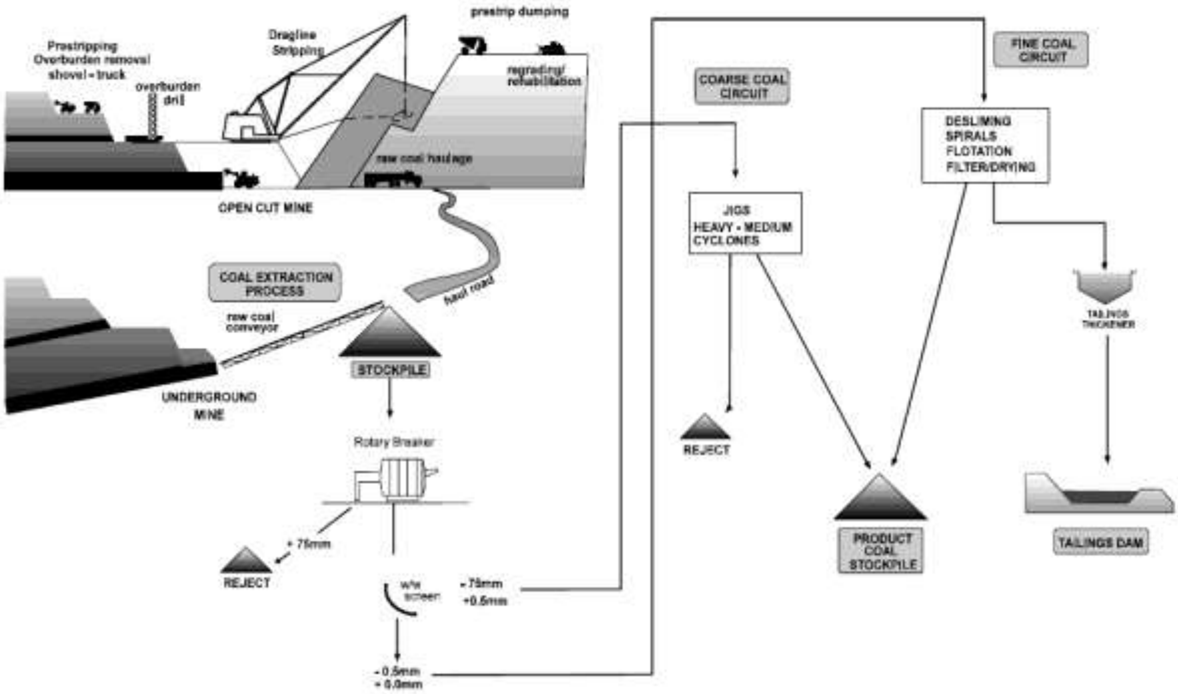

Figure 2 Open-cut and underground coal mining and washing flowchart

3.1 Underground mining

Underground mining in NSW is generally carried out using either the bord and pillar method or the longwall mining method. These methods involve the following procedures:

- Bord and pillar: underground lanes ('bords') are cut into the coal seam with pillars of coal being left to support the roof. Extracting coal while leaving the pillars is known as 'first workings' and will result in minimal surface subsidence (Figure 3[11]). Removing pillars is termed 'second workings' and will result in the collapse of the roof and surface subsidence. In the United States bords are termed "rooms".
- Longwall mining: coal is extracted in a series of panels that may be up to 200 metres wide and two kilometres long. As no coal is left to support the roof at the mining face, hydraulic roof supports must be used to hold it up and the roof is allowed to fall once the coal has been extracted (Figure 4[11]). This method of coal mining causes surface subsidence.

In underground mining, coal is transported from the underground mining face by conveyor to the mine coal handling plant.

The main activities that produce emissions of particulate matter at underground mines are:

- Transport of raw coal from the mine to the raw coal stockpile (run-of-mine (ROM) pad). Wind-blown particulate matter from conveyors or wheel generated particulate matter associated with haul trucks.

- Stockpiling materials on the ROM pad associated with dumping coal from conveyors or trucks. Wind-blown particulate matter from stockpiled coal and emissions associated with transferring coal to the load-in hopper (ROM hopper) of the processing plant.

- Emissions of particulate matter from the processing plant may occur from the dry processing operations such as crushing and screening. Emissions from wet processing operations tend to be minimal.

- Washed or processed coal is then transferred to product stockpiles and subsequently to trucks or trains for transport to the end user. Particulate matter emissions can occur due to wind erosion of product stockpiles if they become sufficiently dry and as a result of loading materials from the stockpile (reclaim). Dumping coal into rail wagons and trucks will also produce emissions of particulate matter.

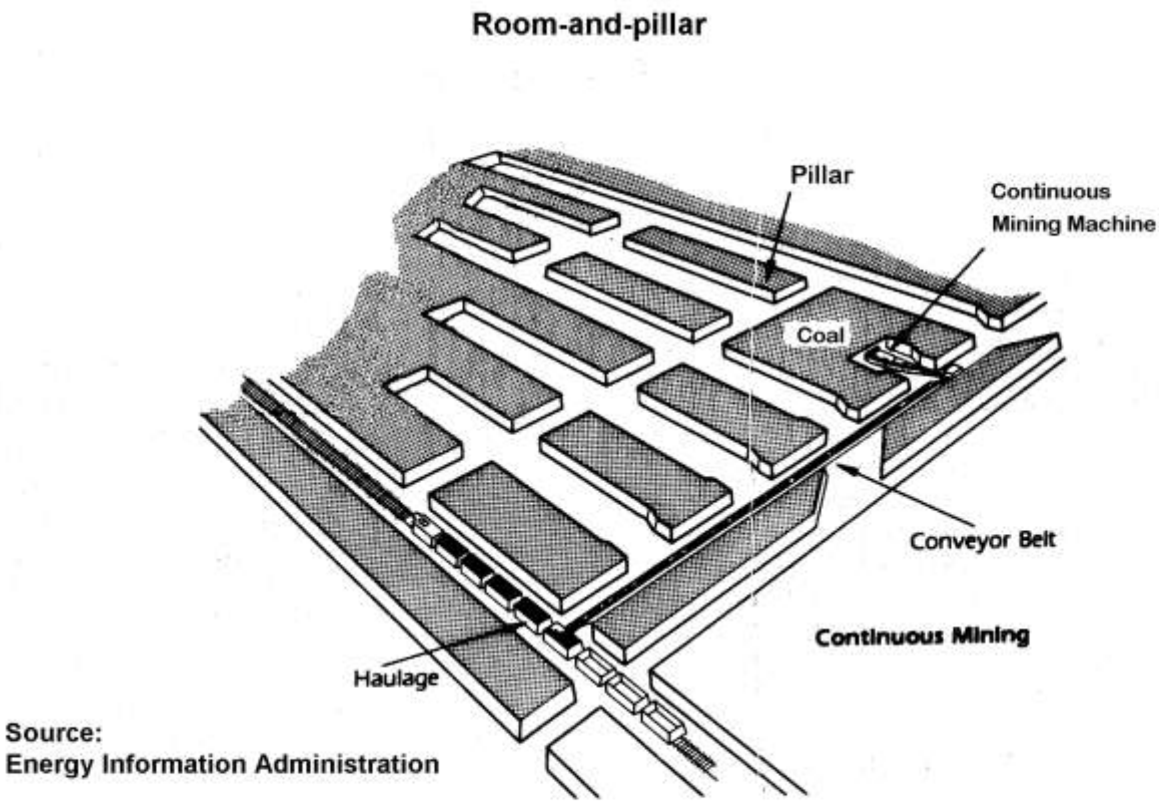

Figure 3 Underground mining using the bord (or room) and pillar mining technique

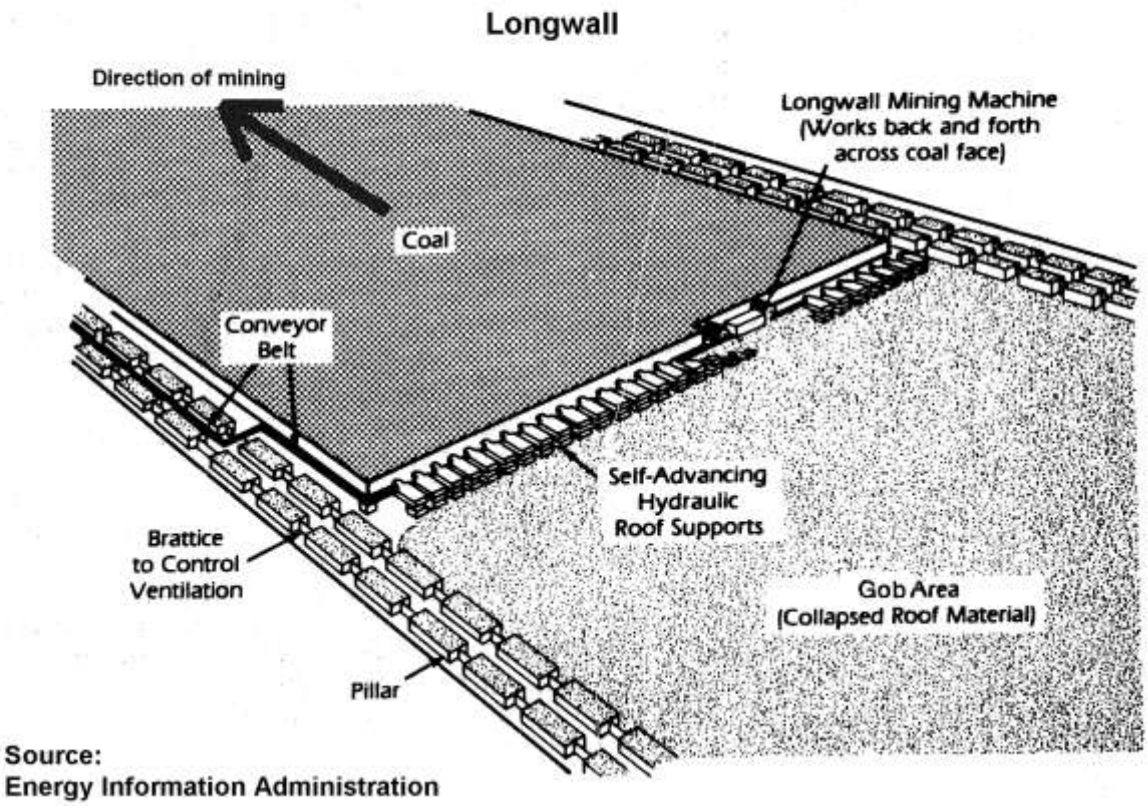

Figure 4 Underground mining using the longwall technique

3.2 Open-cut mining

Mining is undertaken by open-cut methods using predominantly haul trucks, draglines and/or hydraulic excavators. The mining occurs in distinct stages that are described below. The open-cut coal mining process is shown in Figure 5[12].

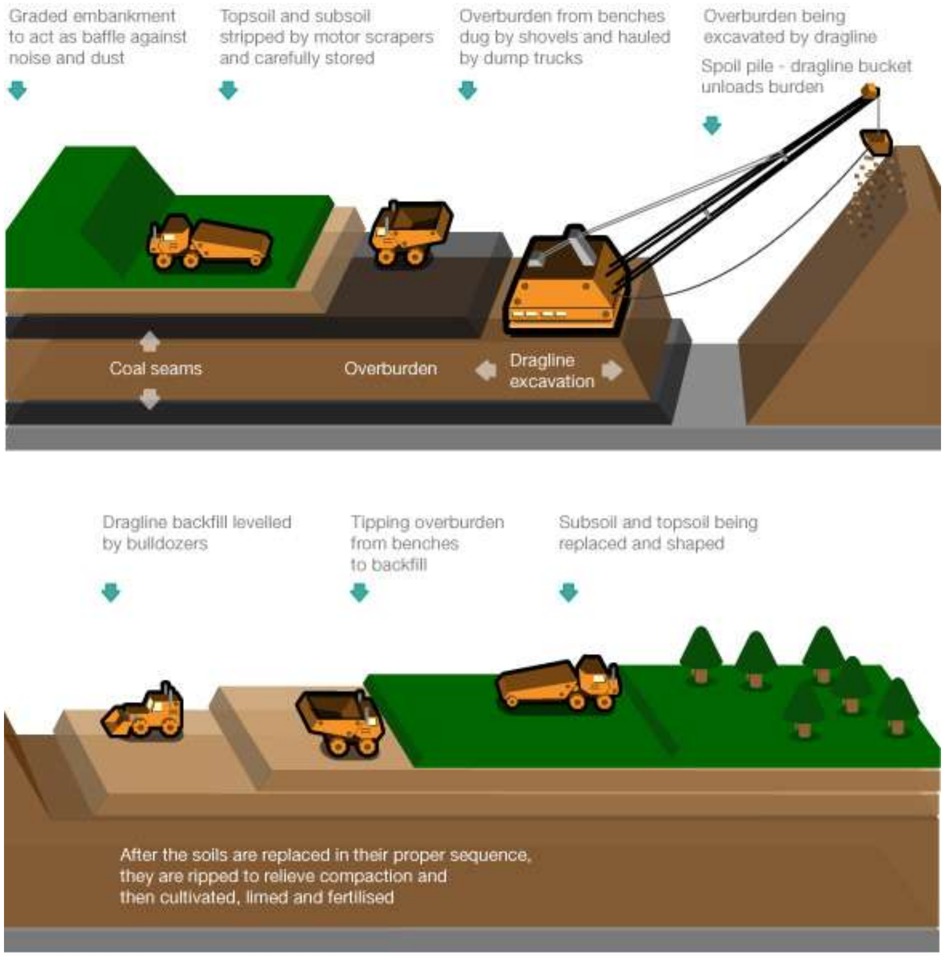

Figure 5 Open-cut coal mining process

3.2.1 Land preparation

Land preparation prior to coal mining is site specific depending on the mining technique to be adopted, the vegetation and terrain. The following approach to land preparation is indicative of the general process of land preparation for open-cut coal mining.

The first stage of the physical mining process involves the removal of the existing trees and vegetation. Cleared timber and vegetation may be mulched and stockpiled to be used on site for later re-use in rehabilitation.

Topsoil is recovered using scrapers and placed directly onto reshaped areas where possible or otherwise stockpiled. The topsoil is recovered during stripping for later re-use on rehabilitation areas. Once established, topsoil stockpiles may be revegetated.

Emissions of particulate matter occur as a result of:

- Use of scrapers.

- Exposure of soil.
- Bulldozing and stockpiling materials.
- Wind erosion of bare ground and topsoil stockpiles.

3.2.2 Blasting

Holes are drilled into overburden and filled with explosives. The overburden is then blasted to fracture the rock enabling more efficient recovery of this material. Vibration, noise and fly-rock can be minimised by optimising the blast design and the timing of the blast to avoid atmospheric conditions that might be conducive to the propagation of noise and through the use of engineering controls on drill rigs.

Emissions of particulate matter occur as a result of:

- Drilling the overburden.
- Wind erosion of drill cuttings.
- Wind erosion of bare ground.
- Blasting overburden.

3.2.3 Overburden removal

Hydraulic excavators (Figure 6[13] and Figure 7[14]) and/or draglines (Figure 8[15]) recover and load blasted overburden into large haul trucks. These trucks transport the material to emplacement areas either within the mine void or outside the void. At some mines, overburden may be used to construct earth bunds to provide a visual screen of operations and to provide a shield to limit the speed of winds travelling across the site.

Emissions of particulate matter occur as a result of:

- Draglines excavating overburden and dumping overburden onto overburden dumps.
- Excavators digging overburden and dumping overburden into haul trucks.
- Wheel generated particulate matter as the haul truck travels from the pit to the in-pit or out-of-pit overburden dump.
- Truck dumping of overburden to the in-pit or out-of-pit overburden dumps, stockpiles or emplacements.
- Wind erosion of in-pit and out-of-pit overburden dumps.

Figure 6 Large excavator loading haul truck

Figure 7 Hydraulic shovel loading haul truck

Figure 8 Dragline

3.2.4 Coal recovery

After removing the overburden, coal seams are mined using hydraulic excavators and loaders with the assistance of dozers. Haul trucks then transport the coal to the processing plant.

Emissions of particulate matter occur as a result of:

- Excavators digging coal and dumping coal into haul trucks.
- Wheel generated particulate matter as the haul truck travels from the pit to the processing plant.
- Truck dumping coal onto the raw coal pad (ROM pad).
- Bulldozers forming the coal into a stockpile.
- Truck or loader dumping coal into the raw coal hopper (ROM hopper).
- Wind erosion of ROM stockpile.

3.2.5 Coal processing and transport off-site

After crushing to size and processing (washing) to remove impurities, coal is stockpiled prior to removal from site. Coal is then either loaded onto rail wagons or road trucks for transport to the port for export or to the end user.

Emissions of particulate matter occur as a result of:

- Coal crushing and screening.
- Transferring coal from the processing plant to the product stockyard by conveyor.
- Stockpiling product coal using fixed or variable height stackers.
- Wind erosion of product stockpile.
- Unloading coal from the product stockpile (reclaiming).
- Transferring coal from the reclaimer to the truck or rail loading facility.
- Dumping coal into rail wagons or trucks.
- Transfer and disposal of coal rejects.

3.2.6 Mined land rehabilitation

As overburden emplacement areas reach final design elevations, dozers are used to shape the land to be consistent with the surrounding environment. These reshaped areas are then re-topsoiled, ripped and sown with a mix of pasture grasses and native trees.

Emissions of particulate matter occur as a result of:

- Earthworks associated with reshaping the land by bulldozer.
- Spreading topsoil.
- Wind erosion of bare ground prior to the establishment of vegetation.

3.3 Highwall mining

Highwall mining is conducted using remote controlled mining machines that are driven into a coal seam to extract the coal. Highwall mining can be used to access coal left behind from previous mining operations or where difficult geological conditions restrict the use of other mining methods. In highwall mining, coal is extracted from the base of a cliff (a highwall) using horizontal drilling to create holes in the coal seam. Pillars are left between areas of coal extraction to support the roof from collapsing. Highwall mining is a relatively new mining method that was introduced to Australia in the 1990s[16].

There are two main types of highwall mining: continuous highwall mining and auger mining (Figure 9).

The potential for emissions of particulate matter from highwall mining will depend on the circumstances where highwall mining is used. However, in general, highwall mining would have equivalent emission sources to an underground mine, but with the addition of emissions associated with the creation of the highwall and wind erosion of exposed areas of overburden.

Figure 9 Highwall mining using an auger miner

4. Air Quality Impacts in Mining Areas

In this section, various measures are considered such as complaints, ambient particulate measurements and non-compliance with environment protection licence conditions to provide a picture of the current issues associated with coal mining in the GMR. The Camberwell Cumulative Impacts Review was also considered in this section to provide insight into the issues that exist in some mining communities and the sense that work needs to be done in various areas to improve the planning, assessment and regulation of coal mining activities to ensure that there is an ongoing minimisation of potential impacts.

4.1 Ambient concentrations of PM_{10} in the Hunter Valley

In the Hunter Valley area, ambient monitoring of PM_{10} is conducted across a network of 60 sites. There are 45 high volume air samplers (HVAS) and 25 continuous monitors (Tapered Element Oscillating Microbalances or TEOMs). Sampling of PM_{10} is conducted once every six days, daily and/or hourly depending on the method used. Monitoring at these sites is conducted as a condition of development approval to indicate levels that occur close to the mines and residences.

In 2010, OEH prepared a document titled *Compendium of Upper Hunter Ambient Air Quality Monitoring Data*. The compendium included the monitoring data collected by coal mining companies in the Hunter Valley[17]. The compendium presents ambient monitoring data for PM_{10} using the *National Environment Protection (Ambient Air Quality) Measure*[18] (Ambient Air Quality NEPM) standards. Ambient data for $PM_{2.5}$ sourced from the Australian Nuclear Science and Technology Organisation monitoring site at Muswellbrook is also presented, using the Ambient Air Quality NEPM advisory reporting standards for $PM_{2.5}$ as a benchmark[19].

The data that formed the basis of OEH's review has been considered in the following section. The monitoring data collected within close proximity to the towns of Singleton and Muswellbrook has been considered specifically.

Tables are provided below that summarise the maximum and 95th percentile, 24-hour average and annual average ground-level concentrations of PM_{10}. Also included in the tables is the number of days when the 24-hour average concentration of PM_{10} has exceeded the Ambient Air Quality NEPM standard of 50 µg/m^3. Years that have more than 5 days with 24-hour average concentrations above 50 µg/m^3 have been shaded red.

The data shows:

- In 2009 the maximum 24-hour average concentrations recorded are significantly higher than for other years. This is partly, though not entirely due to dust storm events that occurred on the 23 and 26 September 2009[20].

- The annual average concentrations of PM_{10} at Muswellbrook are typically between 20 and 25 µg/m^3 (HVAS data) and 15 to 20 µg/m^3 (TEOM data).

- The annual average concentrations of PM_{10} at Singleton are typically between 15 and 30 µg/m^3 (HVAS data). The low data capture rate at some sites makes it difficult to calculate an accurate annual average concentration.

- The 24-hour average, 95th percentile PM_{10} concentrations at Muswellbrook are typically between 25 and 40 µg/m^3 (TEOM data), except for 2009 when levels reach above 50 µg/m^3.

- The maximum 24-hour average PM_{10} concentrations at Muswellbrook have ranged between 40 and 120 µg/m^3, excluding data from 2009.

- At all monitoring stations at Muswellbrook for the year 2009, the 24-hour average concentrations of PM_{10} have exceeded 50 µg/m^3 on more than 5 days per year, ranging between 6 to 30 days. Excluding the days related to the dust storm event, the number of days that exceedances occurred during 2009 are generally greater than for other years. For 2005 to 2008, the number of days exceeding 50 µg/m^3 is lower than 5.

- The 24-hour average, 95th percentile PM_{10} concentrations at Singleton are typically between 37 and 48 µg/m^3 (TEOM data) in years where the data recovery is greater than 80%.

- The maximum 24-hour average PM_{10} concentrations at Singleton have ranged between 40 and 100 µg/m^3.

- At Singleton, the number of days per year that the 24-hour average concentration of 50 µg/m^3 is exceeded has increased since 2005, ranging from 0 to 12 days.

Box and whisker plots of the 24-hour average concentrations of PM_{10} measured at the four TEOM sites at Muswellbrook and Singleton are presented in Figure 11, Figure 12, Figure 13 and Figure 14. Measurements during the dust storm event in 2009 have been removed from these data.

Figure 1 shows the locations of ambient monitoring stations included in OEH's compendium.

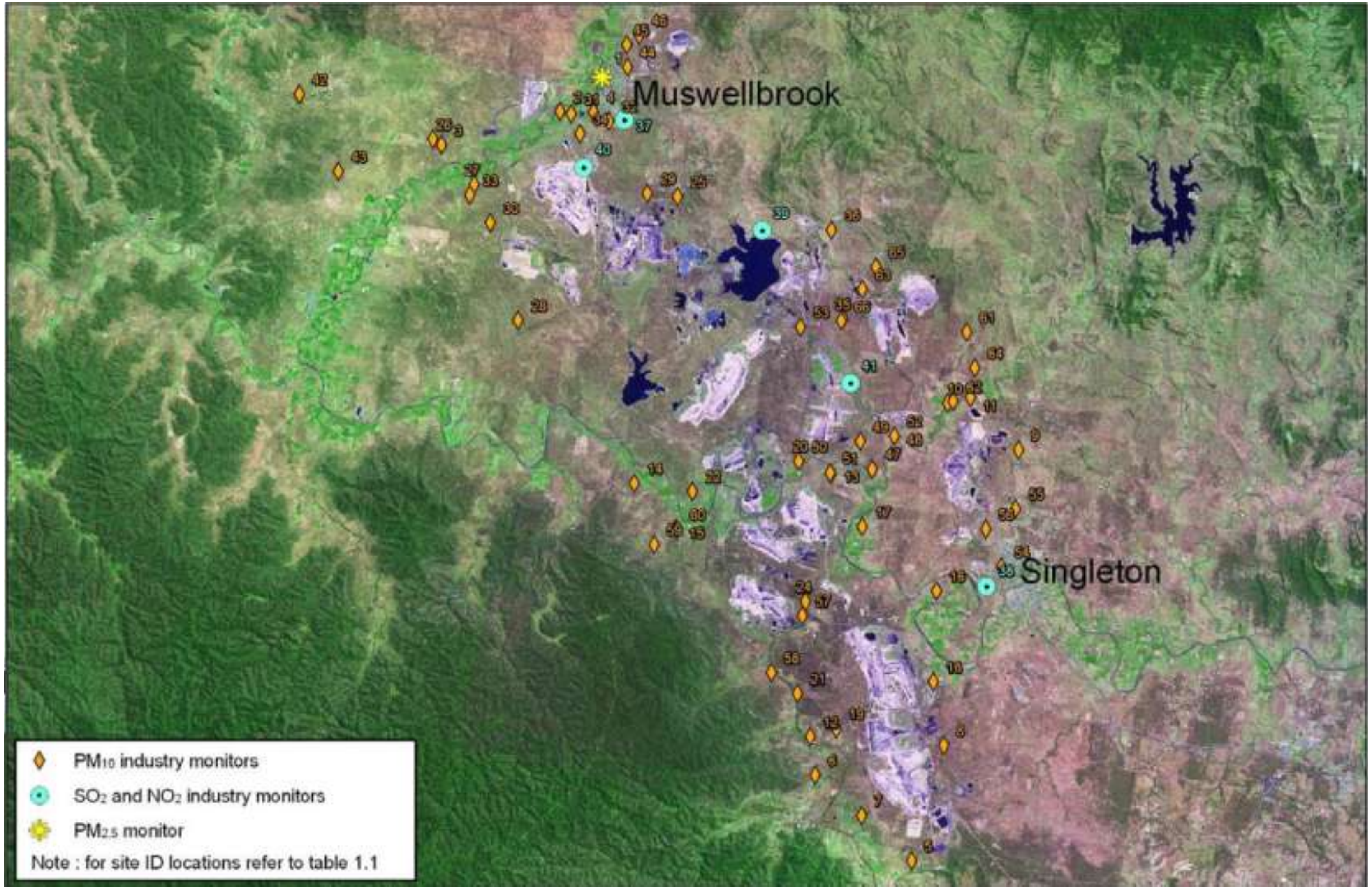

Figure 10 Locations of ambient air quality monitoring stations from OEH Compendium of Upper Hunter Ambient Air Quality Monitoring Data

Table 2 Summary of 24-hour and annual average concentrations of PM_{10} at Muswellbrook

Site name/location	Organisation	Method[1]	Duration	Year	Data capture (%)	Maximum 24-hour (µg/m³)	95th Percentile, 24-hour (µg/m³)[2]	Annual average (µg/m³)	[4]Number of days >50 µg/m³
Site 2 Racecourse Rd	Bengalla Mining Company	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	100	53.3	-	23.3	1
				2006	100	44.8	-	23.7	0
				2007	100	78.1	-	26.5	6
				2008	90	83.6	-	24.8	2
				2009[3]	99	123.0	-	31.5	9
Site 4 St James School	Bengalla Mining Company	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	100	52.2	-	20.2	1
				2006	100	41.8	-	22.3	0
				2007	100	55.0	-	23.3	3
				2008	90	62.4	-	21.9	1
				2009[3]	99	125.0	-	**30.5**	6
Site 31 Sheppard Avenue	Hunter Valley Energy Coal Pty Ltd	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	100	47.4	-	21.8	0
				2006	100	95.7	-	27.9	7
				2007	99	97.2	-	27.8	6
				2008	100	78.9	-	21.0	2
				2009[3]	99	192.0	-	29.8	7
Site 31 Sheppard Avenue	Hunter Valley Energy Coal Pty Ltd	AM-22 TEOM daily	1/01/2009 to 31/12/2009	2009[3]	97	2090.7	59.3	**32.4**	30
Site 32 South Muswellbrook	Hunter Valley Energy Coal Pty Ltd	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	99	60.9	-	22.4	3
				2006	100	66.2	-	22.3	1
				2007	99	64.6	-	23.1	1
				2008	100	84.3	-	20.7	1
				2009[3]	95	71.0	-	27.9	8
Site 32 South Muswellbrook	Hunter Valley Energy Coal Pty Ltd	AM-22 TEOM daily	1/01/2009 to 31/12/2009	2009[3]	94	1959.8	55.1	**31.0**	21

Site name/location	Organisation	Method[1]	Duration	Year	Data capture (%)	Maximum 24-hour ($\mu g/m^3$)	95th Percentile, 24-hour ($\mu g/m^3$)[2]	Annual average ($\mu g/m^3$)	[4]Number of days >50 $\mu g/m^3$
Site 34 Yammanie	Hunter Valley Energy Coal Pty Ltd	AM-22 TEOM daily	1/01/2009 to 31/12/2009	2009[3]	100	1924.0	53.9	**30.8**	21
Site 44 Site 1 - MCC	Muswellbrook Coal Company Ltd	AM-22 TEOM daily	08/03/2005 to 31/12/2009	2005	80	45.5	26.1	13.4	0
				2006	96	56.2	30.9	17.3	2
				2007	98	84.7	35.8	17.2	7
				2008	94	120.5	29.3	14.6	2
				2009[3]	95	1960.0	46.1	25.2	15
Site 45 Site 2 - MCC	Muswellbrook Coal Company Ltd	AM-22 TEOM daily	08/03/2005 to 31/12/2009	2005	80	46.2	30.4	16.3	0
				2006	90	71.6	40.2	21.0	5
				2007	97	73.8	43.5	20.5	14
				2008	90	66.2	28.4	15.6	2
				2009[3]	92	1994.0	47.2	29.2	16
Site 46 Site 3 - MCC	Muswellbrook Coal Company Ltd	AM-22 TEOM daily	08/03/2005 to 31/12/2009	2005	80	44.2	28.5	15.9	0
				2006	95	75.6	37.8	19.8	4
				2007	94	56.2	39.1	18.1	4
				2008	91	124.7	33.7	15.7	3
				2009[3]	89	1942.0	60.1	**31.8**	29

Note:
[1] Monitoring methods are defined in the Approved Methods for Sampling[21]. AM-18 is the Australian Standard for monitoring PM_{10} with a HVAS. AM-22 is the Australian Standard for monitoring PM_{10} with a TEOM.
[2] 24-hour, 95th percentile concentrations were calculated for TEOM data only due to insufficient data for HVAS.
[3] Results include measurements recorded during dust storm events that occurred on 23 September and 26 September 2009.
[4] Since HVAS monitoring for PM_{10} is conducted on one day in six, the actual number of exceedances of the PM_{10} criterion is likely to be higher than reported. The proportion of exceedances is likely to be correct. So the number of exceedances can be inferred from HVAS results assuming the monitor were operated continuously. For example, one exceedance measured over a full year of one day in six monitoring would correspond to exceedances on 1.6% of days or six days per year. Hence one or more HVAS exceedances indicate the likelihood that there would be more than five exceedances of the PM_{10} criterion in a year.

Table 3 Summary of 24-hour and annual average concentrations of PM_{10} at Singleton

Site name/location	Organisation	Method[1]	Duration	Year	Data capture (%)	Maximum 24-hour (µg/m³)	95th Percentile, 24-hour (µg/m³)[2]	Annual average (µg/m³)	[4]Number of days >50 µg/m³
Site 9 HV1 - Bridgman Road	Camberwell Coal Pty Ltd	AM-18 HVAS one in six day	25/08/2005 to 26/12/2009	2005	36	49.0	-	22.9	0
				2006	99	57.0	-	17.4	1
				2007	100	72.0	-	19.9	4
				2008	100	66.0	-	20.6	3
				2009[3]	99	60.0	-	21.7	4
Site 16 Long Point PM_{10}	Coal & Allied Industries Ltd (Hunter Valley Operations)	AM-18 HVAS one in six day	29/06/2009 to 26/12/2009	2009[3]	53	54.7	-	21.9	1
Site 17 Maison Dieu PM_{10}	Coal & Allied Industries Ltd (Hunter Valley Operations)	AM-18 HVAS one in six day	NO DATA	-	-	-	-	-	-
Site 17 Maison Dieu PM_{10}	Coal & Allied Industries Ltd (Hunter Valley Operations)	AM-22 TEOM daily	16/10/2007 to 31/12/2009	2007	21	64.5	50.7	20.7	4
				2008	96	78.0	37.3	18.2	8
				2009[3]	87	149.0	47.7	21	12
Site 54 Mines Rescue	Rix's Creek Pty Limited	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	99	42.0	-	10.5	0
				2006	99	48.0	-	19.7	0
				2007	94	58.0	-	15.4	1
				2008	75	87.0	-	38	12
				2009[3]	39	81.0	-	27.1	3

Site name/location	Organisation	Method[1]	Duration	Year	Data capture (%)	Maximum 24-hour ($\mu g/m^3$)	95^{th} Percentile, 24-hour ($\mu g/m^3$)[2]	Annual average ($\mu g/m^3$)	[4]Number of days >50 $\mu g/m^3$
Site 55 Retreat	Rix's Creek Pty Limited	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	97	83.0	-	25.3	7
				2006	99	57.0	-	23.9	6
				2007	97	89.0	-	26.1	7
				2008	90	71.0	-	29.8	9
				2009[3]	76	69.0	-	25.7	4
Site 56 Rix's Creek	Rix's Creek Pty Limited	AM-18 HVAS one in six day	03/01/2005 to 26/12/2009	2005	92	73.0	-	21.3	2
				2006	85	58.0	-	22.4	4
				2007	90	94.0	-	28.5	5
				2008	93	94.0	-	28.5	8
				2009[3]	46	108.0	-	20.5	3

Note:
[1] Monitoring methods are defined in the Approved Methods for Sampling[21]. AM-18 is the Australian Standard for monitoring PM_{10} with a HVAS. AM-22 is the Australian Standard for monitoring PM_{10} with a TEOM.
[2] 24-hour, 95^{th} percentile concentrations were calculated for TEOM data only due to insufficient data for HVAS.
[3] Results include measurements recorded during dust storm events that occurred on 23 September and 26 September 2009.
[4] Since HVAS monitoring for PM_{10} is conducted on one day in six, the actual number of exceedances of the PM_{10} criterion is likely to be higher than reported. The proportion of exceedances is likely to be correct. So the number of exceedances can be inferred from HVAS results assuming the monitor were operated continuously. For example, one exceedance measured over a full year of one day in six monitoring would correspond to exceedances on 1.6% of days or six days per year. Hence one or more HVAS exceedances indicate the likelihood that there would be more than five exceedances of the PM_{10} criterion in a year.

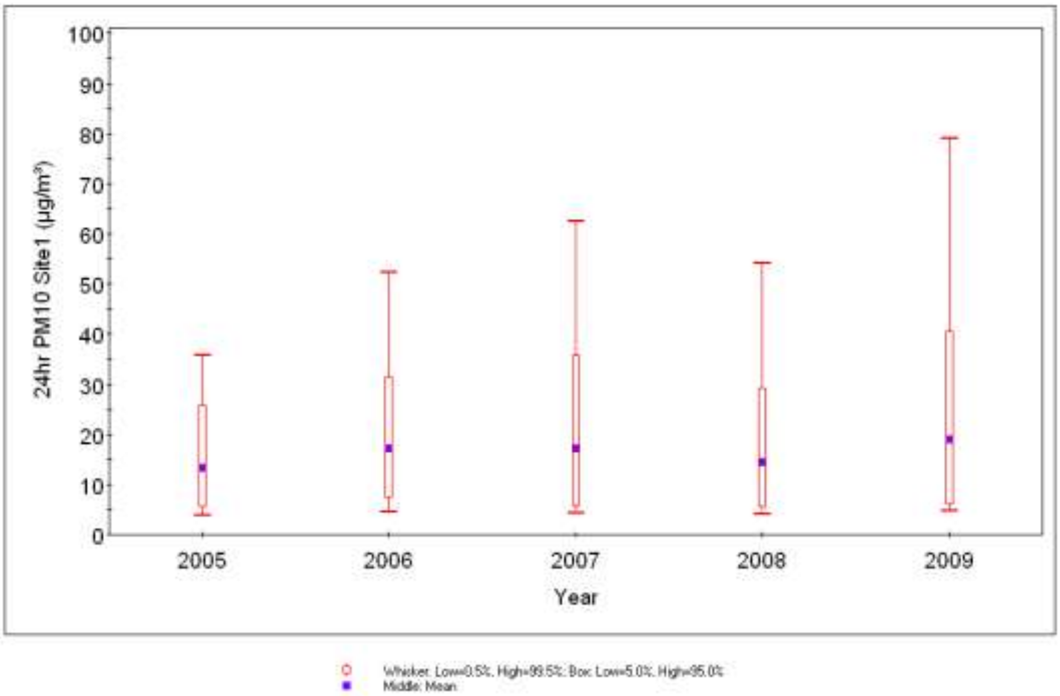

Figure 11 Box and whisker plot of 24-hour average concentrations of PM_{10} recorded at Muswellbrook from 2005-2009, Site 1 Muswellbrook Coal Company

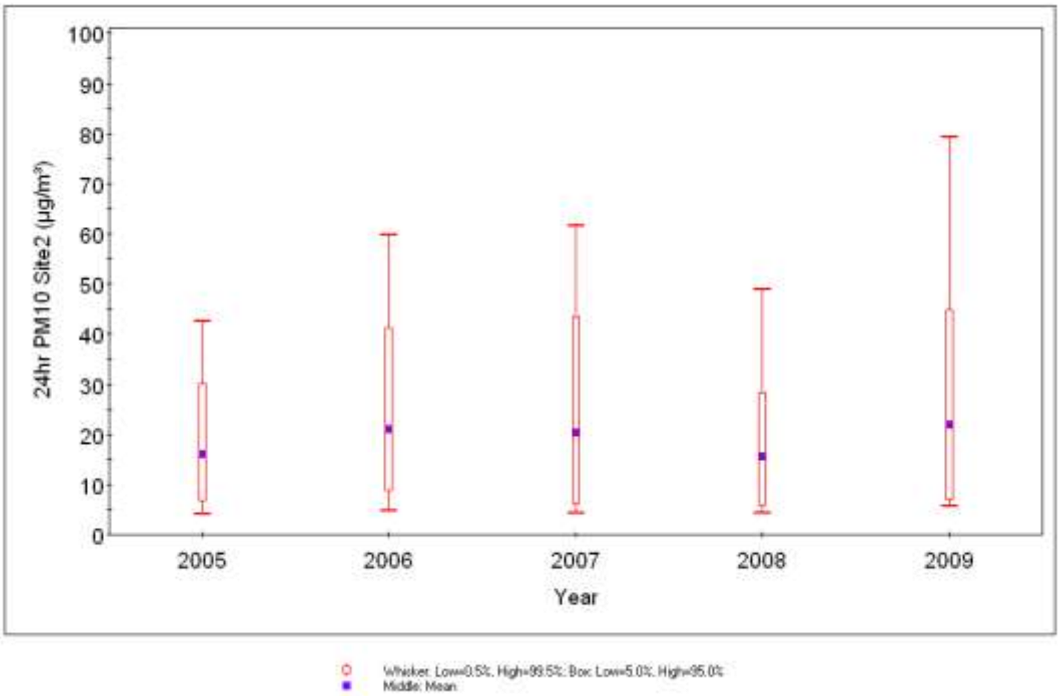

Figure 12 Box and whisker plot of 24-hour average concentrations of PM_{10} recorded at Muswellbrook from 2005-2009, Site 2 Muswellbrook Coal Company

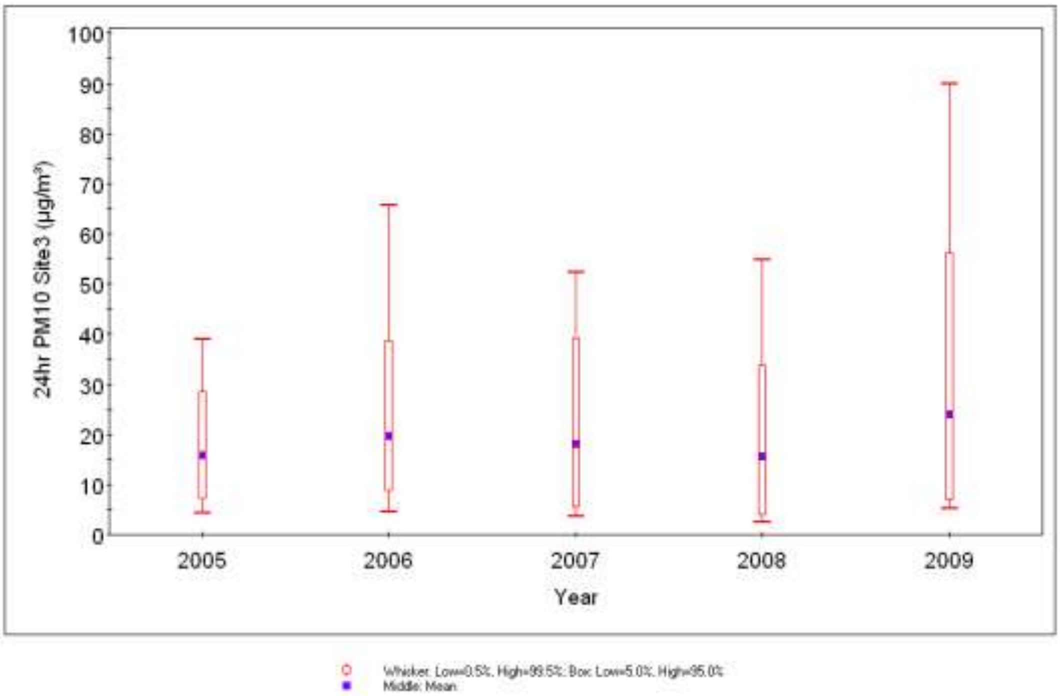

Figure 13 Box and whisker plot of 24-hour average concentrations of PM_{10} recorded at Muswellbrook from 2005-2009, Site 3 Muswellbrook Coal Company

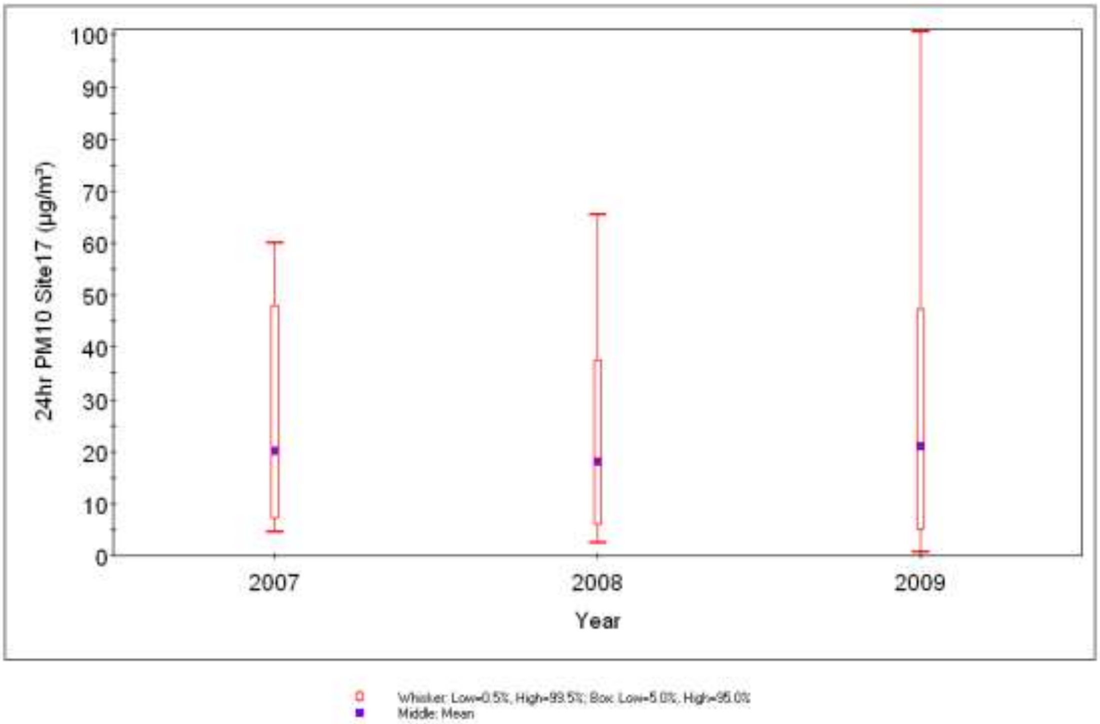

Figure 14 Box and whisker plot of 24-hour average concentrations of PM_{10} recorded at Singleton from 2007-2009, Maison Dieu Coal & Allied Industries Ltd

4.2 Air quality complaints in the GMR

OEH operates the Environment Line so that pollution incidents may be reported. The following information is recorded with each incident:

- Caller name.
- Suburb and Council area.
- Date and location of the incident.
- Description of the incident.

Complaints about air quality issues associated with coal mining activities which are recorded by OEH's Environment Line were provided by OEH for the purpose of this study. The data was provided for each of OEH's Operations Regions where coal mining activities occur for the years 2007, 2008 and 2009. The complaints are summarised in Table 4. The validity of these complaints was not assessed. The total number of complaints is relatively steady from year to year ranging from 103 in 2007 to 120 in 2008.

The majority of complaints (81-84 per year) came from OEH's North East Region that incorporates the Newcastle Coalfield and the Hunter Coalfield. The Metropolitan Region covers the Southern Coalfield and received the least number of complaints (6-11 per year). The Central West Region includes the Western Coalfield and received between 12 and 30 complaints per year.

Table 4 Number of complaints received by OEH's Environment Line in relation to air quality issues associated with coal mines in the GMR, by OEH Region from 2007 to 2009

OEH Region	Number of complaints pertaining to air quality			
	2007	2008	2009	Total
North East	83	84	81	248
Metropolitan	8	6	11	25
Central West	12	30	16	58
Total	103	120	108	331

Table 5 shows the number of complaints by suburb or town as a total for the three years from 2007 to 2009. The greatest number of complaints (81 or 24.5%) was received from people living in Muswellbrook. A further 62 complaints were received from Camberwell and 54 from Singleton. The top three are all in the Hunter Coalfield and represent 60% of all complaints. A total of 11 (or 10%) of complaints were received from Wollar, east of the Wilpinjong and Ulan coal mines.

Table 5 Number of complaints received by OEH's Environment Line in relation to air quality issues associated with coal mines in the GMR, by suburb or town from 2007 to 2009

Suburb	OEH Region	Total complaints	Proportion (%)	Cumulative Proportion (%)
Muswellbrook	North East	81	24.5	24.5
Camberwell	North East	62	18.7	43.2
Singleton	North East	54	16.3	59.5
Wollar	Central West	33	10.0	69.5
Ravensworth	North East	11	3.3	72.8
Mount Thorley	North East	9	2.7	75.5
Russell Vale	Metropolitan	7	2.1	77.6

Suburb	OEH Region	Total complaints	Proportion (%)	Cumulative Proportion (%)
Helensburgh	Metropolitan	6	1.8	79.5
Jerrys Plains	North East	6	1.8	81.3
Cullen Bullen	Central West	5	1.5	82.8
Blackmans Flat	Central West	4	1.2	84.0
Capertee	Central West	4	1.2	85.2
Port Kembla	Metropolitan	4	1.2	86.4
Charbon	Central West	3	0.9	87.3
Fassifern	North East	3	0.9	88.2
Warkworth	North East	3	0.9	89.1
Broke	North East	2	0.6	89.7
Dapto West	Metropolitan	2	0.6	90.3
Lithgow	Central West	2	0.6	90.9
Mudgee	Central West	2	0.6	91.5
Stroud	North East	2	0.6	92.1
Teralba	North East	2	0.6	92.7
Wilpinjong	Central West	2	0.6	93.4
Wybong	North East	2	0.6	94.0
Bellambi	Metropolitan	1	0.3	94.3
Boolaroo	North East	1	0.3	94.6
Bulga	North East	1	0.3	94.9
Cessnock	North East	1	0.3	95.2
Clandulla	Central West	1	0.3	95.5
Corrimal	Metropolitan	1	0.3	95.8
Lidsdale	Central West	1	0.3	96.1
Mount Vincent	North East	1	0.3	96.4
Rix's Creek	North East	1	0.3	96.7
Rothbury North	North East	1	0.3	97.0
Rutherford	North East	1	0.3	97.3
Singleton Heights	North East	1	0.3	97.6
Stroud Road	North East	1	0.3	97.9
Tahmoor	Metropolitan	1	0.3	98.2
Thirroul	Metropolitan	1	0.3	98.5
Toukley	North East	1	0.3	98.8
Ulan	Central West	1	0.3	99.1
Wards River	North East	1	0.3	99.4
Wongawilli	Metropolitan	1	0.3	99.7
Yallah	Metropolitan	1	0.3	100.0
Grand Total		331	100.0	

The reason for complaints is summarised in Table 6. Note that the proportions in Table 6 do not add to 100% because complainants commonly cite multiple reasons for the complaint. For example, the complainant may have identified dust or fume associated with blasting. Dust (85.8%) is the predominant reason cited for complaints. Approximately 17% of complainants identified blasting in the complaint. A further 16% of complainants mentioned that strong wind conditions were a factor in causing the incident.

Table 6 Reason for complaints received by OEH's Environment Line in relation to air quality issues associated with coal mines in the GMR from 2007 to 2009

Reason for complaint	Count[1]	Proportion of total complaints (%)
Dust	284	85.8%
Blasting	57	17.2%
Wind contribution to cause of complaint	54	16.3%
Stench, odour or smell	29	8.8%
Smoke	14	4.2%
Air pollution	11	3.3%
Haze	9	2.7%
Soot	4	1.2%
Smog	2	0.6%
Uncovered load	2	0.6%
Grand Total	331	

Note
[1] Total number of complaints is 331. In most complaints, more than one reason for complaint was cited, hence, the percentages in the third column do not add to 100%.

The location of complainants by suburb or locality that cited dust as the cause of the complaint is illustrated in Figure 15, Figure 16 and Figure 17. Also shown in these figures are the mine locations with the size of the marker for each mine shown proportional to emissions (Section 7).

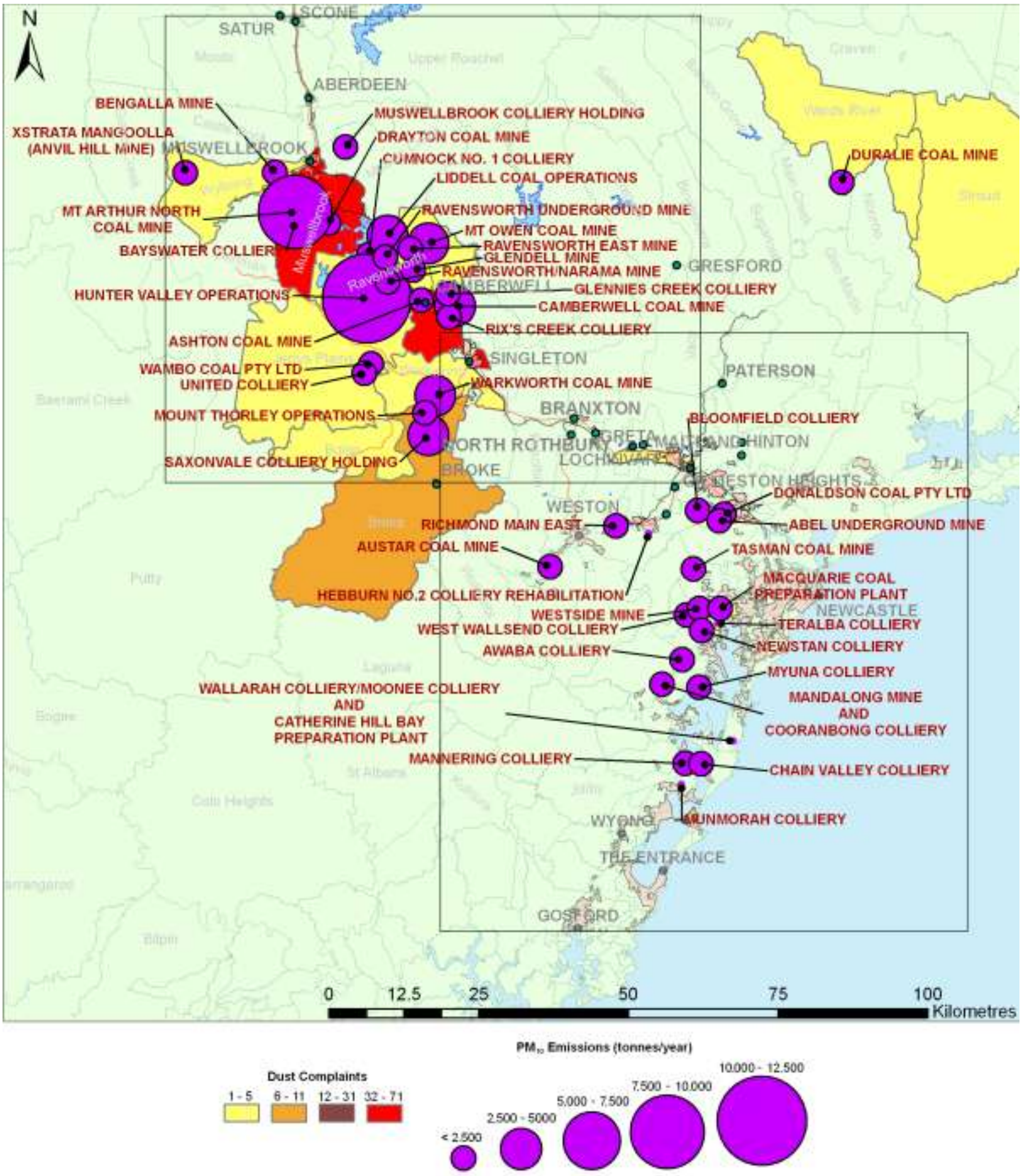

Figure 15 Complaints about dust in the Newcastle and Hunter Coalfields by suburb and relative coal mining emission rates of PM_{10}, 2007-2009

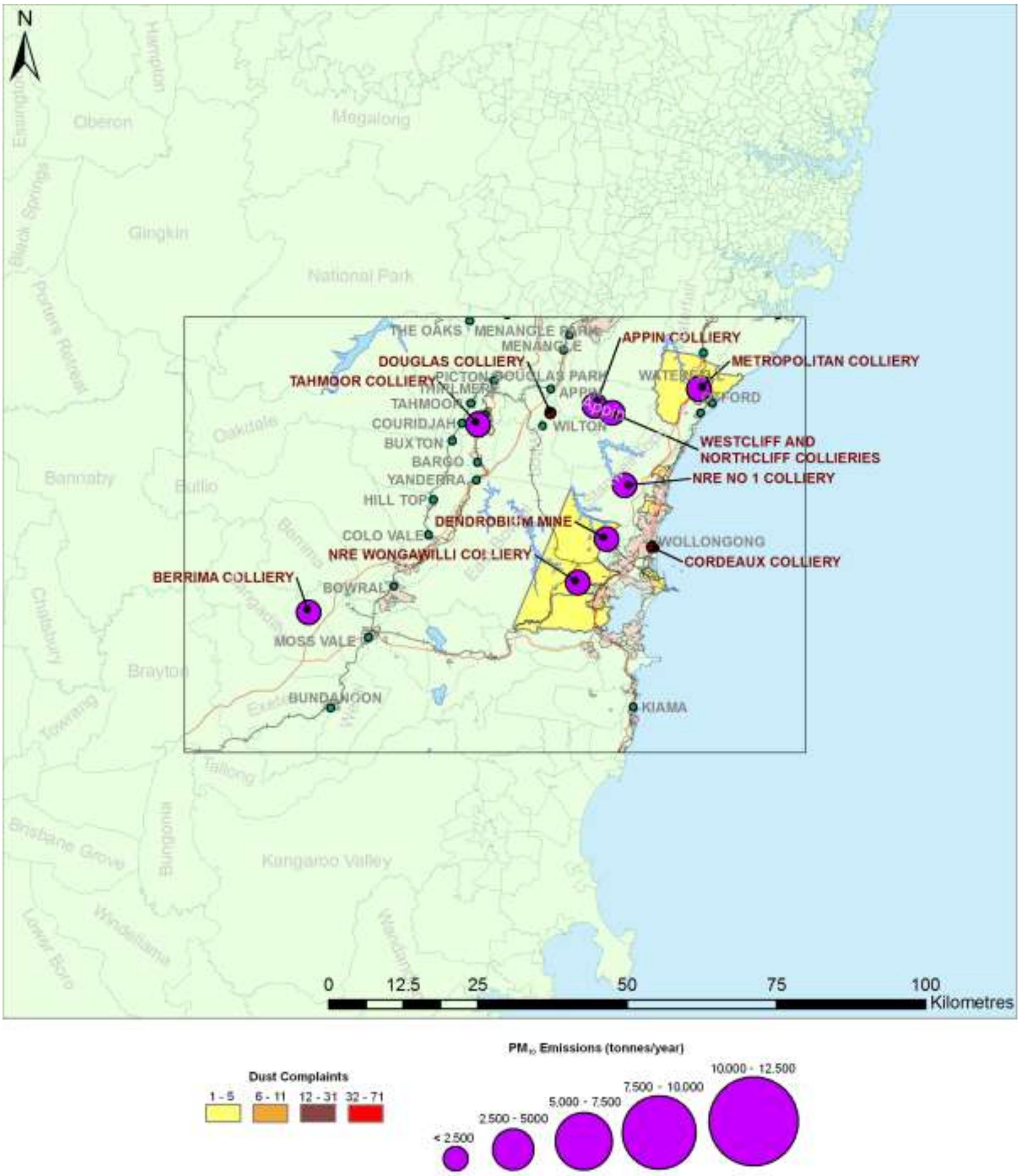

Figure 16 Complaints about dust in the Southern Coalfield by suburb and relative coal mining emission rates of PM_{10}, 2007-2009

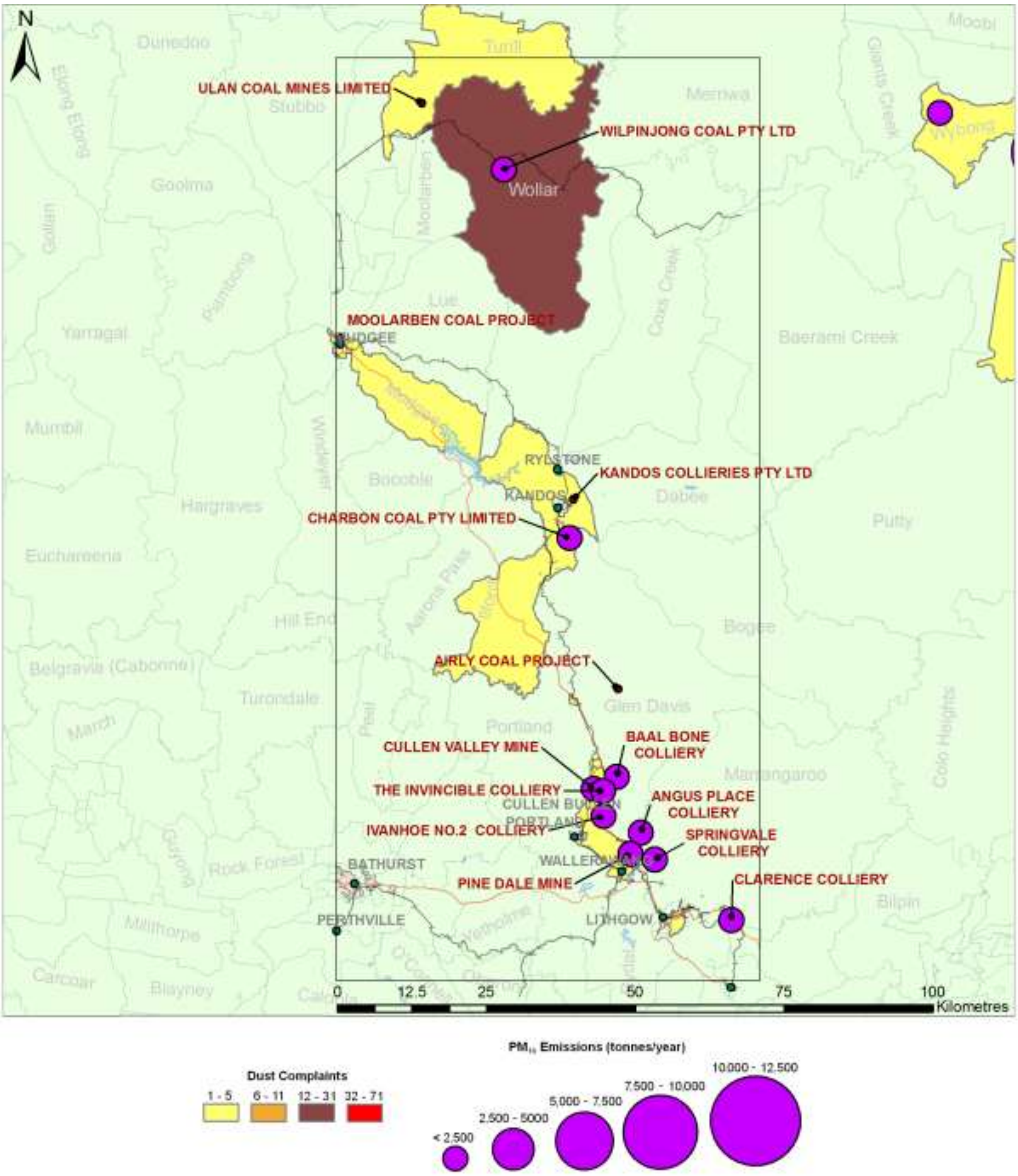

Figure 17 Complaints about dust in the Western Coalfield by suburb and relative coal mining emission rates of PM_{10}, 2007-2009

4.3 Environment Protection Licence conditions and non-compliance

Environment Protection Licences (EPL) are held by all coal mines according to Schedule 1 of the *Protection of the Environment Operations Act 1997*[22] (POEO Act). EPL are described in detail in Section 8.6.1. The EPL conditions that are applied to coal mining activities that operate in the GMR to manage emissions of particulate matter are summarised in Table 7.

Table 7 GMR coal mine Environment Protection Licence conditions relating to air quality, excluding monitoring conditions

Condition	Count	Proportion of GMR coal mining licences with condition (%)[1]
The premises must be maintained in a condition which minimises or prevents the emission of dust from the premises.	58	85.3
All trafficable areas, coal storage areas and vehicle manoeuvring areas in or on the premises must be maintained, at all times, in a condition that will minimise the generation, or emission from the premises, of wind-blown or traffic generated dust.	19	27.9
Activities occurring in or on the premises must be carried out in a manner that will minimise the generation, or emission from the premises, of wind-blown or traffic generated dust.	8	11.8
All operations and activities occurring at the premises must be carried out in a manner that will minimise the emission of dust from the premises.	7	10.3
Guide posts or other control measures must be maintained to define trafficable areas, restricting vehicle movements to these areas and identifying areas to be watered down.	4	5.9
The tailgates of all haulage trucks leaving the premises must be securely fixed prior to loading or immediately after unloading to prevent loss of material.	3	4.4
Trucks entering and leaving the premises that are carrying loads must be covered at all times, except during loading and unloading.	3	4.4
Trucks transporting coal from the premises must be covered immediately after loading to prevent wind blown emissions and spillage. The covering must be maintained until immediately before unloading the trucks.	3	4.4
All operations and activities occurring at the premises must be carried out in a manner that will minimise dust at the boundary of the premises.	1	1.5
Trucks transporting boiler ash from Oberon to the premises must be covered immediately after loading to prevent wind blown emissions and spillage. The covering must be maintained until immediately before unloading the trucks.	1	1.5
Trucks transporting coal from the premises must be covered immediately after loading to prevent wind blown emissions and spillage. The covering must be maintained until immediately before unloading the trucks.	1	1.5
Grand Total	68	

Note
[1] Licences may contain a number of the above conditions and, hence, the proportions do not add to 100%

The majority of coal mining activities in the GMR are required to monitor for at least one and usually a number of the following:

- Ambient concentrations of TSP.
- Ambient concentrations of PM_{10}.
- Dust deposition rate.
- Meteorology.

Monitoring that is required to be conducted under an EPL must be conducted strictly in accordance with the requirements of the *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW*[21] (Approved Methods for Sampling).

Under Section 309 of the POEO Act, OEH is required to keep the Public Register that includes details of non-compliances with Environmental Protection Licence (EPL) conditions. A summary of non-compliances with EPL conditions for coal mining activities in NSW is included in Table 8. A total of 566 non-compliances were identified in the years from 2000 to 2009. The majority of the non-compliances (97.2%) were associated with failures to conduct monitoring in accordance with the EPL.

Examples of those failures include:

- *4 out of 183 Total Suspended Particle samples were not collected due to power supply interruptions or faulty equipment.*
- *High volume sample not monitored on one occasion due to power fault.*
- *Dust monitoring was carried out at a location other than that specified in the map referred to in the EPL.*
- *No samples had been collected from monitoring point 8 on 5 occasions due to the dust gauge being vandalised.*

The remaining 2.8% of non-compliances were due to incidents where particulate matter was found to be a problem or where monitoring showed exceedances of the ambient air quality criteria for total dust deposition rate and increment in dust deposition rate.

Table 8 Non-compliances with Environment Protection Licence conditions as recorded in the public register for coal mining activities from 2000 to 2009

Non-compliance	Count[1]	Proportion (%)
Failures relating to particulate matter monitoring program	550	97.2
Excessive particulate matter from loading or dumping operations	8	1.4
Failure to apply adequate suppression or control	5	0.9
Excessive particulate matter emissions from mining activities	2	0.4
Monitoring results show exceedance of air quality standard or limit	1	0.2
Total	566	100
Note [1]Instances of non-compliance		

The stark difference in the number of non-compliances associated with failures to conduct monitoring in accordance with the EPL conditions and other non-compliances is probably related to the nature of the conditions. The monitoring conditions are prescriptive and are the subject of annual reporting so non compliances can easily be determined. Whereas, the majority of conditions that relate to controlling emissions of particulate matter are not prescriptive, so they can be more challenging to audit, enforce and ensure compliance. Non-compliances in these instances may require a OEH officer to be present to witness the incident and to make a judgement as to whether the incident contravenes the EPL conditions. Alternatively, a OEH officer could request an incident report and determine an appropriate course of action.

4.4 Camberwell Cumulative Impact Review

On 13 July 2010, the Department of Planning released the final Camberwell Cumulative Impacts Review consisting of:

- Expert reports on air quality (particulate matter) (Environ 2009[23]), noise (Wilkinson Murray 2009[24]) and potential contamination of drinking water with lead (Centre for Mined Land Rehabilitation 2009[25]).
- An additional expert report on air quality requested from several mining companies seeking to expand their operations in the vicinity of Camberwell (PAE Holmes 2010[26]).
- A Department of Planning overview and response to the reports[27].

The studies were commissioned in early 2009 in response to public concern over the impact of the existing mining operations on Camberwell and the potential impacts from proposed expansions.

In response to the studies, the NSW Government will implement the following initiatives[27]:

- Employ two Department of Planning compliance officers, who will be based full-time in the Upper Hunter to monitor mines' compliance with conditions of consent.

- Targeting Camberwell as a site for the establishment of an air monitoring station as part of the 14 stations proposed for the Upper Hunter Air Quality Monitoring Network. This will allow residents to access real time data on air quality in the region.

- Requiring mines around Camberwell to employ best practice dust and noise control measures, expanding real-time monitoring and limiting mine operating practices to reduce emissions.

- Ensuring residents are fully informed of potential health impacts of mining operations.

4.4.1 Cumulative Impacts of Particulate Matter – Environ

The expert report on the cumulative levels of particulate matter[23] found the following in relation to existing air quality within Camberwell Village based on 2007-08 monitoring at residential sites:

- *Elevated peak daily PM_{10} concentrations, in excess of health-based ambient air quality limits occur within Camberwell Village. Maximum daily average PM_{10} concentrations sufficiently protective. Average annual PM_{10} concentrations are in the range of 18 μg/m³ to 26 μg/m³ (31% to 87% of the air quality criterion of 30 μg/m³).*

- *The highest PM_{10} concentrations and greatest frequency of days on which concentrations are > 50 μg/m³ occurs within Camberwell Village West, with lower levels and exceedance frequencies at residences situated south of the New England highway.*

- *Despite the lower PM_{10} concentrations measured to the south of the New England highway, PM_{10} concentrations measured across the greater Camberwell area are generally of a similar magnitude.*

- *Concentrations of fine particulates in the less than 2.5 micron diameter size fraction ($PM_{2.5}$) have been measured to exceed National Environment Protection Measure (NEPM) advisory goals. It is conjectured that such exceedances may be primarily due to combustion sources, notably bushfire events.*

- *Based on an analysis of emissions inventory information and ambient air quality data it is concluded that suspended TSP and PM_{10} concentrations within Camberwell Village are routinely dominated by local coal mining emissions. Bushfires and dust storms are recognised as being significant but episodic (infrequent) contributors to peak fine particulate concentrations. The contribution of other sources, including local and remote combustion sources, are anticipated to be a more substantial contributor to fine and ultrafine particulate concentrations.*

- *Elevated ambient PM_{10} concentrations frequently occur during periods of significant wind variations during which time pollutant recirculation and accumulation is likely to be occurring.*

- *Distinguishing the contribution of individual mines to air pollutant episodes (in cases where no significant mine environmental incident was logged) is not possible even with detailed analysis of coincident air quality and meteorological data from several stations.*

- *Diurnal trends in PM_{10} concentrations within Camberwell Village are a function of temporal trends in emissions and the prevailing meteorology. The distinct increase in PM_{10} concentrations in the Camberwell area at 7 am is noted to coincide with the initiation of Ashton Coal Operation Ltd (ACOL)'s open cut mining operations, and occurs ahead of the onset of the higher daytime winds. Daytime wind and mining emissions, including emissions from ACOL and other nearby mines which operate continuously (and potentially increase the intensity of their activities during the daytime), are anticipated to be responsible for the elevated day-time PM_{10} concentrations.*

- *No significant inter-annual trends in PM_{10} concentrations were observed based on the available data. This observation is however subject to uncertainty due to the unavailability of a long-term PM_{10} monitoring data set comprising continuous measurements at a single location.*

- *The highest PM_{10} concentrations and greatest number of peak 24-hour PM_{10} concentrations occur during the September to November period (peaking in October). This period is characterised by more variable wind (prevalence of both west to northwest and southeast to south-southeast flow components) and is likely to be associated with greater air pollutant recirculation and accumulation potentials. Bushfire incidence data could not be obtained to assess the contributions of such natural events to PM_{10} concentrations at this time of year.*

- *Annual dust deposition rates within Camberwell Village were generally found to be within the DECCW criterion of 4 g/m²/month given for cumulative dust deposition. Although this criterion was exceeded within Camberwell Village west during 2007, dust deposition rates during 2008 were below this limit. Notwithstanding these data,* *soiling of surfaces and dust build up in gutters was evident during the visual inspection of premises within Camberwell Village.*

- *Given the controlling influence of local coal mining emissions on suspended particulate concentrations, changes in mining activities were taken to be indicative of potential changes in future air quality within Camberwell. Particulate emissions are anticipated to be of a similar magnitude to those currently experienced until at least 2015 (with emissions being higher than 2009 emissions during certain coming years). Additionally, there is a scheduled progression of mining towards Camberwell Village over the next five years. It is therefore anticipated that without additional dust management measures, PM_{10} concentrations within Camberwell are likely to increase in the next five years.*

The Environ report adopted the European Best Available Technique (BAT) definition of Best Practice, namely, a level of performance towards the upper range of what is economically and technically achievable within an industry sector and considers local factors. Best practice does not necessarily represent "the very best" or "world's best practice". The following conclusions were reached in relation to best practice measures to control particulate matter emissions:

- *There are many activities identified by surrounding mining operations that may be considered to be best practice dust controls, however not all practices are consistent across facilities.*

- *While best practice techniques are identified, findings within Section 3 indicate that there is need for further improvement in operational dust management to ensure that human health is protected at Camberwell within coming years.*

- *Best practice should incorporate the most appropriate techniques at a facility level. Techniques may be rationalised and cost-optimised through site-specific investigations, with source prioritisation based on the contribution of sources to suspended fine particulate concentrations at nearby receptors.*

- *Key areas where dust management may be augmented, in line with best practice, include investigation into the selective use of chemical dust suppressants, the optimisation of reactive monitoring techniques, and the use of predictive forecasting to inform dust management.*

- *For dust management to be effective in practice, it requires to be institutionalised, with dust management responsibilities being set for all levels of personnel, incorporating dust management within Standard Operating Procedures, and routine inspection, corrective action, audit and review to ensure a process of continual improvement.*

- *Effective management of cumulative air quality impacts within Camberwell Village will require a coordinated approach, with the cooperation of all surrounding mining operations, at all levels.*

The Environ report also reached conclusions about the following elements of Airshed Management:

- *Ambient Air Quality Criteria: one set of criteria must be specified for assessing the status of ambient air quality within Camberwell Village. These criteria should be used to assess cumulative air pollutant concentrations, whether measured or predicted, and be referenced by all government agencies.*
- *Responsibility for Managing Air Quality within Criteria: Integrated air quality monitoring and management with active participation by regulatory authorities should be implemented with the effectiveness of such coordinated management gauged based on compliance with air quality criteria.*
- *Air Quality Monitoring: consolidation (and rationalisation) of the current air quality monitoring sites within Camberwell Village and the surrounds, as part of a coordinated management approach.*
- *Area-wide Emissions Inventory and Air Dispersion Modelling:* development of a validated emissions and dispersion model for scenario modelling and evaluation of new projects.
- *Optimisation of Abatement.*
- *Cumulative Assessments for Proposed Developments.*
- *Integrated Consultative Committee for the Camberwell area, comprising representation of all adjacent mines in addition to regulatory authorities and residents, should be considered.*
- *Regular compliance assessments should be undertaken to ensure that local mining operations consistently comply with all requirements. Such assessments should be undertaken by independent parties with expertise in air quality mitigation and should evaluate not only the existence of measures and systems but their effectiveness at maintaining air quality within agreed levels.*

4.4.2 Lead in Drinking Water Report – Centre for Mined Land Rehabilitation

To determine the potential contribution from mining, the Centre for Mined Land Rehabilitation (CMLR) study[25] analysed lead levels in:

- Domestic rainwater tanks in Camberwell and on the outskirts of Muswellbrook.
- Soils in these residential areas.
- House dust samples from Camberwell.
- TSP samples from Ashton and Integra HVAS.
- Mined overburden, coal and topsoil at the three mines in the vicinity of Camberwell.

The study also included background samples taken from Branxton for comparison, which is some distance from mining activities.

The study found that:

- Lead in all samples of tank water was below the health-based lead levels contained in the Australian Drinking Water Guidelines.
- There was no transfer of lead from historical sludge, which is present in the base of some tanks.

- The risk assessment indicated that there was no significant difference between tank water from houses close to coal mining operations and background water samples, including Newcastle town water.
- The analysis of atmospheric particulates concluded that there was no significant transfer of lead from mine overburden material. Mine overburden contained lead at levels below the relevant NEPM soil criteria.
- Samples of house dust from floor wipes, window sill and trough wipes at Camberwell and surrounding areas showed that lead levels were not significant in any house, with respect to human health risk, apart from two window tracks. The study indicated that there was no association with lead in window tracks and an external dust source and recommended routine window trough cleaning to minimise dust build up.
- The study concluded that there was no demonstrated health risk from lead impacts from the coal mining operations studied. Lead levels within rainwater tanks, soils, house dust and atmospheric particulates were all below relevant criteria. The study concluded that it was unnecessary to proceed with further risk assessment.

4.5 Upper Hunter Air Quality Monitoring Network

The NSW Government has begun work to establish an ambient-air monitoring network in strategic locations around Upper Hunter mining areas and populated centres, including Muswellbrook and Singleton. The Upper Hunter Air Quality Monitoring Network[28] (the Network) will continuously measure dust particulates in the air at up to 14 sites throughout the region. Air quality data from the Network will be accessible around the clock via an online website.

Data collected by the Network may be used to identify the causes of changes in air quality and to help identify the major sources of the monitored pollutants. In addition, regional air-quality data from the Network will be compared with relevant national air-quality goals.

Each station will use TEOM monitors to measure PM_{10}. Three of the TEOM monitors will monitor $PM_{2.5}$. Each station will also record wind direction and wind speed to provide an indication of the movement of dust throughout the Upper Hunter Region.

5. Identifying Major Coal Producers

This section provides a review of World coal production by country, region and economic groupings to focus the international literature review on countries and regions that are most likely to have invested heavily in research and development of controls and regulatory regimes for management of particulate matter from coal mining. Key coal mining countries have been identified and their status as OECD or emerging market economies has been documented. In some countries state or provincial governments take an important role in regulating coal mining activities. Hence, some attention is also given to coal production by state or province.

5.1 Coal production by country

The 2010 BP Statistical Review of World Energy[29] reported that world coal production was more than 6.9 billion tonnes in 2009. Coal production occurs in many countries using a variety of surface and underground mining techniques. Open-cut mining accounts for around 80% of production in Australia, while in the USA about 67% of production comes from open-cut mining[30].

Table 9 and Figure 18 show the world's coal production by coal producing country[29]. The top ten countries produce almost 90% of the world's coal. China is the highest coal producer with 44% of total world production in 2009. The United States is the second largest coal producer contributing 14% whilst India and Australia contribute 8% and 6%, respectively. Germany and Poland are the eighth and ninth highest world producers. Of the top ten coal producing countries, four are members of the Organisation for Economic Co-operation and Development (OECD), namely, the United States, Australia, Germany and Poland.

Figure 19 shows world coal production since 1981[29]. The figure shows that China has been the world's largest coal producing country since 1985 when it overtook the United States.

Table 9 World coal production by country for 2009

Country	Member of OECD and year joined	2009 Coal Production (million tonnes per year)	Proportion of total (%)	Cumulative Proportion of total (%)
China	--	3,050.0	44.0%	44.0%
US	Member since 1961	973.2	14.0%	58.0%
India	Non-member	557.6	8.0%	66.0%
Australia	Member since 1971	409.2	5.9%	71.9%
Russian Federation	Non-member	298.1	4.3%	76.2%
Indonesia	Non-member	252.5	3.6%	79.8%
South Africa	Non-member	250.0	3.6%	83.4%
Germany	Member since 1961	183.7	2.6%	86.1%
Poland	Member since 1996	135.1	1.9%	88.0%
Kazakhstan	Non-member	101.5	1.5%	89.5%
Turkey	Member since 1961	84.3	1.2%	90.7%
Ukraine	Non-member	73.7	1.1%	91.8%
Colombia	Non-member	72.1	1.0%	92.8%
Other Europe & Eurasia	N/A	65.4	0.9%	93.8%
Canada	Member since 1961	62.9	0.9%	94.7%
Greece	Member since 1961	62.7	0.9%	95.6%
Other Asia Pacific	N/A	57.8	0.8%	96.4%
Czech Republic	Member since 1995	53.3	0.8%	97.2%
Vietnam	Non-member	45.0	0.6%	97.8%
Romania	Non-member	30.6	0.4%	98.3%
Bulgaria	Non-member	26.9	0.4%	98.7%

Country	Member of OECD and year joined	2009 Coal Production (million tonnes per year)	Proportion of total (%)	Cumulative Proportion of total (%)
Thailand	Non-member	18.8	0.3%	98.9%
United Kingdom	Member since 1961	17.9	0.3%	99.2%
Mexico	Member since 1994	11.1	0.2%	99.3%
Spain	Member since 1961	10.2	0.1%	99.5%
Hungary	Member since 1996	9.0	0.1%	99.6%
Brazil	Non-member	5.1	0.07%	99.69%
Venezuela	Non-member	5.0	0.07%	99.77%
New Zealand	Member since 1973	4.6	0.07%	99.83%
Pakistan	Non-member	3.5	0.05%	99.88%
South Korea	Member since 1996	2.5	0.04%	99.92%
Other Africa	Non-member	1.8	0.03%	99.94%
Zimbabwe	Non-member	1.7	0.02%	99.97%
Japan	Member since 1964	1.3	0.02%	99.99%
Other S. & Cent. America	N/A	0.7	0.01%	100.0%
France	Member since 1961	0.2	0.00%	100.0%
Grand Total		6,940	100	100

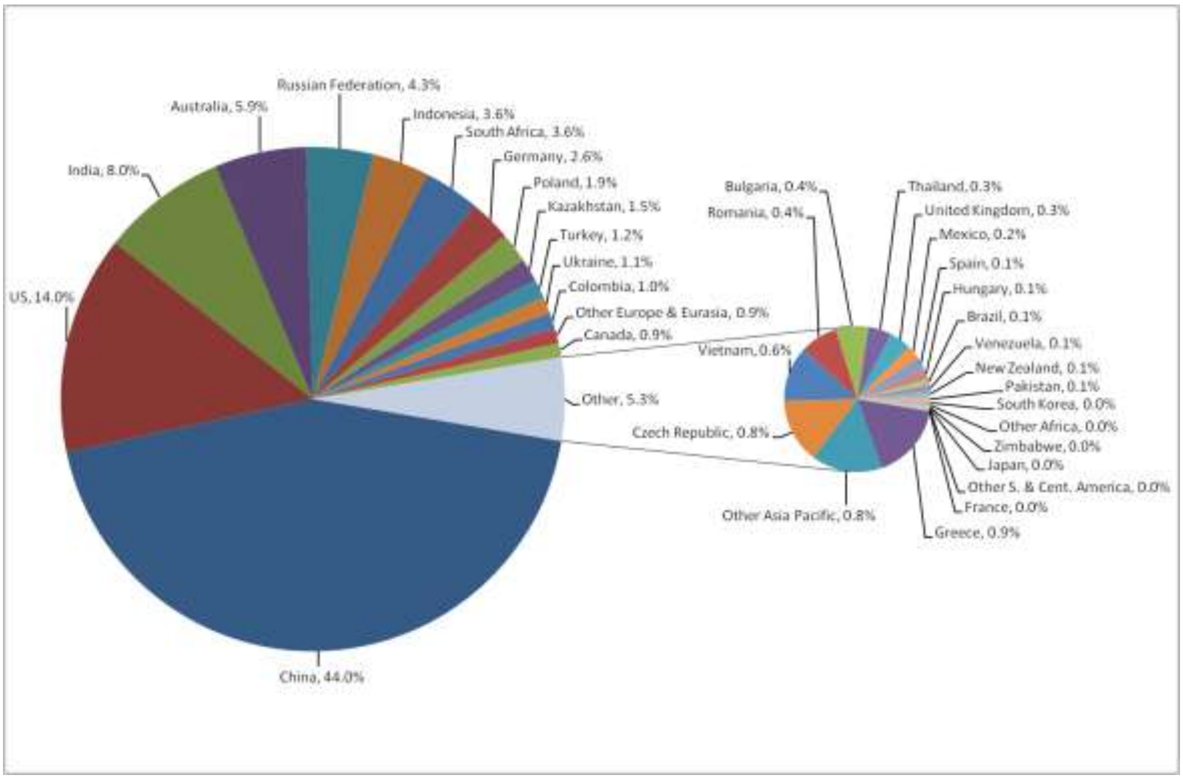

Figure 18 World coal production for 2009 showing contributions from individual countries

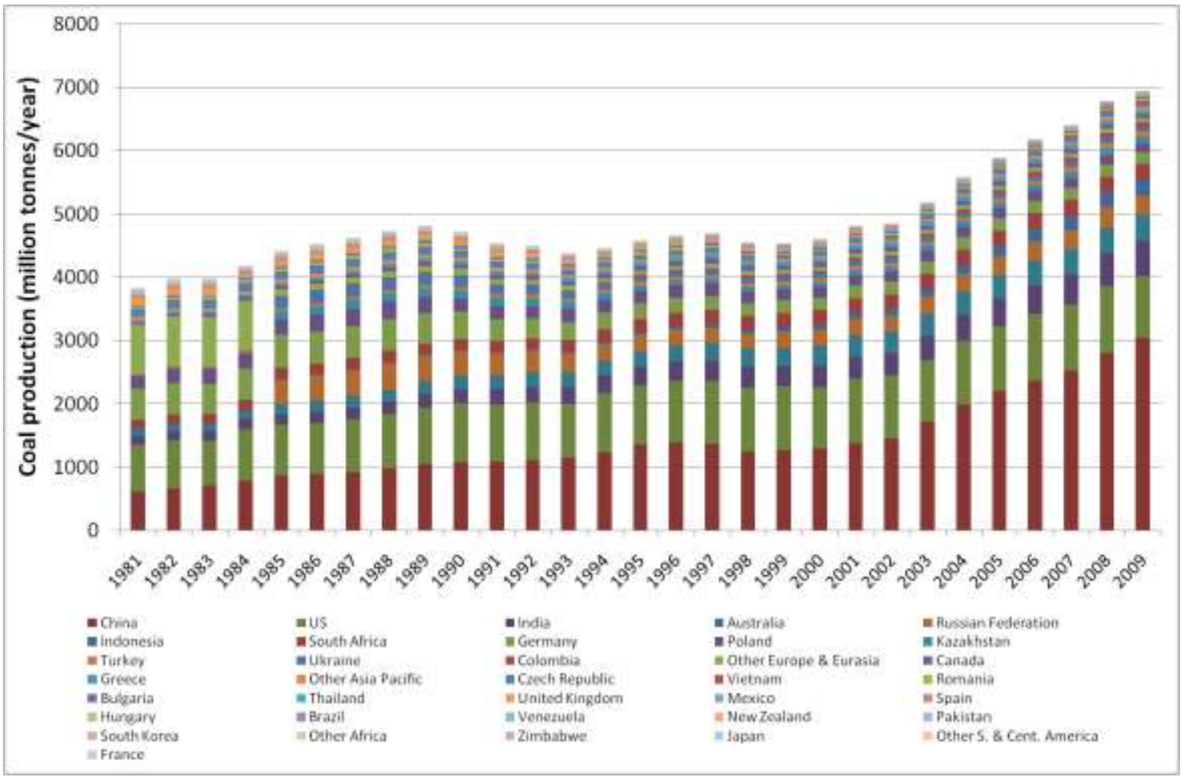

Figure 19 World coal production from 1981 to 2009 showing contributions from individual countries

5.2 Coal production by regional groupings

Table 10 and Figure 20 show the world's coal production by regional groupings of countries[29]. The Asia Pacific region is the highest producer of coal with 63.4% of total world production in 2009. Europe and Eurasia (16.6%) and North America (15.1%) are the second and third highest coal producers by regional grouping.

Figure 21 shows coal production by regional grouping since 1981[29]. The figure shows that the Asia Pacific region has been the world's largest coal producing since 1992. The contribution of the Asia Pacific region to total world production has steadily increased in the 28 years since 1981. Since 2001 production in the Asia Pacific Region has increased substantially. Since 1981 Europe and Eurasian production has gradually fallen in real terms and as a proportion of world production.

Table 10 World coal production by regional groupings for 2009

Continent	2009 Coal Production (million tonnes per year)	Proportion of total (%)	Cumulative Proportion of total (%)
Total Asia Pacific	4,402.8	63.4%	63.4%
Total Europe & Eurasia	1,152.7	16.6%	80.0%
Total North America	1,047.2	15.1%	95.1%
Total Africa	253.5	3.7%	98.8%
Total S. & Cent. America	82.9	1.2%	100.0%
Total Middle East	1.6	0.0%	100.0%
Grand Total	6,940	100	100

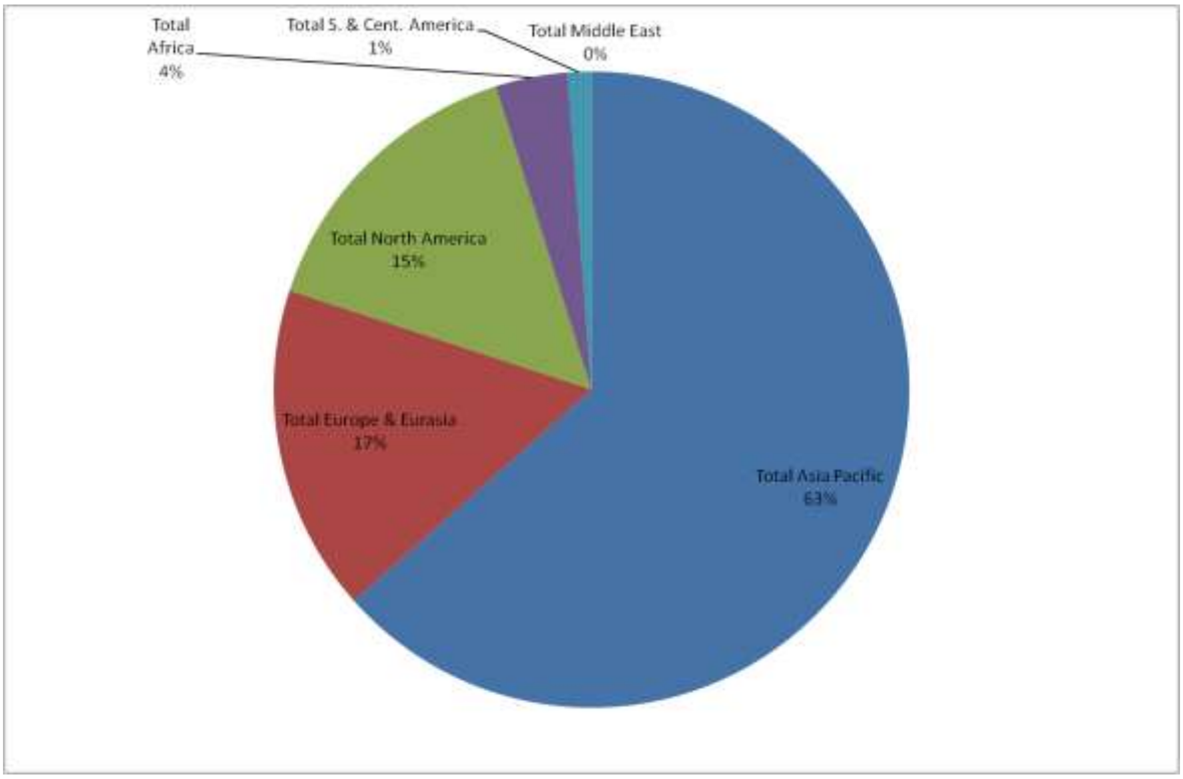

Figure 20 World coal production for 2009 showing contributions of regional groupings

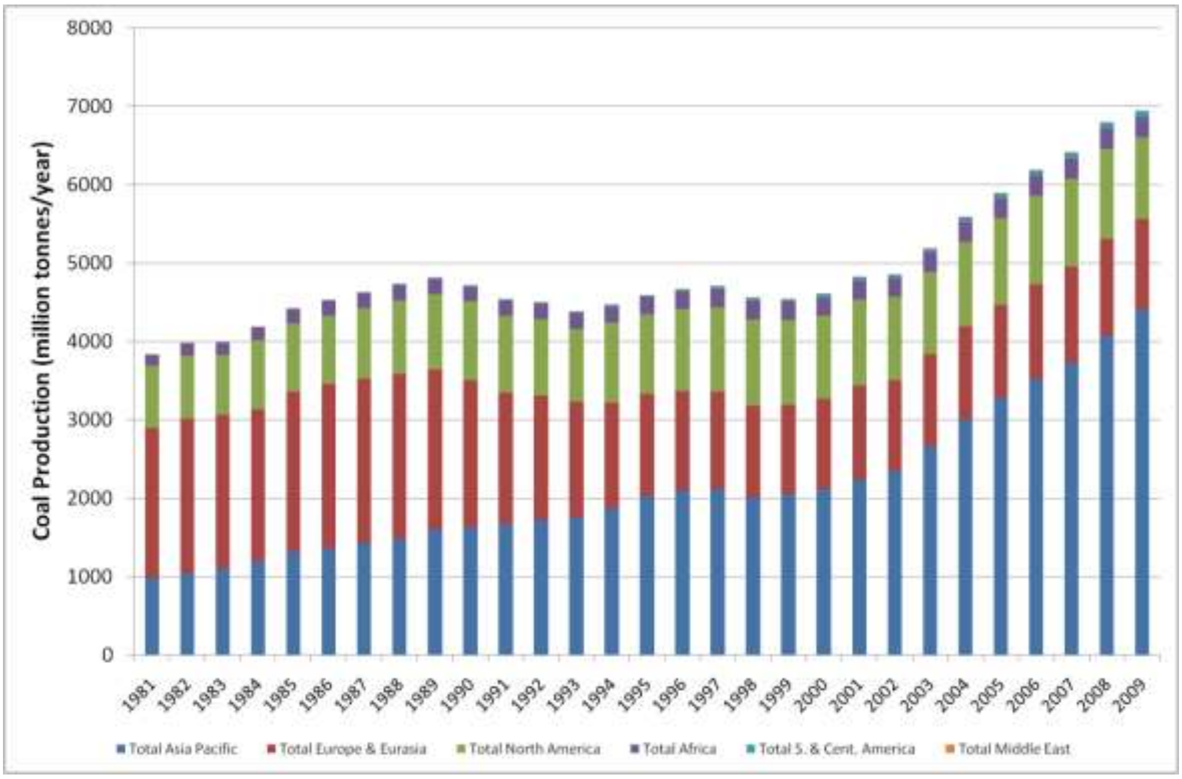

Figure 21 World coal production from 1981 to 2009 showing contributions of regional groupings

5.3 Coal production by national economic groupings

Table 11 show the world's coal production by national economic grouping[29]. Emerging Market Economies (EME) are countries, such as China, undergoing rapid growth and industrialisation. The group Other EMEs includes China and is therefore the highest coal producer with 64% of total world production in 2009. The OECD group is the second largest coal producer contributing 29.2% whilst the Former Soviet Union countries produce 6.9% of world production. Total coal produced by the combined European Union is almost 8% of world production.

Figure 22 shows world coal production since 1981 by national economic grouping[29]. The figure shows that the Other EMEs grouping emerged as the highest coal producer in 1995.

Table 11 World coal production by national economic groupings for 2009

National grouping	2009 Coal Production (million tonnes per year)	Proportion of total[2] (%)
Other EMEs[1]	4436.7	63.9%
OECD	2026.6	29.2%
European Union	536.8[3]	7.7%[2]
Former Soviet Union	477.2	6.9%
Note [1] EME, emerging market economies [2,3] European Union coal producing countries are also counted in the OECD grouping		

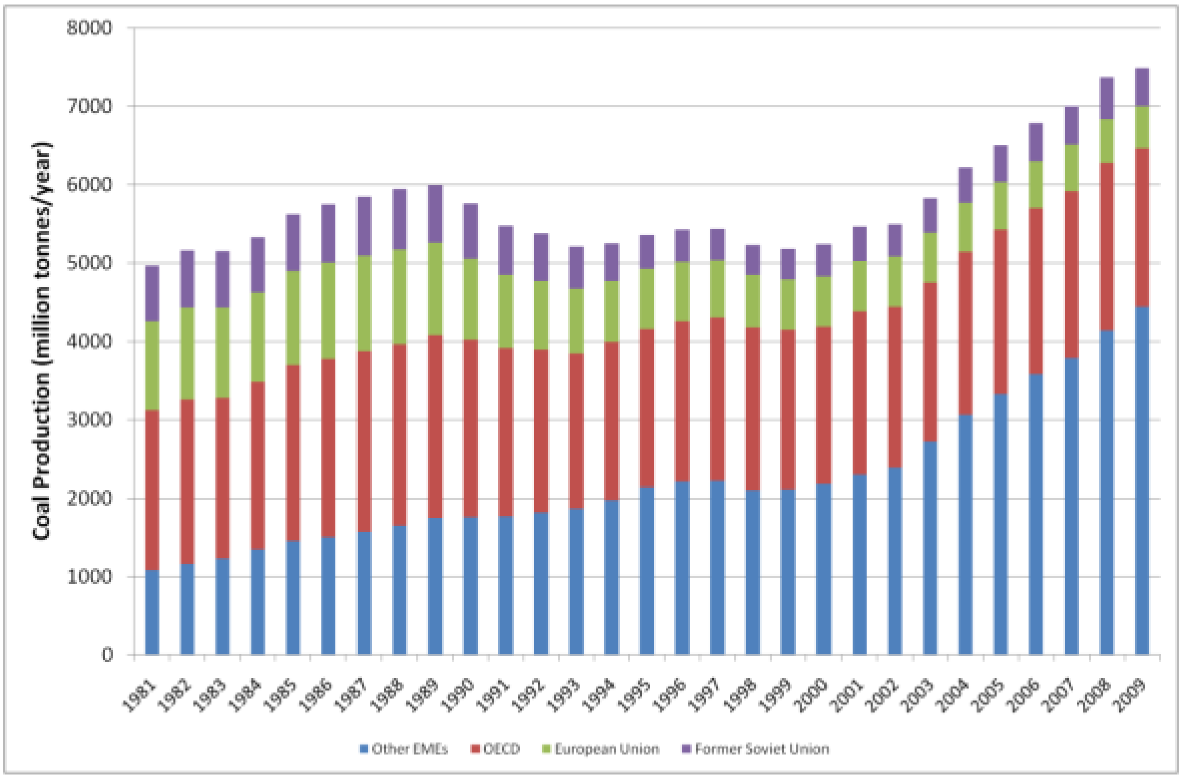

Figure 22 World coal production from 1981 to 2009 showing contributions of national economic groupings

5.4 Coal production in the United States

The U.S. Energy Information Administration provides an annual report on coal production across all states and regions in the United States. A summary of coal production by state and region in 2008 (the latest year of available data) is provided by the US Energy Information Administration and is reproduced in Table 12, Table 13 and Figure 23[31].

The data indicates that the Powder River Basin region in Wyoming is the largest producer of coal in the United States, producing more than double the quantity of coal of the second highest producer, West Virginia in the Appalachian region.

Table 12 United States coal production by state for 2008

State	Rank	2008		Proportion (%)	Cumulative Proportion (%)
		Number of mines	Production (Mt)		
Wyoming	1	20	424	40.0	40.0
West Virginia	2	301	143	13.5	53.4
Kentucky	3	469	109	10.3	63.7
Pennsylvania	4	266	59	5.6	69.3
Montana	5	6	41	3.9	73.1
All other states	6-25	373	285	26.9	100
Grand Total		1,435	1,062	100	100

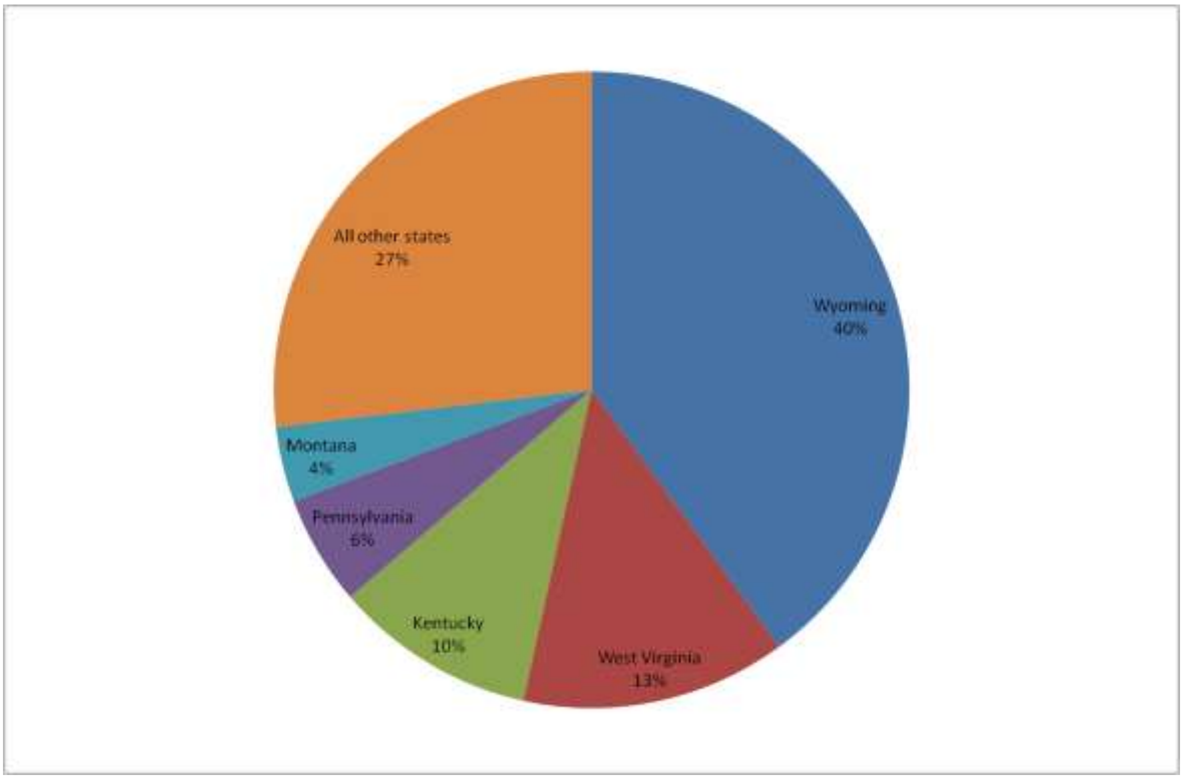

Figure 23 United States coal production by state for 2008

Table 13 United States coal production by coal producing region for 2008

Coal producing region	Rank	2008		Proportion (%)	Cumulative Proportion (%)
		Number of mines	Production (Mt)		
Western Region – Powder River Basin	1	17	450	42.4	42.4
Appalachian Region – Central	2	841	212	20.0	62.4
Interior Region	3	99	133	12.5	74.9
Appalachian Region - Northern	4	378	123	11.6	86.5
Illinois Basin Region	5	72	90	8.5	94.9
Other		28	54	5.1	100.00

6. Coal Production in Australia

This section includes a review of coal production in Australia to provide the local context and identify the key coalfields in NSW. The method of coal mining was considered to determine whether this may have an important bearing on the potential for impact in different regions. Future trends in coal production are also considered, because in general terms increasing production whilst adopting the current approaches to particulate control will lead to increased emissions and potential impacts.

6.1 Coal production by state

Coal is Australia's largest energy resource and Australia has substantial reserves of both black and brown coal, including high quality thermal and metallurgical coal. New South Wales and Queensland have Australia's largest black coal resources with the Sydney basin and Bowen basin containing most of the recoverable black coal, respectively[32]. Total Australian production of black and brown coal in 2007-08 is shown in Table 14[33]. Total Australian production of coal from 1960-61 to 2007-08 is shown in Figure 24[33]. Victorian production of brown coal was 18% of the national total in 2007-08, whilst NSW and Queensland production of black coal was 34% and 45%, respectively.

Table 14 Australian production of black and brown coal by state for 2007-08

State	Coal production 2007-08 (Mt)		Proportion of total coal production (%)	Cumulative proportion of total coal production (%)
	Black	Brown		
Queensland	180.9	-	45.3	45.3
NSW	135.0	-	33.8	79.1
Victoria	-	72.4	18.1	97.2
Western Australia	6.4	-	1.6	98.8
South Australia	3.8	-	1.0	99.8
Northern Territory	0.6	-	0.2	100
Total brown	-	72.4	18.1	
Total black	327.6	-	81.9	
Total	399.1		100	

During 2007-08, Australia produced about 327 million tonnes (Mt) of black coal. Approximately 41.3% or 135 Mt of this came from the coalfields of NSW and 55.4% or 181 Mt came from Queensland. The remainder (3.3% or 11 Mt is produced in Western Australia, South Australia and Tasmania). Figure 25 shows total annual Australian production of black coal and production for each state in the period from 1960-61 to 2007-08. From the mid-80s to the late 90s, black coal production in NSW and Queensland were almost equal. From the late 90s to present, black coal production in Queensland has exceeded that of NSW by 32% on average.

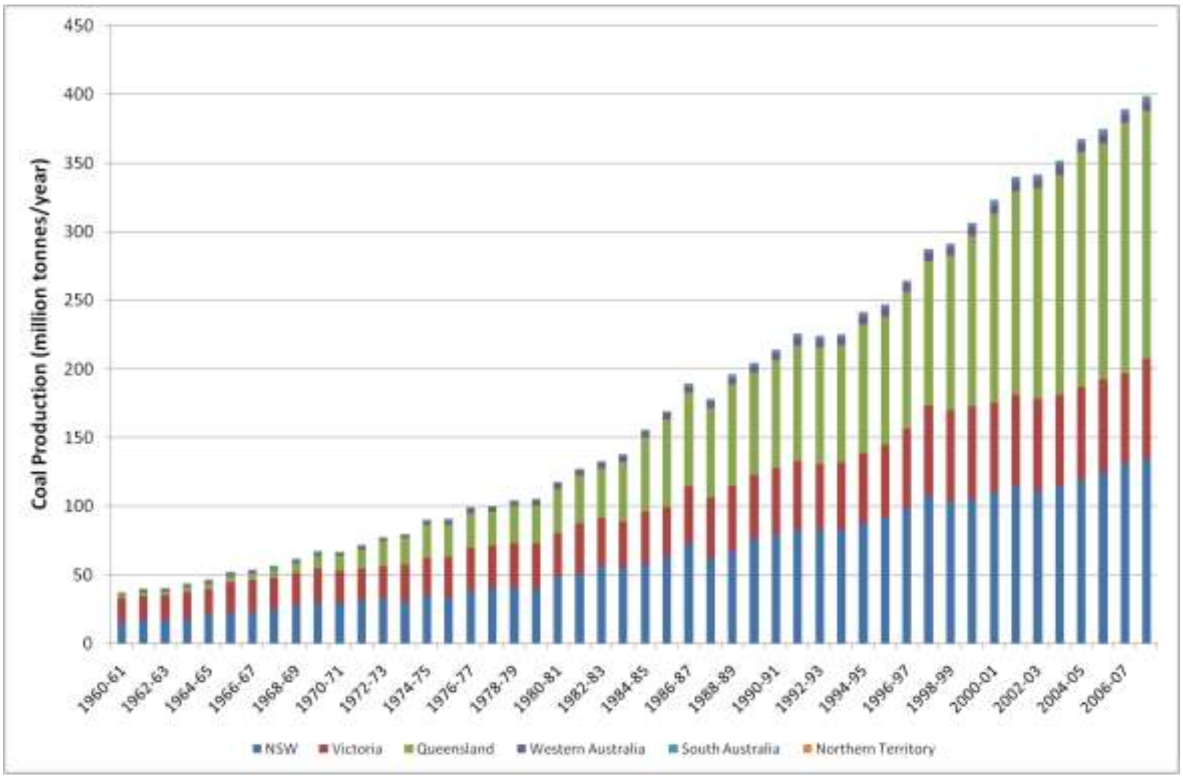

Figure 24 Total Australian coal production by state from 1960-61 to 2007-08

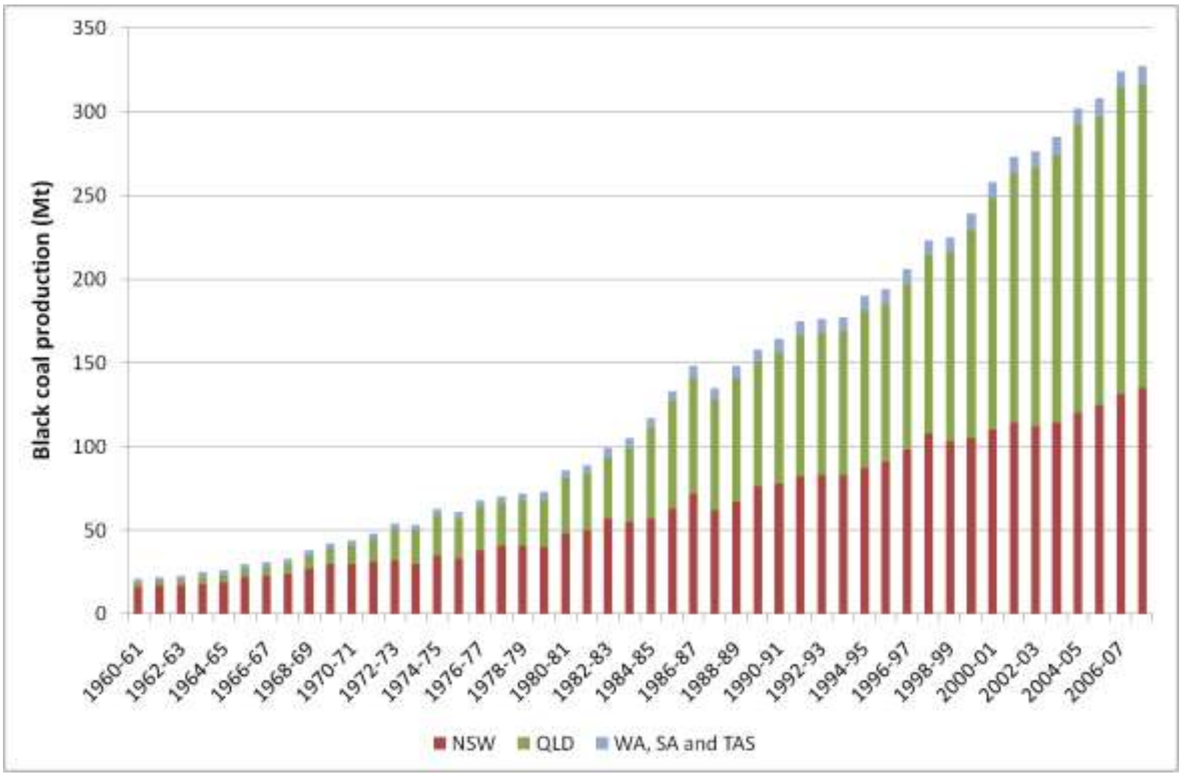

Figure 25 Total Australian black coal production by state from 1960-61 to 2007-08

6.2 Coal production in NSW and GMR

Production of black coal in NSW comes from six coalfields, namely: Hunter, Newcastle, Gloucester, Southern and Western in the Sydney Basin and the Gunnedah Coalfield in the Gunnedah Basin. The locations of coalfields are shown in Figure 26[34]. The Hunter, Newcastle and Southern Coalfields are located within the GMR. The majority of the coal mines in the Western Coalfield are also located within the GMR with the exception of the Ulan Mine.

The Hunter Coalfield is the largest coal-producing region in NSW and is located around Singleton and Muswellbrook. The Hunter Coalfield produces thermal coal for the NSW electricity market and for export. The coal seams in the Hunter are mostly shallow, allowing for a relatively low cost of production.

The Newcastle Coalfield is located around Newcastle, extending about 70 km southwest toward Sydney and 50 km in a north-westerly direction towards Singleton, incorporating Cessnock, Maitland and Wyong. The Newcastle Coalfield produces soft coking coals and thermal coals.

The Southern Coalfield is located northwest, west and southwest of Wollongong reaching Appin to the north, Tahmoor to the northwest and Berrima to the west. The Southern Coalfield is the only source of hard coking coal in NSW. Approximately 50% of the output is used in the domestic steel industry and the remainder is exported as coking and thermal coal.

The Western Coalfield extends from Lithgow to Rylstone and on to Ulan in the northwest.

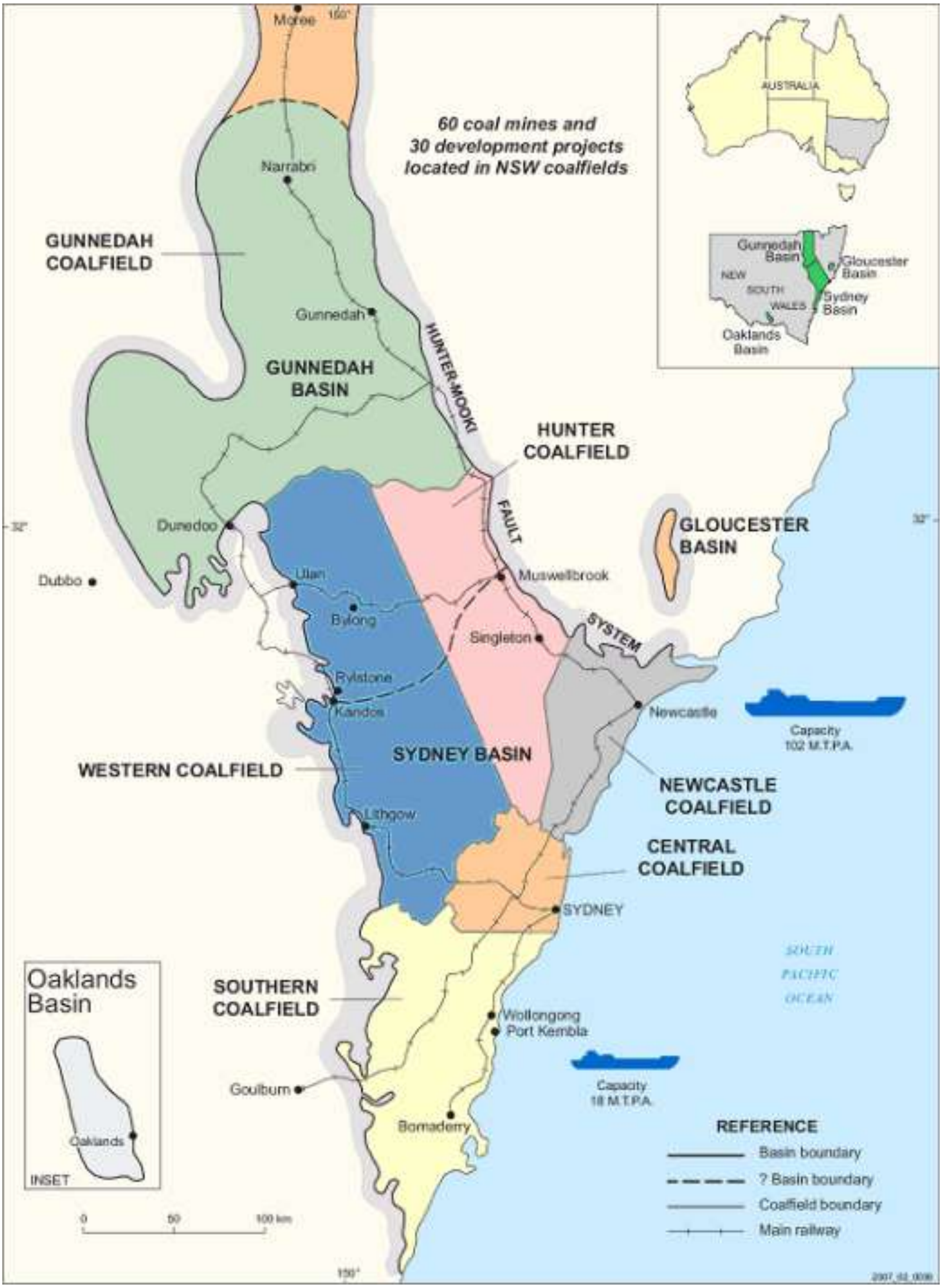

Figure 26 NSW coalfields

Table 15 shows coal production by coalfield as reported by the Department of Primary Industries[35]. In 2007-08 approximately 92% of coal production came from coal mines operating in the GMR.

Table 15 Coal production in NSW for 2006-07 and 2007-08

Coalfield	Coal production (Mt)		Proportion 2007-08 (%)	Cumulative proportion 2007-08 (%)
	2006-07	2007-08		
Hunter	81.2	80.4	59.5	59.5
Western	19.1	22.2	16.4	75.9
Newcastle	14.9	16.1	11.9	87.8
Southern	10.6	10.4	7.7	95.5
Gunnedah	3.5	4.0	3.0	98.6
Gloucester	2.0	1.9	1.4	100
Total NSW	131.3	135.2		
Total GMR	120.6	124.0		
GMR as proportion of NSW (%)	92	92		

6.3 Coal production by mining method in NSW and GMR

Approximately 63% of coal produced in the GMR comes from open-cut mining and the remainder is produced by underground mining. Open-cut mining is conducted by dragline or truck and shovel, accounting for approximately 32% and 30% of total GMR production, respectively. Underground coal mining is conducted using the longwall and bord and pillar techniques. Longwall mining accounts for a further 32% of GMR production whilst the remaining 5% is produced using the bord and pillar technique.

All mining in the Southern Coalfield is conducted using underground mining techniques, whereas a mix of methods is used throughout the other GMR coalfields.

Table 16 summarises coal production in NSW and the GMR by coalfield and mining method[35]. The relative proportions of GMR coal production that occur by each mining method are summarised in Figure 27[35].

Table 16 Coal production in NSW by mining method for 2007-08

Coalfield	Coal (Mt)			
	Open-cut		Underground	
	Dragline	Truck and shovel	Longwall	Bord and Pillar
Hunter	39.4	28.5	12.5	0
Western	2.0	7.6	10.7	2.0
Newcastle	0	2.7	9.7	3.7
Southern	0	0	9.6	0.8
Gunnedah	0	4.0	0	0
Gloucester	0	1.9	0	0
Total NSW	41.4	44.8	42.5	6.5
Total GMR	39.4	36.9	39.2	6.5
Proportion of GMR production by method (%)	32.3	30.3	32.1	5.3

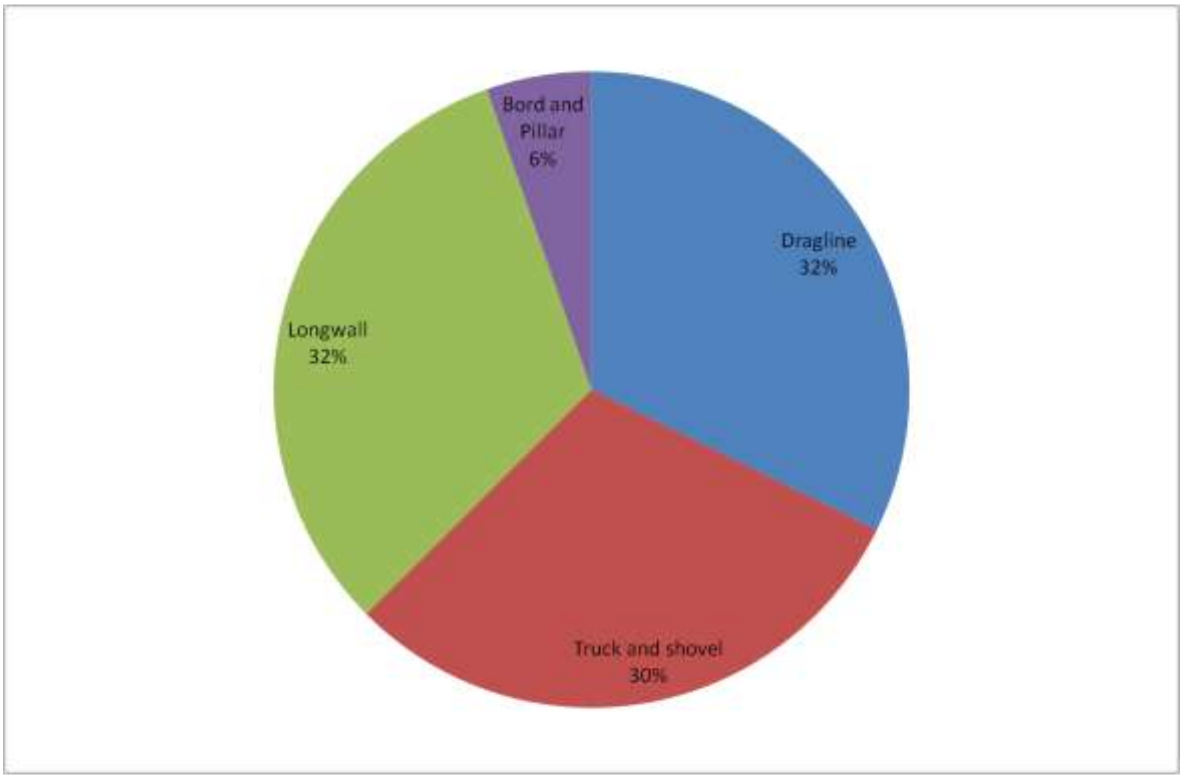

Figure 27 Coal production in the GMR by mining method for 2007-08

6.4 Coal mines in the GMR

Table 17 lists operating coal mines in the Hunter Coalfield and GMR. There are seven dragline operations in the Hunter Coalfield that account for about 49% of coal production in this coalfield. Truck and shovel (35.5%) and underground longwall mining (15.5%) make up the remaining production in the Hunter Coalfield.

Table 17 GMR coal mines in the Hunter Coalfield for 2007-2008

Coal operation	Coal produced (Mt)	EPL	Suburb	Mine Type	Method
Ashton Coal Mine	2.96	11879	Camberwell	OC/UG	Truck & Shovel/Longwall
Bengalla Mine	5.35	6538	Muswellbrook	OC	Dragline
Camberwell Coal Mine (Integra Open-Cut)	2.26	3390	Singleton	OC	Truck & Shovel
Cumnock No. 1 Colliery	0.87	37	Ravensworth	OC	Truck & Shovel
Drayton Coal Mine	4.61	398	Muswellbrook	OC	Dragline
Glendell Mine	1.8[1]	12840	Ravensworth	OC	Truck & Shovel
Glennies Creek Colliery (Integra Underground)	1.57	7622	Singleton	UG	Longwall
Hunter Valley Operations	10.6	640	Singleton	OC	Dragline
Liddell Coal Operations	2.95	2094	Ravensworth	OC	Truck & Shovel
Mount Arthur North Coal Mine	11.75	11457	Muswellbrook	OC	Truck & Shovel
Mt Owen Coal Mine/ Ravensworth East Mine	5.25	4460/ 10860	Ravensworth	OC	Truck & Shovel
Muswellbrook Colliery Holding	1.23	656	Muswellbrook	OC	Truck & Shovel
Ravensworth Underground Mine	0.69	10337	Singleton	UG	Longwall
Ravensworth/Narama Mine	4.15	2652	Ravensworth	OC	Dragline
Rix's Creek Colliery	1.3	3391	Singleton	OC	Dragline
Saxonvale Colliery Holding	9.48	563	Singleton	OC/UG	Dragline/Longwall
United Colliery	2.62	3141	Warkworth	UG	Longwall
Wambo Coal Pty Ltd	3.9	529	Warkworth	OC/UG	Truck & Shovel/Longwall
Warkworth Coal Mine/ Mount Thorley Operations	8.89	1376, 1976	Mount Thorley	OC/CHPP	Dragline
Grand Total	82.24				

Note
[1] Started production in June 2008 not counted in percentages shown above
Mine type: open-cut (OC), underground (UG), combined open-cut and underground (OC/UG), processing plant (CHPP)

Table 18 lists operating coal mines in the Newcastle Coalfield and GMR. About 83% of production is by underground longwall (60%) and bord and pillar (23%) techniques. There are four open-cut truck and shovel operations that account for the remaining 17% of production in the Newcastle Coalfield.

Table 18 GMR coal mines in the Newcastle Coalfield for 2007-2008

Coal operation	Coal produced (Mt)	EPL	Suburb	Mine Type	Method
Abel Underground Mine	0.08[1]	12856	Black Hill	UG	Bord & Pillar
Austar Coal Mine	1.24	416	Pelton	UG	Longwall
Awaba Colliery	0.75	443	Awaba	UG	Bord & Pillar
Bloomfield Colliery	0.46	396	Ashtonfield	OC	Truck & Shovel
Chain Valley Colliery	0.63	1770	Chain Valley Bay	UG	Bord & Pillar
Donaldson Coal Pty Ltd	1.45	11080	Maitland	OC	Truck & Shovel
Mandalong Mine and Cooranbong Colliery	4.77	365	Dora Creek	UG	Longwall
Mannering Colliery	0.83	191	Wyee	UG	Bord & Pillar
Myuna Colliery	1.17	366	Wangi Wangi	UG	Bord & Pillar
Newstan Colliery	2.05	395	Fassifern	UG	Longwall
Oceanic Coal Australia Limited (West Wallsend Colliery)	1.63	1360	Killingworth	UG	Longwall
Tasman Coal Mine	0.33	12483	Seahampton	UG	Bord & Pillar
Westside Mine	0.81	4033	Killingworth	OC	Truck & Shovel
Grand Total	16.2				

Note
[1] Coal production for 2008-09 period not included in percentages shown above.
Mine type: open-cut (OC), underground (UG)

Table 19 lists operating coal mines in the Southern Coalfield and GMR. All production is by underground longwall (92.1%) and bord and pillar (7.9%) techniques.

Table 19 GMR coal mines in the Southern Coalfield for 2007-2008

Coal operation	Coal produced (Mt)	EPL	Suburb	Mine Type	Method
Appin Colliery	1.6	758	Appin	UG	Longwall
Berrima Colliery	0.23	608	Medway	UG	Bord & Pillar
Dendrobium Mine	2.53	3241	Mount Kembla	UG	Longwall
Metropolitan Colliery	1.22	767	Helensburgh	UG	Longwall
Nre No 1 Colliery	0.55	12040	Russell Vale	UG	Bord & Pillar
Nre Wongawilli Colliery	0.04	1087	Wongawilli	UG	Bord & Pillar
Tahmoor Colliery	1.38	1389	Tahmoor	UG	Longwall
Westcliff and Northcliff Collieries	2.88	2504	Appin	UG	Longwall
Grand Total	10.43				
Note: Mine type: open-cut (OC), underground (UG)					

Table 20 lists operating coal mines in the Western Coalfield and GMR. About 55% of production is by underground longwall (43.8%) and bord and pillar (11.6%) techniques. There are four open-cut truck and shovel operations that account for the remaining 44.5% of production in the Western Coalfield.

Table 20 GMR coal mines in the Western Coalfield for 2007-2008

Coal operation	Coal produced (Mt)	EPL	Suburb	Mine Type	Method
Angus Place Colliery	3.21	467	Lidsdale	UG	Longwall
Baal Bone Colliery	1.49	765	Lithgow	UG	Longwall
Charbon Coal Pty Ltd	0.94	528	Charbon	UG	Bord & Pillar
Clarence Colliery	1.49	726	Newnes Junction	UG	Bord & Pillar
Cullen Valley Mine	0.34	10341	Cullen Bullen	OC	Truck & Shovel
Pine Dale Mine	0.24	4911	Lidsdale	OC	Truck & Shovel
Springvale Colliery	2.8	3607	Lidsdale	UG	Longwall
The Invincible Colliery	0.42	1095	Cullen Bullen	OC	Truck & Shovel
Wilpinjong Coal Pty Ltd	5.86	12425	Wollar	OC	Truck & Shovel
Grand Total	16.79				
Note: Mine type: open-cut (OC), underground (UG)					

6.5 Historical trends and future projections in NSW coal production

ABARE predicts that coal production in NSW will grow by 2% per year between 2007-08 and 2029-30[36]. Historical trends in NSW coal production from 1960-61 to 2007-08[33] along with future projections to 2029-30 are presented in Figure 28. This growth would see annual coal production exceeding 200 Mt by the end of this period. The increase in production is expected to be met by development of new mines and expansions of existing mines in the Hunter, Newcastle and Western Coalfields. Extension of existing mines and re-opening and consolidation of other mines is expected to result in a small increase in production in the Southern Coalfield[35].

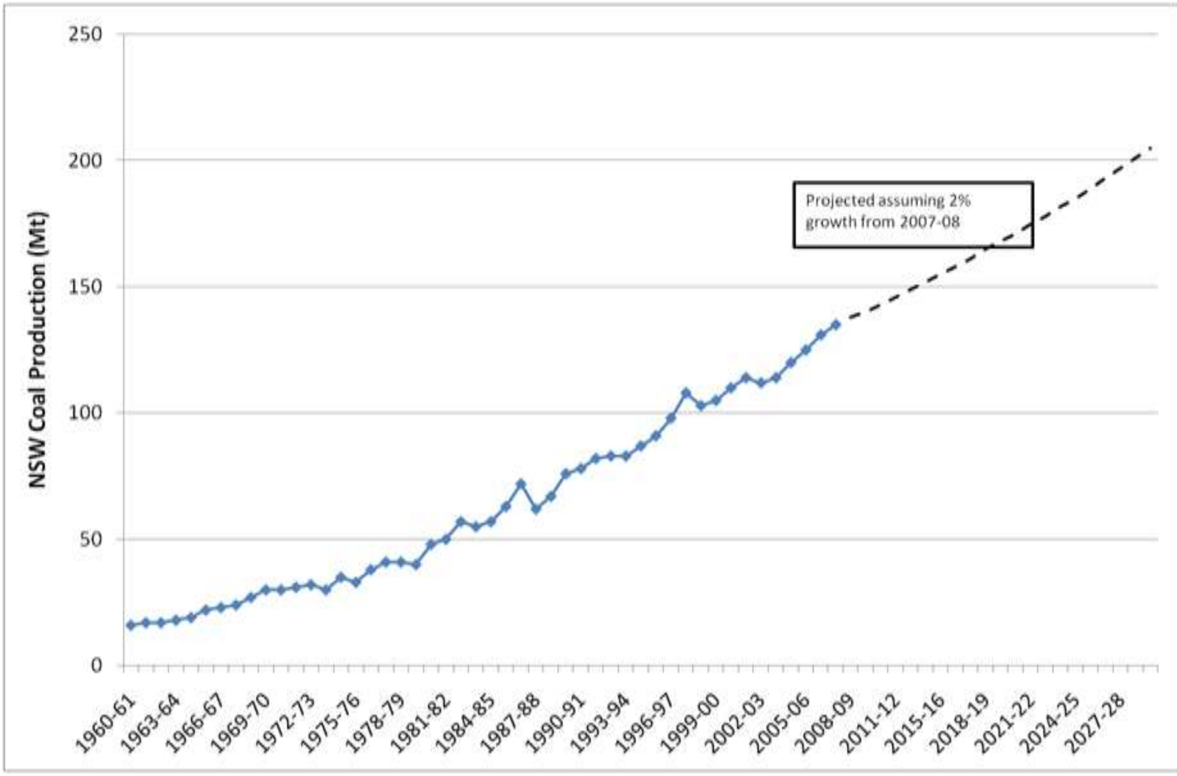

Figure 28 NSW black coal production, historical production from 1960-61 to 2007-08 and future production from 2008-09 to 2029-30

Table 21 to Table 24[37] summarise new coal mining projects that are currently in the planning or development stages for the Hunter, Newcastle, Southern and Western Coalfields. Based on this, there is approximately 91 Mtpa of coal projects that will produce new capacity within the GMR and a further 22 Mtpa of coal projects in the Gunnedah and Gloucester Coalfields.

Approximately, 45% of this new coal production will come from open-cut mines in the Hunter Coalfield.

Table 21 Coal mine development projects in the Hunter Coalfield

Project	Status	Mine type	Expected Startup	New Annual Production Capacity
Blakefield South	New project, under construction	UG	2010	nil (replacement for Beltana)
Mangoola (Anvil Hill opencut)	New project, under construction	OC	2012	9 Mt thermal
Mount Arthur opencut (MAC20)	Expansion, under construction	OC	2011	3.5 Mt thermal
Bickham opencut[1] – north of Scone	New project, EIS under way[1]	OC	2011	2 Mt thermal
Drayton mine extension	Expansion, feasibility study under way	OC	na	2.5 Mt thermal
Hunter Valley Operations Expansion	Expansion, govt approval received	OC	2011	3.6 Mt ROM semi-soft coking and thermal
Mount Arthur North underground	New project, govt approval received	UG LW	2011	8 Mt thermal (ROM)
Mount Pleasant Project	New project, feasibility study completed, on hold	OC	2013	10.5 Mt thermal
Ravensworth North	Expansion, feasibility study under way	OC	2013	9.9 Mt
Saddler's Creek underground and opencut	New project, feasibility study under way	UG/OC	na	2 Mt thermal, 2 Mt coking
South East opencut	Expansion, feasibility study under way	OC	na	2.4 Mt thermal
Warkworth extension	Expansion, feasibility study under way	OC	na	nil (continuation of mining operations)
Total new capacity				53.4 Mt

Note
[1] On 14 May 2010 Premier Kristina Keneally and Minister for Planning Tony Kelly announced the Bickham Coal Project will not proceed. In addition, the NSW Government announced amendments to the Mining State Environmental Planning Policy to prohibit open-cut mining on the Bickham site permanently.

Table 22 Coal mine development projects in the Newcastle Coalfield

Project	Status	Mine type	Expected Startup	New Annual Production Capacity
Austar underground (Stage 3)	Expansion, govt approval received	UG LW	2012-13	3.6 Mt ROM hard coking
Wallarah underground longwall	New project, EIS completed	UG	2013	5 Mt thermal
Total new capacity				8.6 Mt

Table 23 Coal mine development projects in the Southern Coalfield

Project	Status	Mine type	Expected Startup	New Annual Production Capacity
Metropolitan longwall	Expansion, committed	UG LW	na	1 Mt
NRE No. 1 Colliery	Expansion, feasibility study under way	UG	na	2 Mt
NRE No. 1 Colliery (preliminary works project)	Expansion, awaiting govt approval	UG	na	nil (mine upgrade)
Wongawilli Colliery	Expansion, feasibility study under way	UG	na	nil (continuation of mining operations)
Total new capacity				3 Mt

Table 24 Coal mine development projects in the Western Coalfield

Project	Status	Mine type	Expected Startup	New Annual Production Capacity
Moolarben	New project, under construction	OC/UG	2010 OC,	8 Mt OC, up to 4 Mt UG (ROM thermal)
Moolarben (stage 2)	Expansion, EIS under way	OC/UG	na	12 Mt opencut; up to 4 Mt underground (ROM, thermal)
Ulan West	Expansion, feasibility study under way	UG	2012	nil (continuation of mining operations)
Total new capacity				28 Mt

7. Emissions Inventory Data for NSW Coal Mines

This section uses inventory data from various sources to quantify coal mining emissions in the GMR. The inventory data has been derived using the same techniques that are used in dispersion modelling studies to assess new mining projects and data provided by NSW coal mines. A key assumption in using the inventory data in this context is that the potential for impact is proportional to the rate of emission. This is a reasonable assumption that is consistent with the scientific literature. This data has been summarised to show the relative contribution of coal mining to total particulate matter emissions in the GMR as a whole and to the Sydney, Newcastle, Wollongong and Non-Urban Regions within the GMR.

OEH is currently preparing an emissions inventory for the 2008 calendar year. Coal mining data from this inventory was provided to Katestone Environmental for the benchmarking study. This information has been used to determine the relative contributions of specific aspects of the coal mining process to an individual mine's emissions and to overall emissions into the GMR airshed. Individual sources of particulate matter from coal mining activities have been ranked. This data has been used to focus the best practice literature review and review of current practices adopted by the coal mining industry in the GMR.

7.1 National Pollutant Inventory

The National Pollutant Inventory (NPI)[38] has been developed to track emissions to air and water from activities occurring across Australia. The inventory is publicly available on the NPI website. Australian industries that exceed various thresholds are required under legislation in each state or territory to monitor, measure and report their emissions and transfers.

The desired environmental outcomes of the NPI program are to:

- Maintain and improve air and water quality;
- Minimise environmental impacts associated with hazardous waste; and
- Improve the sustainable use of resources.

The NPI contains data on 93 substances that have been identified as important due to their possible effect on human health and the environment. The NPI provides emission rates that are aggregated by premises and reported on an annual basis.

The NPI has six threshold categories with each of the 93 NPI substances listed in one or more of these categories. If a facility exceeds a threshold during a reporting year for a substance on the reporting list, all the emissions of that substance from the facility must be reported to the NPI. In addition, transfers of the substance (if Category 1, 1b or 3) to a mandatory reporting transfer destination must be reported. The six threshold categories are:

- Category 1: based on substance usage – use greater than 10 tonnes per year
- Category 1a: based on substance usage – use greater than 25 tonnes per year of total volatile organic compounds
- Category 1b: based on substance usage – use greater than 5 kg per year of mercury
- Category 2a: based on fuel combusted – burn more than 400 tonnes of fuel or waste per year or burn more than 1 tonne of fuel per hour
- Category 2b: based on fuel combusted – burn more than 2,000 tonnes of fuel or waste per year or consume more than 60,000 megawatt hours of electricity per year or having maximum potential power consumption of 20 megawatts other than for lighting or motive purposes per year

- Category 3: based on substance usage, including transfers

Disaggregated emissions information is required for this study to characterise emissions from individual activities at all coal mines in the GMR. Hence, the NPI data is not sufficient for the purpose of this study.

A summary of emissions of PM_{10} in the GMR by industry grouping from the NPI database[39] for the 2008-09 reporting year is shown in Table 25 and Figure 29.

Table 25 Anthropogenic emissions of particulate matter <10.0 µm in the GMR from NPI 2008-09

Source	PM_{10} (tonnes)	Proportion (%)	Cumulative proportion (%)
Coal Mining [060]	53,190.03	82.18	82.18
Electricity Generation [261]	6,498.44	10.04	92.22
Basic Ferrous Metal Manufacturing [211]	983.65	1.52	93.74
Cement, Lime, Plaster and Concrete Product Manufacturing [203]	749.94	1.16	94.90
Ceramic Product Manufacturing [202]	716.90	1.11	96.01
Construction Material Mining [091]	509.65	0.79	96.79
Petroleum and Coal Product Manufacturing [170]	422.19	0.65	97.45
Basic Non-Ferrous Metal Manufacturing [213]	297.21	0.46	97.90
Glass and Glass Product Manufacturing [201]	273.41	0.42	98.33
Water Transport Support Services [521]	201.09	0.31	98.64
Other	881.63	1.36	100
Total	64,724.15	100.00	

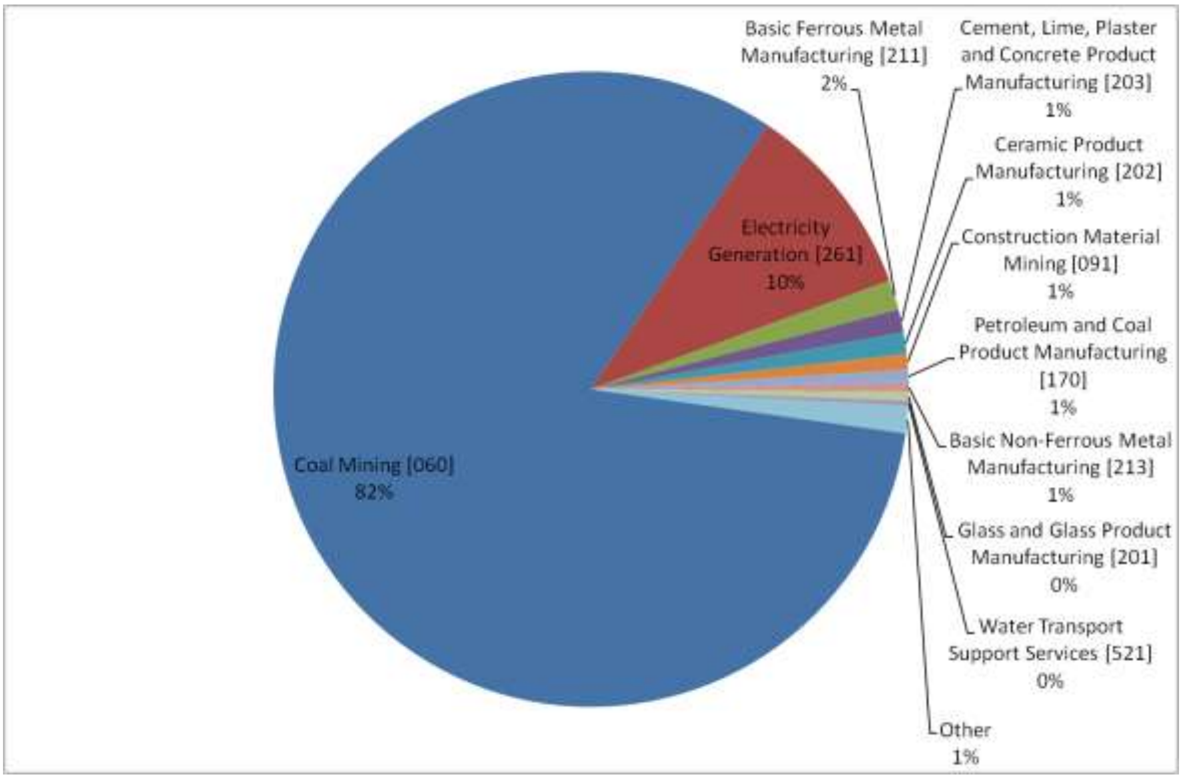

Figure 29 Anthropogenic emissions of particulate matter <10.0 µm in the GMR from NPI 2008-09

7.2 Air Emissions Inventory for the GMR 2003

OEH completed a three year air emissions inventory project in 2007[1]. The base year of the inventory represents activities that took place during the 2003 calendar year. Emission projections are also provided in yearly increments up to the 2031 calendar year. OEH maintains the GMR air emissions inventory to ensure that policy development and state targets for air quality are based on the most credible and up to date evidence.

The GMR measures 210 km (east-west) by 273 km (north-south) and includes the greater Sydney, Newcastle and Wollongong Regions. The GMR covers a total area of 57,330 km^2. Approximately, 76% of the population of NSW resides within the GMR. Figure 30 shows the GMR and the Sydney, Newcastle and Wollongong Regions. The area within the GMR but outside of the Sydney, Newcastle and Wollongong Regions is known as the Non-Urban Region.

The air emissions inventory includes emissions from biogenic (i.e. natural) and anthropogenic (i.e. human derived) sources. The anthropogenic source groups included in the air emissions inventory are as follows:

- Commercial businesses (i.e. non-EPA-licensed)
- Domestic-commercial activities
- Industrial premises (i.e. EPA-licensed)
- Off-road mobile (i.e. non-registered off-road vehicles and equipment)
- On-road mobile (i.e. registered on-road vehicles).

The pollutants inventoried include criteria pollutants specified in the Ambient Air Quality NEPM[18], air toxics associated with the NPI[38] and the *National Environment Protection (Air Toxics) Measure*[40] (Air Toxics NEPM) and any other pollutants associated with state specific programs, including:

- Load Based Licensing (*Protection of the Environment Operations (General) Regulation 1998*)[41]
- *Protection of the Environment Operations (Clean Air) Regulation 2002*[42].

The top ten largest anthropogenic (or man-made) sources of PM_{10} in the GMR, Sydney, Newcastle, Wollongong and Non-Urban Regions are shown in Table 26[43]. This data is summarised for the GMR in Figure 31.

The top ten largest anthropogenic sources of $PM_{2.5}$ in the GMR, Sydney, Newcastle, Wollongong and Non-Urban Regions are shown in Table 27. This data is summarised for the GMR in Figure 32.

Figure 30 GMR, Sydney, Newcastle and Wollongong Regions

Table 26 Ten largest anthropogenic sources of particulate matter <10 µm in the GMR

Source Group	Source Type	Particulate Matter < 10 µm		
		Annual Emissions (tonnes/year)	Proportion of Annual Anthropogenic Emissions (%)	Cumulative (%)
GMR				
Industrial	Coal mining	25,256	33.6	33.6
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	12,584	16.8	50.4
Domestic-Commercial	Solid Fuel Combustion	6,172	8.22	58.6
Industrial	Generation of electrical power from coal	4,816	6.41	65.0
Industrial	Other land-based extraction	3,472	4.62	69.6
Industrial	Crushing, grinding or separating works	2,513	3.34	73.0
Commercial	Poultry Farming (Meat)	1,841	2.45	75.4
Industrial	Hard-rock gravel quarrying	1,687	2.25	77.7
Industrial	Primary iron and steel production	1,620	2.16	79.8
Commercial	Gravel and Sand Quarrying	1,252	1.67	81.5
All	Other	13,915	18.5	100.0
Sydney				
Domestic-Commercial	Solid Fuel Combustion	4,642	21.8	21.8
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	2,794	13.1	34.9
Industrial	Crushing, grinding or separating works	2,051	9.63	44.5
Industrial	Other land-based extraction	1,768	8.30	52.8
On-Road Mobile	Exhaust Emissions Passenger Cars Petrol	867	4.07	56.9
On-Road Mobile	Exhaust Emissions Light Duty - Diesel	866	4.06	61.0
Industrial	Ceramics production (excluding glass)	841	3.95	64.9
Commercial	Poultry Farming (Meat)	831	3.90	68.8
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	702	3.29	72.1
Commercial	Gravel and Sand Quarrying	560	2.63	74.7
All	Other	5,383	25.3	100.0
Newcastle				
Industrial	Coal mining	494	16.8	16.8
Domestic-Commercial	Solid Fuel Combustion	393	13.3	30.1
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	302	10.2	40.3
Industrial	Production of ammonium nitrate	210	7.1	47.5
Industrial	Hard-rock gravel quarrying	158	5.4	52.8
Industrial	Primary aluminium production	153	5.2	58.0
Industrial	Bitumen pre-mix or hotmix production	129	4.4	62.4
Industrial	Crushing, grinding or separating works	93	3.2	65.6
Off-Road Mobile	Commercial Ships	83	2.8	68.4
Commercial	Gravel and Sand Quarrying	81	2.7	71.1
All	Other	851	28.9	100.0
Wollongong				
Industrial	Primary Iron and steel production	1,618	53.3	53.3
Off-Road Mobile	Industrial off-road Vehicles and Equipment	453	14.9	68.3

Source Group	Source Type	Particulate Matter < 10 µm		
		Annual Emissions (tonnes/year)	Proportion of Annual Anthropogenic Emissions (%)	Cumulative (%)
Domestic-Commercial	Solid Fuel Combustion	256	8.4	76.7
Industrial	Coal loading	180	5.9	82.6
Industrial	Coal mining	65	2.2	84.8
Industrial	Coal washery reject or slag landfilling	57	1.9	86.7
Industrial	Inert waste landfilling	45	1.5	88.1
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	42	1.4	89.5
On-Road Mobile	Exhaust Emissions Light Duty - Diesel	38	1.2	90.7
On-Road Mobile	Exhaust Emissions Passenger Cars Petrol	34	1.1	91.9
All	Other	246	8.1	100.0
Non-Urban				
Industrial	Coal mining	24,587	51.4	51.4
Off-Road Mobile	Industrial off-road Vehicles and Equipment	9,036	18.9	70.3
Industrial	Generation of electrical power from coal	4,816	10.1	80.3
Industrial	Other land-based extraction	1,639	3.4	83.8
Industrial	Hard-rock gravel quarrying	1,404	2.9	86.7
Commercial	Poultry Farming (Meat)	953	2.0	88.7
Domestic-Commercial	Solid Fuel Combustion	881	1.8	90.5
Commercial	Gravel and Sand Quarrying	578	1.2	91.7
Off-Road Mobile	Commercial Off-Road Vehicles and Equipment	572	1.2	92.9
Industrial	Solid waste landfilling	392	0.8	93.8
All	Other	2,984	6.2	100.0

Table 27 Ten largest anthropogenic sources of particulate matter <2.5 µm in the GMR

Source Group	Source Type	Particulate Matter < 2.5 µm		
		Annual Emissions (tonnes/year)	Proportion of Annual Anthropogenic Emissions (%)	Cumulative
GMR				
Domestic-Commercial	Solid Fuel Combustion	5,986	19.6	19.6
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	5,191	17.0	36.6
Industrial	Coal mining	4,154	13.6	50.3
Industrial	Generation of electrical power from coal	1,708	5.6	55.9
Industrial	Primary iron and steel production	1,444	4.7	60.6
On-Road Mobile	Exhaust Emissions Light Duty - Diesel	1,073	3.5	64.1
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	1,002	3.3	67.4
On-Road Mobile	Exhaust Emissions Passenger Cars Petrol	972	3.2	70.6
Industrial	Crushing, grinding or separating works	918	3.0	73.6
Industrial	Other land-based extraction	799	2.6	76.2
All	Other	7,253	23.8	100
Sydney				
Domestic-Commercial	Solid Fuel Combustion	4,503	34.3	34.3
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	1,152	8.8	43.1
On-Road Mobile	Exhaust Emissions Light Duty - Diesel	840	6.4	49.5
Industrial	Crushing, grinding or separating works	807	6.2	55.6
On-Road Mobile	Exhaust Emissions Passenger Cars Petrol	797	6.1	61.7
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	681	5.2	66.9
Industrial	Ceramics production (excluding glass)	606	4.6	71.5
Industrial	Other land-based extraction	418	3.2	74.7
Commercial	Poultry Farming (Meat)	237	1.8	76.5
Industrial	Petroleum refining	237	1.8	78.3
All	Other	2,848	21.7	100
Newcastle				
Domestic-Commercial	Solid Fuel Combustion	381	22.6	22.6
Industrial	Production of ammonium nitrate	207	12.3	34.8
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	125	7.4	42.2
Industrial	Bitumen pre-mix or hotmix production	114	6.8	49.0
Industrial	Primary aluminium production	111	6.6	55.6
Off-Road Mobile	Commercial Ships	80	4.7	60.3
Industrial	Production of phosphate fertilizer	78	4.6	64.9
Industrial	Coal mining	71	4.2	69.1
On-Road Mobile	Exhaust Emissions Light Duty - Diesel	60	3.6	72.6
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	52	3.1	75.7
All	Other	409	24.3	100

Source Group	Source Type	Particulate Matter < 2.5 µm		
		Annual Emissions (tonnes/year)	Proportion of Annual Anthropogenic Emissions (%)	Cumulative
Wollongong				
Industrial	Primary iron and steel production	1,442	65.8	65.8
Domestic-Commercial	Solid Fuel Combustion	248	11.3	77.1
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	187	8.5	85.6
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	40	1.9	87.5
On-Road Mobile	Exhaust Emissions Light Duty - Diesel	36	1.7	89.1
Industrial	Coke production	33	1.5	90.6
On-Road Mobile	Exhaust Emissions Passenger Cars - Petrol	32	1.4	92.1
Industrial	Coal loading	19	0.9	93.0
Off-Road Mobile	Commercial Ships	14	0.7	93.6
Industrial	Coal mining	14	0.6	94.2
All	Other	126	5.8	100.0
Non-Urban				
Industrial	Coal mining	4,056	30.1	30.1
Off-Road Mobile	Industrial Off-Road Vehicles and Equipment	3,727	27.6	57.7
Industrial	Generation of electrical power from coal	1,708	12.7	70.3
Domestic-Commercial	Solid Fuel Combustion	855	6.3	76.7
Industrial	Other land-based extraction	368	2.7	79.4
Industrial	Hard-rock gravel quarrying	360	2.7	82.1
Commercial	Poultry Farming (Meat)	272	2.0	84.1
Off-Road Mobile	Commercial Off-Road Vehicles and Equipment	261	1.9	86.0
On-Road Mobile	Exhaust Emissions Heavy Duty Commercial - Diesel	228	1.7	87.7
Industrial	Primary aluminium production	202	1.5	89.2
All	Other	1,456	10.8	100.0

The 2003 air emissions inventory includes wheel generated and exhaust emissions from coal mining vehicles and equipment in the Industrial Off-Road Vehicles and Equipment source type category. With the exception of wheel generated and exhaust emissions, the 2003 inventory shows that the coal mining industry is the:

- Largest industrial emitter of PM_{10} in the NSW GMR, emitting 25,256 tonnes of PM_{10} per year, or 33.6% of anthropogenic emissions
- Largest industrial emitter of PM_{10} in the Newcastle and Non-Urban Regions, emitting 494 tonnes and 24,587 tonnes of PM_{10} per year, respectively
- Third largest emitter of $PM_{2.5}$ in the GMR, emitting 4,154 tonnes of $PM_{2.5}$ per year, or 13.6% of anthropogenic emissions
- Largest industrial emitter of $PM_{2.5}$ in the Non-Urban Region, emitting 4,056 tonnes per year, or 30.1% of anthropogenic emissions

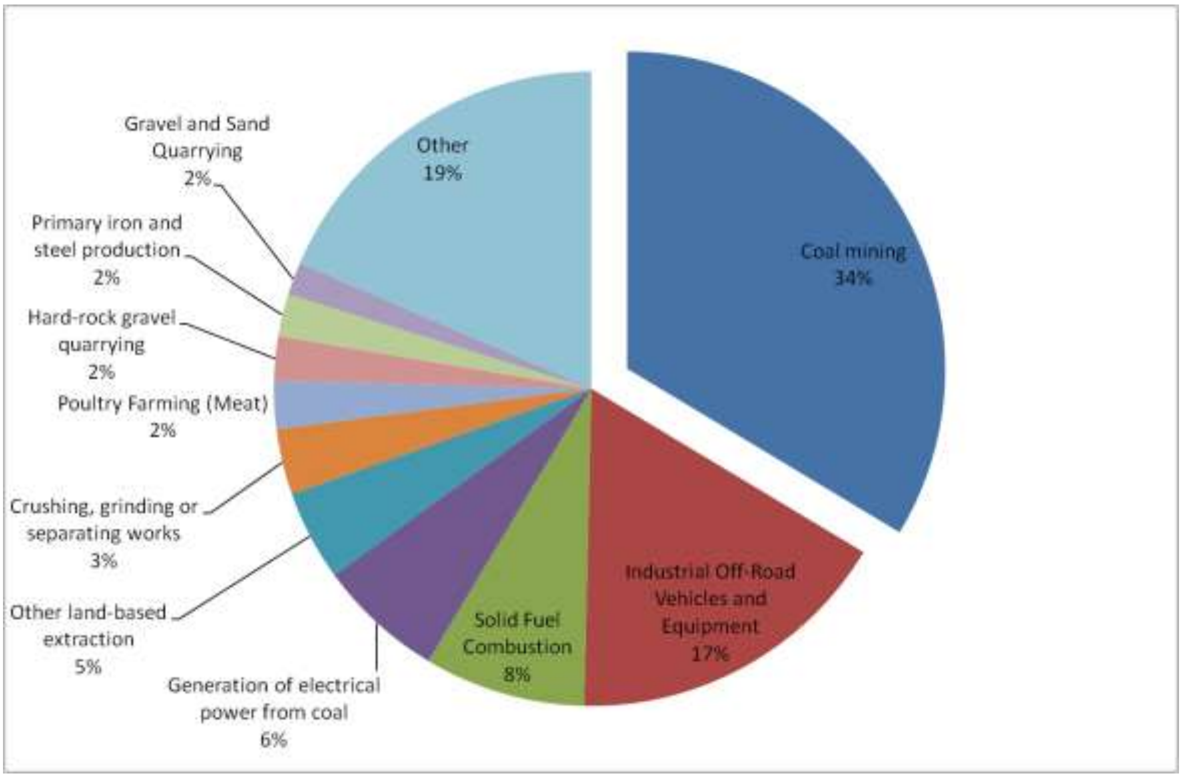

Figure 31 Ten largest anthropogenic sources of particulate matter < 10 µm in the GMR

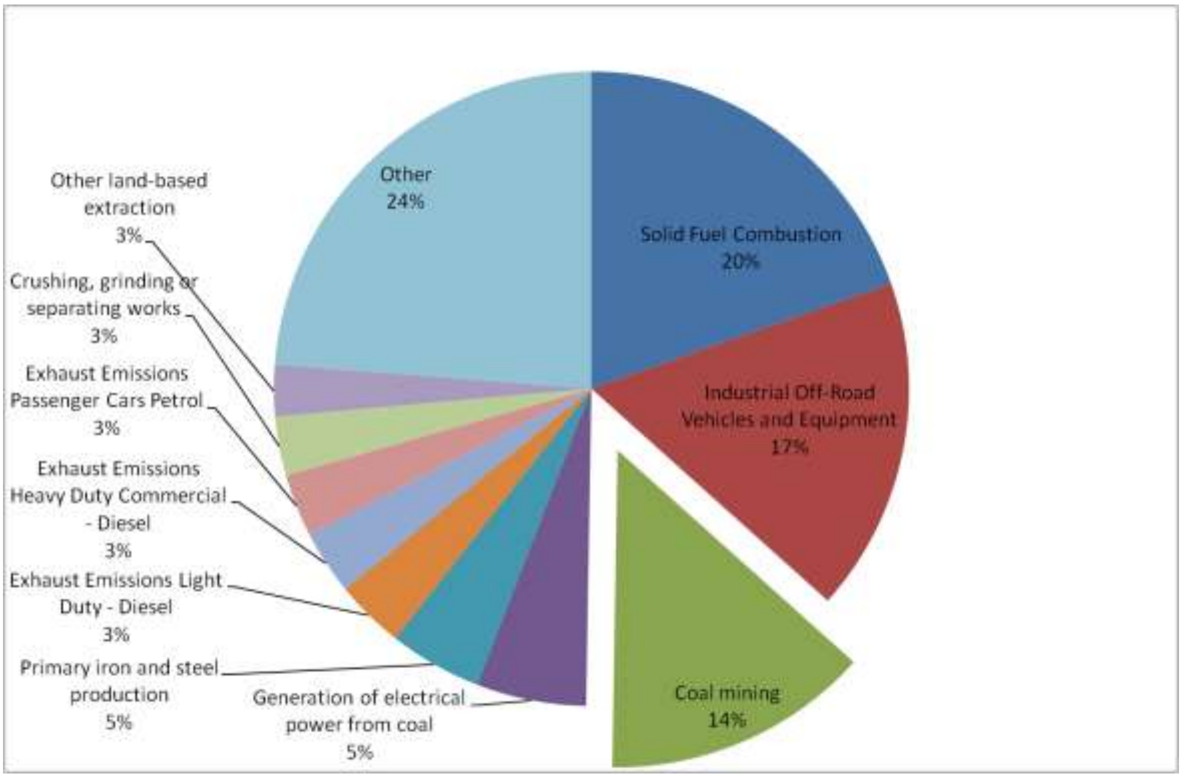

Figure 32 Ten largest anthropogenic sources of particulate matter < 2.5 µm in the GMR

7.3 Coal Mining Air Emissions Inventory for the GMR 2008

7.3.1 Coal Mines Emission Database

In September 2009, OEH wrote to all EPA licensees including all coal mines in the GMR and requested information by Notice under Section 191 of the POEO Act (Appendix B). OEH's approach to updating the inventory aims to minimise duplication with the NPI by utilising the disaggregated data that is prepared by reporting premises. In September 2009, OEH wrote to all EPA licensees including all coal mines in the GMR and requested information by Notice under Section 191 of the POEO Act. The Notice required licensees to complete a questionnaire that included the provision of the following information:

- Details of the operation
- Operating schedule
- Major materials and products
- Air emissions sources
- Fuel combustion
- Fugitive emissions from valves seals
- On-site vehicles
- Materials handling
- Stockpiles and exposed areas
- NPI emissions of particulate matter
- Process flow diagram

OEH provided Katestone Environmental with a database of disaggregated particulate matter emissions for coal mining activities in the GMR. The Coal Mines Emission Database (CMED) is a subset of the information collected for the GMR air emissions inventory.

The CMED is in MS Access 2003 format and includes coal mines in the GMR. Table 28 presents a summary of the information provided in the CMED, including the index for each table, which serves as a linking point to other tables within the database, and standardises data within the database. Figure 33 shows a schematic representation of the tables in the CMED and the relationships between fields and tables.

Table 28 Information included in the Coal Mines Emission Database

Table	Index	Information
tblFacility_Coal_Mine	Facility_ID	Mines location, Licence no. Other miscellaneous information
tblEET	EET_ID	EET Description (using a standard description) Algorithm used in estimating emissions
tblSource_Coal_Mine	Source_ID	Linked to tblEET and details activities that is relevant only to particular mines. This table also provides flexibility in calculating emissions from mine where the calculation factor values (mine data) could vary within the mine
tbl_Substance	Substance_ID	Substance name
tblSource_Substance_Output	No unique index, links on indices for the previous two tables	Control factor applied Source output
tblSources_EET_Calc_Inputs	EET_Calc_Factor_ID EET_Calc_Factor_Type ID	Description of variables used in simple calculation (where Emissions = A * E * C).
tlkpEET_Config_CalcFactorType	CalcFactorType_ID	Description of variables used in complex calculations
tlkpUnit	Unit_ID	Units used in the previous two tables

The output amounts for TSP, PM_{10}, and $PM_{2.5}$ stored in the table 'tblSource_Substance_Output' were re-checked against the calculated output amounts using the calculation factors provided and the equations used. In addition to this, the spreadsheet used to calculate vehicle data for the mines was also provided by OEH.

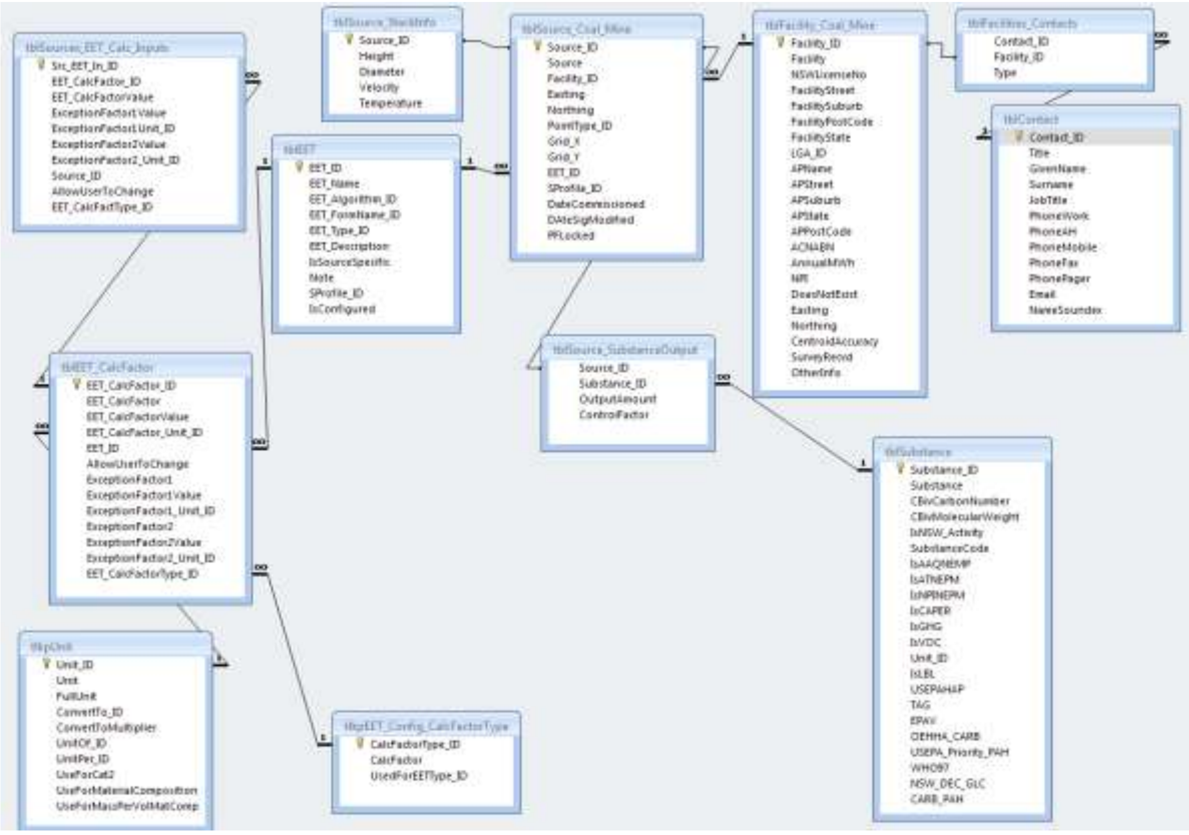

Figure 33 Schematic representation of the Coal Mines Emission Database

Common sources of particulate matter from coal mining identified in the CMED are listed in Table 29. These activities emit varying levels of TSP, PM_{10} and $PM_{2.5}$. The majority of these emissions occur as a result of work done on coal and/or overburden. Particulates are also emitted at coal mines by combustion activities including internal combustion engines (usually diesel), boilers and flares. Emissions from these sources are also included in the inventory and are relevant here, although their relative contribution to emissions is quite small.

Table 29 Common sources of particulate matter from coal mining

Activity	Material	
	Coal	Overburden
Blasting	✓	✓
Bulldozers	✓	✓
Crushing	✓	-
Dragline	✓	✓
Drilling	✓	-
Front-end loaders	✓	✓
Graders	-	✓
Material transfer and conveying	✓	✓
Scrapers	-	✓
Screening	✓	✓
Stacking and reclaiming from stockpiles	✓	-
Train loading	✓	-
Truck loading and unloading	✓	✓
Wheel-generated particulate matter	-	✓
Wind erosion of stockpiles and exposed areas	✓	✓

7.3.2 Coal mines included in the Coal Mines Emission Database

The coal mines for which detailed activity data were available are listed in Table 30. The locations of these coal mines are shown in Figure 34 for the Hunter Coalfield, Figure 35 for the Newcastle Coalfield, Figure 36 for the Southern Coalfield and Figure 37 for the Western Coalfield. The facilities include underground coal mines, open-cut coal mines, coal preparation plants, coal handling facilities and several sites where coal mines are either under construction or have ceased operations.

Table 30 Coal mines included in the Coal Mines Emission Database

Coal operation	EPL	Suburb	Operations type
Abel Underground Mine	12856	Black Hill	Underground mine
Angus Place Colliery	467	Lidsdale	Underground mine
Appin Colliery	758	Appin	Coal handling facility
Ashton Coal Mine	11879	Camberwell	Combined underground and open-cut mining
Austar Coal Mine	416	Pelton	Underground mine
Awaba Colliery	443	Awaba	Underground mine
Baal Bone Colliery	765	Lithgow	Underground mine
Bayswater Colliery	113	Muswellbrook	Open-cut mine
Bengalla Mine	6538	Muswellbrook	Open-cut mine
Berrima Colliery	608	Medway	Underground mine
Bloomfield Colliery	396	Ashtonfield	Open-cut mine
Camberwell Coal Mine	3390	Singleton	Open-cut mine
Chain Valley Colliery	1770	Chain Valley Bay	Underground mine
Charbon Coal Pty Ltd	528	Charbon	Underground mine
Clarence Colliery	726	Newnes Junction	Underground mine
Cullen Valley Mine	10341	Cullen Bullen	Open-cut mine
Cumnock No. 1 Colliery	37	Ravensworth	Open-cut mine
Dendrobium Mine	3241	Mount Kembla	Underground mine
Donaldson Coal Pty Ltd	11080	Maitland	Open-cut mine
Drayton Coal Mine	398	Muswellbrook	Open-cut mine
Glendell Mine	12840	Ravensworth	Open-cut mine
Glennies Creek Colliery	7622	Singleton	Underground mine
Hunter Valley Operations	640	Singleton	Open-cut mine
Ivanhoe No.2 Colliery	631	Portland	Site under care and maintenance contract
Liddell Coal Operations	2094	Ravensworth	Open-cut mine
Macquarie Coal Preparation Plant	1360	Teralba	Coal handling facility
Mandalong Mine and Cooranbong Colliery	365	Dora Creek	Underground mine
Mannering Colliery	191	Wyee	Underground mine
Metropolitan Colliery	767	Helensburgh	Underground mine

Coal operation	EPL	Suburb	Operations type
Mount Arthur Coal	11457	Mount Thorley	Coal handling facility
Mount Thorley Operations	1976	Muswellbrook	Open-cut mine
Mt Owen Coal Mine	4460	Ravensworth	Open-cut mine
Muswellbrook Colliery Holding	656	Muswellbrook	Open-cut mine
Myuna Colliery	366	Wangi Wangi	Underground mine
Newstan Colliery	395	Fassifern	Underground mine
Nre No 1 Colliery	12040	Russell Vale	Underground mine
Nre Wongawilli Colliery	1087	Wongawilli	Underground mine
Pine Dale Mine	4911	Lidsdale	Open-cut mine
Ravensworth East Mine	10860	Ravensworth	Open-cut mine
Ravensworth Underground Mine	10337	Singleton	Underground mine
Ravensworth/Narama Mine	2652	Ravensworth	Open-cut mine
Richmond Main East	13027	Cessnock	Rehabilitated site
Rix's Creek Colliery	3391	Singleton	Open-cut mine
Saxonvale Colliery Holding	563	Singleton	Combined underground and open-cut mining
Springvale Colliery	3607	Lidsdale	Underground mine
Tahmoor Colliery	1389	Tahmoor	Underground mine
Tasman Coal Mine	12483	Seahampton	Underground mine
The Invincible Colliery	1095	Cullen Bullen	Open-cut mine
United Colliery	3141	Warkworth	Underground mine
Wambo Coal Pty Ltd	529	Warkworth	Combined underground and open-cut mining
Warkworth Coal Mine	1376	Mount Thorley	Open-cut mine
West Wallsend Colliery	1360	Killingworth	Underground mine
Westcliff and Northcliff Collieries	2504	Appin	Underground mine
Westside Mine	4033	Killingworth	Open-cut mine
Wilpinjong Coal Pty Ltd	12425	Wollar	Open-cut mine
Xstrata Mangoola (Anvil Hill Mine)	12894	Wybong	Mine under construction

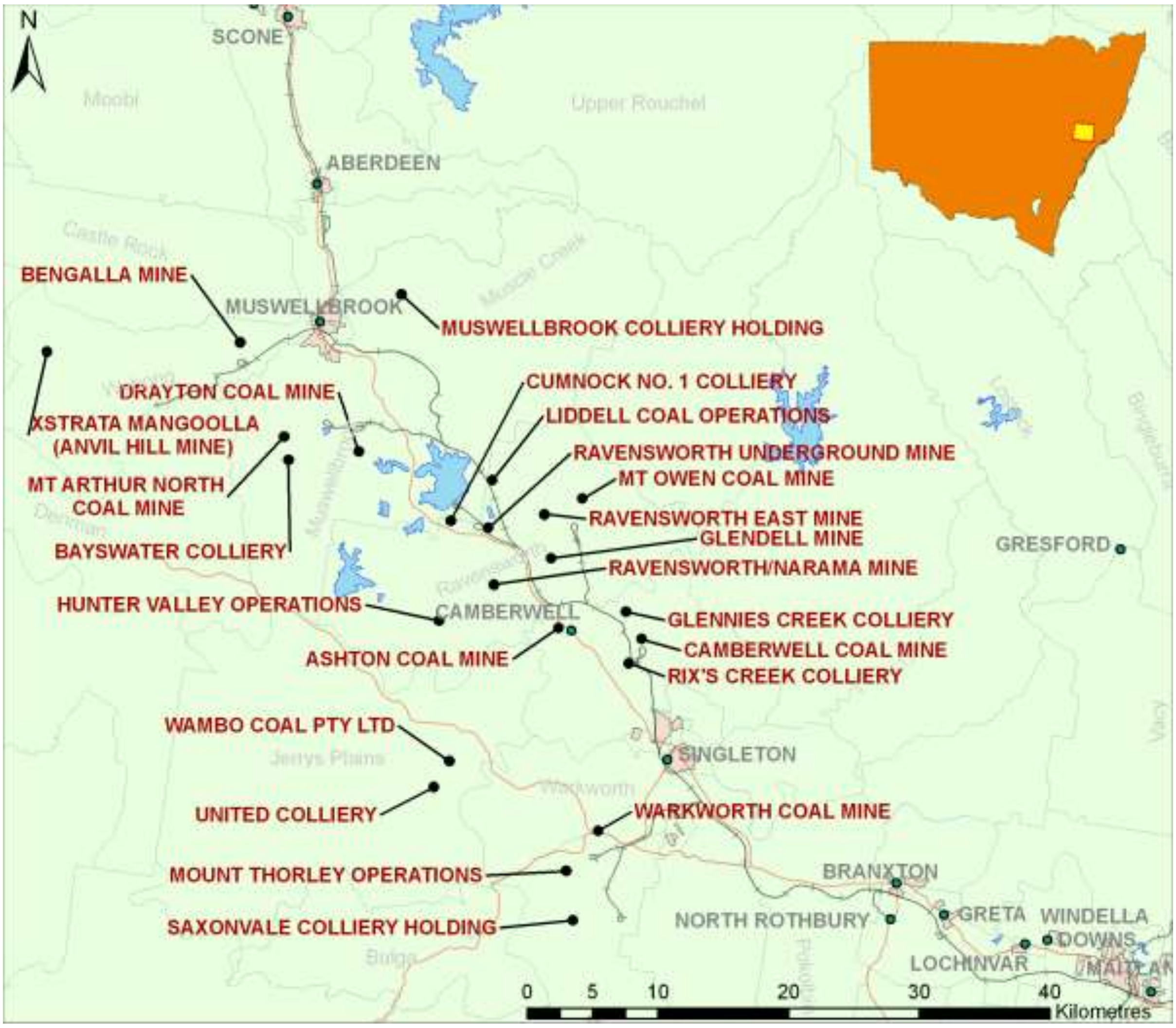

Figure 34 Location of coal mines in the Hunter Coalfield

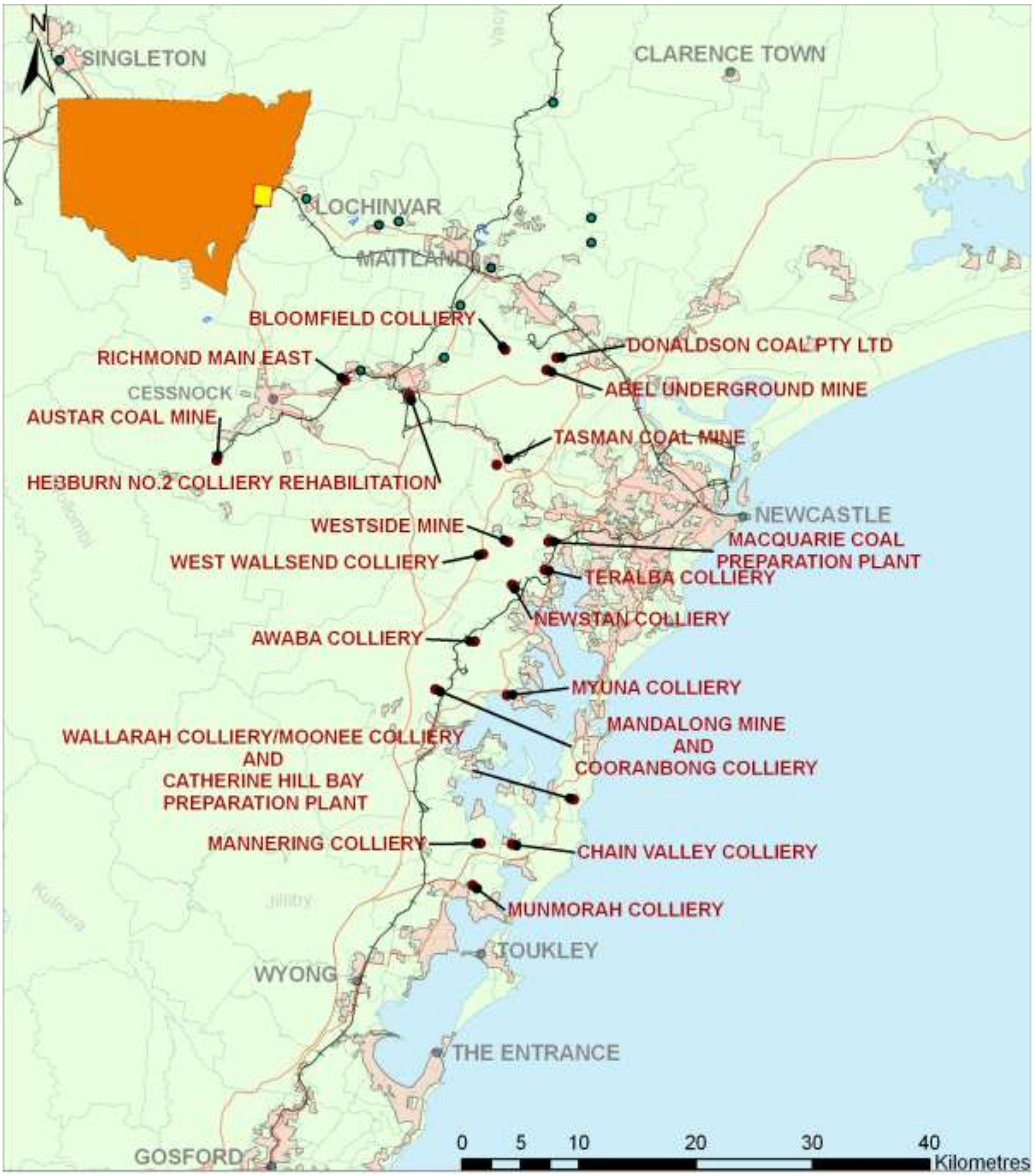

Figure 35 Location of coal mines in the Newcastle Coalfield

Figure 36 Location of coal mines in the Southern Coalfield

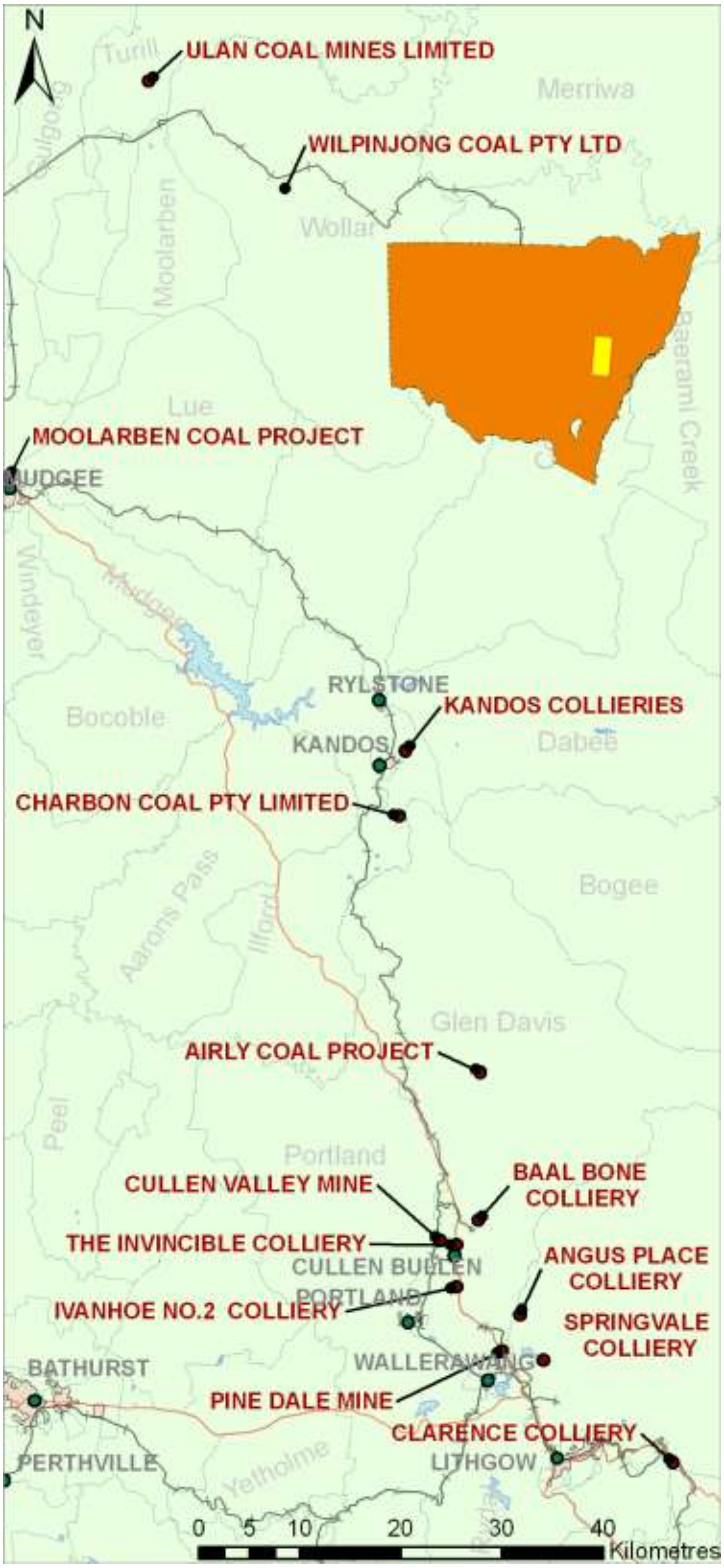

Figure 37 Location of coal mines in the Western Coalfield

7.3.3 Ranking of coal mining activities

Table 31 ranks each activity in order of its relative potential to produce emissions of particulate matter. Activities in Table 31 have been ordered based on the ranking determined for PM_{10} emissions.

Table 31 Ranking of coal mining activities based on total emissions of TSP, PM_{10} and $PM_{2.5}$

Activity	Rank of particle emissions		
	TSP	PM_{10}	$PM_{2.5}$
Wheel generated particulates on unpaved roads	1	1	2
Wind erosion of overburden	2	2	1
Blasting	6	3	3
Bulldozing coal	4	4	5
Trucks unloading overburden	5	5	7
Bulldozing overburden	3	6	4
Front-end loaders on coal	8	7	9
Wind erosion of exposed areas	7	8	6
Wind erosion of coal stockpiles	11	9	8
Unloading from coal stockpiles	10	10	11
Dragline	9	11	10
Front-end loaders on overburden	12	12	12
Trucks unloading coal	13	13	13
Loading coal stockpiles	15	14	16
Graders	14	15	15
Drilling	16	16	18
Coal crushing	18	17	19
Material transfer of coal	19	18	22
Internal combustion engines (Diesel, P>450kW)	21	19	14
Scrapers on overburden	17	20	21
Internal combustion engines (Diesel, P<450kW)	22	21	17
Train loading	20	22	23
Flares	23	23	20
Screening	24	24	24
Material transfer of overburden	25	25	26
Boilers	26	26	25

Table 31 shows that particulate matter generated by wheel-action on unpaved roads generates the greatest amount of TSP and PM_{10}. Wind erosion of overburden was ranked highest for $PM_{2.5}$ and second highest for both TSP and PM_{10} emissions. Blasting ranked third highest for PM_{10} and $PM_{2.5}$ and sixth highest for TSP.

In this analysis, the potential for each activity to impact locations off-site has been assumed to be directly proportional to the magnitude of particle emissions.

It is noted that pit retention factors were taken into account where this information was provided in returned questionnaires when processing emissions inventory data. Hence pit retention of particulate matter has been taken into account in the emission estimates.

Whilst the rankings listed above indicate the general contribution of activities to particulate matter levels, this method may overestimate the significance of several sources due to their location within the mine pit.

For example, blasting would occur within the mine pit for the majority of the time. Particularly for deep mine pits, there is limited exchange between the air above the pit rim and within the pit itself. Therefore emissions of particulate matter from activities within the pit would be retained inside it. This pit retention may decrease TSP emissions by a factor of 50% and PM_{10} and $PM_{2.5}$ emissions by 5%[10].

On the other hand, anecdotal evidence from mines in the GMR suggests that pit retention may not be as effective for long deep open-cut mines when the wind runs parallel with the length of the open-cut. Enhanced particulate matter emissions can occur in this circumstance offsetting the benefit of pit retention.

Further research is required to verify or dispel this phenomenon.

Table 32 and Figure 38 show the proportion of total TSP emissions that are produced by various activities conducted at GMR coal mines. Table 32 suggests that the top three activities produce 80% of the TSP emissions associated with GMR coal mines, whilst the top ten activities produce 97% of TSP emissions.

Table 32 Proportion of total TSP emissions produced by various coal mining activities based on data from GMR coal mines

Source type	Rank	TSP Emissions (tonnes/year)	Proportion (%)	Cumulative Proportion (%)
Wheel generated dust	1	81,643	52.4	52.4
Wind Erosion (overburden)	2	28,907	18.6	70.9
Bulldozers	3	14,156	9.1	80.0
Trucks (dumping overburden)	4	6,295	4.0	84.1
Blasting	5	5,508	3.5	87.6
Exposed area (wind erosion)	6	3,732	2.4	90.0
Loaders (coal)	7	3,384	2.2	92.2
Dragline (Other)	8	2,956	1.9	94.1
Unloading from stockpiles (coal)	9	2,520	1.6	95.7
Wind Erosion (coal)	10	2,453	1.6	97.3
Loaders (overburden)	11	1,237	0.8	98.0
Trucks (dumping coal)	12	1,108	0.7	98.8
Graders	13	690	0.4	99.2
Loading stockpiles (coal)	14	576	0.4	99.6
Drilling	15	301	0.2	99.8
Other		363	0.2	100.0
Grand total		155,830	100	

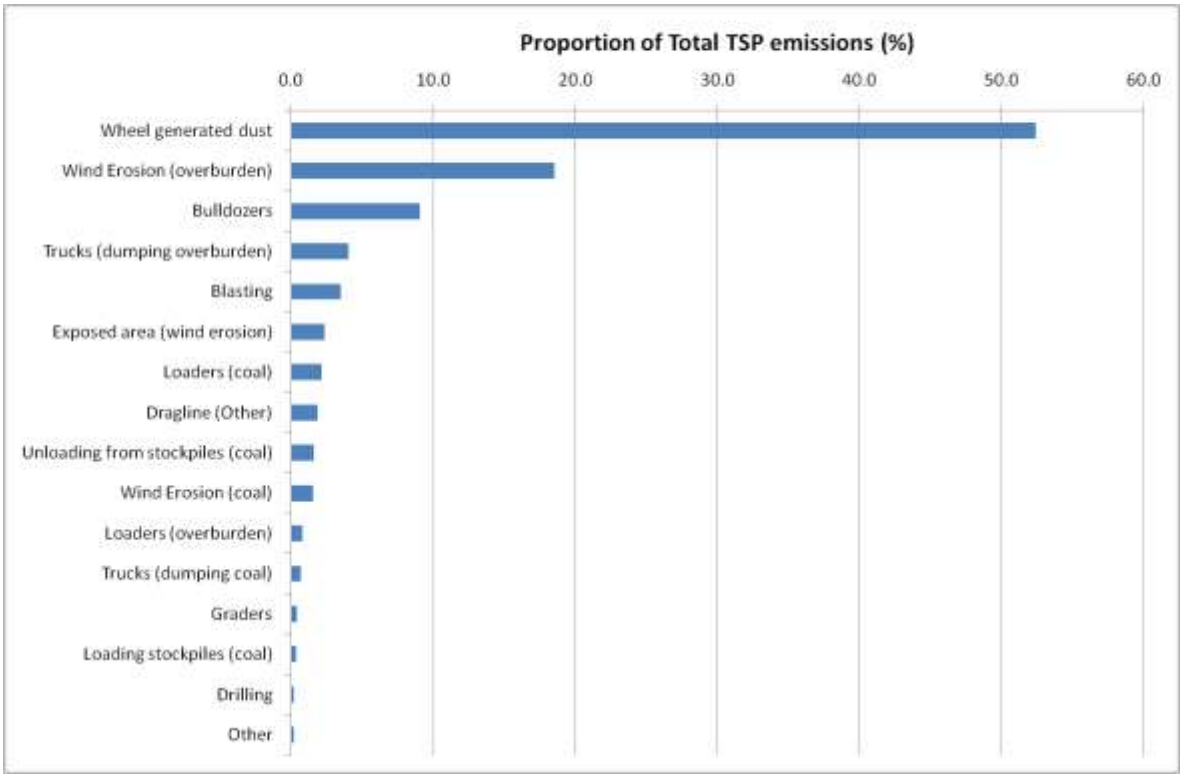

Figure 38 Proportion of total TSP emissions produced by various coal mining activities based on data from GMR coal mines

Table 33 and Figure 39 show the proportion of total PM_{10} emissions that are produced by various activities conducted at GMR coal mines. Table 33 suggests that the top three activities produce over 70% of the PM_{10} emissions associated with GMR coal mines, whilst the top ten activities produce 97% of PM_{10} emissions.

Table 33 Proportion of total PM_{10} emissions produced by various coal mining activities based on data from GMR coal mines

Source type	Rank	PM_{10} Emissions (tonnes/year)	Proportion (%)	Cumulative Proportion (%)
Wheel generated dust	1	23,272	39.1	39.1
Wind Erosion (overburden)	2	16,246	27.3	66.5
Bulldozers	3	4,939	8.3	74.8
Blasting	4	3,329	5.6	80.4
Trucks (dumping overburden)	5	2,480	4.2	84.5
Loaders (coal)	6	2,141	3.6	88.1
Exposed area (wind erosion)	7	1,866	3.1	91.3
Wind Erosion (coal)	8	1,227	2.1	93.3
Unloading from stockpiles (coal)	9	1,092	1.8	95.2
Dragline (Other)	10	924	1.6	96.7
Loaders (overburden)	11	707	1.2	97.9
Trucks (dumping coal)	12	471	0.8	98.7
Loading stockpiles (coal)	13	245	0.4	99.1
Graders	14	172	0.3	99.4
Drilling	15	166	0.3	99.7
Other		182	0.3	100.0
Grand total	-	59,457	100	

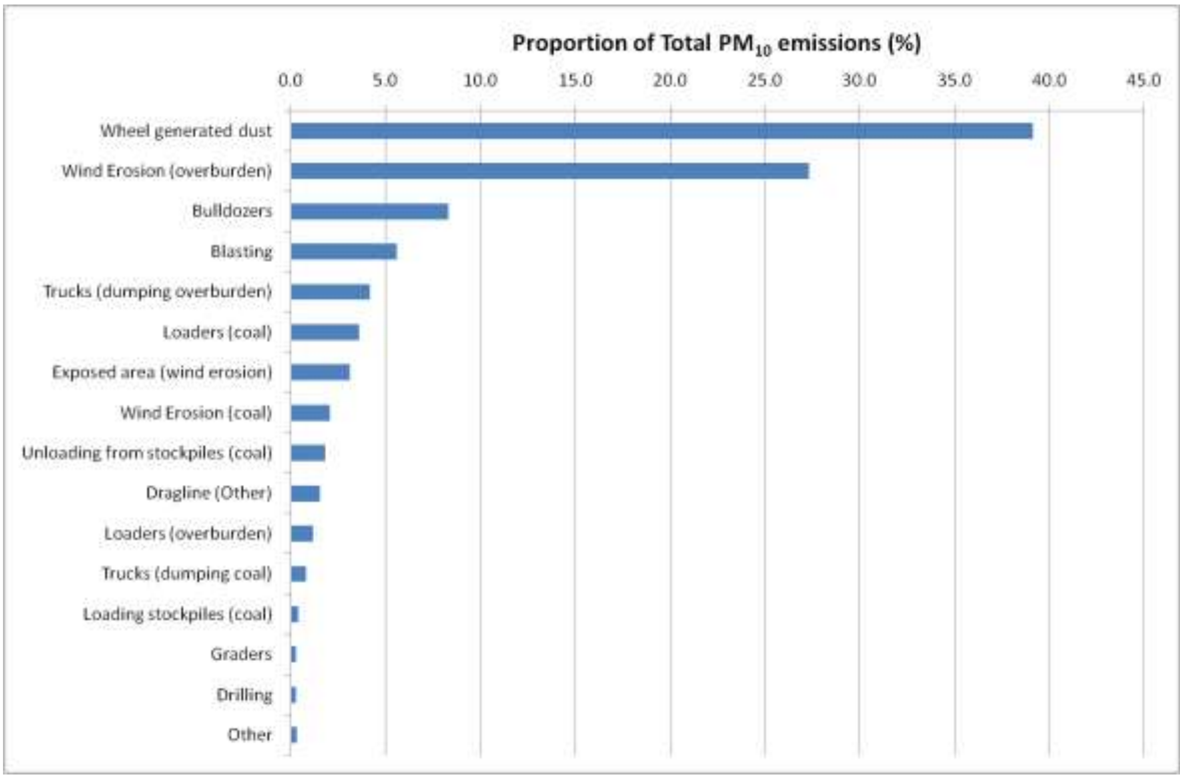

Figure 39 Proportion of total PM_{10} emissions produced by various coal mining activities based on data from GMR coal mines

Table 34 and Figure 40 show the proportion of total $PM_{2.5}$ emissions that are produced by various activities conducted at GMR coal mines. Table 34 suggests that the top three activities produce 75% of the $PM_{2.5}$ emissions associated with GMR coal mines, whilst the top ten activities produce 97% of $PM_{2.5}$ emissions.

Table 34 Proportion of total $PM_{2.5}$ emissions produced by various coal mining activities based on data from GMR coal mines

Source type	Rank	$PM_{2.5}$ Emissions (tonnes/year)	Proportion (%)	Cumulative Proportion (%)
Wind Erosion (overburden)	1	3,272	31.8	31.8
Wheel generated dust	2	2,327	22.6	54.4
Blasting	3	2,121	20.6	75.1
Bulldozers	4	887	8.6	83.7
Exposed area (wind erosion)	5	373	3.6	87.3
Trucks (dumping overburden)	6	324	3.1	90.5
Wind Erosion (coal)	7	247	2.4	92.9
Loaders (coal)	8	209	2.0	94.9
Dragline (Other)	9	138	1.3	96.2
Unloading from stockpiles (coal)	10	118	1.1	97.4
Loaders (overburden)	11	70	0.7	98.1
Trucks (dumping coal)	12	53	0.5	98.6
Internal Combustion Engine (Diesel, P>450kW)	13	34	0.3	98.9
Graders	14	32	0.3	99.2
Loading stockpiles (coal)	15	27	0.3	99.5
Other		55	0.5	100.0
Grand total		10,286	100	

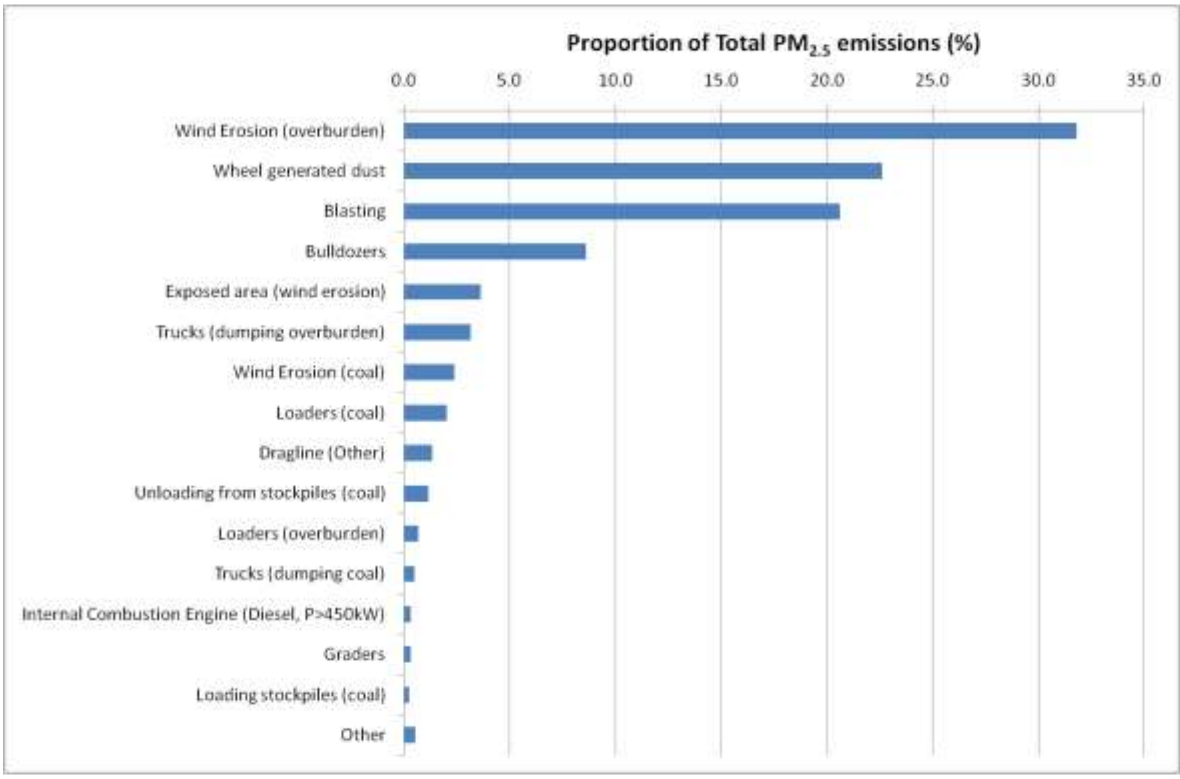

Figure 40 Proportion of total $PM_{2.5}$ emissions produced by various coal mining activities based on data from GMR coal mines

7.3.4 Ranking of coal mine premises

To gain an overview of the contribution from different coal facilities to emissions of particulate matter, facilities have been ranked in Table 35 based on total amount of particles emitted per year, ordered by PM_{10} ranking. The rankings of the top six mines are the same for TSP and PM_{10}. The mines have also been ranked on coal throughput and the type of mine has been specified.

Table 35 Ranking of coal mines based on total particle emissions

Coal mine	EPL	Type	Annual ROM coal 2008 throughput (Mtpa)	Rank of coal throughput	Rank of particle emissions		
					TSP	PM_{10}	$PM_{2.5}$
Hunter Valley Operations	640	OC	17.2	1	1	1	1
Mt Arthur North Coal Mine	11457	OC	14.0	2	2	2	2
Saxonvale Colliery Holding	563	COMB	10.8	5	3	3	3
Warkworth Coal Mine	1376	OC	12.8	3	4	4	4
Mt Owen Coal Mine	4460	OC	10.9	4	5	5	6
Camberwell Coal Mine	3390	OC	2.2	22	6	6	7
Liddell Coal Operations	2094	OC	9.5	6	12	7	5
Drayton Coal Mine	1323	OC	4.2	13	7	8	10
Wambo Coal Pty Ltd	529	COMB	4.5	10	8	9	14
Bengalla Mine	6538	OC	5.3	8	11	10	13
Mount Thorley Operations	1976	HDL	0.4	49	13	11	9
Ravensworth/Narama Mine	2652	OC	4.3	11	9	12	11
Wilpinjong Coal Pty Ltd	12425	OC	7.3	7	10	13	15
Ravensworth East Mine	10860	OC	3.5	15	15	14	8
Muswellbrook Colliery Holding	656	OC	1.2	37	16	15	12
Cumnock No. 1 Colliery	37	OC	0.9	39	14	16	19
Ashton Coal Mine	11879	COMB	3.1	16	17	17	17
Glendell Mine	12840	OC	2.3	20	18	18	16

Coal mine	EPL	Type	Annual ROM coal 2008 throughput (Mtpa)	Rank of coal throughput	Rank of particle emissions		
					TSP	PM_{10}	$PM_{2.5}$
Rix's Creek Colliery	3391	OC	2.0[c]	24	19	19	18
Donaldson Coal Pty Ltd	11080	OC	1.3	33	20	20	20
Bloomfield Colliery	396	OC	0.8[c]	42	21	21	21
Westside Mine	4033	OC	0.9	41	22	22	22
Westcliff And Northcliff Collieries	2504	UG	4.2	12	24	23	27
Baal Bone Colliery	765	UG	1.3	32	23	24	23
Cullen Valley Mine	10341	OC	0.9	40	25	25	25
Bayswater Colliery	113	OC	0.8	44	31	26	24
Newstan Colliery	395	UG	1.7	29	27	27	31
Pine Dale Mine	4911	OC	0.3	50	26	28	28
Ravensworth Underground Mine	10337	UG	1.8	28	29	29	26
The Invincible Colliery	1095	OC	0.2	53	30	30	29
United Colliery	3141	UG	1.9	25	28	31	32
Macquarie Coal Preparation Plant	1360	HDL	2.7[a]	18	32	32	30
Springvale Colliery	3607	UG	3.7	14	35	33	33
Glennies Creek Colliery	7622	UG	1.3	31	33	34	36
Tahmoor Colliery	1389	UG	1.9	27	34	35	35
Charbon Coal Pty Limited	528	UG	1.2	36	36	36	39
Clarence Colliery	726	UG	1.9	26	37	37	38
Austar Coal Mine	416	UG	1.1	38	39	38	34
Mandalong Mine And Cooranbong Colliery	365	UG	4.7	9	38	39	40
Dendrobium Mine	3241	UG	3.0	17	40	40	41
Angus Place Colliery	467	UG	2.2	21	41	41	42
Metropolitan Colliery	767	UG	1.2	35	42	42	44
West Wallsend Colliery	1360	UG	2.7	18	43	43	45
Tasman Coal Mine	12483	UG	0.6	48	44	44	43
Nre No 1 Colliery	12040	UG	0.7	46	45	45	46
Abel Underground Mine	12856	UG	0.3	51	49	46	37
Appin Colliery	758	HDL	-[a]	-[a]	47	47	48
Nre Wongawilli Colliery	1087	UG	0.2	54	46	48	47
Awaba Colliery	443	UG	0.8	43	48	49	49
Mannering Colliery	191	UG	0.6	47	50	50	50
Chain Valley Colliery	1770	UG	0.7	45	52	51	52
Richmond Main East	13027	REHAB	-[a]	-[a]	51	52	51
Berrima Colliery	608	UG	0.2	52	53	53	53
Ivanhoe No.2 Colliery	631	MAINT	-[a]	-[a]	54	54	54
Myuna Colliery	366	UG	1.2	34	55	55	55
Xstrata Mangoolla (Anvil Hill Mine)	12894	CONSTRT	-[a]	-[a]	56	56	56

Note:
[a] No mining occurs at this site
[b] Following codes used to represent operations type:

COMB	Combined underground and open-cut mining
CONSTRT	Mine under construction
HDL	Coal handling facility
MAINT	Site under care and maintenance contract
OC	Open-cut mine
REHAB	Rehabilitated site
UG	Underground mine

[c] Tonnage advised in submissions from Bloomfield Group to OEH dated 4 February 2011

In general, underground mines emit less particulate matter than open-cut mines because minimal overburden needs to be disturbed and the key activities that produce particulate matter occur below ground. This is reflected in the rankings, with the majority of underground mines ranking lower for emissions of particulate matter than open-cut mines.

Facilities that have coal handling operations only, such as Mount Thorley Operations, Macquarie Coal Preparation Plant and Appin Colliery would be expected to have similar emissions as underground mines. Mount Thorley Operations appears unusual in that regard, as it ranks reasonably high for particle emissions and is on a comparative level to open-cut mines. This is likely to be due to the large number of overburden stockpiles at this site, and consequently wind erosion of overburden stockpiles contributes a large amount to the facility's total particle emissions compared with other similar facilities.

A coal facility that handles large amounts of coal would be expected to emit a higher amount of particulate matter than a facility with a smaller annual coal throughput. For example, Hunter Valley Operations has the largest annual coal throughput of the facilities in the list at 17.2 Mtpa and has reported correspondingly high emissions of particulate matter due to the amount of material handled. However, Camberwell Coal Mine has a comparatively low annual coal throughput at 2.2 Mtpa, yet is ranked within the top ten of the facilities for emissions of particulate matter. This is due in part to the high level of particulate matter generated by haul trucks travelling on unpaved roads at this site.

Similarly, Muswellbrook Colliery ranks 38th in terms of its coal production, but ranks between 12th and 16th for emissions of particulate matter. A relatively large amount of emissions occur from this site due to trucks travelling on unpaved roads. Blasting also contributes a large proportion to the facility's emissions of particulate matter, considering its comparatively small annual coal throughput.

The differences between emission rankings may be due to factors such as a low strip ratio, increased use of emission controls or a difference in the inherent dustiness of the coal and overburden handled at each facility.

Table 36, Table 37 and Table 38 rank coal mines based on annual emissions of TSP, PM_{10} and $PM_{2.5}$, respectively. The estimated emission rates of each particulate matter metric is shown as well as the proportion that each mine contributes to total GMR coal mining emissions.

Table 36 Ranking of coal mines based on TSP emissions with proportion and cumulative proportion of total coal mining emissions

Coal Mine	EPL	Type	Rank	TSP (tonnes/year)	Proportion (%)	Cumulative proportion (%)
Hunter Valley Operations	640	OC	1	27,928	17.92	17.92
Mt Arthur North Coal Mine	11457	OC	2	17,710	11.36	29.29
Saxonvale Colliery Holding	563	COMB	3	13,755	8.83	38.11
Warkworth Coal Mine	1376	OC	4	10,575	6.79	44.90
Mt Owen Coal Mine	4460	OC	5	8,275	5.31	50.21
Camberwell Coal Mine	3390	OC	6	8,173	5.24	55.45
Drayton Coal Mine	1323	OC	7	7,339	4.71	60.16
Wambo Coal Pty Ltd	529	COMB	8	6,875	4.41	64.58
Ravensworth/Narama Mine	2652	OC	9	6,131	3.93	68.51
Wilpinjong Coal Pty Ltd	12425	OC	10	5,604	3.60	72.11
Bengalla Mine	6538	OC	11	5,591	3.59	75.69
Liddell Coal Operations	2094	OC	12	5,073	3.26	78.95
Mount Thorley Operations	1976	HDL	13	3,929	2.52	81.47
Cumnock No. 1 Colliery	37	OC	14	3,531	2.27	83.74
Ravensworth East Mine	10860	OC	15	3,420	2.19	85.93
Muswellbrook Colliery Holding	656	OC	16	3,044	1.95	87.88
Ashton Coal Mine	11879	COMB	17	2,686	1.72	89.61
Glendell Mine	12840	OC	18	2,502	1.61	91.21
Rix's Creek Colliery	3391	OC	19	2,030	1.30	92.52
Donaldson Coal Pty Ltd	11080	OC	20	1,710	1.10	93.61

Coal Mine	EPL	Type	Rank	TSP (tonnes/year)	Proportion (%)	Cumulative proportion (%)
Bloomfield Colliery	396	OC	21	1,156	0.74	94.36
Westside Mine	4033	OC	22	1,057	0.68	95.03
Baal Bone Colliery	765	UG	23	706	0.45	95.49
Westcliff And Northcliff Collieries	2504	UG	24	687	0.44	95.93
Cullen Valley Mine	10341	OC	25	681	0.44	96.36
Pine Dale Mine	4911	OC	26	655	0.42	96.79
Newstan Colliery	395	UG	27	589	0.38	97.16
United Colliery	3141	UG	28	465	0.30	97.46
Ravensworth Underground Mine	10337	UG	29	438	0.28	97.74
The Invincible Colliery	1095	OC	30	421	0.27	98.01
Bayswater Colliery	113	OC	31	334	0.21	98.23
Macquarie Coal Preparation Plant	1360	HDL	32	320	0.21	98.43
Glennies Creek Colliery	7622	UG	33	297	0.19	98.62
Tahmoor Colliery	1389	UG	34	293	0.19	98.81
Springvale Colliery	3607	UG	35	262	0.17	98.98
Charbon Coal Pty Limited	528	UG	36	246	0.16	99.14
Clarence Colliery	726	UG	37	222	0.14	99.28
Mandalong Mine And Cooranbong Colliery	365	UG	38	186	0.12	99.40
Austar Coal Mine	416	UG	39	168	0.11	99.51
Dendrobium Mine	3241	UG	40	135	0.09	99.59
Angus Place Colliery	467	UG	41	120	0.08	99.67
Metropolitan Colliery	767	UG	42	90	0.06	99.73
West Wallsend Colliery	1360	UG	43	66	0.04	99.77
Tasman Coal Mine	12483	UG	44	64	0.04	99.81
Nre No 1 Colliery	12040	UG	45	56	0.04	99.85
Nre Wongawilli Colliery	1087	UG	46	47	0.03	99.88
Appin Colliery	758	HDL	47	45	0.03	99.91
Awaba Colliery	443	UG	48	36	0.02	99.93
Abel Underground Mine	12856	UG	49	32	0.02	99.95
Mannering Colliery	191	UG	50	23	0.01	99.96
Richmond Main East	13027	REHAB	51	23	0.01	99.98
Chain Valley Colliery	1770	UG	52	18	0.01	99.99
Berrima Colliery	608	UG	53	9	0.01	100
Ivanhoe No.2 Colliery	631	MAINT	54	2	0	100
Myuna Colliery	366	UG	55	2	0	100
Xstrata Mangoolla (Anvil Hill Mine)	12894	CONSTRT	56	1	0	100
Grand total				155,830	100.0	

Table 37 Ranking of coal mines based on PM_{10} emissions with proportion and cumulative proportion of total coal mining emissions

Coal Mine	EPL	Type	Rank	PM_{10} (tonnes/year)	Proportion (%)	Cumulative proportion (%)
Hunter Valley Operations	640	OC	1	11,633	19.56	19.56
Mt Arthur North Coal Mine	11457	OC	2	7,524	12.65	32.22
Saxonvale Colliery Holding	563	COMB	3	4,653	7.83	40.04
Warkworth Coal Mine	1376	OC	4	3,494	5.88	45.92
Mt Owen Coal Mine	4460	OC	5	2,859	4.81	50.73
Camberwell Coal Mine	3390	OC	6	2,727	4.59	55.31
Liddell Coal Operations	2094	OC	7	2,660	4.47	59.79
Drayton Coal Mine	1323	OC	8	2,497	4.20	63.99
Wambo Coal Pty Ltd	529	COMB	9	2,166	3.64	67.63
Bengalla Mine	6538	OC	10	2,098	3.53	71.16
Mount Thorley Operations	1976	HDL	11	1,958	3.29	74.45

Coal Mine	EPL	Type	Rank	PM_{10} (tonnes/year)	Proportion (%)	Cumulative proportion (%)
Ravensworth/Narama Mine	2652	OC	12	1,816	3.05	77.51
Wilpinjong Coal Pty Ltd	12425	OC	13	1,757	2.95	80.46
Ravensworth East Mine	10860	OC	14	1,704	2.87	83.33
Muswellbrook Colliery Holding	656	OC	15	1,274	2.14	85.47
Cumnock No. 1 Colliery	37	OC	16	1,120	1.88	87.35
Ashton Coal Mine	11879	COMB	17	1,095	1.84	89.19
Glendell Mine	12840	OC	18	1,063	1.79	90.98
Rix's Creek Colliery	3391	OC	19	833	1.40	92.38
Donaldson Coal Pty Ltd	11080	OC	20	596	1.00	93.39
Bloomfield Colliery	396	OC	21	505	0.85	94.23
Westside Mine	4033	OC	22	415	0.70	94.93
Westcliff And Northcliff Collieries	2504	UG	23	268	0.45	95.38
Baal Bone Colliery	765	UG	24	268	0.45	95.83
Cullen Valley Mine	10341	OC	25	248	0.42	96.25
Bayswater Colliery	113	OC	26	234	0.39	96.64
Newstan Colliery	395	UG	27	204	0.34	96.99
Pine Dale Mine	4911	OC	28	204	0.34	97.33
Ravensworth Underground Mine	10337	UG	29	204	0.34	97.67
The Invincible Colliery	1095	OC	30	157	0.26	97.94
United Colliery	3141	UG	31	155	0.26	98.20
Macquarie Coal Preparation Plant	1360	HDL	32	140	0.24	98.43
Springvale Colliery	3607	UG	33	110	0.18	98.62
Glennies Creek Colliery	7622	UG	34	98	0.16	98.78
Tahmoor Colliery	1389	UG	35	97	0.16	98.95
Charbon Coal Pty Limited	528	UG	36	80	0.13	99.08
Clarence Colliery	726	UG	37	80	0.13	99.22
Austar Coal Mine	416	UG	38	79	0.13	99.35
Mandalong Mine And Cooranbong Colliery	365	UG	39	71	0.12	99.47
Dendrobium Mine	3241	UG	40	49	0.08	99.55
Angus Place Colliery	467	UG	41	44	0.07	99.62
Metropolitan Colliery	767	UG	42	39	0.07	99.69
West Wallsend Colliery	1360	UG	43	31	0.05	99.74
Tasman Coal Mine	12483	UG	44	31	0.05	99.79
Nre No 1 Colliery	12040	UG	45	21	0.04	99.83
Abel Underground Mine	12856	UG	46	20	0.03	99.86
Appin Colliery	758	HDL	47	20	0.03	99.90
Nre Wongawilli Colliery	1087	UG	48	16	0.03	99.92
Awaba Colliery	443	UG	49	16	0.03	99.95
Mannering Colliery	191	UG	50	10	0.02	99.97
Chain Valley Colliery	1770	UG	51	8	0.01	99.98
Richmond Main East	13027	REHAB	52	5	0.01	99.99
Berrima Colliery	608	UG	53	4	0.01	100
Ivanhoe No.2 Colliery	631	MAINT	54	1	0.00	100
Myuna Colliery	366	UG	55	1	0.00	100
Xstrata Mangoolla (Anvil Hill Mine)	12894	CONSTRT	56	0	0.00	100
Grand total				59,457	100.0	

Table 38 Ranking of coal mines based on $PM_{2.5}$ emissions with proportion and cumulative proportion of total coal mining emissions

Coal Mine	EPL	Type	Rank	$PM_{2.5}$ (tonnes/year)	Proportion (%)	Cumulative proportion (%)
Hunter Valley Operations	640	OC	1	2,322	22.58	22.58
Mt Arthur North Coal Mine	11457	OC	2	1,089	10.59	33.16
Saxonvale Colliery Holding	563	COMB	3	720	7.00	40.17
Warkworth Coal Mine	1376	OC	4	507	4.93	45.09
Liddell Coal Operations	2094	OC	5	492	4.78	49.88
Mt Owen Coal Mine	4460	OC	6	470	4.57	54.45
Camberwell Coal Mine	3390	OC	7	447	4.35	58.79
Ravensworth East Mine	10860	OC	8	418	4.06	62.86
Mount Thorley Operations	1976	HDL	9	385	3.74	66.60
Drayton Coal Mine	1323	OC	10	356	3.46	70.06
Ravensworth/Narama Mine	2652	OC	11	348	3.38	73.45
Muswellbrook Colliery Holding	656	OC	12	333	3.24	76.68
Bengalla Mine	6538	OC	13	333	3.24	79.92
Wambo Coal Pty Ltd	529	COMB	14	298	2.90	82.82
Wilpinjong Coal Pty Ltd	12425	OC	15	278	2.70	85.52
Glendell Mine	12840	OC	16	270	2.63	88.15
Ashton Coal Mine	11879	COMB	17	206	2.00	90.15
Rix's Creek Colliery	3391	OC	18	150	1.46	91.61
Cumnock No. 1 Colliery	37	OC	19	141	1.37	92.98
Donaldson Coal Pty Ltd	11080	OC	20	99	0.96	93.94
Bloomfield Colliery	396	OC	21	93	0.90	94.85
Westside Mine	4033	OC	22	81	0.79	95.63
Baal Bone Colliery	765	UG	23	43	0.42	96.05
Bayswater Colliery	113	OC	24	42	0.41	96.46
Cullen Valley Mine	10341	OC	25	40	0.39	96.85
Ravensworth Underground Mine	10337	UG	26	38	0.37	97.22
Westcliff And Northcliff Collieries	2504	UG	27	37	0.36	97.58
Pine Dale Mine	4911	OC	28	28	0.27	97.85
The Invincible Colliery	1095	OC	29	24	0.23	98.08
Macquarie Coal Preparation Plant	1360	HDL	30	23	0.22	98.31
Newstan Colliery	395	UG	31	23	0.22	98.53
United Colliery	3141	UG	32	19	0.18	98.72
Springvale Colliery	3607	UG	33	15	0.15	98.86
Austar Coal Mine	416	UG	34	15	0.15	99.01
Tahmoor Colliery	1389	UG	35	12	0.12	99.12
Glennies Creek Colliery	7622	UG	36	11	0.11	99.23
Abel Underground Mine	12856	UG	37	11	0.11	99.34
Clarence Colliery	726	UG	38	10	0.10	99.44
Charbon Coal Pty Limited	528	UG	39	10	0.10	99.53
Mandalong Mine And Cooranbong Colliery	365	UG	40	9	0.09	99.62
Dendrobium Mine	3241	UG	41	7	0.07	99.69
Angus Place Colliery	467	UG	42	6	0.06	99.75
Tasman Coal Mine	12483	UG	43	5	0.05	99.80
Metropolitan Colliery	767	UG	44	4	0.04	99.83
West Wallsend Colliery	1360	UG	45	3	0.03	99.86
Nre No 1 Colliery	12040	UG	46	3	0.03	99.89
Nre Wongawilli Colliery	1087	UG	47	3	0.03	99.92
Appin Colliery	758	HDL	48	2	0.02	99.94
Awaba Colliery	443	UG	49	2	0.02	99.96
Mannering Colliery	191	UG	50	1	0.01	99.97
Richmond Main East	13027	REHAB	51	1	0.01	99.98
Chain Valley Colliery	1770	UG	52	1	0.01	99.99
Berrima Colliery	608	UG	53	1	0.01	100

Coal Mine	EPL	Type	Rank	$PM_{2.5}$ (tonnes/year)	Proportion (%)	Cumulative proportion (%)
Ivanhoe No.2 Colliery	631	MAINT	54	0	0.00	100
Myuna Colliery	366	UG	55	0	0.00	100
Xstrata Mangoolla (Anvil Hill Mine)	12894	CONSTRT	56	0	0.00	100
Grand total				10,286	100.0	

7.3.5 Ranking of coalfields

Emission rates of TSP, PM_{10} and $PM_{2.5}$ by coalfield are shown in Table 39 and Figure 41 to Figure 43. Table 39 shows that the Hunter Coalfield produces 90% of TSP, 91% of PM_{10} and 92% of $PM_{2.5}$ associated with GMR coal mines.

Table 39 TSP, PM_{10} and $PM_{2.5}$ emission rates by coalfield

Coalfield	TSP		PM_{10}		$PM_{2.5}$	
	Emission rate (tonnes/year)	Proportion of total (%)	Emission rate (tonnes/year)	Proportion of total (%)	Emission rate (tonnes/year)	Proportion of total (%)
Hunter	140,422	90.1	54,004	90.8	9,418	91.6
Western	8,919	5.7	2,948	5.0	455	4.4
Newcastle	5,128	3.3	1,992	3.3	345	3.4
Southern	1,361	0.9	514	0.9	68	0.7
Total GMR	155,830	100.0	59,457	100.0	10,286	100.0
Gloucester	2,512		829		115	

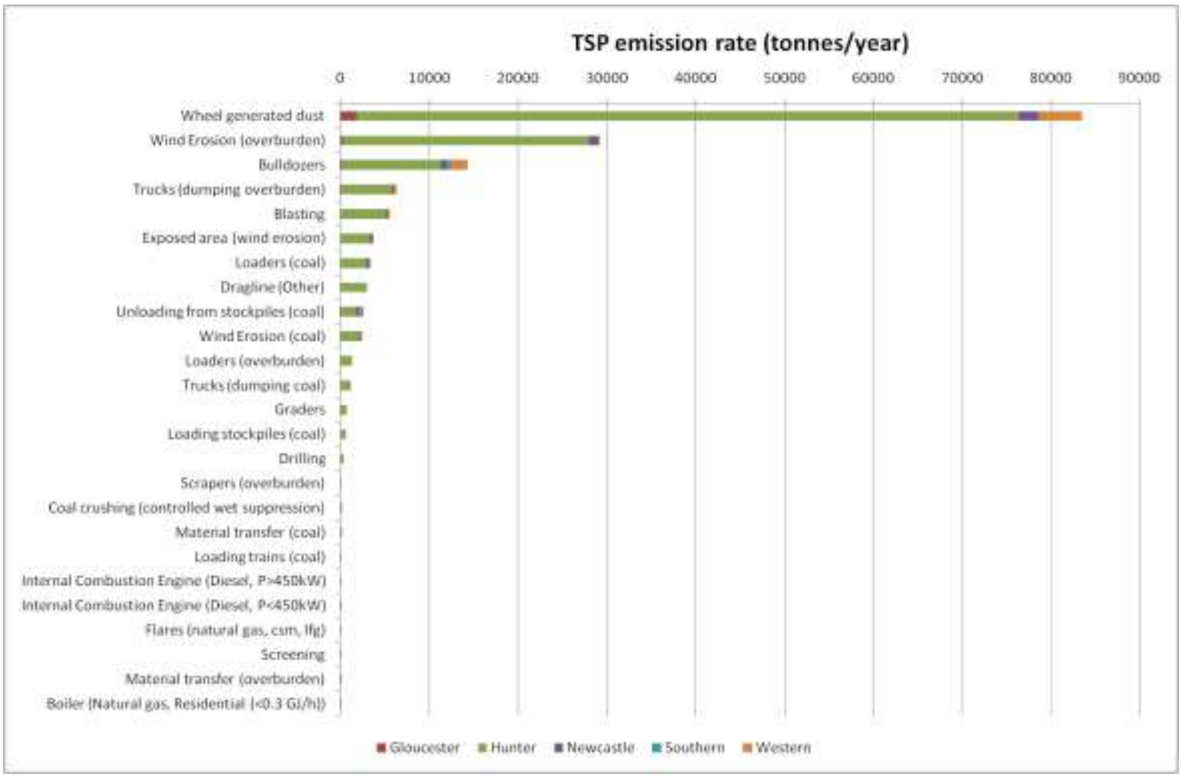

Figure 41 TSP emission rate by coalfield

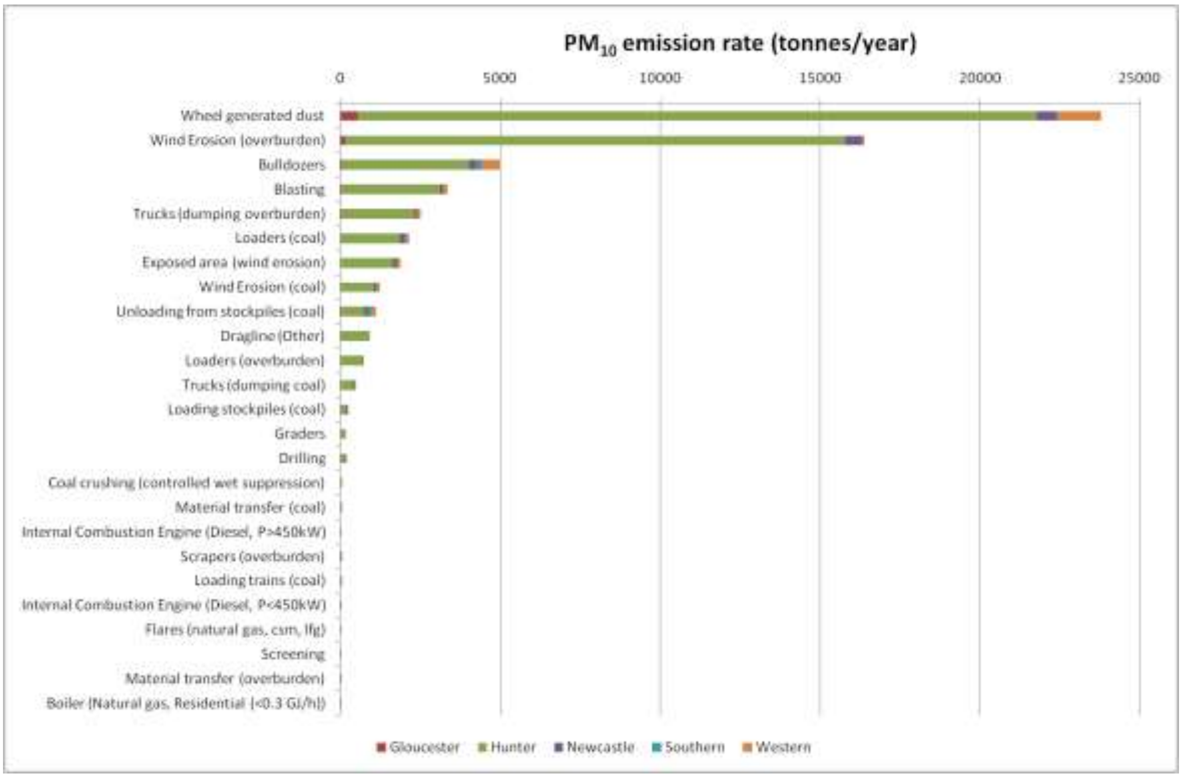

Figure 42 PM_{10} emission rate by coalfield

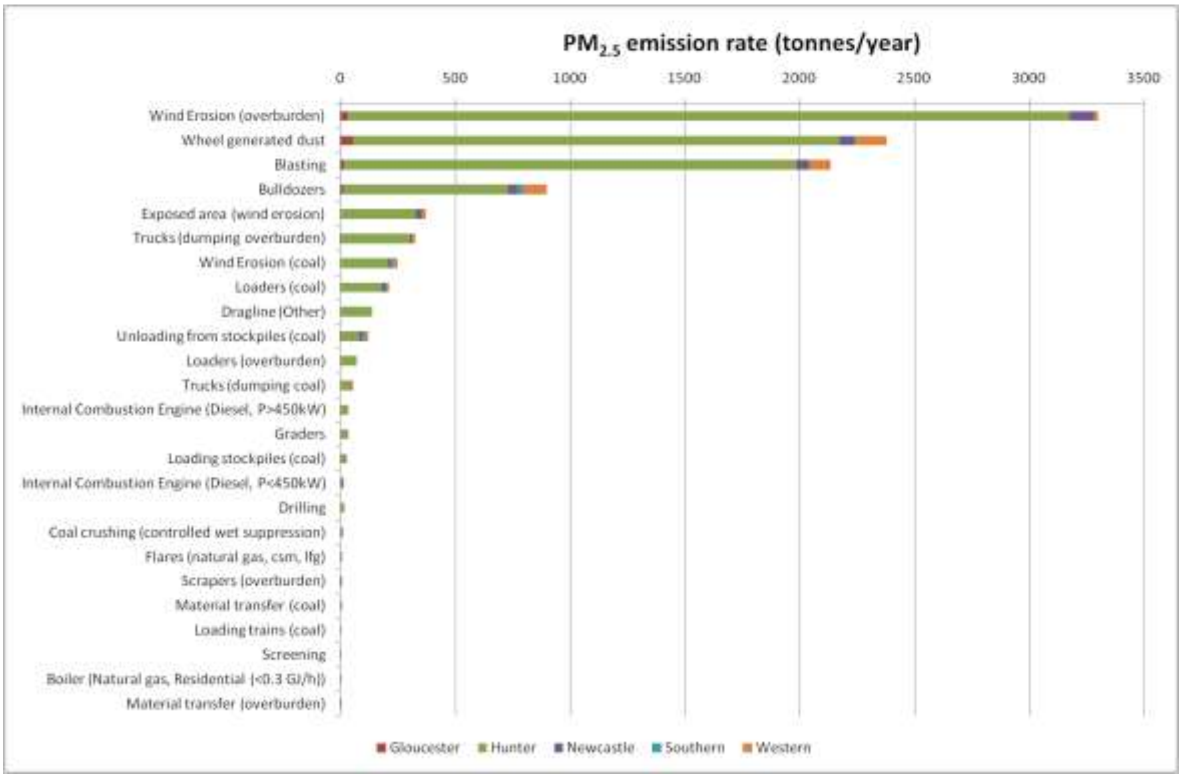

Figure 43 $PM_{2.5}$ emission rate by coalfield

8. Legislative Frameworks for Coal Mining

This section summarises the results of research into the regulatory frameworks for the management of particulate matter emissions from coal mining in major coal producing countries and a comparison against current practice in NSW. Countries that are members of the Organisation for Economic Co-operation and Development (OECD) were the focus of this research, but consideration was also given to the frameworks adopted in non-member countries that are major coal producers. The concept of best practice is considered and the procedures used to plan, develop and regulate coal mining activities are discussed.

8.1 Selection criteria for literature review

The review of legislative frameworks for the management of air quality in coal mining regions was undertaken using a number of selection criteria. The NSW legislative framework was compared to other Australian states in addition to international jurisdictions by considering the:

- Level of economic development in the country including membership of the Organisation for Economic Co-operation and Development (OECD)
- Quantity of coal produced by the country or region and rank in world coal production
- Approaches taken in different geographical regions of the world
- Level of environmental management and regulation in the country or region including extent of legislative framework
- Historical development of environmental management and regulation in the country or region
- Availability and transparency of legislative framework documentation (rated primarily on accessibility of information provided on government websites)

The criteria have been developed into a selection matrix as presented in Table 40.

Table 40 Selection matrix for the review of legislative frameworks in air quality management for coal mining countries and regions

Region	Country or region	Coal production 2009 [MTPA] (rank)	OECD member	Extent of environmental framework	Accessibility to legislation	Included in review process
Asia	China	3050.0 (1)	No	Moderate to high	Inconsistent due to language barrier	Yes
North America	United States	973.2 (2)	Yes	Very high Federal and State	Very good Federal and State	Yes
	Wyoming/ Powder River Basin					Yes
	West Virginia/ Appalachia					Yes
	Arizona/ Western region					Yes
Asia	India	557.6 (3)	No	Not determined	Not determined	No
Oceania	Australia	409.2 (4)	Yes	High Federal and State	Good Federal and State	Yes
	Queensland					Yes
	Victoria					Yes
Europe	Russia	298.1 (5)	No	Moderate	Inconsistent due to language barrier	No
Asia	Indonesia	252.5 (6)	No	Moderate	Poor to moderate	No
Africa	South Africa	250.0 (7)	No	Moderate to high	Good	Yes
Europe	Germany	183.7 (8)	Yes	High	Good	Yes
Europe	Poland	135.1 (9)	Yes	Not determined	Not determined	No
Europe	Kazakhstan	101.5 (10)	No	Not determined	Not determined	No
Europe	Turkey	84.3 (11)	Yes	Not determined	Not determined	No
Europe	Ukraine	73.7 (12)	No	Not determined	Not determined	No
South America	Columbia	72.1 (13)	No	Not determined	Not determined	No
North America	Canada	62.9 (14)	Yes	High Federal and Provincial/Territorial	Good Federal and Provincial/Territorial	Yes
	Ontario					Yes
	Quebec					Yes
	British Columbia					Yes
	Alberta					Yes
Europe	Greece	62.7 (15)	Yes	Not determined	Not determined	No
Europe	Czech Republic	53.3 (16)	Yes	Not determined	Not determined	No
Asia	Vietnam	45.0 (17)	No	Not determined	Not determined	No
Europe	United Kingdom	17.9 (21)	Yes	Not determined	Not determined	Yes
Europe	Spain	10.2 (23)	Yes	Not determined	Not determined	No
South America	Brazil	5.1 (25)	No	Not determined	Not determined	No

Region	Country or region	Coal production 2009 [MTPA] (rank)	OECD member	Extent of environmental framework	Accessibility to legislation	Included in review process
South America	Venezuela	5.0 (26)	No	Not determined	Not determined	No
Oceania	New Zealand	4.6 (27)	Yes	High	Good	Yes
Asia	South Korea	2.5 (29)	Yes	Not determined	Not determined	No
Asia	Japan	1.3 (31)	Yes	Not determined	Not determined	No

8.2 Definitions of best practice

The concept of best practice attempts to incorporate various technical, logistical, economic, environmental and managerial considerations of the methods of production into a balanced and optimal outcome for all stakeholders. The degree of emphasis placed on each of these elements, depends on the risk posed by an activity or pollutant. The emission of highly toxic air pollutants that bio-accumulate and/or are carcinogenic (such as dioxins and furans) are commonly required to be minimised to the maximum extent achievable with a strong emphasis on avoidance, technology, diligent management and environmental considerations, but to a lesser extent on economic considerations. For air pollutants that are considered to have a lower risk and reversible effects, there may be greater acceptance of some minor degradation of air quality provided that an ongoing minimisation is achieved and operation occurs within the environmental legislation.

In the NSW air quality regulatory framework, concepts of best practice are used, but the term “best practice” does not explicitly appear in the legislation. For pollutants such as particulate matter with no safe level of exposure, best practice is the guiding principle in meeting an objective of the *Protection of the Environment Operations Act 1997 (*POEO Act)[22], which is to reduce the risks to human health by reducing emissions to harmless levels (Chapter 1, Section 3). Best practice is also the guiding principle in meeting the general air pollution provisions of the POEO Act. Sections 124 to 126 of the POEO Act require that air pollution related activities be conducted in a proper and efficient manner, while section 128 requires that all necessary practicable means are used to prevent or minimise air pollution.

Section 128 of the POEO Act makes it an offence to emit air pollutants from a point that exceeds a limit prescribed in a regulation defined under the POEO Act. One air quality regulation exists under the act, the *Protection of the Environment Operations (Clean Air) Regulation 2002*[44] (Clean Air Regulation). While the Clean Air Regulation prescribes a minimum level of performance, it can be made tighter through Environment Protection Licence (EPL) conditions. The Clean Air Regulation is an example of the application of best practice, because it applies a minimum standard of performance that has been developed for the NSW context with reference to international regulation and literature, is updated periodically and is applied regardless of the local circumstances that might otherwise permit a lower level of emission control (e.g. remoteness from sensitive land-use).

Compliance with the Clean Air Regulation is sufficient in the majority of circumstances to ensure that there is a low risk of impact on air quality and that air quality standards are met by a reasonable margin. Tighter limits than the regulation are usually only required where there is a regional cumulative air quality problem such as photochemical smog or particle pollution.

For sources of air pollutants not covered by a regulation, Section 128 of the POEO Act also states:

> *“...the occupier of any premises must carry on any activity, or operate any plant, in or on the premises by such practicable means as may be necessary to prevent or minimise air pollution.”*

This section may also be considered to require best practice that is equivalent to that applied to point sources in NSW through the Clean Air Regulation. Most EPL conditions for coal mines restate this requirement (Section 4).

The concept of minimising emissions to the maximum extent achievable is referred to in the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW*[45] (Approved Methods for Modelling), in reference to toxic air pollutants, which states:

> *"Principal toxic air pollutants must be minimised to the maximum extent achievable through the application of best-practice process design and/or emission controls. Decisions with respect to achievability will have regard to technical, logistical and financial considerations. Technical and logistical considerations include a wide range of issues that will influence the feasibility of an option: for example, whether a particular technology is compatible with an enterprise's production processes. Financial considerations relate to the financial viability, of an option. It is not expected that reductions in emissions should be pursued 'at any cost'. Nor does it mean that the preferred option will always be the lowest cost option. However it is important that the preferred option is cost-effective. The costs need to be affordable in the context of the relevant industry sector within which the enterprise operates. This will need to be considered on a case-by-case basis through discussions with the EPA"*

No guidelines exist in NSW that might allow Section 128 of the POEO Act to be interpreted consistently across coal mining activities. Conditions of approval for coal mining activities that are issued by the Department of Planning do not require mining operations to demonstrate the implementation of best practice controls. Rather, the standard conditions in relation to air quality require that the activity does not cause additional exceedances of air quality standards. Although, in relation to blasting activities most new approvals contain the following condition (emphasis added):

> *9. During mining operations on site, the Proponent shall implement <u>best blasting practice</u> to:*
> *(a) protect the safety of people, property, public infrastructure, and livestock; and*
> *(b) <u>minimise the dust and fume emissions</u> from blasting at the project, to the satisfaction of the Director-General.*

In Victoria, the *State Environment Protection Policy (Air Quality Management)* (SEPP(AQM))[46] provides a framework for the management of emissions from industry to the air environment while ensuring that air quality objectives are met. The SEPP(AQM) introduces the concept of best practice and Maximum Extent Achievable (MEA) for the mining industry through the *Protocol for Environmental Management - Mining and Extractive Industries* (PEM)[47]. The PEM defines best practice as:

> *"the best combination of eco-efficient techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity"*

MEA is defined in the SEPP(AQM)[46] as:

> *"a degree of reduction in the emission of wastes from a particular source that uses the most effective, practicable means to minimise the risk to human health from those emissions and is at least equivalent to or greater than that which can be achieved through application of best practice"*

The European Parliament, according to *Directive 2008/1/EC*[48], has adopted the concept of best available techniques (BAT) in the Integrated Pollution Prevention and Control BAT Reference Documents[49]. The documents provide a guideline for the control and management of emissions from a range of industrial activities. Relevant to this study is

Management of Tailings and Waste-Rock in Mining Activities[49] (referred to as the Tailings BREF).

A definition of best available techniques is provided in Article 2 of the Directive[48], and states:

> *"best available techniques" means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:*
>
> *(a) "techniques" shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned*
>
> *(b) "available techniques" means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator*
>
> *(c) "best" means most effective in achieving a high general level of protection of the environment as a whole*

The concept of best available control technology (BACT) is incorporated into the United States federal regulatory framework and promulgated in the *Clean Air Act 1990*[50] under the regulation: *40 CFR Part 60 Standards of Performance for New Stationary Sources*[51]. In accordance with the Act, the United States Environmental Protection Agency (US EPA) determines the emission limit, and appropriate air pollution control technology to achieve that limit, on a case by case basis. The BACT is selected based on factors such as energy consumption, source emissions, air quality impact and economic costs of implementation and operation.

The BACT standard is significantly more stringent than the Reasonably Available Control Technology (RACT) standard but less stringent than the Lowest Achievable Emission Rate (LAER) standard. The LAER standard is applied to the assessment of new sources planned for development in non-attainment areas to determine whether they are acceptable under State Implementation Plan (SIP) guidelines.

8.3 Air quality management, regulation and administration of coal mining

Government administration of coal mining operations varies across the major coal producing countries. Mining legislation is promulgated and administered at either federal or state/provincial government levels, or a combination of both, while in some jurisdictions local government in mining areas have developed their own legislation and management framework. Legislation that regulates mining activities may also be promulgated by different government departments that administer mining, natural resource management, the environment, industrial relations and public health and safety. These departments may be at the federal or state government levels and result in apparent legislative overlap.

8.3.1 Australia

In Australia, air quality management is administered at the federal and state/provincial government levels. In Australia, the National Environment Protection Council (NEPC) has set air quality standards for six criteria pollutants including particulate matter, promulgated under the *National Environment (Ambient Air Quality) Measure* (Ambient Air Quality NEPM)[18]. The state environmental regulatory bodies are responsible for setting ambient air quality objectives and assessment criteria to manage air quality issues associated with emissions from industry and other major sources.

8.3.2 New South Wales

In NSW, environmental protection from the effects of coal mining is primarily administered under the *Protection of the Environment (Operations) Act 1997*[22] (POEO Act). The POEO Act provides a framework for the:

- Development of Protection of the Environment Policies
- Licensing by OEH of activities that are defined under Schedule 1 of the POEO Act
- Development of regulations and guidelines that promulgate impact assessment criteria and emission standards for industry
- Definition of offences and penalties in relation to air pollution under Sections 124-129
- Provision of a mechanism for public participation in the environmental assessment of activities that may be licensed by OEH, in conjunction with the *Environmental Planning and Assessment Act 1979*[52] (EP&A Act)

Air quality assessment criteria are promulgated by OEH in the Approved Methods for Modelling[45], which lists the statutory methods and air quality criteria that are to be used to model and assess emissions and impacts of air pollutants from stationary sources in New South Wales. The Approved Methods for Modelling provide air quality assessment criteria for TSP, PM_{10} and dust deposition rates.

8.3.3 Queensland

Queensland's primary legislation for environmental regulation is the *Environmental Protection Act 1994*[53] (Qld EP Act). The object of the Qld EP Act is to protect Queensland's environment while allowing for development that improves the total quality of life both now and in the future, in a way that maintains the ecological processes on which life depends. In particular, the Qld EP Act:

- Gives the Environment Minister the power to create Environmental Protection Policies such as the *Environment Protection (Air) Policy 2008*[54](Air EPP)
- Defines the framework for licensing Environmentally Relevant Activities (ERA). ERAs are defined in Schedule 1 of the *Environmental Protection Regulation 1998*[55]
- Defines environmental harm, the offences of causing environmental harm and penalties
- In conjunction with the *Sustainable Planning Act 2009*[56], defines the framework for the approval of new ERAs
- Defines best practice environmental management
- Defines the general environmental duty

The Air EPP specifies air quality indicators and objectives for the air environment of Queensland. In addition to reporting in accordance with the requirements of the Ambient Air

Quality NEPM[18], the Queensland Government has adopted the Ambient Air Quality NEPM standards for the six criteria air pollutants (including PM_{10}) and the advisory reporting standards for $PM_{2.5}$ as objectives in the Air EPP.

8.3.4 Victoria

The administrative and legislative framework governing mining and extractive industries in Victoria differs from that in NSW and Queensland, with the Earth Resources Regulation Branch of the Department of Primary Industries responsible for environmental regulation under the *Extractive Industries Development Act 1995*[47]*, Mineral Resources Development Act 1990*[57] *and the Environment Effects Act 1978*[58]*.* Appropriate authorisation from the Department of Primary Industries is required in the form of a licence, work authority or work plan approval, before the following are conducted:

- Mineral exploration
- Mining
- Extractive Industry

Work Plans submitted as part of the approval process for exploration and mining tenements must address environmental issues including particulate matter and air quality. Other activities associated with coal mining are regulated under the *Environment Protection Act 1970*[59] (Vic EP Act) and using licences that are issued by the Environment Protection Authority (EPA).

The Vic EP Act gives the Governor in Council, on the recommendation of the EPA, the power to issue State Environment Protection Policies. The SEPP(AQM)[46] establishes a framework for:

- Defining the principles, approaches and measures for managing air quality at local, regional and State levels
- Managing emissions
- Defines three classes of air quality indicators
    - *Class 1 indicators: common or widely distributed air pollutants which are established as environmental indicators in the State environment protection policy (Ambient Air Quality) and may threaten the beneficial uses of both local and regional air environments*
    - *Class 2 indicators: hazardous substances that may threaten the beneficial uses of the air environment by virtue of their toxicity, bio-accumulation or odorous characteristics*
    - *Class 3 indicators: extremely hazardous substances that are carcinogenic, mutagenic, teratogenic, highly toxic or highly persistent, and which may threaten the beneficial uses of the air environment*
    - Unclassified indicators are indicators of local amenity and aesthetic enjoyment and include odour and total suspended particulates. Mining activities may affect one or more indicators in each class and may also affect amenity
- Developing a program for action to protect the air environment of Victoria and achieve the regional air quality objectives contained in the SEPP(AQM)
- Addressing global environmental issues

Government agencies are required to apply the policy when making decisions, formulating strategies and implementing programs. The SEPP(AQM) defines the responsibilities of all Victorians, and seeks environmental improvement through regulatory measures, economic incentives and co-operative arrangements. The SEPP(AQM) requires that best practice management and controls are implemented in all circumstances. Where Class 3 indicators are likely to be emitted, emissions must be controlled to the maximum extent achievable.

The SEPP(AQM) states that the Authority will employ statutory and non-statutory instruments and measures to implement the SEPP(AQM). This includes protocols for environmental management. The *Protocol for Environmental Management: Mining and Extractive Industries*[47] (PEM) is an incorporated document of the SEPP(AQM). The PEM supports the interpretation of the SEPP(AQM) and sets out the statutory requirements for the management of emissions from mining and extractive industries. All mining and extractive industries are required to comply with the SEPP(AQM). Proposals requiring an Environment Effects Statement or an EPA Works Approval and Licence are required to make an assessment in accordance with the PEM. The Department of Primary Industries may specifically request an assessment in accordance with the PEM.

The PEM specifies the requirements for conducting an air quality study to assess the potential impacts of mining and extractive industries, including:

- Assessment criteria
- Level of assessment – depending on the scale or size of the operation and the location of the site
- Monitoring requirements for impact assessment
- Modelling methodology

8.3.5 United States

In contrast to the combination of both federal and state government frameworks used in Australia, the United States has a more top down approach to environmental and industrial legislation and administration. Industrial and environmental regulation is incorporated into United States Code of Federal Regulation that is administered by Congress. The state governments are then mandated to enact and administer the federal code.

Coal mining is administered by the Office of Surface Mining Reclamation and Enforcement (OSM) within the federal government Department of the Interior. OSM's role is to enforce mining laws, 'balance the need to protect the environment from the adverse effects of surface coal mining with the Nation's need for coal as an essential energy source' and ensure that 'coal mining operations are conducted in an environmentally responsible manner and that the land is adequately reclaimed during and following the mining process'. These objectives are administered by OSM under the *Surface Mining Control and Reclamation Act 1977*[60] (SMCRA).

OSM developed a nationwide program incorporating state governments and Indian Tribes to achieve its goals of assuring the protection of citizens and the environment from the adverse effects of coal mining and to restore the land to beneficial use when the mining operations ceased. OSM and its partners are also responsible for reclaiming and restoring lands and water degraded by mining operations prior to 1977. The primary responsibility for regulating surface coal mining activities now resides with the state jurisdiction within which the coal mining activity is taking place. OSM now performs an oversight role.

In conjunction with the SMCRA, the affects of coal mining on the air environment are administered by the US EPA under the *Clean Air Act 1990*[50] (CAA). The CAA framework provides regulation for the following governance pursuant to the coal mining industry:

- Title I - Air Pollution Prevention and Control
    - Part A –

        - National Ambient Air Quality Standards
        - Standards of Performance for New Stationary Sources
        - Air quality control regions
        - State implementation plans for national primary and secondary ambient air quality standards
        - Federal enforcement
        - Non-compliance penalty
        - Emission factors
    - Part C
        - Prevention of Significant Deterioration of Air Quality (Subpart 1 Clean Air, Subpart 2 Visibility Protection)
    - Part D
        - Plan Requirements for Nonattainment Areas
- Title II - Emission Standards for Moving Sources
    - Part A
        - Motor Vehicle Emission and Fuel Standards
- Title V - Permits

The CAA requires the US EPA to set the *National Ambient Air Quality Standards* (NAAQS)[61], referred to as 40 CFR Part 50, for pollutants considered harmful to public health and the environment, that is, the criteria pollutants including PM_{10} and $PM_{2.5}$. The states are then obliged to set air quality standards for regional air quality management and application in the development approval process at a level equivalent to, or more stringent, than the NAAQS.

In accordance with the CAA, the EPA is required to classify regions across the United States under the Prevention of Significant Deterioration (PSD) regulations into areas that have or have not attained the NAAQS for all pollutants. Areas that do not meet the air quality standards for one of the NAAQS criteria pollutants may be designated as non-attainment, with an area that fails to meet the NAAQS required to produce a State Implementation Plan (SIP). The SIP is an enforceable plan developed and administered at the state and local government level that details how the area will attain compliance with the NAAQS according to the CAA (Maricopa County, 2010)[62].

The CAA also provides for *Standards of Performance for New Stationary Sources*[63] regulations including the *Standards of Performance for Coal Preparation Plants* promulgated under *40 CFR Part 60 Subpart Y*[51]. The regulations ensure that BACT standards are implemented into the design, construction and operation of the facility or source being developed. The standards of performance comprise emission limits and the measurement and monitoring requirements to assess compliance. The standards of performance are then included in the permit for the source in accordance with the requirements of the CAA.

The two primary coal producing states in the United States are Wyoming (Powder River Basin) and West Virginia (Appalachia Region). In Wyoming, the Wyoming Department of Environmental Quality (WDEQ) promulgated the *Wyoming Air Quality Standards and Regulations*[64] (WAQS&R) that provide the legislative framework for regulating air quality management issues such as those associated with the coal mining industry. In West Virginia, coal mining and the related air quality affects are administered by the Department of Environmental Protection (WVDEP), Division of Mining and Reclamation under the *West Virginia Coal Surface Reclamation Mining Rule*[65] *(38 CSR 2)* and the Division of Air Quality under the *West Virginia Air Pollution Control Act*[66]. In general, the Wyoming and West Virginia legislature have adopted the requirements of the federal CAA. The WDEQ and WVDEP manage the attainment of air quality standards and SIPs in the coal mining regions and the approval and permitting of coal mines and emission sources.

8.3.6 Canada

In Canada, mining is administered at both the federal and provincial/territorial government level. The federal government has the authority over uranium mining, mining activities in two of the three territories and offshore, mining of federal lands, and fiscal responsibilities to stimulate investment, encourage production and enhance competitiveness and trade. Some of the federal responsibilities related to fisheries, protected areas and the environment also apply to mining projects. The provincial governments are responsible for managing resources, making land-use decisions, issuing licences and permits, conducting monitoring of activities, collecting mining royalties and provincial taxes and health and safety (United Nations, 2010)[67].

At the federal government level, no single mining law exists, with federal legislation of mining pursuant to the *Canadian Environmental Protection Act 1999*[68] (CEPA), *Canadian Environmental Assessment Act*[69] (CEAA), *Fisheries Act*[70], *Navigable Waters Act*[71] and *Migratory Birds Act*[72]. Federal regulations relevant to the management of environmental effects associated with mining are largely focussed on mine effluent and its impacts on natural waterways and aquatic ecosystems, i.e. fisheries. Health and safety of mining industry workers is regulated under the *Canadian Labour Code Part II*[73], including the duties of employers, employees and the establishment of the Coal Mining Safety Commission. The CEPA is the primary element of the legislative framework for protecting the Canadian environment and human health and allows the federal government to regulate and control substances through national quality objectives, guidelines and/or standards. In regard to mining developments, proposed projects are carefully assessed in accordance with the framework promulgated in the CEAA to ensure compliance with environmental and human health standards before permit approval is granted.

The Canadian federal government sets "...the *National Ambient Air Quality Objectives* on the basis of recommendations from the Federal-Provincial Working Group on Air Quality Objectives and Guidelines consisting of representatives from both Canadian health and environment departments. Objectives may be promulgated by Environment Canada and/or Health Canada under the CEPA, Part 1, Section 8, and adopted by provincial and territorial jurisdictions for enforcement as standards" (CNAAQO, 1999[68]). The CEPA provides objectives for the protection of three levels of environmental values which encompass the environment and human health. The three levels of objectives are referred to as: Desirable, Acceptable and Tolerable. The CEPA includes Desirable, Acceptable and Tolerable objectives for TSP, while a single Reference Level is set for $PM_{2.5}$.

Canadian provincial and territorial governments are responsible for many aspects of air pollution control and regulation. However, air quality management regulation is integrated under the CEPA.

In Ontario, coal mining activities are administered by the Mines and Minerals Division of the Ministry of Northern Development, Mines and Forestry, in accordance with various provincial laws including the *Mining Act 1990*[74]. Environmental protection regulation and the *Ambient Air Quality Criteria*[75] in the province have been developed by the Ontario Ministry of Environment (MOE) in accordance with the Ontario *Environmental Protection Act 1990*[76]. Regulations and assessments made in accordance with the *Environmental Protection Act* are administered by the MOE.

In Quebec, legislation providing for ambient air standards is administered by the Ministère du Développment durable, de l'Environnement et des Parcs and promulgated under the *Environmental Quality Act*[77] (EQA). The Ministry has also promulgated general emission standards for particulate matter under the EQA. These emission standards for particulate matter are relevant to industrial development but not specifically designed for the coal mining industry. In British Columbia, coal mining and its related environment effects are administered by the Ministry of Energy, Mines and Petroleum Resources and the Ministry of Environment under provincial legislation including the *Mines Act (including Health, Safety & Reclamation Code & Mineral Exploration Code)*[78], *Environmental Assessment Act*[79], *Environment and Land Use Act*[80], *Environment Management Act*[81]and *Health Act*[82]. In Alberta, coal mining activities are administered by the Ministry of Energy under the *Mines and Minerals Act 2000*[83] (MMA) and the *Mines and Minerals Administration Regulation*[84]. Administration of portions of the MMA is shared with the Sustainable Resource Development Department[85]. Environmental legislation relevant to the mining industry includes *Environmental Protection and Enhancement Act*[86], *Environmental Assessment (Mandatory and Exempted Activities) Regulation*[87] and *Environmental Assessment Regulation*[87].

8.3.7 European Union

In Europe, the characteristics of air pollution dispersion and the spatial distribution of the countries and their populations result in the sharing of air quality impacts between neighbours. Consequently, the European Commission has worked to unify the ambient air quality standards and objectives of its member states. The Parliament of the European Union (EU), under *Directive 96/62/EC 1996*[88], outlined a framework for the assessment and management of ambient air quality throughout the member states. The Directive describes the following:

Articles -

1. Objectives
2. Definitions
3. Implementation and responsibilities
4. Setting of limit values and alert thresholds for ambient air
5. Preliminary assessment of ambient air quality
6. Assessment of ambient air quality
7. Improvement of ambient air quality
8. Measures applicable in zones where levels are higher than the limit value
9. Requirements in zones where the levels are lower than the limit value
10. Measures applicable in the event of the alert thresholds being exceeded

Annex

1. List of atmospheric pollutants to be taken into consideration in the assessment and management of ambient air quality
2. Factors to be taken into consideration when setting limit values and alert thresholds
3. Guidelines for selecting air pollutants for consideration
4. Information to be included in the local, regional or national programmes for the improvement in the ambient air quality

In 2008, a new Directive 2008/50/EC[89] on ambient air quality and cleaner air for Europe was promulgated. Directive 2008/50/EC includes the following key elements:

- *The merging of most of the existing legislation into a single directive (except for the fourth daughter directive) with no change to existing air quality objectives.*
- *New air quality objectives for $PM_{2.5}$ (fine particles) including the limit value and exposure related objectives – exposure concentration obligation and exposure reduction target.*
- *The possibility to discount natural sources of pollution when assessing compliance against limit values.*

- *The possibility for time extensions of three years (PM_{10}) for complying with limit values, based on conditions and the assessment by the European Commission.*

The EU Member States were given two years to transpose the new Directive into national legislation, with the existing legislation in force in the interim period. Some provisions of the new Directive such as $PM_{2.5}$ monitoring requirements were to be implemented sooner.

Other legislation relevant to particulate matter:

1. Council Directive 96/62/EC[88] on ambient air quality assessment and management is commonly referred to as the Air Quality Framework Directive. It describes the basic principles as to how air quality should be assessed and managed in the Member States. It lists the pollutants for which air quality standards and objectives will be developed and specified in legislation.
2. Council Directive 1999/30/EC[88] relating to limit values for particulate matter in ambient air. The directive is the so-called "First Daughter Directive". The directive describes the numerical limits and thresholds required to assess and manage air quality impacts for particulate matter. It addresses both PM_{10} and $PM_{2.5}$ but only establishes monitoring requirements for fine particles.
3. Council Decision 97/101/EC[88] establishing a reciprocal exchange of information (EoI) and data from networks and individual stations measuring ambient air pollution within the Member States. This "EoI Decision" describes the procedures for the dissemination of air quality monitoring information by the Member States to the Commission and to the public.
4. Commission Decision 2004/461/EC[90] laying down a questionnaire for annual reporting on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC and under Directives 2000/69/EC[88] and 2002/3/EC[88] of the European Parliament and of the Council. This decision specifies the format and content of Member States' Annual Report on ambient air quality in their territories.

8.3.8 Germany

In Germany, the federal government has developed a comprehensive legislative framework in the area of mining law, 'implementing integrated risk prevention through an inter-media approach with strict requirements on concessions, health and safety, environment and other issues as well as differentiated mechanisms for compliance and monitoring'. Mining legislation comprises a series of laws and ordinances, providing for a uniform law supervised by one single administration. This legislation includes *Federal Mining Act 1980*[91] (FMA), *Federal General Mining Ordinance 1995*[92], *Health and Safety Mining Ordinance 1991*[92] and *Ordinance on the Environmental Impact Assessment of Mining Projects 1990*[93].

The German system has also been strengthened during the past thirty years through the transfer of new European legislation on concessions, environment and health and safety in the extractive industries into the German legislation. These include the transposition of the European Union's Environmental Impact Assessment Directive 85/337/EEC[94] and Mining Waste Directive 2006/21/EC[95] for the mining sector within the procedures of mining law, rather than in general environmental law through an amendment of the FMA and an additional ordinance[92].

The monitoring of compliance with the provisions of mining law is administered by the mining authority. The authority can order the implementation of the measures required to comply with mining laws and ordinances and for the mitigation of associated risks.

The framework for ambient air quality assessment and management is promulgated under the *Federal Immission Control Act (Technical Instructions on Air Quality Control) 1990*[96] (TA Luft). Ambient air quality standards are promulgated for PM_{10} concentrations and dust deposition.

8.3.9 New Zealand

In New Zealand, the allocation of rights to prospect, explore or mine minerals or coal that is owned by the Crown is administered by Crown Minerals, a Department of the Ministry of Economic Development[97], under the *Crown Minerals Act 1991*[98]. Crown Minerals issue permits to proponents seeking to prospect, explore or mine minerals or coal.

Environmental issues relating to mining are administered under the *Resource Management Act 1991*[99], with local government authorities managing resource consents required under the Act. This process is separate from obtaining a permit for mineral rights under the Crown Minerals Act. The purpose of the Resource Management Act is to promote sustainable management of natural and physical resources, including use and development. Notwithstanding the issuance of a permit under the Crown Minerals Act or consent under the Resource Management Act, neither provides the right of access to the land in which the exploitable resource is situated. Land access is determined by direct negotiation with the land owner.

Prior to commencing ay work on the ground, an applicant must ascertain and obtain what is required in terms of:

- *A minerals permit from Crown Minerals under the Crown Minerals Act*
- *An access arrangement from the land owner and occupier*
- *Resource Consent(s) from either the District Council or the Regional Council under the Resource Management Act 1991*

The Crown Minerals Act requires the Minister of Energy to prepare minerals programs that outline the policies and regulations for the allocation of permits and collection of Crown royalties. The Crown Minerals (Minerals and Coal) Regulations 2007[100] set out the requirements and procedures for explorers and miners to:

- *apply for a permit under the Crown Minerals Act 1991*
- *make permit change applications*
- *make royalty returns and payments*
- *report to the Crown on prospecting and exploration*
- *lodge cores and samples with the Crown*

The Crown Minerals (Minerals fees) Regulations 2006[101] outline fees payable for the matters specified under the Crown Minerals Act for minerals and coal.

8.4 Approvals process for coal mining

The approvals process for major industrial projects such as the development of coal mining operations is broadly similar across the economically developed world. Most jurisdictions have promulgated legislation for the planning and development of major projects, with regulation in place to outline the administrative requirements for project approval and provide guidance through the process of environmental impact assessment. The administration of coal mine planning, development and assessment legislation is carried out at the federal and/or state government level, by government departments responsible for the environment or mining and resource development and in accordance with environmental and/or mining laws. Notwithstanding this, the legislative framework for coal mine development approval is broadly similar and comprises:

- Provision of an exploration licence
- Declaration of discovery of a new resource, application for development and initial project design
- Terms of reference for the assessment of environmental impacts, provided by the regulator
- Assessment of potential environmental impacts associated with the development including preparation of an environmental impact statement in consultation with stakeholders
- Review of the environmental impact statement by the administrative bodies responsible for the relevant laws pursuant to coal mining in the jurisdiction and other stakeholders such as the public
- Response by the proponent to issues raised during the review process
- Provision of unconditional or conditional planning consent by the regulator
- Provision for the negotiation of conditions before licensing
- Compliance with the conditions of consent
- Project approval or refusal
- Application for a licence to carry out the project in accordance with the conditions of approval
- Provision of a licence to carry out the mining activity in accordance with the conditions of approval and relevant environmental protection and mining regulations
- Project commencement

8.4.1 New South Wales

In NSW, the Department of Planning administers the *Environmental Planning and Assessment Act 1979*[52] (EP&A Act). Applications for the development of new coal mining activities are assessed under Part 3A of the EP&A Act[52]. Part 3A relates to the designation and assessment of developments that are designated as Major Projects.

The Major Project designation triggers the need to prepare an Environmental Assessment (EA) for approval by the Minister for Planning. At any stage of the process the Minister for Planning may request the Planning Assessment Commission (PAC) to review or advise on any aspect of a major project or a concept plan. The approvals process consists of the following major steps:

1. Development declared a Major Project.
2. Initial project application is made. Applicant may submit a preliminary Environmental Assessment with the application.
3. The Director-General of the Department of Planning prepares Environmental Assessment requirements in consultation with relevant public authorities such as OEH. The requirements outline the key issues that a proponent must address in its Environmental Assessment of the project.
4. An Environmental Assessment is prepared, preferably in consultation with relevant community, councils and State agencies.
5. Public exhibition, consultation and review. The Environmental Assessment is exhibited for a minimum of 30 days by the Department of Planning.
6. Consideration of submissions and finalisation of assessment. The Department of Planning provides copies of public submissions or a summary of public submissions received through the exhibition period to the proponent and the proponent may be required to prepare a response to the issues raised.
7. The Director-General of the Department of Planning provides an Environmental Assessment report to the Minister for Planning that includes, amongst other things, any advice provided by public authorities on the project and, if recommending approval, draft conditions of approval.
8. The Minister of Planning may approve or refuse the carrying out of the project and determines the conditions that apply to the carrying out of the project considering the Director-General's findings.
9. Compliance with the conditions of approval is the responsibility of the proponent. The Department of Planning monitors compliance and enforces the conditions of approval. The Department of Planning conducts inspections and compliance audits of approved projects. Non-compliance could attract enforcement actions such as rectification works, fines or the commencement of legal proceedings in the Land and Environment Court.

A particular development or development type may be declared a Major Project to be assessed under Part 3A of the EP&A Act. Major projects are identified either in:

- *State Environmental Planning Policy (Major Development) 2005*[102] (Major Development SEPP).
- An order by the Minister for Planning published in the NSW Government Gazette.

Schedule 1 of the Major Development SEPP describes the types (also known as classes) of development that may be declared a Part 3A project, and include developments in the "mining, petroleum production, quarries and associated processing industries" classification. Under Clause 5 of the Major Development SEPP, the development of a coal mine is designated as a Major Project. The Minister for Planning is therefore the approval authority for coal mine developments. The Major Development SEPP states:

Group 2 Mining, petroleum production, extractive industries and related industries

5 Mining

(1) Development for the purpose of mining that:
- *(a) is coal or mineral sands mining, or*
- *(b) is in an environmentally sensitive area of State significance, or*
- *(c) has a capital investment value of more than $30 million or employs 100 or more people.*

(2) *Extracting a bulk sample as part of resource appraisal or a trial mine comprising the extraction of more than 20,000 tonnes of coal or of any mineral ore.*
(3) *Development for the purpose of mining related works (including primary processing plants or facilities for storage, loading or transporting any mineral, ore or waste material) that:*
    (a) *is ancillary to or an extension of another Part 3A project, or*
    (b) *has a capital investment value of more than $30 million or employs 100 or more people.*

Development consent conditions that are applied to mining activities by the Department of Planning to control the emission of particulate matter are summarised below. There are two Schedules of conditions:

- Administrative Conditions
- Specific Environmental Conditions

Administrative conditions include:

- On approval such as:
  (a) Timeframe of operation;
  (b) Total tonnage of coal extracted; and
  (c) Seam base, below which coal cannot be extracted.
- Requirement to prepare and implement monitoring programs, management plans and an Environmental Management Strategy as approved in accordance with the conditions of this approval.
- Requirement that plant and equipment used on site are:
  (a) Maintained in a proper and efficient condition; and
  (b) Operated in a proper and efficient manner.

Specific Environmental Conditions that have relevance to the control and management of particulate matter from mining activities include:

- Impact Assessment Criteria as shown in Table 41, Table 42 and Table 43. Except for the air quality-affected land referred to in the development consent, the Proponent shall ensure that dust generated by the projects does not cause additional exceedances of the impact assessment criteria at any residence on privately-owned land or on more than 25 percent of any privately-owned land. For example the approval for the Wilpinjong Coal Project[103].

Table 41 Long term impact assessment criteria for particulate matter used in Department of Planning Project Approvals

Pollutant	Averaging period	Criterion
Total suspended particulate matter (TSP)	Annual	90 µg/m³
Particulate matter < 10 µm (PM_{10})	Annual	30 µg/m³

Table 42 Short term impact assessment criteria for particulate matter used in Department of Planning Project Approvals

Pollutant	Averaging period	Criterion
Particulate matter < 10 µm (PM_{10})	24 hour	50 µg/m³

Table 43 Long term impact assessment criteria for deposited dust used in Department of Planning Project Approvals

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m²/month	4 g/m²/month

- Land Acquisition Criteria as shown in Table 44, Table 45 and Table 46. If the particulate emissions that are generated by the project exceed the land acquisition criteria at any privately-owned land, the Proponent shall, upon receiving a written request for acquisition from the landowner, acquire the land in accordance with additional procedures for air quality and noise management that may be detailed in a schedule of the project approval. For example the approval for the Wilpinjong Coal Project.

Table 44 Long term land acquisition criteria for particulate matter used in Department of Planning Project Approvals

Pollutant	Averaging period	Criterion
Total suspended particulate matter (TSP)	Annual	90 µg/m³
Particulate matter < 10 µm (PM_{10})	Annual	30 µg/m³

Table 45 Short term land acquisition criteria for particulate matter used in Department of Planning Project Approvals

Pollutant	Averaging period	Criterion	Percentile[1]	Basis
Particulate matter < 10 µm (PM_{10})	24-hour	150 µg/m³	99[2]	Total[3]
Particulate matter < 10 µm (PM_{10})	24-hour	50 µg/m³	98.6	Increment[4]

Note
[1] Based on the number of block 24-hour averages in an annual period.
[2] Excludes extraordinary events such as bushfires, prescribed burning, dust storms, sea fog, fire incidents, illegal activities or any other activity agreed by the Director-General in consultation with OEH
[3] Background PM_{10} concentrations due to all other sources plus the incremental increase in PM_{10} concentrations due to the mine alone.
[4] Incremental increase in PM_{10} concentration due to the mine alone.

Table 46 Long term land acquisition criteria for deposited dust used in Department of Planning Project Approvals

Pollutant	Averaging period	Maximum increase in deposited dust level	Maximum total deposited dust level
Deposited dust	Annual	2 g/m²/month	4 g/m²/month

- Additional air quality impact mitigation measures may be required to be implemented for landowners listed in the Approval. Upon receiving a written request, the Proponent must implement feasible and reasonable air quality mitigation measures such as: air conditioning and first flush drinking water collection systems.
- Operating conditions:
  - (a) Visible levels of particulate matter assessed regularly and used as a trigger to relocate, modify or stop mining activities to minimise air quality impacts on privately owned land.
  - (b) Real-time monitoring assessed regularly and used as a trigger to relocate, modify or stop mining activities to ensure compliance with the impact assessment criteria.
  - (c) Take all practicable measures to minimise off-site odour and fume emissions generated by spontaneous combustion or blasting activities.

- Monitoring conditions that require the preparation and implementation of an Air Quality Monitoring Program that includes high volume air samplers, real-time monitoring of particulate matter and meteorological monitoring.

The approvals include *Additional Procedures for Air Quality and Noise Management* that includes the following:

- A requirement to notify each landowner that is listed in the approval for Acquisition Upon Request within 1 month of approval that they have the right to require the Proponent to acquire their land at any stage of the project.
- A requirement to notify the Department of Planning and affected landowners and tenants if monitoring shows exceedance of the impact assessment criteria specified in the approval, if exceedance was not predicted in the EA. A requirement that the Proponent provide quarterly monitoring results to the relevant parties until the results show that the project complies with the impact assessment criteria. The Proponent is also required to send landowners and tenants a copy of the NSW Health fact sheet "Mine Dust and You"[5].
- If a landowner considers that the project is exceeding the impact assessment criteria and this was not identified in the Environmental Assessment, the landowner may make a request in writing to the Department of Planning for an independent review to be conducted. Based on the results of this independent review, the Department of Planning may:
    - Conclude that the impact assessment criteria are not being exceeded and the independent review may be discontinued.
    - Require all feasible and reasonable mitigation measures to be implemented by the Proponent.
    - Secure a written agreement with the landowner.
    - Require the Proponent to acquire all or part of the landowner's land.
    - In the case where a number of mines contribute to exceedances of the impact assessment criteria, then the Proponent and the other contributing mines will acquire the land on an equitable basis.

The approval contains conditions relating to Environmental Management, Monitoring, Auditing and Reporting that includes:

- A requirement to prepare an Environmental Management Strategy that includes:
    - Keeping the community and relevant agencies informed
    - Managing complaints
    - Dispute resolution
    - Responding to non-compliances
    - Managing cumulative impacts
    - Monitoring
    - Integrating incident and reporting processes into a single system
    - Role, responsibility and accountability of personnel
- Expectations with respect to reporting incidents
- A requirement to submit an Annual Environmental Management Report annually to the Department of Planning, the Community Consultative Committee and relevant agencies. That, amongst other things:
    - Identifies standards and performance measures
    - Describes work carried out in the last 12 months
    - Describes work to be carried out over the next 12 months
    - Summarises complaints and monitoring results
    - Identifies and discusses exceedances of approval and licence conditions
    - Describes actions being taken to ensure compliance

- A requirement to commission an Independent Environmental Audit of the project every 3 years to assess the environmental performance of the project and whether the project is complying with the relevant requirements in the approval and relevant mining lease and licence requirements
- A requirement to operate a Community Consultative Committee
- To provide copies of the following documents to relevant agencies, the Community Consultative Committee and to make the documents available on the company's website:
    - Any strategy, plan or program required under the approval
    - Any audits required under the approval
    - The Annual Environmental Management Report (AEMR)
    - Monitoring results required under the approval

8.4.2 Queensland

In Queensland, environmental impact assessment may be conducted under the:

- *Sustainable Planning Act 2009*[56] (SPA)
- *Environmental Protection Act 1994*[53] (Qld EP Act)
- *State Development and Public Works Organisation Act 1971*[104] (SDPWOA)

These legislative frameworks provide for the assessment and approval of a variety of development projects, including:

- Under SPA - routine building or land use change requests and major infrastructure proposals such as power stations, community infrastructure and major transport infrastructure.
- Under Qld EP Act - mining, petroleum and gas activities, with an environmental impact assessment either undertaken voluntarily by the project proponent or at the request of the Queensland Minister responsible for Environment based on environmental impact assessment trigger criteria. These projects are exempt from SPA as outlined in the *Mineral Resources Act 1989*[105] and the *Petroleum and Gas Act 2004*[106].
- Under SDPWOA - a small number of projects that may be considered significant by the Queensland Government and will require an environmental impact statement (EIS) to be prepared under the SDPWOA. These projects are generally highly important or complex projects, which require centralised government coordination of environmental assessment by the Coordinator-General.

Under the Qld EP Act terms of reference are developed that provide the minimum expectations for the scope of the EIS. DERM has published generic terms of reference that are used as the basis to develop the terms of reference. Key elements of the generic terms of reference are[107]:

- Preparation of a description of environmental values (existing air quality, meteorology, sensitive land-uses)
- Quantify potential impacts and mitigation measures

The draft terms of reference are made available for a minimum period of 30 business days so that stakeholders and any member of the public can review the document and comment on what values, impacts and commitments should be considered in the EIS.

When the proponent has produced the EIS, it is made available for a minimum period of 30 business days for stakeholders and the public to review the document, and to submit comments on the quality of the proponent's assessment and commitments.

The key elements of the process under SDPWOA are as follows:

- Initial advice statement – process for declaration of a significant project
- Significant project declaration
- Referral to Commonwealth Government (for determination if a 'controlled action' is required)
- Preparation of terms of reference (public comment is provided at this stage)
- Preparation of an environmental impact statement (EIS)
- Review and assessment of EIS (public comment is provided at this stage)
- Preparation of a supplementary EIS report (if required)
- Preparation of the Coordinator-General's EIS evaluation report

The air quality impact assessment process is guided by the terms of reference. The objectives that are specified in the Air EPP are used to determine whether potential impacts are acceptable or whether more effective controls are required to ameliorate potential impacts. Detailed technical elements of the air quality impact assessment process, such as acceptable dispersion models and characterisation of existing air quality and meteorology are not codified in Queensland.

Notwithstanding the above, in the Gladstone airshed on the Central Coast of Queensland, the Queensland Government has adopted a more detailed approach to airshed planning and management.

In December 1993 approximately 6,800 hectares of land at Aldoga, northwest of Gladstone, was declared a state development area. The declaration followed an extensive review of land in the Gladstone region suitable for future large-scale industrial development. In 2001, the Queensland Government commissioned the development of a modelling tool to assist air quality management and planning in the Gladstone State Development Area (GSDA). The Gladstone Airshed Modelling System (GAMS) utilises the TAPM and Calpuff dispersion models and provides a framework to allow new industrial sources to be assessed for regional air quality impacts using a consistent methodology.

GAMS comprises a three-dimensional meteorological field for the region being assessed and a database of existing emissions and source characteristics for sources and air pollutants of interest. The performance of the meteorological and dispersion modelling of existing sources has been evaluated against monitoring information. New proposals can be readily incorporated into GAMS, which can be run simply and efficiently to provide an indication of the Gladstone airshed's capacity for development.

The Queensland Government, through the Department of Infrastructure and Planning maintains the modelling system with regular updates of the models and emissions inventory.

8.4.3 United States

In the United States, every agency in the executive branch of the federal government has a responsibility to implement the *National Environmental Policy Act 1969*[108] (NEPA). The NEPA was the first major environmental law promulgated in the United States, it established national environmental policies and is the primary legislation that requires federal agencies to undertake assessments of the environmental effects of proposed actions prior to making decisions. The *NEPA* was promulgated as it was recognised that the actions of the federal government could cause significant environmental effects. The Council on Environmental Quality states:

> *"The range of actions that cause significant environmental effects is broad and includes issuing regulations, providing permits for private actions, funding private actions, making federal land management decisions, constructing publicly-owned facilities, and many other types of actions"*

The NEPA provides a process for agencies to assess the environmental and related social and economic effects of their proposed actions. The process also applies to a Federal agency's:

> *"decisions for actions, including financing, assisting, conducting, or approving projects or programs; agency rules, regulations, plans, policies, or procedures; and legislative proposals"*

The primary responsibility for administering NEPA policies is vested in the Council on Environmental Quality[108] (CEQ), established by Congress within NEPA. The CEQ is positioned in the Executive Office of the President and has many responsibilities, including "the responsibility to ensure that Federal agencies meet their obligations under the Act. CEQ oversees implementation of NEPA, principally through issuing and interpreting NEPA regulations that implement the procedural requirements of NEPA. CEQ also reviews and approves Federal agency NEPA procedures, approves alternative arrangements for compliance with NEPA in the case of emergencies, and helps to resolve disputes between Federal agencies and with other governmental entities and members of the public"[108]. "The CEQ regulations set forth minimum requirements for agencies" and also call for "agencies to create their own implementing procedures that supplement the minimum requirements based on each agency's specific mandates, obligations, and missions. These agency-specific NEPA procedures account for the slight differences in agencies' NEPA processes"[108].

The NEPA provides the framework for companies applying for a permit issued by a federal agency. When a coal mining company applies for a permit to develop a resource the agency that is being asked to issue the permit must evaluate the environmental effects of the permit decision under the NEPA. A primary objective of the NEPA process is to provide information on the consequences of an agency approving an action, to allow decision-makers to make informed decisions. The NEPA analyses should also consider how NEPA policy will be incorporated into the decision to the extent consistent with other considerations of national policy.

The lead agency responsible for managing the NEPA process will depend on the proposed action. Large, complex projects such as coal mines may involve federal agencies as well as state, local and Tribal agencies that may take a joint leadership role in the process and share responsibilities for the management of the NEPA process, including public involvement and the preparation of documents. Cooperating agencies provide special expertise in their area with respect to the evaluation of the environmental impact of a proposed action or a reasonable alternative. Once the lead agency has developed a proposed action or received a proposal from a developer, consideration of the proposal determines one of three possible courses of assessment the agency will pursue:

1. Categorical Exclusion (CE)
2. Environmental Assessment (EA)
3. Environmental Impact Statement (EIS)

The NEPA process is outlined in the flow diagram presented in Figure 44[109].

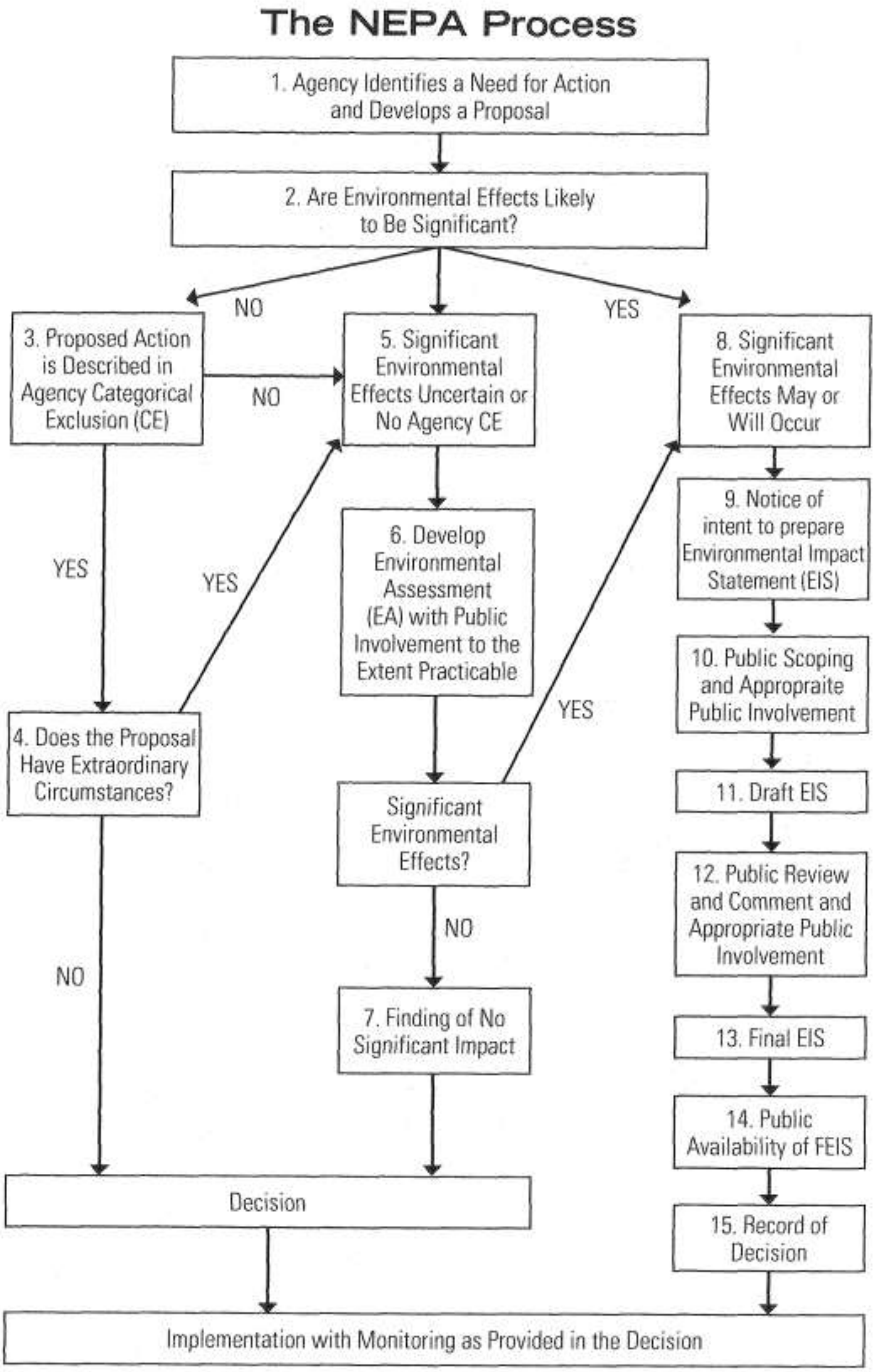

Figure 44 The National Environmental Policy Act process

The Council on Environmental Quality describes the three courses of action as follows[109]:

Categorical Exclusion

A Categorical Exclusion (CE) is a category of actions that the agency has determined does not individually or cumulatively have a significant effect on the quality of the human environment. Agencies develop a list of CEs specific to their operations when they develop or revise their NEPA implementing procedures in accordance with CEQ's NEPA regulations. A CE is based on an agency's experience with a particular kind of action and its environmental effects. The agency may have studied the action in previous EAs, found no significant impact on the environment based on the analyses, and validated the lack of significant impacts after the implementation. If this is the type of action that will be repeated over time, the agency may decide to amend their implementing regulations to include the action as a CE. In these cases, the draft agency procedures are published in the Federal Register, and a public comment period is required. Participation in these comment periods is an important way to be involved in the development of a particular CE.

If a proposed action is included in the description provided for a listed CE established by the agency, the agency must check to make sure that no extraordinary circumstances exist that may cause the proposed action to have a significant effect in a particular situation. If there are no extraordinary circumstances indicating that the effects of the action may be significant, then the agency can proceed with the action. If the proposed action is not included in the description provided in the CE established by the agency, or there are extraordinary circumstances, the agency must prepare an EA or an EIS, or develop a new proposal that may qualify for application of a CE. When the agency does not know or is uncertain whether significant impacts are expected, the agency should prepare an EA to determine if there are significant environmental effects.

Environmental Assessment

The purpose of an Environmental Assessment (EA) is to determine the significance of the environmental effects and to look at alternative means to achieve the agency's objectives. The EA is intended to be a concise document that:

1. *Briefly provides sufficient evidence and analysis for determining whether to prepare an EIS*
2. *Aids an agency's compliance with NEPA when no environmental impact statement is necessary*
3. *Facilitates preparation of an Environmental Impact Statement when one is necessary (CEQ NEPA Regulations, 40 C.F.R. § 1508.9)*

An EA should include brief discussions of:

- *the need for the proposal*
- *alternative courses of action for any proposal which involves unresolved conflicts concerning alternative uses of available resources*
- *the environmental impacts of the proposed action and alternatives*
- *a listing of agencies and persons consulted (CEQ NEPA Regulations, 40 C.F.R. § 1508.9(b)*

Because the EA serves to evaluate the significance of a proposal for agency actions, it should focus on the context and intensity of effects that may "significantly" affect the quality of the human environment. Often the EA will identify ways in which the agency can revise the action to minimize environmental effects. When preparing an EA, the agency has discretion as to the level of public involvement. The CEQ regulations state that the agency shall involve environmental agencies, applicants, and the public, to the extent practicable, in preparing EAs. Sometimes agencies will choose to mirror the scoping and public comment *periods that are found in the EIS process. Some agencies keep a notification list of parties interested in a particular kind of action or in all agency actions. Other agencies simply prepare the EA and not all agencies systematically provide information about individual EAs.*

The EA process concludes with either a Finding of No Significant Impact (FONSI) or a determination to proceed to preparation of an EIS. A FONSI is a document that presents the reasons why the agency has concluded that there are no significant environmental impacts projected to occur upon implementation of the action. The EA is either summarized in the FONSI or attached to it. In two circumstances, the CEQ regulations require agencies to make the proposed FONSI available for public review for 30 days. Those situations are:

- *if the type of proposed action hasn't been done before by the particular agency, or*
- *if the action is something that typically would require an EIS under the agency NEPA procedures*

If this is the case, the FONSI is usually published in the Federal Register, and the notice of availability of the FONSI will include information on how and where to provide comments. If the requirement for a 30 day review is not triggered the FONSI often will not be published in the Federal Register. It may be posted on the agency's website, published in local newspapers or made available in some other manner.

Environmental Impact Statements
A Federal agency must prepare an Environmental Impact Statement (EIS) if it is proposing a major federal action significantly affecting the quality of the human environment.

The EIS process begins with publication of a Notice of Intent (NOI), stating the agency's intent to prepare an EIS for a particular proposal. The NOI is published in the Federal Register, and provides some basic information on the proposed action in preparation for the scoping process. The NOI provides a brief description of the proposed action and possible alternatives. It also describes the agency's proposed scoping process, including any meetings and how the public can get involved. The NOI will also contain an agency point of contact who can answer questions about the proposed action and the NEPA process.

The scoping process is the best time to identify issues, determine points of contact, establish project schedules, and provide recommendations to the agency. The overall goal is to define the scope of issues to be addressed in depth in the analyses that will be included in the EIS. Specifically, the scoping process will:

- *Identify people or organizations who are interested in the proposed action*
- *Identify the significant issues to be analyzed in the EIS*
- *Identify and eliminate from detailed review those issues that will not be significant or those that have been adequately covered in prior environmental review*
- *Determine the roles and responsibilities of lead and cooperating agencies*
- *Identify any related EAs or EISs*
- *Identify gaps in data and informational needs*
- *Set time limits for the process and page limits for the EIS*
- *Identify other environmental review and consultation requirements so they can be integrated with the EIS*
- *Indicate the relationship between the development of the environmental analysis and the agency's tentative decision-making schedule*

Federal agencies might require the proponent to pay for the preparation of analyses, but the agency remains responsible for the scope and accuracy of the analysis. An important requirement of the EA and EIS process is the investigation of alternative methods and proposals for carrying out the action, in addition to the costs and benefits of not carrying out the action and the NEPA applies when an agency has discretion to choose among one or more alternative means of accomplishing a particular goal. However, the NEPA "does not require the decision-maker to select the environmentally preferable alternative or prohibit adverse environmental effects", as decision-makers must consider multiple issues and policy considerations such as social, economic, technical or national security interests[109].

The US EPA's Office of Federal Activities reviews EISs and some EAs issued by federal agencies and provides comments to the public by publishing summaries in the Federal Register. The US EPA's reviews are intended to assist federal agencies to improve their NEPA analyses and decisions.

8.4.4 Germany

In Germany, mining legislation includes various regulations and mechanisms for project development and the approvals process including compliance with, and monitoring of, health, safety and environmental performance standards. Mining activities are subject to a two-step authorisation procedure:

1. The granting of an exploration or exploitation license that confers the exclusive right to explore for or exploit the mineral resources specified in the license

2. The approval of an operations plan for mining operations ranging from the beginning of exploration to the reclamation of land surfaces used by mining. There are four kinds of operations plan including the:

    - skeleton operations plan
    - main operations plan
    - special operations plan
    - mine closure operations plan

The provision of an exploration or exploitation license is subject to a development approvals and consultation process with the various authorities safeguarding public interests. Consultation with local government planning authorities and other groups is carried out if the mining operations plan conflicts with various interests across jurisdictions. For major mining activities, where open-cut surface mining exceeds an area of twenty five hectares, the skeleton operations plan is subject to an environmental impact assessment with the consultation of the broad public.

The *Federal Mining Act (1980)*[91] and the *Ordinance on the Environmental Impact Assessment for Mining Projects (1990)*[93] integrate the environmental impact assessment into the skeleton operations plan procedure with specific provisions taking into account the dynamic character of mining activities. In order to guarantee the participation of the public and all stakeholders, the approval of a skeleton operations plan with an environmental impact assessment by the mining authority is subject to a formal plan approval procedure according to the *German Administrative Procedure Act*[110]. This procedure includes the processing of all necessary permits and accommodates the examination and consultation of all issues by all administrations and stakeholders.

8.5 Air quality impact assessment for coal mining

8.5.1 New South Wales

In NSW, air quality impact assessments of coal mining activities are carried out in accordance with the Approved Methods for Modelling[45], which lists the statutory methods for modelling and assessing emissions of air pollutants from stationary sources. The Approved Methods for Modelling is subordinate legislation promulgated under Part 4 of the Clean Air Regulation.

The Approved Methods for Modelling covers the following aspects of air quality impact assessment that are specific to coal mines:

- *preparation of emissions inventory data*
- *preparation of meteorological data*
- *methods for accounting for background concentrations and dealing with elevated background concentrations*
- *dispersion modelling methodology*
- *interpretation of dispersion modelling results*
- *impact assessment criteria for particulates (TSP), PM_{10} and deposited dust*

The Approved Methods for Modelling specifies two levels of impact assessment:

- *Level 1 – screening-level dispersion modelling technique using worst-case input data*
- *Level 2 – refined dispersion modelling technique using site-specific input data*

The impact assessment levels are designed so that the impact estimates from the second level should be more accurate than the first. This means that, for a given facility, the result of a Level 1 impact assessment would be more conservative and less specific than the result of a Level 2 assessment. It is not intended that an assessment should routinely progress through the two levels. If air quality impact is considered to be a significant issue, there is no impediment to immediately conducting a Level 2 assessment. Equally, if a Level 1 assessment conclusively demonstrates that adverse impacts will not occur, there is no need to progress to Level 2.

The Approved Methods for Modelling specifies five main stages in an air quality impact assessment:

1. *Input data collection*
2. *Dispersion modelling*
3. *Processing dispersion model output data*
4. *Interpretation of dispersion modelling results*
5. *Preparation of an impact assessment report*

Emissions information for coal mines is typically estimated using emission factors published in the National Pollutant Inventory handbooks[38] or US EPA's Clearinghouse for Inventories & Emissions Factors (AP-42)[111] and coal mine production and extraction rates. An emission inventory is then developed for all sources with consideration of the individual source's physical characteristics.

The meteorological data used in the dispersion modelling is one factor that determines the level of assessment.

- *Level 1 impact assessments are conducted using 'synthetic' worst-case meteorological data*
- *Level 2 impact assessments are conducted using at least one year of site-specific meteorological data. The meteorological data must be 90% complete in order to be acceptable for use in Level 2 impact assessments (i.e. for one year, there can be no more than 876 hours of data missing). If site-specific meteorological data are not available for a Level 2 impact assessment, at least one year of site-representative meteorological data must be used. The site representative data should be:*
  - *preferably collected at a meteorological monitoring station. Where measured data is unavailable or of insufficient quality for dispersion modelling purposes, a meteorological data file may be generated using a prognostic meteorological model such as TAPM*
  - *correlated against a longer-duration site-representative meteorological database of at least five years (preferably five consecutive years) to be deemed acceptable. It must be clearly established that the data adequately describes the expected meteorological patterns at the site under investigation (e.g. wind speed, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift)*

Dispersion modelling is then used to predict ground-level concentrations of particulate matter for assessment against the impact assessment criteria, specified in the Approved Methods for Modelling.

An air quality impact assessment report must clearly document the methodology and result of the assessment. The minimum requirements regarding the information contained within an impact assessment report are specified below.

Site plan

- *Layout of the site clearly showing all unit operations*
- *All emission sources clearly identified*
- *Plant boundary*
- *Sensitive receptors (e.g. nearest residences)*
- *Topography*

Description of the activities carried out on the site

- *A process flow diagram clearly showing all unit operations carried out on the premises*
- *A detailed discussion of all unit operations carried out on the site, including all possible operational variability*
- *A detailed list of all process inputs and outputs*
- *Plans, process flow diagrams and descriptions that clearly identify and explain all pollution control equipment and techniques for all processes on the premises*
- *A description of all aspects of the air emission control system, with particular regard to any fugitive emission capture systems (e.g. hooding, ducting), treatment systems (e.g. scrubbers, bag filters) and discharge systems (e.g. stacks)*
- *The operational parameters of all emission sources, including all operational variability, i.e. location, release type (stack, volume or area) and release parameters (e.g. stack height, stack diameter, exhaust velocity, temperature, emission concentration and rate)*

Emissions inventory

- *A detailed discussion of the methodology used to calculate the expected pollutant emission rates for each source*

- *All supporting reports of source emission tests. All analytical reports must contain all the information specified in Section 4 of DEC (2005)*
- *Methodologies used to sample and analyse for each of the pollutants considered*
- *Detailed calculations of pollutant emission rates for each source*
- *Tables showing all release parameters of stack and fugitive sources (e.g. temperature, exit velocity, stack dimensions, and emission concentrations and rates), and all pollutant emission concentrations with a comparison of the emission concentrations against the relevant requirements of the Regulation*

Meteorological data

Level 1 meteorological data

- *A description of the techniques used to prepare the meteorological data in a format for use in the dispersion modelling*
- *The meteorological data used in the dispersion modelling supplied in a Microsoft Windows-compatible format*

Level 2 meteorological data

- *A detailed discussion of the prevailing dispersion meteorology at the proposed site. The report should typically include wind rose diagrams; an analysis of wind speed, wind direction, stability class, ambient temperature and mixing height; and joint frequency distributions of wind speed and wind direction as a function of stability class*
- *Demonstration that the site-representative data adequately describes the expected meteorological patterns at the site under investigation (e.g. wind speed, wind direction, ambient temperature, atmospheric stability class, inversion conditions and katabatic drift)*
- *A description of the techniques used to prepare the meteorological data into a format for use in the dispersion modelling*
- *A quality assurance and quality control analysis of the meteorological data used in the dispersion modelling. Provide and discuss any relevant results of this analysis*
- *The meteorological data used in the dispersion modelling supplied in a Microsoft Windows-compatible format*

Background air quality data

- *Methods used to sample and analyse for each of the pollutants considered*
- *A detailed discussion of the methodology used to calculate the background concentrations for each pollutant*
- *Tables summarising the ambient monitoring data*

Dispersion modelling

- *A detailed discussion and justification of all parameters used in the dispersion modeling and the manner in which topography, building wake effects and other site-specific peculiarities that may affect plume dispersion have been treated*
- *A detailed discussion of the methodology used to account for any atmospheric pollutant formation and chemistry*
- *A detailed discussion of air quality impacts for all relevant pollutants, based on predicted ground-level concentrations at the plant boundary and beyond, and at all sensitive receptors*
- *Ground-level concentrations, hazard index and risk isopleths (contours) and tables summarising the predicted concentrations of all relevant pollutants at sensitive receptors*
- *All input, output and meteorological files used in the dispersion modelling supplied in a Microsoft Windows-compatible format*

8.5.2 Victoria

In Victoria, air quality management of coal mining operations must be carried out in accordance with the requirements of the SEPP (AQM)[46]. The level of impact assessment required is dependent on:

- The scale or size of the operation
- The location of the site

Emissions of Class 1 and 2 indicators must be controlled by the application of best practice, while Class 3 environmental indicators must be controlled to the Maximum Extent Achievable (MEA)[46]. The PEM[47] states:

In some situations extensive monitoring and modelling data may be required to assess the level of impact that emissions from the operations on site may have on the beneficial uses of the air environment defined in the policy.

*A **level 1** assessment is required when developments are located close to residential areas or urban areas and have the potential to give rise to significant offsite impacts. These assessments are the most rigorous and require the most extensive modelling and monitoring data.*

*A **level 2** assessment is required when the proposed development is in a rural location with residences in close proximity or where a small operation is located in an urban area.*

*A **level 3** assessment is required when the development is in a rural location with no residences nearby. A level 3 assessment is the least onerous due to a lower potential risk arising from emissions from the proposed operations compared to operations requiring a level 1 or level 2 assessment. A level 3 assessment may be required when the development is small, in a location remote from residences, or where it is considered that the off-site impacts would be small compared to sites requiring level 1 or level 2 assessments.*

For mines and quarries with less than 50,000 tonnes/yr extraction, no modelling assessment of air quality is required but emissions on site must be controlled by the application of best practice site management.

For all proposals requiring an air quality assessment the following indicators must be assessed:

- PM_{10}
- $PM_{2.5}$
- Respirable crystalline silica (defined as the $PM_{2.5}$ fraction)

Depending on the location of the mining or extractive operations other substances may also require assessment, including:

- arsenic
- heavy metals (e.g., antimony, lead etc)
- hydrogen cyanide and CN
- polycyclic aromatic hydrocarbons [PAHs] (as benzo-a-pyrene [BaP])
- naturally occurring asbestos
- radionuclides

The MEA strategies are more stringent than best practice and consider site-specific emission control rather than industry wide technologies and procedures. The PEM also states:

> *Best practice and MEA go beyond consideration of technological control and include application of the wastes hierarchy with avoidance being the primary aim.*
>
> *The identification of indicators that may be present at individual sites needs to be undertaken in the early stages of planning and prior to the air quality assessment being commenced to ensure that the appropriate indicators are included in the assessment. Advice from EPA should be obtained at this early stage. Schedule A of the SEPP (AQM) should be consulted to identify potential substances that may require assessment. If an assessment is not to be undertaken for key indicators, such as respirable crystalline silica, then supporting evidence needs to be provided to show why an assessment is not required.*
>
> *Identification of all indicators of concern and assessment of these indicators must be conducted. In doing this assessment all sources need to be considered including emissions from haul roads, crushers, generators, processing operations (including leaching), mining operations and any other plant operations on the site. The type of rock and soil also needs to be considered. For Level 1 and 2 assessments mobile sources (such as trucks and graders) also need to be included.*
>
> *For large area-based sources of emissions such as mines and quarries the majority of emissions from the site arise from many ground level sources such as disturbance of soil due to earth moving equipment and vehicle emissions. It is appropriate that the criteria used to assess the potential impacts from these operations are directly related to the protection of the health of the surrounding population and sensitive land uses.*

The impacts of a new proposal are estimated using an approved dispersion model and the impacts are assessed against the design impact assessment criteria, in accordance with the SEPP (AQM). The existing air quality in the vicinity of the proposal is also considered in the cumulative impact assessment. The PEM states:

> *It is important that emissions from industries, including mining and extractives, do not contribute to a deterioration of air quality in urban centres and regional towns and townships. Although the assessment criteria have been established for mining and extractive industries there may be some situations where the assessment criteria cannot be met at the nearest sensitive location to the operation, no additional management practices can be practically applied and the predicted impact from the proposed expansion or operation extends into urban areas or townships. These situations are likely to be rare.*
>
> *In these situations assessment of the predicted emissions on existing air quality within the urban area or township may be required. Advice should be sought from EPA on the need for such an assessment. If required, the assessment should be undertaken at locations where the general population of the town is likely to be exposed (e.g., town centre) rather than the nearest residence. Background (existing air quality) data must be included in the modelling.*

An analysis of existing air quality levels is an important part of the impact assessment and approvals process. The data requirements are[47]:

- Level 1: Real time continuous 24-hour PM_{10} and $PM_{2.5}$ data for a 12-month period, analysis of crystalline silica ($PM_{2.5}$ fraction) and heavy metal content (PM_{10}) (where applicable)
- Level 2: Continuous representative 24-hour PM_{10} and $PM_{2.5}$ data for a 12-month period, representative analysis of crystalline silica ($PM_{2.5}$ fraction) and heavy metal content of PM_{10}
- Level 3: no monitoring data is required prior to the assessment

Meteorological information suitable for application in dispersion modelling should also be collected at the site during the same period as the ambient air quality observations are recorded. Data requirements are[47]:

- *Level 1 assessments data from the area where the operation is proposed needs to be collected. This must be done prior to the air quality assessment commencing. In some circumstances data may be available from EPA.*
- *Level 2 assessments data collected by EPA that is considered representative of the location where the mining or extractives operation is proposed can be used. In some circumstances representative data may not be available and some monitoring may be required.*
- *Data for locations in Melbourne, Geelong and the Latrobe Valley can be obtained from EPA. Availability of appropriate data for other regional centres should be confirmed with EPA. If appropriate data is not available in these locations or for other areas where Level 1 or Level 2 operations are planned and appropriate data is not available, twelve months of data needs to be collected or developed (e.g., through modelling with approval from EPA) by the proponent prior to the assessment being undertaken. Use of alternative background data may be used if agreed by EPA.*

Dispersion modelling is to be used to provide broad guidance as to the potential environmental impacts associated with the proposal, as the predicted outcomes are highly dependent on emission rate estimation, meteorological data and background levels. These parameters are all highly variable with a high degree of uncertainty with regard to mining applications. Modelling results should be presented using contour plots illustrating the predicted ground-level concentrations in the area surrounding the proposal, time series analysis of predicted impacts at the most affected sensitive receptors and a general discussion on the analysis of the modelling results including the degree of uncertainty in the results[47].

8.5.3 United States

In the United States, a Draft EIS is first prepared for public comment. On completion, the "EPA publishes a Notice of Availability in the Federal Register informing the public that the draft is available for comment. The EPA notices are also available at www.epa.gov/compliance/nepa/eisdata.html. Based on the communication plan established by the agency, websites, local papers, or other means of public notice may also be used. The comment period is at least 45 days long, although it may be longer based on requirements spelled out in the agency specific NEPA procedures or at the agency's discretion. During this time, the agency may conduct public meetings or hearings as a way to solicit comments. The agency will also request comments from other Federal, State, Tribal, and local agencies that may have jurisdiction or interest in the matter."

A key aspect of the Draft EIS is the provision of a statement of "Purpose and Need", to describe the objectives and goals of the proposed action. The statement explains to the stakeholders why an agency action is necessary, and serves as the basis for identifying the reasonable alternatives that meet the purpose and need[109].

The identification and evaluation of alternative ways of meeting the purpose and need of the proposed action is the heart of the *NEPA* analysis. The lead agency or agencies must objectively evaluate all reasonable alternatives and briefly discuss the reasons for having eliminated any alternatives. Reasonable alternatives are those that substantially meet the agency's purpose and need. If the agency is considering an application for a permit or other federal approval, the agency must still consider all reasonable alternatives. Reasonable alternatives include those that are practical or feasible from the technical and economic standpoint and using common sense, rather than simply desirable from the standpoint of the applicant. Agencies are obliged to evaluate all reasonable alternatives in enough detail so that a reader can compare and contrast the environmental effects of the various alternatives.[109]

Agencies must always describe and analyse a "no action alternative". The "no action" alternative is what would happen if the agency did not act upon the proposal for agency action. If an agency has a preferred alternative when it publishes a draft EIS, the draft must identify which alternative the agency prefers. All agencies must identify a preferred alternative in the final EIS, unless another law prohibits it from doing so.[109]

The agency must analyse the full range of direct, indirect, and cumulative effects of the preferred alternative and of the reasonable alternatives identified in the draft EIS. They include ecological, aesthetic, historic, cultural, economic, social, or health impacts, whether adverse or beneficial. The draft EIS will contain a description of the environment that would be affected by the various alternatives.[109]

In the Final EIS, the agency will provide further explanation of its findings or conduct further analyses to address the comments provided by stakeholders on the Draft EIS. Investigation of new alternatives to the proposed action may also be required. On completion, the EPA will publish the document and publish a Notice of Availability in the Federal Register. The consultation period is a minimum of thirty days before the agency can make a decision on their proposed action, unless the agency couples the thirty days with a formal internal appeals process.[109]

The final step for agencies in the EIS process is the Record of Decision (ROD) document. This document states that the decision has:

- *Identified the alternatives considered in the EIS including the environmentally preferred alternative*
- *Discussed mitigation plans including any enforcement and monitoring commitments*

Included in the ROD document are all of the agency's considerations including the:

- National policy contemplated in its decision on whether or not to approve and action, and if so, how to proceed
- Practical means adopted to avoid or minimize environmental harm, and if not, why not

The ROD is a publicly available document and is sometimes published in the Federal Register or on the agency's website.

There is also occasion when the federal agency is required to prepare a supplement to an existing EIS. Substantial changes made to any proposed action after the publication of the Draft or Final EIS that are relevant to environmental concerns or are likely to alter the impacts assessed in the initial document will require the preparation of a Supplemental EIS.

An agency may also prepare a Supplemental EIS if it determines that doing so will further the purposes of the NEPA[109].

Guidance on the requirements for air quality impact assessment for coal mines in the United States is provided at the federal and state government agency levels, with the US EPA publishing extensive documentation on process and emission rates and characteristics and the application and validation of dispersion models used in the assessment. The US EPA provides support on emissions estimation for mining activities including:

- Emission Factors[111]
- Modelling guidance[112,113,114]

The state environmental agencies also provide guidance on the assessment of air quality impacts. The two principle coal mining states, Wyoming and West Virginia, both provide guidance:

- Wyoming Department of Environmental Quality
    - Guidance for Submitting Major Source/PSD Modelling Analyses[115]
    - Guidance for Conducting Near-Field Modelling Analyses for Minor Sources[116]
    - Coal Mine Permitting Guidance[117]
- West Virginia Department of Environmental Protection Division of Mining and Reclamation
    - Permitting Handbook[118]

The documents provide guidance on the following matters:

- Model selection
    - AERMOD for near-field <50 kilometre assessment
    - CALPUFF for far-field >50 kilometre assessment
- Receptor grid
    a) Generate a base receptor grid using UTM coordinates in Cartesian arrays as follows:
        - ≤50-meter (m) spacing along the ambient boundary/facility fenceline
        - 100-m spacing from the ambient boundary to a distance of 1.0 kilometer (km) from the grid origin (the grid origin should be centered at the approximate mid-point of the modelled sources at the facility in question)
        - 250-m spacing from 1.0 km to 3.0 km
        - 500-m spacing from 3.0 km to 10.0 km
        - 1000-m spacing from 10.0 km to 25.0 km (and beyond)
        - The receptor grid should be expanded beyond 25 km if the initial grid does not capture the full extent of the significant impact of the proposed source(s). Fine-spaced (100-m or less) receptors should be used to refine the maximum predicted impacts if they occur in an area with receptor spacing of 250-m or more

    b) AERMAP processing should make use of the number of NED or 7.5-minute DEM files needed to fully determine the hill height scale for each receptor (10% slope from each receptor). The WDEQ Air Quality Division prefers that applicants use NED files, either 1 arc second/30-metre resolution files or 1/3 arc second/10-meter resolution files (if available)

- Meteorological data
  - Applicants should use the most recent five-year period of meteorological data that are representative of the project area. At least one year of on-site meteorological data may be used to fulfil this requirement. Document and submit Quality Assurance (QA) procedures that were followed in preparing any meteorological data
  - The WDEQ Air Quality Division has developed AERMET-derived meteorological data for several locations in Wyoming
- Modelling approach
- Emission inventories
- Application of BACT
- Assessment of PM_{10} background
- Equipment and process area description
- Land use and the effect of mine operations on the land including soil:
  - The application must include a discussion of the land status for the current year and for the years modelled. In the discussion, include a table that summarizes disturbed acreage as follows:
    - Topsoil stripping (include areas stripped for sediment control and diversions)
    - Topsoil piles - assume piles from previous year and current year as disturbed
    - Reclaimed areas - assume previous and current year reclamation as disturbed acreage
    - Overburden stockpile areas
    - Mine facility areas (excluding buildings and treated areas)
    - All roads in the mine permit area
    - Active coal pit areas
  - Maps are to be submitted that delineate the various disturbance areas and the size of the areas should be noted on the maps

8.6 Licensing of coal mines

8.6.1 New South Wales

Environmental Protection Licences (EPL) permit the holder of the licence to undertake an activity that is included in Schedule 1 of the *Protection of the Environment (Operations) Act 1997*[22] (POEO Act). Licences specify the intensity of the activity that can be undertaken and the conditions that must be met whilst the activity is undertaken with respect to regulating the activity's environmental impact.

Section 309 of the POEO Act requires OEH to keep the Public Register. Section 308 of the POEO Act defines that the following are to be included in the public register:

- Environment Protection Licences
- Applications for new licences and to transfer or vary existing licences
- Environment protection and noise control notices
- Convictions in prosecutions under the POEO Act
- The results of civil proceedings
- Licence review information. Submissions regarding licence review can be made at any time
- Exemptions from the provisions of the POEO Act or regulations
- Approvals granted under clause 9 of the POEO (Control of Burning) Regulation
- Approvals granted under clause 7A of the POEO (Clean Air) Regulation

Coal mining premises that undertake an activity listed in Schedule 1 of the POEO Act, and conduct this activity above the identified thresholds, must hold an environment protection licence. In Schedule 1, a coal mine is defined as:

28 Mining for coal

(1) This clause applies to mining for coal, meaning the mining, processing or handling of coal (including tailings and chitter) at underground mines or open cut mines.

(2) The activity to which this clause applies is declared to be a scheduled activity if:

(a) it has a capacity to produce more than 500 tonnes of coal per day, or

(b) it has disturbed, is disturbing or will disturb a total surface area of more than 4 hectares of land by:

(i) clearing or excavating, or

(ii) constructing dams, ponds, drains, roads, railways or conveyors, or

(iii) storing or depositing overburden or coal (including tailings and chitter).

All activities holding an EPL must:

- Keep a record of pollution complaints
- Prepare an Annual Return that includes:
  (a) a Statement of Compliance
  (b) a Monitoring and Complaints Summary
- Report incidents causing or threatening material harm as soon as practicable after the person becomes aware of the incident in accordance with the requirements of Part 5.7 of the POEO Act

In the event that adverse impacts occur or are suspected to have occurred, OEH can issue one of the following notices under Chapter 4 of the POEO Act to deal with the impacts:

- Clean-up notice
- Compliance cost notice
- Prevention notice
- Prohibition notice

Under Section 175 of the POEO Act, a requirement to conduct an environmental audit can be imposed on a licensee.

175 Circumstances in which mandatory environmental audit can be imposed

Conditions requiring the undertaking of a mandatory environmental audit may only be imposed if the appropriate regulatory authority reasonably suspects:

(a) that the holder of the licence has on one or more occasions contravened this Act, the regulations or the conditions of the licence, and

(b) that the contravention or contraventions have caused, are causing or are likely to cause, harm to the environment.

Whilst OEH may include monitoring requirements on EPL, OEH doesn't include ambient air quality standards. However, assessment criteria are used for reporting and as a trigger for further investigation of elevated particulate matter levels as follows:

- Monitoring results are compared against the criteria.
- Any exceedances of the criteria at sensitive receptors are identified.
- The cause of any exceedances are investigated and reported.
- Actions are identified and implemented to ensure that impacts will be minimised in the future.

To determine whether particulate matter emissions from a facility may be the cause of a complaint, an air quality assessment study is required to be undertaken in accordance with the Approved Methods for Modelling.

The Approved Methods for Modelling lists the statutory methods and air quality criteria that are to be used to model and assess emissions and impacts of air pollutants from stationary sources in New South Wales. The assessment criteria summarised in Table 47 are relevant to the assessment of coal mines.

Table 47 Assessment criteria relevant to coal mining in NSW

Pollutant	Criteria	Units	Averaging period
Particulates as TSP	90	µg/m³	Annual
Dust deposition rate	2 increment 4 total	g/m^2/month	Annual
Particulates as PM_{10}	50 30	µg/m³ µg/m³	24-hour Annual

Sampling and analysis of air pollutants that are required to be conducted under the POEO Act must be conducted in accordance with the Approved Methods for Sampling[21]. Table 48 summarises sampling methods that are relevant to the measurement of particulate matter from mining activities. A number of methods have been superseded and the Approved Methods for Sampling should be updated to reflect this.

Table 48 Ambient air quality sampling and analysis methods relevant to coal mining in NSW

Method no.	Parameter measured	Method
AM-1	Guide for the siting of sampling units	AS 2922–1987[1]
AM-2	Guide for measurement of horizontal wind for air quality applications	AS 2923–1987
AM-3	Preparation of reference test atmospheres	AS 3580.2.1–1990[2] or AS 3580.2.2–1990[3] as appropriate
AM-4	Meteorological monitoring guidance for regulatory modelling applications	USEPA (2000) EPA 454/R-99-005
AM-15	Particulate matter – TSP – high volume sampler method	AS 2724.3-1984[4]
AM-17	Particulate matter – impinged matter – directional dust gauge method	AS 2724.5-1987
AM-18	Particulate matter – PM_{10} – high volume sampler with size-selective inlet	AS 3580.9.6-1990[5]
AM-19	Particulates – deposited matter – gravimetric method	AS 3580.10.1-1991[6]
AM-22	Particulate matter – PM_{10} – TEOM	AS 3580.9.8-2001[7]

Note:
[1] Superseded by 3580.1.1:2007
[2] Standard withdrawn
[3] Superseded by AS 3580.2.2:2009
[4] Superseded by AS 3580.9.3:2003
[5] Superseded by AS 3580.9.6:2003
[6] Superseded by AS 3580.10.1:2003
[7] Superseded by AS 3580.9.8-2008

The load-based licensing (LBL) scheme[119] sets limits on the pollutant loads emitted by licensed activities by linking licence fees to pollutant emissions. The LBL scheme also provides the infrastructure for emissions trading schemes. These enable emissions to be controlled from groups of licensees as well as from individual premises by allowing licensees to buy and sell credits for reducing emissions.

Coal mining activities are not subject to the requirements of load-based licensing in NSW.

8.6.2 Queensland

In Queensland, typical conditions contained in Development Approvals and Environmental Authorities issued include:

> ***Dust Nuisance.***
> *The release of dust and/or particulate matter resulting from the ERA must not cause an environmental nuisance at any nuisance sensitive or commercial place.*
>
> *Dust and particulate matter resulting from the ERA must not cause the following levels to be exceeded when measured at any nuisance sensitive place*
>
> *(a) dust deposition of 120 milligrams per square metre per day, when monitored in accordance with Australian Standard AS 3580.10.1 of 2003 (or more recent editions); or*
>
> *(b) a concentration of particulate matter with an aerodynamic diameter of less than 10 micrometre (µm) (PM_{10}) suspended in the atmosphere of 150 micrograms per cubic metre over a 24 hour averaging time, at a nuisance sensitive or commercial place downwind of the site, when monitored in accordance with Australian Standard AS 3580.9.6 of 2003 (or more recent*

editions) 'Ambient Air – Particulate matter – Determination of suspended particulate PM_{10} high-volume sampler with size-selective inlet – Gravimetric method'; or

Any alternative method of monitoring PM_{10} which may be permitted by the 'Air Quality Sampling Manual' as published from time to time by the administering authority.

8.6.3 United States

In the United States, the Clean Air Act 1990[50] provides for a national operating permitting system for major sources of air pollution known as *40 CFR Part 70 – State Operating Permit Programs*[120]. Under this section of the Act, known as Title V, state and local air pollution control agencies issue permits that contain all of the requirements that are needed for a source to maintain compliance with state and federal air pollution control regulations. Permits are issued for a fixed term of five years in the case of affected sources, and for a term not to exceed five years in the case of all other sources. Title V permits are directly enforceable by the authority issuing the permit and the Environmental Protection Agency. In addition to this, permits are also subject to the citizen suit provisions of the Act.

The Title V permit should be regarded as a living document that reflects the changing conditions at a facility. The issuance of the permit as part of a facility's development approval process does not end the relevance of a broader 'purposes' discussion for that facility. Permit content requirements are outlined in *40 CFR Section 70.6*[120] of the United States Federal Register.

In 2004, the Clean Air Act Advisory Committee established a Task Force on the Title V Implementation Experience to report on stakeholder experience with the implementation of the Title V operating permit program. The Task Force agreed that the primary purposes of the permitting program include, but are not limited to, the following:

- *Consolidation of all Clean Air Act requirements into one document*
- *Enhancement of public participation in decisions about applicability of the requirements to major facilities*
- *Provision of the opportunity to judicially challenge these decisions*
- *Enhancement of the ability to enforce Clean Air Act requirements through, among other things,*
    - *compliance certifications*
    - *providing certainty to permitted facilities regarding which regulatory obligations apply*

The Task Force observed that, whether intentional or not, the implementation of the Title V program appears to have, or may be credited with:

- *Providing the impetus to resolve longstanding issues of interpreting Federal or SIP standards, sometime through revision of the standard itself*
- *Providing the incentive to resolve longstanding compliance problems at facilities applying for a permit so that compliance can be certified and a schedule of compliance avoided*
- *Raising the statutory profile of compliance through certifications*
- *Forcing the resolution of issues that otherwise may have persisted in a state of stalemate (or perhaps acknowledged ignorance by all sides)*
- *Providing an opportunity for the people living near a facility to find out more about it, even if they otherwise agree with the permitting*

Coal Preparation and Processing Plants that process more than 181 metric tonnes of coal per day are pursuant to the *Standards of Performance 40 CFR Part 60 Subpart Y*[51]. This regulation provides for standards of performance including emission concentration and opacity standards, performance tests, monitoring and record keeping requirements as well as the implementation of Best Available Control Technology (BACT) and management techniques for particulate emissions. This regulation is applicable to the following activities:

- Thermal dryers
- Pneumatic coal-cleaning equipment (air tables)
- Coal processing and conveying equipment (including breakers and crushers)
- Coal storage systems
- Transfer systems
- Loading systems
- Open storage piles

A proponent initiating a project must undergo new source review and obtain a pre-construction permit or a permit waiver authorising construction of the project. This process ensures that the project will comply with the air quality requirements at the time of construction. To ensure on-going compliance, the operating permit program requires on-going monitoring of emission sources and/or source control systems. The *NEPA* approvals process including the environmental impact statement requires the air quality impact assessment be carried out with consideration of BACT emission control technology in accordance with the *Standards of Performance 40 CFR Part 60 Subpart Y*[51]. The BACT controls are then passed on through the condition of approval for the project to the operating permit.

The permitting of coal mining operations under the *Clean Air Act, 40 CFR Part 60 Subpart Y*, is subject to application fees and a rate of activity-based fee system. In West Virginia, the Department of Environmental Protection charge a Certificate to Operate (CTO) fee and a Certified Emissions Statement (CES) fee if a facility exceeds specific thresholds for stationary source emissions. The CES for the 2010-11 fiscal year equivalent to US$23.92 per ton of particulate matter emitted. Based on estimated dust emissions from 2009, this would equate to $4.7M if applied to the coal mining industry in NSW.

8.6.4 New Zealand

In New Zealand, Crown Minerals, a department of the Ministry of Economic Development, issue permits under the Crown Minerals Act 1991 for people to prospect, explore or mine Crown owned minerals. For the purpose of permitting, Crown Minerals defines each activity as follows:

> ***Prospecting****: is usually very low impact work. Often only literature search, geological mapping and rock chip sampling or aerial surveys over a relatively large geographical area are undertaken. A prospecting permit is initially granted for a period up to two years and is for the purpose of identifying land in general likely to contain exploitable minerals.*
>
> *If no previous work has been successfully done to locate a possible deposit for the specified mineral within the application area and only geological mapping, a geochemical survey or aerial geophysical survey is proposed, then the applicant should apply for a prospecting permit. If there has been previous prospecting, exploration or mining, then the applicant should be intending to explore at a minimum, as prospecting will not materially add to the existing knowledge.*

Exploration*: involves many different methods and will include all work undertaken until actual mining. An exploration permit is initially granted for a period up to five years and is for the purpose of identifying mineral deposits and evaluating the feasibility of mining.*

This work may include a literature review, drilling, trenching, grid geological mapping and even geotechnical work. Depending on the work intended, it may be best to directly apply for an exploration permit rather than a prospecting permit.

Mining*: involves the economic recovery of an identified mineral resource. The nature and extent of the mineral deposit must have been clearly defined during exploration and the size of the resource (the reserves) accurately known. The applicant should be able to outline the grades and tonnage expected and the degree of confidence associated with the outline. A mining permit can be granted up to a period of forty years depending on the size of the resource. It is more common for mining permits to be granted for periods up to twenty years.*

A summary of how the permitting system in New Zealand operates in provided in Table 49.

Table 49 Summary of the New Zealand permit system

Component	Prospecting permit	Exploration permit	Mining permit
Purpose	To identify land likely to contain exploitable deposits	To identify deposits and evaluate the feasibility of mining	Economic recovery of an identified resource
Which permit?	Previous work has not located a possible deposit	Often applied for first, rather than a prospecting permit, when higher impact work intended	The nature and extent of the mineable mineral resource or exploitable mineral deposit are known accurately
Activities	Very low impact, e.g. literature search, geological mapping, hand sampling or aerial surveys	May include literature review, drilling, bulk sampling and mine feasibility studies	Mineral extraction
Allocation	Acceptable work programme offer	- Acceptable work programme offer - As a subsequent exploration permit following a prospecting permit - Newly available acreage (NAA) – competitive permit allocation process over available land following permit expiry, surrender, revocation or relinquishment	- Acceptable work programme offer - As a subsequent mining permit following an exploration permit - Newly available acreage (NAA) – competitive permit allocation process over available land following permit expiry, surrender, revocation or relinquishment
Exclusive right	Yes, unless non exclusive permit sought	Yes	Yes
Duration	- 2 years - Renewal up to another 2 years	- 5 years - Renewal up to another 5 years over half of area - Appraisal extension possible	Up to 40 years but commonly under 20 years (related to extent of reserves and resources and work programme)

Component	Prospecting permit	Exploration permit	Mining permit
Size	No upper limit - relates to work programme	No upper limit - relates to work programme	Related to extent of discovery and work programme
Royalties	Not applicable	Not applicable unless annual production is greater than $200,000 in value	For permits under the 1996 minerals programmes, 1% ad valorem royalty (AVR) for net sales revenues up to $1 million per annum. Where net sales revenues over $1 million pa, higher of either 1% AVR or 5% accounting profits royalty For permits under the 2008 minerals programme: - specific rate royalty (SRR) for low value to volume minerals and tiered AVR for precious metals and platinum group elements
Legislation	- Crown Minerals Act 1991 - Crown Minerals (Minerals and Coal) Regulations 2007 - Crown Minerals (Minerals Fees) Regulations 2006 - Minerals Programme for Minerals (other than coal & petroleum) 1996 - Minerals Programme for Coal 1996 - Minerals Programme for Minerals (Excluding Petroleum) 2008		

8.7 Emission limits and ambient air quality standards

8.7.1 United States

In the United States, under the Clean Air Act[50] (Section 111), the term 'standard of performance' means:

> *a standard for emissions of air pollutants which reflects the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction and any non-air quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated*.

Standards of performance with regard to emissions to air have been promulgated for a large range of industrial activities including the coal mining industry.

The federal regulations for the standards of performance are primarily concerned with emissions standards for specific emission sources associated with operating plant including sources of fuel combustion. Standards of Performance for Coal Preparation Plants are promulgated in *40 CFR Part 60 Subpart Y*[51], while Standards of Performance for Fossil-Fuel-Fired Steam Generators including coal combustion for power generation are promulgated in *40 CFR part 60 Subpart D*[51].

The standards of emissions for Coal Preparation and Processing Plants that process more than 181 metric tonnes of coal per day are summarised in Table 50.

Table 50 Summary of *40 CFR Part 60 Subpart Y – Standards of Performance for Coal Preparation and Processing Plants*

Emission source	Equipment construction, reconstruction or modification date	Emission standard	
		Mass of particulate matter (g/dscm)	Visibility (% opacity)
Thermal dryers	Constructed, reconstructed or modified on and before 28/04/2008	0.070	20
	Constructed or reconstructed after 28/04/2008	0.023	10
	Modified after 28/04/2008	0.070	20
Pneumatic coal cleaning equipment	Constructed, reconstructed or modified on and before 28/04/2008	0.040	10
	Constructed, reconstructed or modified after 28/04/2008	0.023	5
Coal processing and conveying equipment, coal storage, transfer and loading systems	Constructed, reconstructed or modified on and before 28/04/2008	N/A	20
	Constructed, reconstructed or modified after 28/04/2008	0.023	10
Open storage stockpile including loading, unloading and conveying	The owner or operator of an open storage pile, which includes the equipment used in the loading, unloading, and conveying operations of the affected facility, constructed, reconstructed, or modified after May 27, 2009, must prepare and operate in accordance with a submitted fugitive coal dust emissions control plan	N/A (see Table 51)	

An outline of the requirements for dust emissions management plans for open storage stockpiles including loading, unloading and conveying systems at Coal Preparation and Processing Plants is presented in Table 51.

Table 51 Summary of *40 CFR Part 60 Subpart Y Section 60.255* – Dust emissions management plans for open storage stockpiles including loading, unloading and conveying at Coal Preparation and Processing Plants

Section	Fugitive coal dust emissions control plan
(c)	*Applicable to activities constructed, reconstructed or modified after 27/05/2009 must prepare and operate in accordance with a submitted fugitive coal dust emissions control plan that is appropriate for the site conditions as specified in paragraphs (c)(1) through (6) of this section*
(c) (1)	*The fugitive coal dust emissions control plan must identify and describe the control measures the owner or operator will use to minimize fugitive coal dust emissions from each open storage pile.*
(c) (2)	*One or more of the following control measures are to be used to minimize to the greatest extent practicable fugitive coal dust:* • *Locating the source inside a partial enclosure* • *Installing and operating a water spray or fogging system* • *Applying appropriate chemical dust suppression agents on the source (when the provisions of paragraph (c)(6) of this section are met)* • *Use of a wind barrier, compaction, or use of a vegetative cover* *The owner or operator must select, for inclusion in the fugitive coal dust emissions control plan, the control measure or measures listed in this paragraph that are most appropriate for site conditions. The plan must also explain how the measure or measures selected are applicable and appropriate for site conditions. In addition, the plan must be revised as needed to reflect any changing conditions at the source.*
(c) (3)	*Petition to the Administrator can be made to approve, for inclusion in the plan, alternative control measures other than those specified in paragraph (c)(2) of this section as specified in paragraphs (c)(3)(i) through (iv) of this section. However,*

Section	Fugitive coal dust emissions control plan
	(i) The petition must include a description of the alternative control measures, a copy of the fugitive coal dust emissions control plan that includes the alternative control measures, and information sufficient for EPA to evaluate the demonstrations required by paragraph (c)(3)(ii) of this section. *(ii) The owner or operator must either demonstrate that the fugitive coal dust emissions control plan that includes the alternate control measures will provide equivalent overall environmental protection or demonstrate that it is either economically or technically infeasible for the affected facility to use the control measures specifically identified in paragraph (c)(2).* *(iii) While the petition is pending, the owner or operator must comply with the fugitive coal dust emissions control plan including the alternative control measures submitted with the petition. Operation in accordance with the plan submitted with the petition shall be deemed to constitute compliance with the requirement to operate in accordance with a fugitive coal dust emissions control plan that contains one of the control measures specifically identified in paragraph (c)(2) of this section while the petition is pending.* *(iv) If the petition is approved by the Administrator, the alternative control measures will be approved for inclusion in the fugitive coal dust emissions control plan for the affected facility. In lieu of amending this subpart, a letter will be sent to the facility describing the specific control measures approved. The facility shall make any such letters and the applicable fugitive coal dust emissions control plan available to the public. If the Administrator determines it is appropriate, the conditions and requirements of the letter can be reviewed and changed at any point.*
(c) (4)	*The owner or operator must submit the fugitive coal dust emissions control plan to the Administrator or delegated authority as specified in paragraphs (c)(4)(i) and (c)(4)(ii) of this section.* *(i) The plan must be submitted to the Administrator or delegated authority prior to startup of the new, reconstructed, or modified affected facility, or 30 days after the effective date of this rule, whichever is later.* *(ii) The plan must be revised as needed to reflect any changing conditions at the source. Such revisions must be dated and submitted to the Administrator or delegated authority before a source can operate pursuant to these revisions. The Administrator or delegated authority may also object to such revisions as specified in paragraph (c)(5) of this section.*
(c) (5)	*The Administrator or delegated authority may object to the fugitive coal dust emissions control plan as specified in paragraphs (c)(5)(i) and (c)(5)(ii) of this section.* *(i) The Administrator or delegated authority may object to any fugitive coal dust emissions control plan that it has determined does not meet the requirements of paragraphs (c)(1) and (c)(2) of this section.* *(ii) If an objection is raised, the owner or operator, within 30 days from receipt of the objection, must submit a revised fugitive coal dust emissions control plan to the Administrator or delegated authority. The owner or operator must operate in accordance with the revised fugitive coal dust emissions control plan. The Administrator or delegated authority retain the right, under paragraph (c)(5) of this section, to object to the revised control plan if it determines the plan does not meet the requirements of paragraphs (c)(1) and (c)(2) of this section.*
(c) (6)	*Where appropriate chemical dust suppression agents are selected by the owner or operator as a control measure to minimize fugitive coal dust emissions,* *(1) only chemical dust suppressants with Occupational Safety and Health Administration (OSHA)-compliant material safety data sheets (MSDS) are to be allowed;* *(2) the MSDS must be included in the fugitive coal dust emissions control plan; and* *(3) the owner or operator must consider and document in the fugitive coal dust emissions control plan the site-specific impacts associated with the use of such chemical dust suppressants*

The standard *40 CFR part 60 Subpart Y Section 60.255* promulgates the performance emission tests and other compliance monitoring requirements stack sources as well as for open storage stockpiles including loading, unloading and conveying systems. The regulation states:

a) *An owner or operator of each affected facility that commenced construction, reconstruction, or modification on or before April 28, 2008, must conduct all performance tests required by Section 60.8 to demonstrate compliance with the applicable emission standards using the methods identified in Section 60.257*

b) *An owner or operator of each affected facility that commenced construction, reconstruction, or modification after April 28, 2008, must conduct performance tests according to the requirements of Section 60.8 and the methods identified in Section 60.257 to demonstrate compliance with the applicable emissions standards in this subpart as specified in paragraphs (b)(1) and (2) of Section 60.255*

8.7.2 Canada

In Canada, the Quebec Ministère du Dévelopment durable, de l'Environnement et des Parcs has promulgated general emission standards for particulate matter under the *Environmental Quality Act*[121]. These standards do not refer directly to particulate emissions associated with general mining or coal mining activities however, they are relevant in terms of environmental impact assessment for developments. Section 24 states:

> *Except for the special cases provided for in Divisions IX to XV, XVII to XXII, XXIV, XXVI to XXVIII and in section 25, <u>no one may emit particulate matters into the atmosphere in excess of the hourly quantities allowed respectively for existing and new stationary sources</u> in Schedules A and B.*

It should noted, that the Divisions of the Act referred to as exceptions to the emissions standards promulgated under Section 24 are pursuant to the following industrial activities, and do not include the coal mining industry:

Division IX – Use of Fossil Fuels
Division X – Metal Purification Plant
Division XI – Aluminium Smelters
Division XII – Cement Plants
Division XIII – Coke Manufacturing Plants
Division XIV – Wood Burning
Division XV – Refractory Powder Production Plants
Division XVII – Steel and Cast Iron Foundries
Division XVIII – Charcoal Kilns
Division XIX – Incinerators
Division XX – Asbestos Industry
Division XXI – Secondary Lead Smelters
Division XXII – Oil Refineries and Petrochemical Plants
Division XXIV – Treatment of Metallic Surfaces
Division XXVI – Iron Ore Pelletising Plant
Division XXVII – Ferroalloy Plants
Division XXVIII – Primary Non-Ferrous Metal Smelters

Schedules A and B provide for variable emission rate standards for particulate matter based on the scale of operations. For Schedule A, emissions standards are calculated using the following equations:

- *Interpolation of the data in Schedule A, for process weight rates under 25 tonnes per hour, shall be accomplished by use of the equation:*

$$E = 2.0 \times p^{0.67}$$

- *Interpolation and extrapolation of the data in Schedule A, for process weight rates equal to or in excess of 25 tonnes per hour, shall be accomplished by use of the equation:*

$$E = 25.0 \times p^{0.11} - 18$$

Where:

E is the emission standard in kg/hour
P is the process weight in tonnes/hour

For Schedule B, emissions standards are calculated using the following equations:

- *Interpolation of the data in Schedule B, for process weight rates under 25 tonnes per hour, shall be accomplished by use of the equation:*

$$E = 1.7 \times p^{0.62}$$

- *Interpolation and extrapolation of the data in Schedule A, for process weight rates equal to or in excess of 25 tonnes per hour, shall be accomplished by use of the equation:*

$$E = 8.0 \times p^{0.16}$$

Where:

E is the emission standard in kg/hour
p is the process weight in tonnes/hour

Section 25 - Concentration of the standards state:

> *'No mill, distillery, brewery, powder milk plant, fertilizer mixing plant, concrete plant, vitreous enamel, earthenware, and ceramic products plant, polyvinyl chloride production or processing plant or wood processing plant must emit particulate matter into the atmosphere with a concentration higher than 50 milligrams per cubic metre, under standard conditions.*
>
> *This standard applies also to emissions coming from any transfer of bulk material except wood, any storage in confined environment, any digging other than the sinking of a supply water well, any welding operation metal works in indoor sandblasting and to any process for the preparation, concentration, agglomeration or drying of ore or ore concentrate, as well as to the related handling operations done in a plant for the preparation, concentration, agglomeration or drying of metallic ores, except for the process of aluminium hydrate calcining*'.

Fugitive emission standards are also promulgated under the *Environmental Quality Act*, *Regulation respecting the quality of the atmosphere* in *Division VII, Fugitive Emissions Sections 17 – 23.* Section 17 of the regulation pertains to dust emissions non-specific to the mining industry and is associated with:

> *'any person who wrecks, builds, repairs or maintains a building or a thoroughfare'*

and states that that person must:

> *'spread water or another dust control product to prevent the raising of dust in all cases where the carrying out of such activity brings about the emission of dust'*

Notwithstanding this, Section 19 of the regulation, titled *Transfer and Fee Fall*, is relevant to the mining industry, and states:

> *In the case where the transfer or free fall of materials of any kind including aggregates, mine rejects ore, ore concentrate or pellets, brings about the emission of dust which can be seen in the atmosphere more than two metres away from the emission source, the person responsible for that source of atmospheric contamination must take the necessary measures so that:*
>
> *a) the stationary transfer point is included in an enclosed space equipped with ducts which draw dust to a dust collector so that the emissions of particulate matters into the atmosphere are in compliance with the concentration standard established in section 25; or*
>
> *b) the free fall height of these materials does not exceed two metres.*

8.7.3 Germany

In Germany, standards of emissions for coal mining activities are not specifically addressed in TA Luft[96]. Notwithstanding this, the regulation provides a general description of emission management and reduction strategies for emissions associated with transporting, loading and unloading, storing and working with solid substances. No emission concentration standards have been promulgated.

8.7.4 South Africa

In South Africa, the Department of Environmental Affairs and Tourism has promulgated an extensive list of air emission standards for industry under the *National Environment Management: Air Quality Act* in *Government Gazette No. 33064 on 31 March 2010*[122]. However, emission standards for the bulk handling and storage of minerals and ore, promulgated under *Category 5: Mineral Processing, Storage and Handling – Subcategory 5.1: Storage and handling of ore and coal* do not apply to mine sites and works as defined under the *Mine Health and Safety Act 1996*[123].

8.7.5 Ambient air quality standards for particulate matter

A comparison of ambient air quality standards for particulate matter including total suspended particulate (TSP), PM_{10}, $PM_{2.5}$ and deposited dust that are promulgated in various national and state/provincial jurisdictions are presented in Table 52 to Table 60. The list of jurisdictions reviewed includes OECD (Organisation for Economic Co-operation and Development) countries and other major coal producing nations and regions.

The World Health Organisation (WHO) publishes air quality guidelines[124] from time to time. These guidelines are intended to support actions which are aimed at achieving air quality levels that protect public health in different contexts. In relation to the setting of air quality standards the WHO states:

> *Air quality standards are an important instrument of risk management and environmental policy, and should be set by each country to protect the health of its citizens. The standards set in each country will vary according to specific approaches to balancing risks to health, technological feasibility, economic considerations and other political and social factors. This variability will depend on the country's level of development, capability in air quality management and other factors. The guidelines recommended by WHO acknowledge this heterogeneity and recognize in particular that, in formulating policy targets, governments should consider their own local circumstances carefully before using the guidelines directly as legal standards.*

A detailed description of the derivation of the WHO air quality guidelines is contained in the reference cited above. The numerical value of the WHO air quality guidelines for PM_{10} are based on studies of the health effects associated with $PM_{2.5}$ exposures in cities located in developed and undeveloped countries throughout the world. A $PM_{2.5}$:PM_{10} ratio of 0.5 is used to derive the numerical guideline value for PM_{10} from the $PM_{2.5}$ guideline.

The following comments are relevant in relation to these tables:

- No impact assessment criterion has been specified by OEH for 24-hour average TSP. The Canadian province of Alberta provides a 24-hour average TSP criterion of 100 µg/m³, which is the most stringent criterion of all jurisdictions considered in the review.
- The annual average TSP impact assessment criterion adopted by OEH is less stringent than the strictest limits adopted by other jurisdictions considered in the review. The Canadian provinces of Alberta, British Columbia and Ontario and the Government of Canada provide an annual average TSP criterion of 60 µg/m³, which is the most stringent criterion of all jurisdictions considered in the review.
- The 24-hour average PM_{10} impact assessment criterion adopted by OEH is consistent with the strictest limits adopted by other jurisdictions considered in the review.
- In New Zealand the ambient air quality standard for PM_{10} is based on a risk-based approach and is equivalent to the standards set in Australia, the United Kingdom and California. The standard allows for five exceedances of the 24-hour average concentration threshold of 50 µg/m^3, with a maximum threshold not to be exceeded of 120 µg/m^3. Where the standard is not met, regional councils must make that non-compliance public. In air sheds where the standard is not achieved, regional councils can only grant resource consents if they are confident that the net result of all activities in their air shed results in an improvement in air quality. The New Zealand standard is currently under review.
- The annual average PM_{10} impact assessment criterion adopted by OEH is less stringent than the strictest limits adopted by other jurisdictions considered in the

review. The World Health Organisation, California and Scotland provide annual average PM_{10} criteria that are equal to or less than 20 µg/m³, which are the most stringent criteria of all jurisdictions considered in the review.

- No impact assessment criteria have been specified in NSW for $PM_{2.5}$. Annual average and 24-hour average criteria have been specified by most jurisdictions considered in the review.
- The impact assessment criteria for deposited dust adopted in NSW are consistent with the strictest limits adopted by other jurisdictions considered in the review.

Table 52 Summary of air quality standards and objectives for 24-hour average total suspended particulates

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Number of allowable exceedances	Comment
Canada (national)	120	0	Acceptable limit. Based on Canadian National Ambient Air Quality Objectives, converted from ppmv to $\mu g/m^3$ at 0°C and 1 atmosphere
	400	0	Tolerable limit. Based on Canadian National Ambient Air Quality Objectives, converted from ppmv to $\mu g/m^3$ at 0°C and 1 atmosphere
Ontario, Canada	120	0	Based on Ontario's Ambient Air Quality Criteria, converted from ppmv to $\mu g/m^3$ at 10°C and 1 atmosphere
Quebec, Canada	150	0	The TSP values for Quebec are referred to as 'Suspended Particulates'.
British Columbia, Canada	150	0	Level A
	200	0	Level B
	260	0	Level C
Alberta, Canada	100	0	Based on pulmonary effects.
China (national)	120	0	Grade I Standard I
	300	0	Grade II Standard II
	500	0	Grade III Standard III

Table 53 Summary of air quality standards and objectives for annual average total suspended particulates

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Comment
New South Wales, Australia	90	None
Queensland, Australia	90	None
Canada (national)	60	Desirable limit. Based on Canadian National Ambient Air Quality Objectives, converted from ppmv to $\mu g/m^3$ at 0°C and 1 atmosphere
	70	Tolerable limit. Based on Canadian National Ambient Air Quality Objectives, converted from ppmv to $\mu g/m^3$ at 0°C and 1 atmosphere
Ontario, Canada	60	Based on Ontario's Ambient Air Quality Criteria, converted from ppmv to $\mu g/m^3$ at 10°C and 1 atmosphere
Quebec, Canada	70	Annual geometric average. The TSP values for Quebec are referred to as 'Suspended Particulates'.
British Columbia, Canada	60	Level A
	70	Level B
	75	Level C
Alberta, Canada	60	Geometric mean.
China	80	Grade I Standard I
	200	Grade II Standard II
	300	Grade III Standard III

Table 54 Summary of air quality standards and objectives for 24-hour average PM_{10}

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Number of allowable exceedances	Comment
World Health Organisation	50	3	None
Ambient Air Quality NEPM, Australia	50	5	Applicable in towns with a population greater than 25,000
New South Wales, Australia	50	0	None
Queensland, Australia	50	5	None
Victoria, Australia	60	0	None
New Zealand	50	5[1]	None
	120[1]	0	None
United States (national)	150	See comment	Not to be exceeded more than once per year on average over 3 years
Wyoming, United States	150	1	None
West Virginia, United States	150	1	None
California, United States	50	0	None
European Union	50	35	Legal nature: Limit value enters into force 1/01/2005
United Kingdom (national)	50	35	To be achieved by 31/12/2004 and maintained thereafter
Scotland, UK	50	7	To be achieved by 31/12/2010 and maintained thereafter. Indicative 2010 objectives for PM_{10} (from the 2000 Strategy and 2003 Addendum) have been replaced by an exposure reduction approach for $PM_{2.5}$ (except in Scotland)
Germany	50	35	Immission value of PM_{10} in order to ensure the protection on human health
Ontario, Canada	50	0	Based on Ontario's Ambient Air Quality Criteria, converted from ppmv to $\mu g/m^3$ at 10°C and 1 atmosphere
British Columbia, Canada	50	0	Level B
South Africa	120	4	Compliance date: 24/12/2009 to 31/12/2014
	75	4	Compliance date: From 1/01/2015
China	50	0	Grade I Standard I
	150	0	Grade II Standard II
	250	0	Grade III Standard III

Note
[1]In response to submissions, the Ministry for the Environment plans to amend the standards to PM_{10}. Regional councils will be required to decide whether to monitor for PM_{10}, to publicly report any exceedances, and to use the standard as the basis for regional air shed planning. Regional councils will be required to comply with a 'proxy air plan' of no more than 1 exceedance of 50 ug/m^3 by 2013. Councils can choose to implement an air quality plan that is stricter than the proxy air plan. The proposed upper limit of 120 ug/m^3 will be removed, and the number of allowable exceedances will be reduced from 5 to 1. No resource consent application will be granted where that consent is the primary source of exceedances. In a polluted airshed, an application may be granted if it will not adversely affect air quality improvement as accounted for in the regional air quality plan.

Table 55 Summary of air quality standards and objectives for annual average PM_{10}

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Comment
World Health Organisation	20	None
New South Wales, Australia	30	None
Wyoming, United States	50	None
California, United States	20	Annual arithmetic mean
European Union	40	Legal nature: Limit value enters into force 1/01/2005
United Kingdom (national)	40	To be achieved by 31/12/2004 and maintained thereafter
Scotland, UK	18	To be achieved by 31/12/2010 and maintained thereafter. Indicative 2010 objectives for PM_{10} (from the 2000 Strategy and 2003 Addendum) have been replaced by an exposure reduction approach for $PM_{2.5}$ (except in Scotland)
Germany	40	Immission value of PM_{10} in order to ensure the protection on human health
South Africa	50	Compliance date: 24/12/2009 to 31/12/2014
	40	Compliance date: From 1/01/2015

Table 56 Summary of air quality standards and objectives for 1-hour average $PM_{2.5}$

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Number of allowable exceedances	Comment
Alberta, Canada	80	0	Derived from Canada wide objective

Table 57 Summary of air quality standards and objectives for 24-hour average $PM_{2.5}$

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Number of allowable exceedances	Comment
World Health Organisation	25	3	None
Ambient Air Quality NEPM, Australia	25	0	Goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of the review of this measure scheduled to commence in 2005.
Queensland, Australia	25	0	None
Victoria, Australia	36	0	None
	3	0	Respirable crystalline silica as $PM_{2.5}$
United States (national)	35	See comment	To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 $\mu g/m^3$
Wyoming, United States	65	See comment	The 98.0th percentile or 7th highest 24-hour average concentration is assessed. The standard is currently under review since the amendment of the NAAQS of $PM_{2.5}$ to 35 $\mu g/m^3$.
West Virginia, United States	35	See comment	The 98.0th percentile or 7th highest 24-hour average concentration is assessed
California, United States	35	See comment	There is no separate 24-hour average $PM_{2.5}$ standard in California; however, the USEPA standard of 35 $\mu g/m^3$ applies. To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 $\mu g/m^3$.
Canada (national)	30	0	Based on Canadian National Ambient Air Quality Objectives, converted from ppmv to $\mu g/m^3$ at 0°C and 1 atmosphere
Ontario, Canada	30	See comment	Based on Ontario's Ambient Air Quality Criteria, converted from ppmv to $\mu g/m^3$ at 10°C and 1 atmosphere. 98th Percentile averaged over 3 consecutive years.
Quebec, Canada	30	0	None
British Columbia, Canada	25	0	Based on annual 98th percentile value
Alberta, Canada	30	0	Based on Canada wide objective

Table 58 Summary of air quality standards and objectives for 3-year average $PM_{2.5}$

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Comment
European Union	20	Exposure concentration obligation. Legally binding in 2015 (years 2013, 2014, 2015)
	18	Exposure reduction target. Reduction to be attained in 2020, determined on the basis of the value of exposure indicator in 2010

Table 59 Summary of air quality standards and objectives for annual average $PM_{2.5}$

Jurisdiction	Standard/ objective ($\mu g/m^3$)	Comment
World Health Organisation	10	None
Ambient Air Quality NEPM	8	Goal is to gather sufficient data nationally to facilitate a review of the Advisory Reporting Standards as part of the review of this measure scheduled to commence in 2005.
Queensland, Australia	8	None
Wyoming, United States	15	None
West Virginia, United States	15	None
California, United States	12	Annual arithmetic mean
South Africa	50	Compliance date: Immediate to 31/12/2014
	40	Compliance date: From 1/01/2015
European Union	25	Legal nature: Target value enters into force 1/01/2010, Limit value enters into force 1/01/2015
United Kingdom (except Scotland)	25	To be achieved by 2020 and maintained thereafter
Scotland, UK	12	To be achieved by 2020 and maintained thereafter
United Kingdom, urban areas	See comment	Target of 15% reduction in concentrations at urban background. To be achieved between 2010 and 2020 and maintained thereafter
British Columbia, Canada	8	Annual arithmetic mean. Air quality objective.
	6	Annual arithmetic mean. Planning goal.
United States	15	Arithmetic average. To attain this standard, the 3-year average of the weighted annual mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 15 µg/m3

Table 60 Summary of air quality standards and objectives for deposited dust

Jurisdiction	Standard/objective	Comment
Quebec, Canada	7.5 tonnes/km²/month (7.5 g/m²/month)	None
Alberta, Canada	53 mg/100 cm²/month (5.3 g/m²/month)	In residential and recreation areas
	158 mg/100 cm²/month (15.8 g/m²/month)	In commercial and industrial areas
New South Wales, Australia	2 g/m²/month	Incremental. 2 g/m²/month corresponds to 67 mg/m²/day
	4 g/m²/month	Total. 4 g/m²/month corresponds to 133 mg/m²/day
Queensland, Australia	120 mg/m²/day (3.6 g/m²/month)	Informal advice from the DERM. This is equivalent to the dust deposition goal used in NSW for mining projects
Germany	0.35 g/m²/day (10.5 g/m²/month)	Immission value of PM_{10} for the protection against nuisance or significant disadvantage due to dustfall (non-dangerous dust)

Notes on the European Union Air Quality Standards:
[1] Under the new Directive the Member State can apply for an extension until three years after the date of entry into force of the new Directive (i.e. May 2011) in a specific zone. Request is subject to assessment by the Commission. In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (35 days at 75 µg/m^3 for daily PM_{10} limit value, 48 µg/m^3 for annual PM_{10} limit value).
[2] Standard introduced by the new Directive.
[3] The new Directive is introducing additional $PM_{2.5}$ objectives targeting the exposure of the population to fine particles. These objectives are set at the national level and are based on the average exposure indicator (AEI). The average exposure indicator is determined as a 3-year running annual mean $PM_{2.5}$ concentration averaged over the selected monitoring stations in agglomerations and larger urban areas, set in urban background locations to best assess the $PM_{2.5}$ exposure to the general population.
[4] Depending on the value of AEI in 2010, a percentage reduction requirement (0, 10, 15 or 20%) is set in the Directive. If AEI in 2010 is assessed to be over 22 µg/m^3, all appropriate measures need to be taken to achieve 18 µg/m^3 by 2020.

Under European Union law a limit value is legally binding from the date it enters into force subject to any exceedances permitted by the legislation. A target value is to be attained as far as possible by the attainment date and so is less strict than a limit value.

Principles
European legislation on air quality is built on certain principles. The first of these is that the Member States divide their territory into a number of zones and agglomerations. In these zones and agglomerations, the Member States should undertake assessments of air pollution levels using measurements and modelling and other empirical techniques. Where levels are elevated, the Member States should prepare an air quality plan or programme to ensure compliance with the limit value before the date when the limit value formally enters into force. In addition, information on air quality should be disseminated to the public. (Europa, 2010)[89]

9. International Techniques for Controlling Particulate Matter Emissions from Coal Mining

This section summarises the results of research into international techniques for controlling particulate emissions from coal mining. Best practice measures have been identified and the reduction in emissions that is achievable through the application of best practice has been quantified where possible.

9.1 Introduction

The literature review aimed to provide a comprehensive statement of techniques used internationally for the management of particulate matter emissions from coal mining activities.

The review has focused on literature from a range of sources including:

- Government departments/agencies (e.g. legislation, guidelines, handbooks, research)
- Journal papers and articles
- Information published by coal mining companies

The review has focused on literature published in major coal producing countries that are likely to have spent significant resources on development of measures to minimise emissions from coal mining activities. Key countries include:

- Australia
- United States
- Canada
- Germany
- United Kingdom

Information has also been drawn from:

- South Africa
- India
- China
- Russia
- European Union

Best practice has been determined considering the EU[48] and EPA Victoria[46] definitions of best practice, namely:

> *"the best combination of eco-efficient techniques, methods, processes or technology used in an industry sector or activity that demonstrably minimises the environmental impact of a generator of emissions in that industry sector or activity"*
>
> *"best available techniques" means the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole:*

(a) *"techniques" shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned*
(b) *"available techniques" means those developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator*
(c) *"best" means most effective in achieving a high general level of protection of the environment as a whole*

The focus of the literature review has been to identify techniques that are used in the coal mining industry that have been demonstrated to achieve a reduction in emissions of particulate matter.

The starting point of this literature review is the estimation and prioritisation of emission sources. Quantification of emissions of particulate matter from coal mining activities has been conducted, as detailed in Section 7, using emission factors from the NPI Emission Estimation Technique (EET) Manual for Mining[10] and US Environmental Protection Agency's (US EPA) AP-42 emission factors[125]. The NPI emission factors were based on US Environmental Protection Agency AP-42 emission factors that were in print at the time that the NPI EET Manual for Mining was produced and, to a lesser extent, factors developed jointly by the State Pollution Control Commission (SPCC) and the NSW Coal Association in the 1980s[126].

The following general equation is used to calculate the emission rate of an air pollutant using emission factors.

$$E = EF_{i,j} \times A \times \left(1 - \frac{CF_{i,j,k}}{100}\right)$$

Where:

E is the emission rate in units of mass per unit time.
$EF_{i,j}$ is the uncontrolled emission factor for source i and pollutant j in units of mass per unit activity rate.
A is the activity rate.
$CF_{i,j,k}$ is the control factor achieved for source i and pollutant j by applying control k, as a percent.

The terms control factor and control efficiency are used interchangeably in the NPI EET Manual for Mining. However, in other jurisdictions such as in Michigan in the United States, the control efficiency and control factor are defined as the complement of each other. That is CE = (1-CF/100).

For consistency with the NPI, the control factor is calculated as follows:

$$CF_{i,j,k} = \left(\frac{E_{i,j} - E_{i,j,k}}{E_{i,j}}\right) \times 100$$

Where:

$CF_{i,j,k}$ is the control factor achieved for source i and pollutant j by applying control k, as a percent.
$E_{i,j}$ is the uncontrolled emission rate for source i and pollutant j.
$E_{i,j,k}$ is the controlled emission rate achieved for source i and pollutant j by applying control k.

As defined above, the control factor is equivalent to the term Overall Emission Reduction Efficiency (ER) that is used by the US EPA[127]. The general form of the emission equation that is used by the US EPA to estimate emissions is as follows:

$$E = EF \times A \times \left(1 - \frac{ER}{100}\right)$$

Where:

E is the emission rate
EF is the uncontrolled emission factor
A is the activity rate
ER is the overall emission reduction efficiency, as a percent

Whilst the quantification and prioritisation of emissions has been based on the best Australian information there are some potential issues with the NPI EET Manual for Mining, including:

- Some of the emission factors in the NPI derive from older editions of AP-42 that have been subsequently withdrawn.
- The NPI does not provide information on the valid range of the variables (such as moisture and silt content) used in the equations, although defaults are provided. The AP-42 emission factors[125] include a valid range of values for the variables based on the test work that produced the emission factors and the geometric mean of the variables.
- There is no supporting information or guidance for the correct use of the control factors.

The following sections include a comparison of the emission factors from the NPI EET Manual for Mining with the emission factors published in AP-42. Recommendations from the comparison to improve emission estimation using emission factors are as follows:

- Greater reliance should be placed on the current version of AP-42 emission factors in impact assessment and in future development of emissions inventories.
- Testing should be conducted at NSW coal mines using techniques that are equivalent to those used to develop the AP-42 emission factors to evaluate the suitability of the AP-42 emission factors for conditions in NSW. Relevant findings and guidance on the local application of the AP-42 emission factors could be incorporated into a guidance document for estimating emissions from mining activities.

- Where the AP-42 emission factors are reproduced in guidance documents, valid ranges of variables and geometric means that can be used with the AP-42 emission factors should also be reproduced with the emission factors.
- Default emission factors should be avoided. The onus to demonstrate the validity of data should remain with the coal mine. Air quality impact assessments that have been reviewed within this study were found to rarely rely upon local measurements of variables such as surface silt and moisture contents. Such data should be routinely collected and used in emission estimation.

9.2 Haul roads

9.2.1 Overview

Of all sources of particulate matter from coal mining activities in the GMR, wheel generated emissions, which is mainly generated by trucks travelling on unsealed haul roads, has been ranked number 1 in terms of emissions of TSP and PM_{10} and number 2 in terms of emissions of $PM_{2.5}$. Haul roads have been estimated to contribute 52.4% of TSP, 39.1% of PM_{10} and 22.6% of $PM_{2.5}$ emissions from coal mines in the GMR.

Grading of haul roads has been ranked number 13 in terms of emissions of TSP and number 14 in terms of emissions of PM_{10} and $PM_{2.5}$. Grading has been estimated to contribute 0.4% of TSP and 0.3% of PM_{10} and $PM_{2.5}$ emissions from coal mines in the GMR.

The review of international literature relating to the control of particulate matter emissions from wheel action on haul roads identified that an extensive amount of research has been conducted into this issue. The NPI emission estimation equations for unpaved haul roads and graders[10] are reproduced in Table 61 and Table 62. Table 63 and Table 64 show the NPI default emission factor equation variables and range and geometric mean of variables from the AP-42 for haul roads and graders.

Table 61 NPI and AP-42 TSP and PM_{10} emission factor equations for haul roads

Species	NPI[10]	AP-42[128]
TSP	$EF_{TSP} = 2.82 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.5} \times \left(\frac{M}{0.2}\right)^{-0.4}$	$EF_{TSP} = \frac{0.4536}{1.6093} \times 4.9 \times \left(\frac{s}{12}\right)^{0.7} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$
PM_{10}	$EF_{PM10} = 0.733 \times \left(\frac{s}{12}\right)^{0.8} \times \left(\frac{W}{3}\right)^{0.4} \times \left(\frac{M}{0.2}\right)^{-0.3}$	$EF_{PM10} = \frac{0.4536}{1.6093} \times 1.5 \times \left(\frac{s}{12}\right)^{0.9} \times \left(\frac{W \times 1.1023}{3}\right)^{0.45}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor (kg/km) EF_{PM10} is the PM_{10} size specific emission factor (kg/km) *s* is the surface material silt content (%) *W* is the mean vehicle weight in tonnes *M* is the surface material moisture content (%)	Where: EF_{TSP} is the TSP size specific emission factor (kg/km) EF_{PM10} is the PM_{10} size specific emission factor (kg/km) *s* is the surface material silt content (%) *W* is the mean vehicle weight in tonnes 0.4536 is the unit conversion factor kg/lb 1.6093 is the unit conversion factor km/mile 1.1023 is the unit conversion factor tonne/ton

Table 62 NPI and AP-42 TSP and PM_{10} emission factor equations for graders

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 0.0034 \times S^{2.5}$	$EF_{TSP} = 0.0034 \times S^{2.5}$
PM_{10}	$EF_{PM10} = 0.0034 \times S^{2.0}$	$EF_{PM10} = 0.6 \times 0.0056 \times S^{2.0}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor (kg/km) EF_{PM10} is the PM_{10} size specific emission factor (kg/km) *S* is the mean vehicle speed in km/hr	Where: EF_{TSP} is the TSP size specific emission factor (kg/km) EF_{PM10} is the PM_{10} size specific emission factor (kg/km) *S* is the mean vehicle speed in km/hr

Table 63 Emission factor equation variables for haul roads showing NPI default values and range and geometric means of AP-42 variables

Parameter	NPI Defaults[10]	AP-42[125]	
		Range	Geometric mean
Surface material silt content (%)	10	1.2-19.2	4.3
Mean vehicle weight (tonnes)	48	20.9-260	110
Surface material moisture content (%)	2	0.3-20.1	2.4

Table 64 Emission factor equation variable for graders showing NPI default value and range and geometric mean of AP-42 variable

Parameter	NPI Defaults[10]	AP-42[125]	
		Range	Geometric mean
Vehicle speed (km/hr)	-	8.0-19.0	11.4

Figure 45 is a plot showing the sensitivity of the NPI emission estimation equation for PM_{10} to average vehicle weight, surface silt and moisture contents. Also plotted is the AP-42 emission estimation equation. The solid lines in the plot represent the results of the NPI emission estimation equation for the range of silt and moisture contents specified in AP-42, with the dotted lines representing the results of the AP-42 emission estimation equation. The red solid and dotted lines represent the results of the NPI and AP-42 emission estimation equations respectively, for the default conditions defined in the NPI EET Manual for Mining.

The NPI emission estimation equation for unpaved roads is similar to the current AP-42 equation with the exceptions that AP-42 does not include the moisture term and there are differences in the values of the exponents. In effect, the AP-42 emission estimation equation is set at a neutral moisture level of 0.2% relative to the NPI emission estimation equation.

The plot shows that the NPI emission estimation equation produces a higher upper bound set of results when the lower bound moisture content and upper bound surface silt contents are used. The upper bound set of results for the NPI emission estimation equation is between 2.1 and 2.3 times higher than the upper bound result using the AP-42 emission estimation equation. The lower bound results for the AP-42 estimation equation are more than two times higher than the lower bound results for the NPI emission estimation equation. The NPI default moisture level of 2% provides a 50% reduction in particulate matter emissions compared with the AP-42 default moisture level of 0.2%.

The differences are due to:

- The effect of moisture in the NPI emission estimation equation, which causes the NPI emission factor to be higher than the AP-42 emission factor by 1.76 times for a low moisture content and lower than the AP-42 emission factor by a factor of 0.29 for high moisture contents.
- The k factors (after correcting for the difference in units (lb/mile vs kg/km)), which causes the NPI emission factor to be higher than the AP-42 emission factor by 1.73 times.
- Differences in the exponents in the emission estimation equations and the apparent failure of the NPI emission estimation equation to correct from imperial short tons to metric tonnes. Combined these result in the NPI emission estimation equation being lower than the AP-42 emission estimation equation by a factor of 0.77.

Based on the information presented in Figure 45, the NPI emission estimation equations for the default surface silt and moisture contents appear to be low by a factor of 0.66 to 0.71 depending on the vehicle weight.

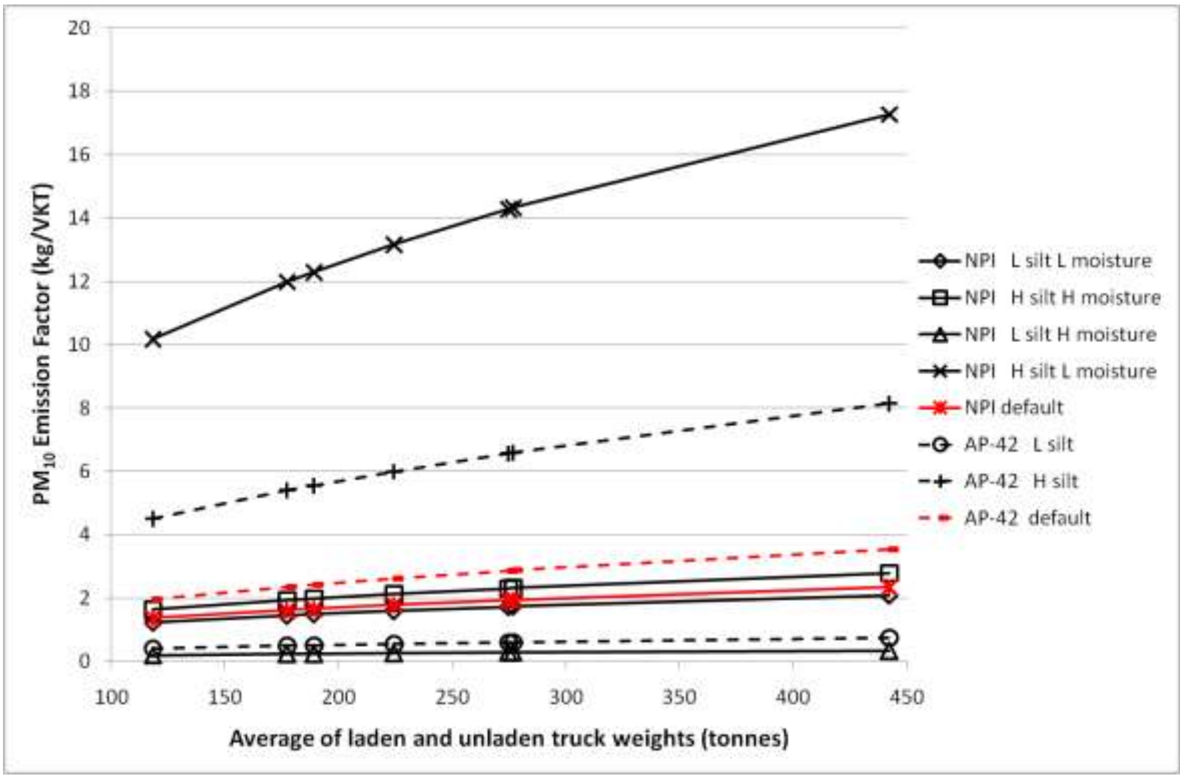

Figure 45 NPI and AP-42 PM_{10} emission factors for haul roads and sensitivity to average vehicle mass, surface silt and moisture contents

The results of the emission estimation equation for grading are shown in Figure 46 for PM_{10}. The NPI and AP-42 emission estimation equations are equivalent. The figure shows the sensitivity of the emission estimation equation to grader speed. AP-42 notes that the valid range of speeds is relatively narrow, from 8 km/hr to 19 km/hr. A doubling in speed results in a four times increase in the emission factor, indicating that the emission factor is very sensitive to speed.

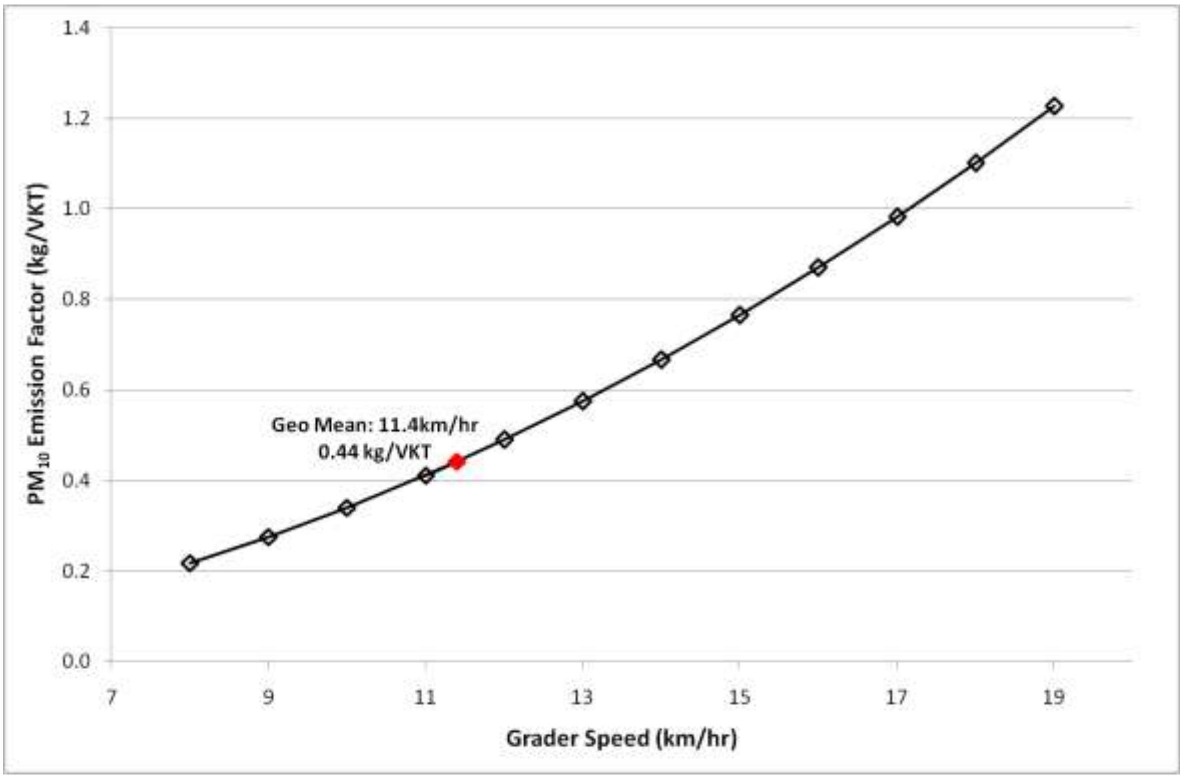

Figure 46 NPI and AP-42 PM_{10} emission factors for graders and sensitivity to average vehicle speed

The amount of wheel generated particulate matter from an unpaved haul road is a function of two factors[129]:

- The erodibility of the wearing course – road design
- The erosivity of the actions to which the wearing course is subjected – road maintenance and management

The first is a property of the design of the haul road whilst the second is affected by how the road is used and managed. It is usually more cost effective to design and plan appropriately to control particulate matter emissions from the onset. Hence, good haul road design is a fundamental component of particulate matter minimisation[130]. In terms of the use and management of the road, there are three methods that have been demonstrated to be effective in controlling emissions of particulate matter from unpaved haul roads[131]:

- Surface treatments
- Surface improvements
- Vehicle restrictions

Vehicle restrictions include limitations placed on the number, weight and speed of vehicles. The emission factors for unpaved roads developed by the US EPA[128] show that traffic volume is more important than vehicle weight. Hence, fewer trips using larger vehicles will cause lower emissions of particulate matter than a greater number of trips with smaller trucks. Hence, transitioning fleets to larger capacity haul trucks may be a viable strategy to reduce emissions of particulate matter. The reduction in emissions associated with fewer trips will more than offset any minor increase in emissions associated with a larger drop height of larger capacity vehicles.

Surface improvements include using materials with a lower silt content to construct haul roads. Typically haul road construction material is sourced onsite, if this material has poor bonding properties or a high proportion of fine material (e.g. silt) the dustiness of the haul road may increase along with the costs of maintaining the road surface. Increasing the amount of large aggregates in the construction material by adding gravel or slag can reduce the dustiness of haul roads and reduce maintenance costs as the road is less susceptible to deterioration.

Surface treatments or suppressants by their nature will require reapplication. However, improving the wearing course will increase the longevity of the surface treatment resulting in the need for fewer applications[132].

9.2.2 Design

The design of a haul road needs to consider a number of elements and one of these is the minimisation of particulate matter emissions. The design factors that are relevant to the minimisation of these emissions are:

- Design of haul road cross section
    - The preparation of a suitable road sub-base. Thompson & Visser[137] recommend a California Bearing Ratio (CBR) of over 80% for the wearing course material to minimise rutting, sinking and overall deterioration of the road. The California Bearing Ratio (CBR) is a test undertaken to compare the bearing capacity of a given soil as a percentage of the bearing capacity of well-graded crushed stone (a high quality crushed stone should have a CBR of 100%).
    - The placement of materials within the cross section of the haul roads so the stiffest material is placed as close to the upper surface as possible[133].
    - The amount of compaction of material within the cross sectional design.
- Road construction materials
    - The composition of the material used for the haul road has a significant impact on the tendency for emissions of particulate matter to occur[134]. Thompson & Visser[137] document an approach to the selection of appropriate wearing course materials and recommend some material selection guidelines. The surface material selected for haul road construction is most frequently gravel or crushed stone. This is mainly due to cost effectiveness of the material and availability[137]. However, the actual cost effectiveness of this material may be poor over the longer term if a large amount of maintenance is required[137].
    - The type of aggregate used dictates the most suitable approaches to control particulate matter emissions[135]. For example, for gravel road surfaces with minimal fines, chemical suppressants cannot compact the surface or form a new surface and therefore do not provide a substantial additional benefit from watering alone.
    - The durability of the material used for the road surface is critical. As part of the compilation of the Guidelines for Mine Haul Road Design in Canada, Tannant & Regensburg[133] surveyed mines in Canada. It was found that 91% of mines reported haul road deterioration was caused by watering, rain and run off. The deterioration of a haul road may lead to increased nuisance issues. However, a

well-designed haul road will resist deterioration and will enable management and maintenance actions to be implemented more readily, improving energy efficiency, driver comfort and emissions of particulate matter as a consequence.

- Road surface
    - Particulate matter emissions are proportional to the silt content of the material used for the road (i.e. lower silt content will result in a lower emission rate of particulate matter).
    - The silt content of the road surface will determine how successful suppressants may be. For example at silt contents greater than 20-25% suppressants are unlikely to be effective[135].

- Haulage road planning and alignment
    - Particulate matter emissions are proportional to VKT (i.e. lower VKT will result in a lower emission rate of particulate matter).
    - The amount of traffic and speed of vehicles on unpaved haul roads has been shown to be an effective mitigation technique[136].
    - Haul roads that are redundant should be shut down and revegetated as soon as practical.
    - Conveyors can be used in place of haul roads, particularly on high traffic routes that are relatively static during the mine life.

A well planned and designed haul road will allow for easier management and maintenance, increased productivity (becoming more cost effective) and minimise emissions of particulate matter.

9.2.3 Maintenance and management

The objective of road maintenance is to restore the road to (or as near to as possible) the original design, whilst management of the road is aimed at effectively controlling particulate matter through a range of surface improvement and treatments.

Thomson & Visser[137] introduce the concept of structured management maintenance systems (MMS) for mine haul roads. The ideal maintenance strategy for mine haul roads minimises total road user costs as the mine must operate and maintain the haul route[137]. The term user cost encompasses road maintenance costs and vehicle operating costs[137]. The maintenance program selected should aim to optimise both of these costs.

The issue of inadequate maintenance has been observed to be a problem in Indian mines, where for example, sprinkler systems were shown to be installed but not working properly[138]. An audit and compliance regime is important to ensure that available infrastructure is maintained to ensure that emissions of particulate matter are minimised in practice.

9.2.4 Surface improvements

The obvious improvement in this area is the paving of a previously unpaved area[131]. This would provide the most effective control method for the emissions of particulate matter[129]. However, this solution has a high financial cost and therefore may not be suitable for many coal mining activities due to their size and nature. A paved haul road would still require ongoing maintenance and would need to be swept regularly to remove surface silt.

An alternative to paving is the addition of lower silting materials to the surface of a haul road[131]. Lower silting materials include gravel, aggregate and the resurfacing of haul roads as part of haul road maintenance. The use of fly ash may be appropriate in coal mines that are located within close proximity to a power station. Fly ash can be used as an economical cementing agent to improve the construction material properties[133]. The exact effectiveness of using this product is determined by the proportion of calcium oxide in the fly ash. If there is a high percentage of calcium oxide then the product will be self cementing[133]. The use of this product has been done on a trial basis at a mine in Canada[133].

The gradation of materials can be used to restore the surface layer of the haul road by removing ruts, potholes and smoothing the surface layer.

9.2.5 Surface treatments

The choice of treatment (water or suppressants) will be dependent on a number of factors such as cost, road surface type and availability.

9.2.5.1 Watering

Watering of haul roads is a standard practice in the majority of coal producing countries as it is an effective method to control emissions of particulate matter. However, where water supply is limited or costly, watering may not be an adequate or desirable solution. In addition, watering of roads can result in a slippery surface and in some cases the addition of water can lead to the production of increased fine particles[139]. The loss of fine particulates from the surface through run off and wind erosion can cause an increase in surface roughness and lead to the formation of potholes and a destruction of the haul road surface[139].

Water carts are the most common technique used for the application of water to haul roads. New water truck technology includes the following:

- Water sprayed as a function of ground speed versus motor speed for reduced water wastage
- Finer mists from spray bars
- Closer proximity of spray heads to the ground surface
- Adding surfactants to improve water performance
- GPS tracking of spray areas[139]

Watering can be applied using a variety of methods and is not limited to a traditional water cart. The type of spraying system technology selected depends on the source of particulate matter emissions and local conditions. There is a range of different spray types and nozzles utilised to optimise the beneficial effects of watering[140].

An ultrasonic dry fogging system can apply watering using a compression system, with a water droplet size of 0.3-0.5 mm. For each volume unit the number of droplets will increase as droplet size decreases. The smaller the droplet size the larger surface area affinity for particles increases. This system can thereby agglomerate and suppress emissions of particulate matter at the source[141].

The NPI handbook provides two control factors for watering based on the water application rate:

- Level 1 watering (2 litres/m²/hr): 50%
- Level 2 watering (>2 litres/m²/hr): 75%

9.2.5.2 Chemical suppressants

Chemical suppressants can either compact the surface or form a new surface. The type of suppressant will depend on the road material that needs to be controlled and the rate and characteristics of the traffic[135]. It is important to prepare the road surface in a suitable manner to enhance the effectiveness of the specific suppressant method[142]. For example, some suppressants require a dry surface for application, whilst others require a surface that is not compacted.

The control efficiencies of suppressants depend on:

- Dilution rate of the mixture
- Application rate
- Time between applications
- Size, speed and volume of traffic
- Meteorological conditions
- Characteristics of the road

The ARRB Group (formerly the Australian Road Research Board) undertook a literature review of over 110 reports documenting suppressants[129]. The aim of the report was to document the effectiveness of a range of suppressants using the results from 30 of these reports in conjunction with survey answers from Local Authorities in Australia. This document may be used as a reference guide to the range of suppressants available as it contains supplier data and economic analyses. The report included two figures in the form of flow charts that show decision makers how to select an appropriate control method and how to select a suitable chemical suppressant.

Suppliers of suppressants to the Australian market have supplied information about the benefits of their products for controlling emissions from haul roads. Dust deposition observations were conducted on a typical open cut coal mine site to determine the effectiveness of chemical suppressants on coal mine haul roads. Under identical operational conditions, dust deposition was 37% less following application of the suppressant compared with the application of water (L. Xavier, Vital Chemical Pty Ltd, 25 June 2010, pers. comm.).

Operating costs were also compared for water application and suppressant solution application by Vital Chemical. It was noted that lower water tanker operational hours were required for suppressant solution application than were required for application of water only. The lower operational costs balanced the cost of suppressant chemical, resulting in reduced haul road emissions with a very small increase in overall operational cost (L. Xavier, Vital Chemical Pty Ltd, 25 June 2010, pers. comm.).

An Australian study by RST – Dust Earth and Water Solutions (P. Heinburger, RST – Dust Earth and Water Solutions, pers. comm. 5 July 2010) of typical haul road management operations concluded that use of suppressant solution achieved the following compared with use of water only:

- Reduction in water applied per square metre: 57%
- Time between watering: 166.7%

However, variable operating conditions at open cut mine sites may warrant different strategies. The most cost effective management strategy may require a mix of suppressant application combined with water application. Water application may be used following previous application of suppressant solution to reactivate the previously applied suppressant chemical. A typical application rate for both options is likely to be one litre per square metre for each pass of haul road surface.

The proportion of suppressant chemical in water varies with product supplier recommendations, but a typical solution could comprise 5% chemical. Cost of suppressant has been quoted as $0.14 per square metre for an average program. Frequency of application also varies with different products and is dependent on traffic frequency. Application has been quoted as low as fortnightly for the first two months and then monthly for the next four to six months (L. Xavier, Vital Chemical Pty Ltd, 25 June 2010, pers. comm.).

The US Department of Agriculture has published a document titled *Dust Palliative and Selection Application Guide*[143]. The document contains details of the attributes, application rates and origin of a range of suppressants. It is important to acknowledge that cost effectiveness is an important issue, but also the availability of materials with which to derive a chemical suppressant is particularly critical. This document also has a flow chart detailing the decision making process for selecting a cost effective suppressant.

The following categories of suppressants are identified in the literature[134]:

- Hygroscopic salts
- Lignosulphonates
- Petroleum (or sulphonated petroleum) resins
- Tar- and bitumen-emulsion products
- Polymer emulsions

Table 65 shows a summary of the above chemical suppressants by climate, wearing course and traffic limitations, as taken from Thompson & Visser[134].

Thompson & Visser[134] found that for spray-on techniques the control efficiencies observed were in the 40 to 60% range and decrease rapidly over time whereas for the mix-in techniques this range was higher at 60 to 70% for the first 7 weeks. The highest control efficiency measured was 92% for tar/bitumen emulsion products, immediately following application.

The work of Thompson & Visser[134] highlights that suppressants are not the only solution to manage particulate matter emissions if the course wearing material is the cause of particulate matter emissions.

Table 65 A summary of usability issues for each suppressant class

	Hygroscopic salts	Lignosulphonates	Petroleum-and-tar bitumen based products	Others (sulponated petroleum, Ionic products, polymers and enzymes)
Climatic limitations	Salts lose effectiveness in continual dry periods with low relative humidity. Selection dependant on relative humidity and potential to water road surface.	Retains effectiveness during long dry periods with low humidity.	Generally effective, regardless of climate but will pothole (small diameter) in wet weather where fines content of wearing course is high.	Generally effective, regardless of climate.
Wearing course material limitations	Recommended for use with moderate surface fines (max 10-20%<0.075 mm). Not suitable for low fines materials or high shrinkage product/PI[1] low CBR[2] or slippery materials.	Recommended for use where high (<30%< 0.075 mm) fines exist in a dense graded travel with no loose material.	Performs best with low fines content (<10%<0.075 mm). Use low viscosity products on dense fine grained material, more viscous products on looser, open-textured material.	PI range 8-35 Fines limit 15-55% <0.075 mm. Minimum density ratio 98%. Performance may be dependent on clay mineralogy (enzymes).
Treatment maintenance and self-repair capability	Reblade under moist conditions. $CaCl_2$ is more amenable to spray-on application. Low shrinkage product materials may shear and corrugate with high speed trucks. Shear can self-repair.	Best applied as an initial mix-in and quality of construction important. Low shrinkage product materials may shear and corrugate with high speed trucks. Tendency to shear or form 'biscuit' layer in dry weather – not self-repairing.	Requires sound base and attention to compaction moisture content. Slow speed, tight radius turning will cause shearing – not self-repairing, but amenable to spot repairs.	Mix-in application-sensitive to construction quality. Difficult to maintain – rework. Generally no problem once cured.
Tendency to leach out or accumulate	Leaches down or out of pavement. Repeated applications accumulate.	Leaches in rain if not sufficiently cured. Gradually oxidize and leach out. Repeated applications accumulate.	Does not leach Repeated applications accumulate.	Efficiency depends on the cation exchange capacity of the host material. Repeated applications accumulate.
Comments	A high fines content may become slippery when wet. Corrosion problems may result.	Generally ineffective if wearing course contains little fine material or there is excessive loose gravel on the road.	Long lasting – more effective in dry climates. May cause layering after several spray-on re-treatments especially where fines content is >15%.	Generally ineffective if material is low in fines content or where loose gravel exists on surface. Curing period required.
Notes [1] Plasticity index [2] California bearing ratio (%)				

9.2.6 Summary

Wheel generated particulate matter associated with trucks travelling on unpaved haul roads is a major source of particulate matter emissions and so haul roads require a significant amount of attention in their design, maintenance and management to minimise emissions. Best practice haul road design should include:

- Minimisation of the distance travelled by taking the most direct route to the destination
- Road safety (minimise steepness of ramps to less than 8%, eliminate sweeping intersections and avoid potential for equipment interactions)
- Optimise surface drainage, particularly at intersections
- Optimise base materials to reduce silt content and increase the retention of larger aggregates, particularly at intersections
- Restrict vehicle speeds on all roads to 40 km/hr or less
- Use larger trucks to minimise number of trips

Best practice haul road maintenance should include:

- Scheduled grading and gravelling of heavy traffic areas such as intersections
- Watering, application of chemical suppressants or paving of light traffic areas, such as the CHPP, underground mine portals and workshop and administrative areas
- Regular resurfacing of high traffic areas such as intersections to reduce silt build up
- Regular maintenance of drainage design features at intersections (cross fall or camber)

Best practice haul road management should include:

- Diligent monitoring and application of controls as surface dries out to avoid excessive emissions. Real-time triggers should be used to identify problem areas for targeted application of controls.
- Regular watering of haul roads and at the direction of haul truck operators or the Open Cut Examiner (OCE)
- Do not allow haul roads to become saturated as this will increase emissions once it dries out
- Regular grading and maintenance of intersections

Table 66 summarises the control measures used for haul roads.

Alternatives to hauling using trucks on unpaved roads should also be considered. The use of conveyors to replace haul routes is one such approach.

With respect to grading emissions, there is very little information available in the literature that would provide a basis to define best practice. However, the NPI handbook for mining[10] recommends a control factor of 50% for scrapers working on topsoil where the soil is naturally or artificially moist. A similar reduction would be expected to be achieved for graders. The emission factors for graders suggest that a 75% reduction could be achieved by reducing the speed of the grader from 16 km/hr to 8 km/hr.

Table 66 Best practice control measures to reduce particulate matter emissions from haul roads

Control Measure		Effectiveness
Vehicle Restrictions	Reduction from 75 km/hr to 50 km/hr	40-75%[129]
	Reduction from 65 km/hr to 30 km/hr	50-85%[129]
	Grader speed reduction from 16 km/hr to 8 km/hr	75%[a]
Surface Improvements	Pave the surface	>90%[131]
	Low silt aggregate	30%[144]
	Oil and double chip surface	80%[144]
Surface Treatments	Watering (standard procedure)	10-74%[131]
	Watering Level 1 (2 l/m²/hr)	50%[10]
	Watering Level 2 (>2 l/m²/hr)	75%[10]
	Watering grader routes	50%[10]
	Watering twice a day for industrial unpaved road	55%[131]
	Suppressants	84%[131]
	Hygroscopic salts	Av. 45% over 14 days[134]
		82% within 2 weeks[134]
	Lignosulphonates	66-70% over 23 days[134]
	Polymer emulsions	70% over 58 days[134]
	Tar and bitumen emulsions	70% over 20 days[134]
Other	Use larger vehicles rather than smaller vehicles to minimise number of trips	90t to 220t: 40%[a] 140t to 220t: 20%[a] 140t to 360t: 45%[a]
	Use conveyors in place of haul roads	>95%[a]

Note:
[a] Reductions achieved by the use of larger vehicles, conveyors and lower grader speeds have been calculated from the emission factors for these activities

9.3 Wind erosion

9.3.1 Overview

Of all sources of particulate matter from coal mining activities in the GMR, wind erosion of overburden, was ranked number 2 in terms of emissions of TSP and PM_{10} and number 1 in terms of emissions of $PM_{2.5}$. Wind erosion of exposed areas and coal stockpiles also ranked highly. Wind erosion has been estimated to contribute 22.3% of TSP, 32.3% of PM_{10} and 37.7% of $PM_{2.5}$ emissions from coal mines in the GMR. A summary of rankings and proportional contributions to GMR emissions of particulate matter is included in Table 67.

Table 67 Contribution of various wind erosion sources to GMR emissions of TSP, PM_{10} and $PM_{2.5}$

Wind erosion	TSP			PM_{10}			$PM_{2.5}$		
	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)
Overburden	2	28,906	18.6	2	16,246	27.3	1	3,272	31.8
Exposed areas	6	3,732	2.4	7	1,866	3.1	5	373	3.6
Coal	10	2,453	1.6	8	1,227	2.1	7	247	2.4

The NPI and AP-42 emission estimation equations for TSP and PM_{10} for wind erosion from exposed areas and overburden stockpiles are reproduced Table 68. The table shows that emissions from erodible surfaces are dependent on surface area.

Table 68 NPI and AP-42 TSP and PM_{10} emission factor equations for wind erosion of exposed areas including overburden stockpiles

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 0.4$	$EF_{TSP} = 0.85$
PM_{10}	$EF_{PM10} = 0.2$	$EF_{PM10} = 0.5 \times 0.85$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/ha/hr EF_{PM10} is the PM_{10} size specific emission factor in kg/ha/hr	Where: EF_{TSP} is the TSP size specific emission factor in Mg/ha/yr EF_{PM10} is the PM_{10} size specific emission factor in Mg/ha/yr. The factor of 0.5 has been taken from AP-42[145]

The AP-42 emission factor for TSP is equivalent to 0.1 kg/ha/hr. This is 25% of the NPI emission factor for TSP.

The NPI and AP-42 emission estimation equations for TSP and PM_{10} for wind erosion from active coal stockpiles are reproduced Table 69 and show that emissions from erodible surfaces are dependent on surface area, wind conditions and other factors.

Table 69 NPI and AP-42 TSP and PM_{10} emission factor equations for wind erosion of active coal stockpiles

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 1.9 \times \left(\frac{s}{1.5}\right) \times 365 \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right)$	$EF_{TSP} = 1.8 \times u$
PM_{10}	$EF_{PM10} = 0.5 \times 1.9 \times \left(\frac{s}{1.5}\right) \times 365 \times \left(\frac{365-p}{235}\right) \times \left(\frac{f}{15}\right)$	$EF_{PM10} = 0.5 \times 1.8 \times u$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/ha/yr. Default of 0.4 kg/ha/hr is recommended. EF_{PM10} is the PM_{10} size specific emission factor in kg/ha/yr. Default of 0.2 kg/ha/hr is recommended. *s* is the silt content (%) *p* is the number of days when rainfall is greater than 0.25mm *f* is the percentage of the time that the wind speed is greater than 5.4 m/s at the mean height of the stockpile	Where: EF_{TSP} is the TSP size specific emission factor in kg/ha/hr EF_{PM10} is the PM_{10} size specific emission factor in kg/ha/hr. The factor of 0.5 has been taken from AP-42[145] *u* is the wind speed (m/s)

Figure 47 is a plot showing the NPI default emission factor and AP-42 emission estimation equation for PM_{10} for active coal stockpiles showing sensitivity to the wind speed. Figure 48 shows the NPI emission factor equation for PM_{10} for active stockpiles. The plots show the following:

- The NPI default emission factor for wind erosion is between 2 and 22% of the AP-42 emission factors for wind erosion of active storage piles.
- The NPI default emission factor for wind erosion corresponds to the NPI emission factor equation with values for silt content of 15% and frequency of winds greater than 5.4 m/s of between 5-10%.
- No account is taken for the fact that no emissions will occur at surface wind speeds that are less than the threshold friction velocity of the coal.

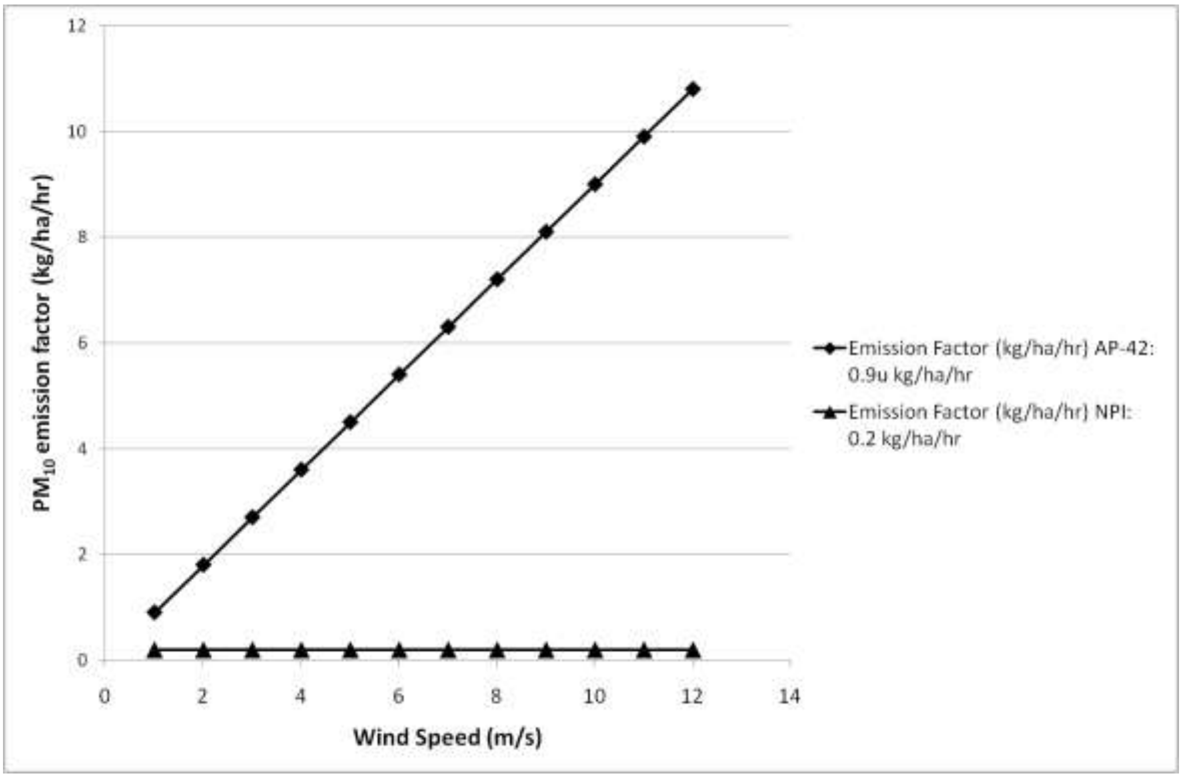

Figure 47 NPI default emission factor and AP-42 emission factor equation for PM_{10} from wind erosion of active coal stockpiles showing sensitivity to wind speed

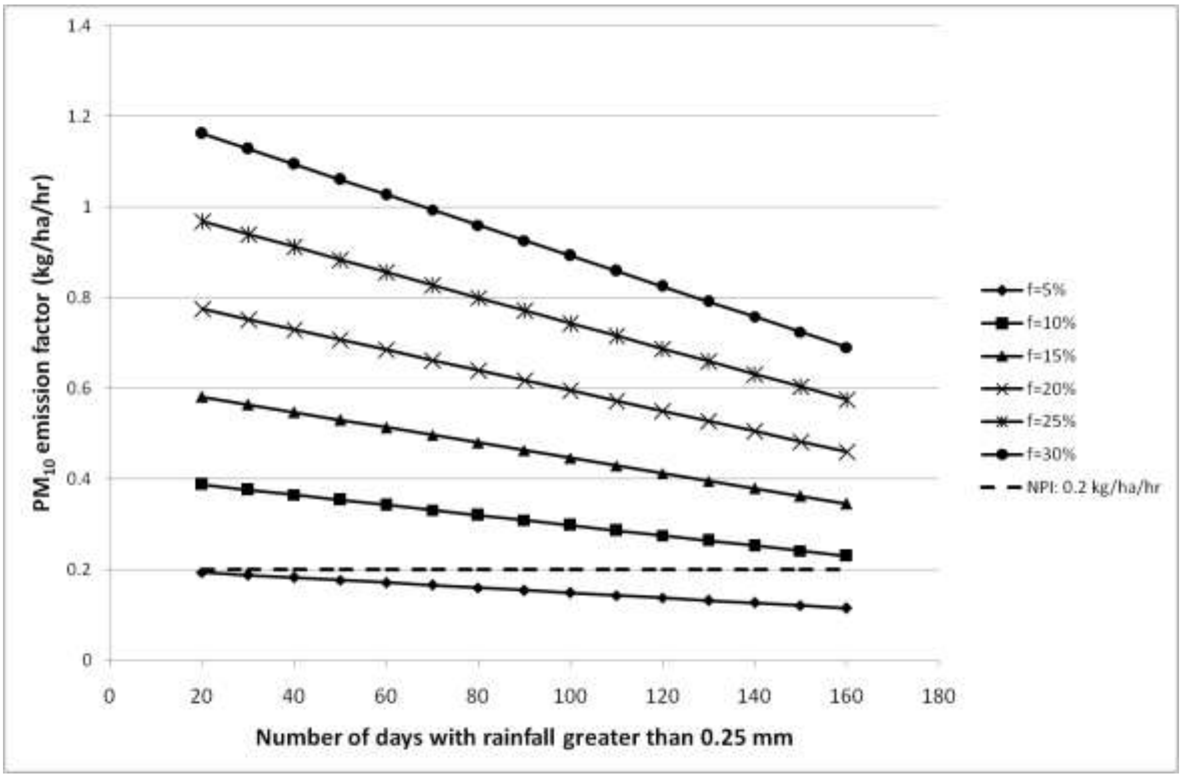

Figure 48 NPI emission factor equation for PM_{10} from wind erosion of active coal stockpiles and NPI default emission factor

The wind erosion of exposed areas can cause significant emissions of particulate matter. Due to the nature of coal mining activities, the large areas of erodible material may need to be exposed to the wind at a given time providing a substantial challenge for mitigation, particularly during strong wind conditions.

Lift-off of particulate matter caused by wind erosion can develop in three stages as the surface wind speed increases:

1. Saltation: is the term adopted for the initial stage when particles begin to move on the surface prior to becoming airborne
2. Minor lift-off: refers to the stage where very fine particles become airborne
3. Major lift-off: refers to the stage where relatively large quantities of variable size particles become airborne

The surface wind speeds that produce these stages of wind erosion depend on the nature of the erodible material. Materials that contain minimal amounts of finer particles or that have a large proportion of larger particles will tend to be more resistant to major lift-off as are materials that form a surface crust, whereas finer materials are characterised by relatively low surface wind speed thresholds for saltation, minor and major lift-off.

The threshold friction velocity is defined as the point at which wind erosion is initiated. The threshold friction velocity depends on the size distribution of surface particles, such that the larger the particles, the lower the potential for emissions. If the wind speed near the surface of the erodible materials is less than the threshold friction velocity, particulate emissions will not occur. If the wind speed is greater than the threshold friction velocity particulate emissions will occur. Threshold friction velocities for various materials[145] are reproduced in Table 70 along with the corresponding wind speed at 10 metres.

Table 70 Threshold friction velocity for various materials

Material	Threshold friction velocity (m/s)	Wind speed at 10 metres corresponding to threshold friction velocity (m/s)	Roughness height (cm)
Overburden[a]	1.02	20.7	0.3
Scoria (roadbed material)[a]	1.33	27.0	0.3
Ground coal (surrounding coal pile)[a]	0.55	15.8	0.01
Uncrusted coal pile[a]	1.12	22.7	0.3
Scraper tracks on coal pile[a,b]	0.62	15.1	0.06
Fine coal dust on concrete pad[c]	0.54	11.5	0.2

Note
[a] Western surface coal mine (US)
[b] Lightly crusted
[c] Eastern power plant (US)

In most circumstances, the 1-hour average wind speed at 10 metres above the ground rarely exceeds the wind speed that corresponds to the threshold friction velocity shown in Table 70. However, wind gusts can quickly deplete a substantial portion of the erosion potential. The AP-42 Industrial Wind Erosion[145] recommends that emissions should be related to the gusts of highest magnitude. Emissions associated with wind erosion are also dependent on the frequency of disturbance of the surface. Disturbance leads to a replenishment of erodible materials at the surface that is available to be entrained in the wind.

The AP-42 Western Surface Coal Mining[125] recommends using the procedure contained in AP-42 Industrial Wind Erosion[145] to estimate emissions on short timescales (e.g. the worst case day). The procedure can be applied to a range of materials including those identified in Table 70 that are subject to disturbance. This procedure is not routinely used to quantify emissions from coal mines in Australia.

The following subsections deal separately with measures to control emissions of particulate matter due to wind erosion of exposed areas and stockpiles. The reason for this separation is that stockpiles tend to be more exposed to the ambient wind due to their height and shape and stockpiles are continuously active meaning that extra attention needs to be paid to stockpiles to minimise emissions. Notwithstanding this, the key techniques for minimising emissions of particulate matter from stockpiles and exposed areas are[131]:

- Stabilise the erodible surface (e.g. by increasing the moisture content of the aggregate material being stored)
- Shield the erodible surface from the prevailing wind

9.3.2 Exposed areas and overburden emplacements

The two fundamental drivers of particulate matter emissions caused by wind erosion are the area exposed to wind erosion and the strength of the wind. The available control measures aim to minimise the influence of one or both of these factors. To mitigate emissions of particulate matter due to wind erosion of open exposed areas the following techniques are recommended in the literature including:[131, 153, 10, 146]

- Minimise pre-strip areas as far as is practicable
- Minimise out-of-pit dumping and maximise in-pit dumping to ensure that overburden dumps have shielding from the prevailing wind
- Paving – usually feasible for small areas in and around workshops
- Fencing, bunding or shelterbelts to reduce ambient wind speeds
- Adding gravel to the surface to reduce surface fines content and to reduce the surface wind speed
- Spillage clean-up
- Watering
- Chemical suppressants
- Revegetation – use of vegetation as an interim measure to minimise emissions of particulate matter from areas that may be exposed for extended period of time
- Rehabilitation – use of vegetation and land-contouring to produce the final post-mining land-form

Avoidance of particulate matter emissions from exposed areas can be achieved by minimising areas exposed to the wind through progressive, but minimal, pre-stripping prior to mining and accelerated rehabilitation of mining areas once mining is complete.

Mobile tankers can be used to successfully reduce emissions from accessible exposed site areas. These essentially un-trafficked areas can be sprayed with water containing suppressant chemical to achieve a reduction in emissions lasting several weeks before the need to respray the surface.

One of the most effective control measures for exposed areas is the revegetation of exposed soil or the rehabilitation of land once mining is complete. Rehabilitation and revegetation are widely used in Australia and internationally with varying degrees of success to control emissions of particulate matter from exposed areas and to return mined areas to a suitable landscape with minimal erosion potential[147]. Rehabilitation is achieved by firstly surface contouring the mined landform and secondly by restoring the vegetation[147]. By revegetating areas of land progressively as the mine develops the act of reclamation can be gradual and reduce emissions of particulate matter at the same time. Reclamation is required in the USA under the *Surface Mine Control and Reclamation Act of 1977*[148] and since this time the practice has evolved rapidly and is very successful in managing fugitive emissions of particulate matter from wind erosion.

Due to the long term operational aspects of open cut coal mining, there can be an extended period before overburden emplacements can be the subject of final site rehabilitation. It is therefore appropriate to consider the use of interim vegetation of overburden emplacements. Hydraulic mulch seeding is a broad-scale planting process that utilises a slurry of seed and mulch to commence revegetation. It is a technique that has been used successfully to quickly establish vegetative cover at mine sites. Similarly, aerial seeding can be used to establish vegetative cover over broad and otherwise inaccessible areas at mine sites. Aerial seeding trials have been timed to take place before forecast rain periods. The method has been demonstrated to be cost effective in New South Wales with the cost of aerial services to conduct the seeding about one third of the cost of the seed and fertiliser.

The development of a green belt area using trees or shrubbery as a natural barrier to emissions of particulate matter[137] and winds have been used in some countries. A shelter-belt attenuation model has been developed to allow for the performance of such a measure to be optimised[137]. Maiti and Banerjee[141] reported that the use of plants in the Jharia Coalfields in Eastern India can be effective, acting as filter to emissions of particulate matter.

Table 71 summarises the control measures used for exposed areas and overburden emplacements.

Table 71 Best practice control measures to reduce particulate matter emissions from exposed areas and overburden emplacements

Control Measure		Effectiveness
Avoidance	Minimise pre-strip. EMP should specify a benchmark for optimal performance and report annually against benchmark.	100% per m^2 of pre-strip avoided
Surface stabilisation	Watering	50%[144]
	Chemical suppressants	70%[144] 84%[149]
	Paving and cleaning	>95%[144]
	Apply gravel to stabilise disturbed open areas	84%[149]
	Rehabilitation. EMP should specify a rehabilitation goal and report annually against progress to meeting goal.	99%[10]
Wind speed reduction	Fencing, bunding, shelterbelts or in-pit dump. Height should be greater than the height of the erodible surface	30%[144] 70-80%[150]
	Vegetative ground cover	70%[144]

Best practice measures to control emissions of particulate matter from exposed areas include:

- Minimise pre-strip to a maximum of one block ahead
- Maximise rehabilitation works
- If exposed area is a potential source of particulate matter emissions and is likely to be exposed for more than 3-month, revegetation should take place
- Strategic use of watering, suppressants and hydraulic mulch seeding to minimise emissions of particulate matter depending on circumstances
- Pave areas where practical e.g. around offices, carparks, maintenance and storage areas

9.3.3 Coal stockpiles

Coal stockpiled on the ROM pad and on product stockpiles provides an erodible surface for the wind generation of particulate matter emissions. In addition to stockpile area and height, emissions generated by wind erosion are also dependent on the frequency of disturbance of the erodible surface. Over time the surface of an undisturbed stockpile will become depleted in erodible material and emissions of particulate matter will reduce. However, the nature of ROM and product coal stockpiles is that they are frequently disturbed, causing fresh surface material to be exposed restoring the erosion potential[151].

There are several common stockpile shapes and this and the stockpile height can have an important effect on the surface area that is predominantly exposed to wind erosion[152]. Stockpile shape and orientation can be optimised at the site design stage to minimise the area of the stockpile that is directly exposed to strong winds and to take advantage of the sheltering effect of other stockpiles, nearby terrain or vegetation[130].

For existing stockpiles, the control measures identified in the literature to minimise stockpile emissions include:[131,153,146,10,130,154]

- Fencing, bunding or shelterbelts to reduce ambient wind speeds
- Watering to minimise lift-off with automatic control through continuous cycling and increased application based on meteorological conditions
- Chemical suppressants to bind loose fine surface material in response to adverse weather conditions
- Minimise residence time of coal in stockpiles
- Spillage clean-up
- Surface covering
- Bypassing stockpiles to load directly into ROM bin or onto train

Structures can be used to reduce emissions of particulate matter, such as earth walls (berms) or fences[130]. Berms can act as a wind break by preventing the erosive and drying effects of the wind[130]. Berms can also reduce the amount of water and use of suppressants making it a cost effective option in many cases[130]. Billman and Arya[155] found that a 50% porous windbreak of equal height to the pile height and equal length to the pile length at the base, located one pile height from the base of both piles was found to be quite effective in reducing wind speeds over much of the pile. Zimmer[156] conducted field studies of the effectiveness of wind screens and determined that the most effective screens for reducing the wind speed had the following dimensions relative to the height of the stockpile:

- Height: 1.25 times the height of the stockpile
- Width: 1.5 times the height of the stockpile
- Distance upwind: 2.0 times the height of the stockpile

Chemical suppressants can be applied to coal stockpiles to reduce the effects of wind erosion by binding the surface into a crust. Spraying of suppressants onto stockpiles is normally carried out by truck to target application to problem areas. There are number of local and international companies that sell suppressants into the Australian market.

Shielding, wind fences, chemical additive controls or intensively monitored water spray systems can reduce emissions of particulate matter. Bohn[144] report a control efficiency of up to 30% for vegetative wind breaks. Carnes[157] report values of up to 80% for wind screens or fences. Stunder[158] concluded from wind tunnel studies that efficiencies of 15-60% could be expected, depending on stockpile shape, windbreak porosity, length and height. A 50% porosity windbreak located three stockpile heights upstream was considered optimal. Windbreaks downwind do not provide any reduction in particulate matter transport, although trees downwind may help to knock out particulate matter.

Faveri[159] in similar studies confirmed wind speed reductions as the key advantage of windbreaks and showed that chemical additives used in combination with windbreaks of optimal size could achieve efficiencies of 85% for up to 10 days for moderate to high wind speeds. The applicability of these laboratory-measured efficiencies to a coal surface kept moist is unknown as the moisture will increase threshold velocities and reduce emission rates without windbreaks.

Stockpile profile management should be further investigated. A pointed apex or conical form will tend to accelerate wind flow near regions of high curvature and generate vortices in strong winds which will result in increased emissions of particulate matter. A smooth whaleback profile is preferable. Orienting stockpiles so that the smallest cross-sectional area is exposed to the high frequency of strong winds will minimise surface drying and wind erosion. Martin and Drehmel[160] report a control efficiency of up to 60% for pile shaping and orientation.

Wind speed increases with height from ground, so imposing limits on stockpile height will reduce the velocity of wind over the surface and hence the entrainment of particulate matter. Bohn[144] reports a control efficiency of up to 30% by reduction of pile height.

For storage pile wind erosion, the estimated control efficiency for water sprays is reported at 50%[163] to 80%[144]. Modern automated sprays may be capable of better performance than this.

Chemical wetting agents are reported to provide a control efficiency of 80-99%[161], 85%[162] and 90%[163]. A surface crusting agent is reported to provide a control efficiency of 95%[164] to approximately 99%[144].

Table 72 summarises the control measures used for coal stockpiles.

Table 72 Best practice control measures to reduce particulate matter emissions from coal stockpiles

Control Measure		Effectiveness
Avoidance	Bypassing stockpiles	100% reduction in wind erosion for coal bypassing stockpiles
Surface stabilisation	Water spray	50%[163]
	Chemical wetting agents	80-99%[165] 85%[162] 90%[163]
	Surface crusting agent	95%[164]
	Carry over wetting from load in	80%[164]
Enclosure	Silo with bag house	100%[144] 95-99%[163] 99%[166]
	Cover storage pile with a tarp during high winds	99%[a]
Wind speed reduction	Vegetative wind breaks	30%[144]
	Reduced pile height	30%[144]
	Wind screens/wind fences	>80%[157] 75-80%[150]
	Pile shaping/orientation	<60%[160]
	Erect 3-sided enclosure around storage piles	75%[167]

Note
[a] Estimated based on the effectiveness of chemical surface treatments

Best practice measures to control emissions of particulate matter from coal stockpiles include:

- Shaping and orientation to minimise emissions of particulate matter
- Stockpile watering on continuous cycle with modification of cycle depending on prevailing weather conditions to allow greater or lesser watering intensity

9.4 Bulldozing

Of all sources of particulate matter from coal mining activities in the GMR, bulldozing was ranked number 3 in terms of emissions of TSP and PM_{10} and number 4 in terms of emissions of $PM_{2.5}$. Bulldozing has been estimated to contribute 9.1% of TSP, 8.3% of PM_{10} and 8.6% of $PM_{2.5}$ emissions from coal mines in the GMR.

In open-cut coal mines, dozers are used for various purposes including:

- Smoothing and contouring overburden stockpiles
- General earthworks
- Managing and forming coal storage piles
- Assisting in reclaiming coal from stockpiles

At underground mines, bulldozers may be used to manage overburden stockpiles and to assist in reclaiming coal from stockpiles.

Particulate matter emissions occur as a result of the bulldozer movement and the effect of the tracks finely grinding the soil or coal. Emissions of particulate matter are enhanced by the airflow generated by the bulldozer's cooling fans and diesel exhaust and if the bulldozer repeatedly traverses the same ground.

The bulldozing emission estimation equations for PM_{10} emissions from bulldozing coal and overburden that are contained in the NPI[10] and AP-42[125] are reproduced Table 73 and Table 74. The TSP equations are equivalent. The PM_{10} equations are also equivalent although there is a minor difference in the way the PM_{10} equations are expressed.

Table 73 NPI and AP-42 TSP and PM_{10} emission factor equations for bulldozing coal

Species	NPI	AP-42
TSP	$EF_{TSP} = 35.6 \times s^{1.2} \times M^{-1.4}$	$EF_{TSP} = 35.6 \times s^{1.2} \times M^{-1.4}$
PM_{10}	$EF_{PM10} = 6.33 \times s^{1.5} \times M^{-1.4}$	$EF_{PM10} = 0.75 \times 8.44 \times s^{1.5} \times M^{-1.4}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/hr EF_{PM10} is the PM_{10} size specific emission factor in kg/hr *s* is the silt content (%) *M* is the surface material moisture content (%)	Where: EF_{TSP} is the TSP size specific emission factor in kg/hr EF_{PM10} is the PM_{10} size specific emission factor in kg/hr *s* is the silt content (%) *M* is the surface material moisture content (%)

Table 74 NPI and AP-42 TSP and PM_{10} emission factor equations for bulldozing overburden

Species	NPI	AP-42
TSP	$EF_{TSP} = 2.6 \times s^{1.2} \times M^{-1.3}$	$EF_{TSP} = 2.6 \times s^{1.2} \times M^{-1.3}$
PM_{10}	$EF_{PM10} = 0.34 \times s^{1.5} \times M^{-1.4}$	$EF_{PM10} = 0.75 \times 0.45 \times s^{1.5} \times M^{-1.4}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/hr EF_{PM10} is the PM_{10} size specific emission factor in kg/hr *s* is the silt content (%) *M* is the surface material moisture content (%)	Where: EF_{TSP} is the TSP size specific emission factor in kg/hr EF_{PM10} is the PM_{10} size specific emission factor in kg/hr *s* is the silt content (%) *M* is the surface material moisture content (%)

The NPI does not provide information on the valid range of the variables (such as moisture and silt content) used in the equations, although defaults are provided. AP-42 includes a valid range of values for the variables based on the test work that produced the emission factors and the geometric mean of the variables. These values are compared in Table 75.

Table 75 shows the following:

- The default values for silt and moisture contents of coal and overburden are quite different to the geometric means of these variables reported in AP-42
- The default values for moisture content specified in the NPI for coal and overburden are both outside the valid ranges for these variables
- The emission factors calculated using the NPI defaults for silt and moisture content provide PM_{10} emission factors for bulldozing coal and overburden that are 5.4 and 11.8 times higher than those calculated from the silt and moisture content geometric means published in AP-42

Table 75 NPI and AP-42 emission factors for bulldozing on coal and overburden using NPI defaults and AP-42 geometric means of silt and moisture content variables

Source	AP-42					NPI		
	Silt (%)		Moisture (%)		EF using geo means	Silt default (%)	Moisture default (%)	EF using defaults
	Range	Mean	Range	Mean				
Bulldozing coal	6.0-11.3	8.6	4.0-22.0	10.4	6.0	7	2.5	32.5
Bulldozing overburden	3.8-15.1	6.9	2.2-16.8	7.9	0.34	10	2	4

The NPI and AP-42 emission factor equations for bulldozers operating on coal and overburden are plotted in Figure 50. The figure shows the following:

- The emission factors for bulldozers operating on coal are substantially greater than the emission factors for bulldozers operating on overburden.
- There is a considerable range in emission factors across the range in moisture contents. A six-fold reduction in moisture content results in a more than ten-fold increase emission factor for bulldozers operating on both coal and overburden.
- Near the lower bound moisture content (3.8%), the emission factors for bulldozers operating on coal are substantially greater than the emission factors for bulldozers operating on overburden. Near the lower bound moisture content, bulldozers operating on coal produce between 9 and 118 times more emissions than bulldozers operating on overburden.

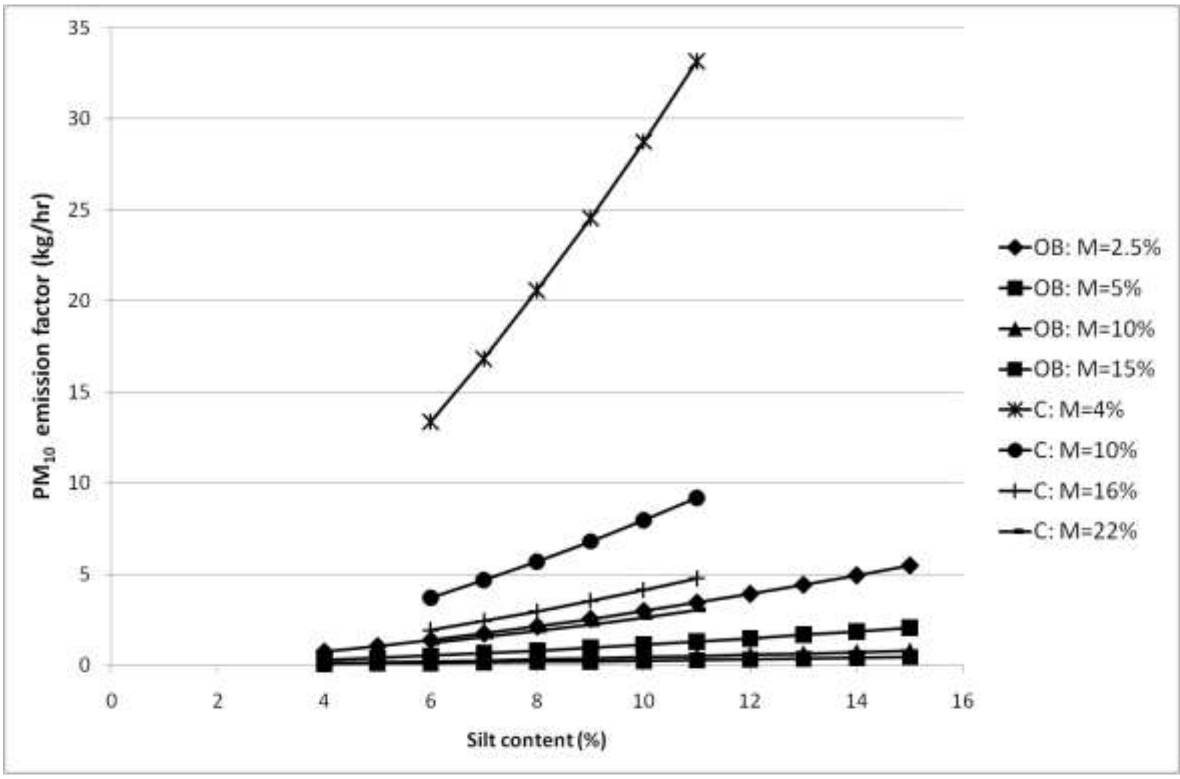

Figure 49 NPI and AP-42 emission factor equations for PM_{10} from bulldozers operating on coal (C) and overburden (OB) showing sensitivity to moisture content (M) and silt content

There is very little information in the literature on minimising emissions of particulate matter from bulldozers. The NPI states that there are no controls to reduce emissions from bulldozers working on coal or other materials. The NPI provides a 50% control factor for scrapers operating on topsoil when the soil is naturally or artificially moist and it is likely that a similar effect would be achieved for bulldozers if the working areas could be kept moist.

A detailed evaluation of options to control emissions of particulate matter from bulldozers was conducted by Connell Hatch for the RG Tanna Coal Terminal[153]. Options considered in this study included:

- Minimising travel speed and travel distance
- Stabilising bulldozer travel routes and use of water or suppressants on travel routes
- Manage coal moisture to ensure coal is sufficiently moist when working
- Modify design of the bulldozer to minimise emissions

There is no information available that would allow the benefit of minimised travel speed of bulldozers to be determined. The emission rate of particulate matter due to bulldozing is directly related to the number of hours of operation. Hence, a reduction in the number of hours of operation would result in a proportional reduction in emissions. However, whilst bulldozer use may be optimised to minimise emissions, substantial reduction in emissions would not be practical without a redesign of the mining operation to substantially eliminate the need for bulldozing. This was considered to be impractical and, hence, the effectiveness of this measure has not been quantified.

With respect to the bulldozers at RG Tanna Coal Terminal, Connell Hatch found that the bulldozer manufacturer had not considered particulate matter emissions induced by the

machine in the basic machine design. Whilst some avenues for redesign were considered possible, these have not been pursued.
Table 76 summarises the control measures used for bulldozing operations.

Table 76 Best practice control measures to reduce particulate matter emissions from bulldozers

Control measure		Effectiveness
Bulldozer	Minimise travel speed and distance	Not quantified
	Keep travel routes and materials moist	50%[10]

9.5 Blasting and drilling

9.5.1 Overview

Of all sources of particulate matter in coal mining activities in the GMR, blasting was ranked number 5 in terms of emissions of TSP, number 4 in terms of emissions of PM_{10} and number 3 in terms of emissions of $PM_{2.5}$. Blasting has been estimated to contribute 3.5% of TSP, 5.6% of PM_{10} and 20.6% of $PM_{2.5}$ emissions from coal mines in the GMR. Drilling was ranked number 15 in terms of emissions of TSP and PM_{10} and number 17 in terms of emissions of $PM_{2.5}$. Drilling has been estimated to contribute 0.2% of TSP, 0.3% of PM_{10} and 0.1% of $PM_{2.5}$ emissions from coal mines in the GMR. A summary of rankings and proportional contributions to GMR emissions of particulate matter is included in Table 77.

Table 77 Contribution of blasting and drilling to GMR emissions of TSP, PM_{10} and $PM_{2.5}$

Activity	TSP			PM_{10}			$PM_{2.5}$		
	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)
Blasting	5	5,508	3.5	4	3,329	5.6	3	2,121	20.6
Drilling	15	301	0.2	15	166	0.3	17	14	0.1

Blasting and drilling are two activities that are closely associated within the activities of an open-cut mine. The activity of blasting involves the breakup of soil and rock by explosives. It is then removed by draglines or by shovel and truck. The breakup of material during the blasting process has the potential to generate large volumes of particulate matter as the force behind the blasts is considerable. Once the coal seam is exposed, it is drilled, fractured and systematically mined in strips. Drilling produces a relatively minor amount of particulate matter emissions from an open cut mine in comparison to haul roads or wind erosion[10].

The NPI and AP-42 emission estimation equations for blasting activities quantify the emission rate of particulate emissions per unit area of the blast. The equations for TSP and PM_{10} are shown in Table 78.

Table 78 NPI and AP-42 TSP and PM_{10} emission estimation equations for blasting

Species	NPI	AP-42
TSP	$EF_{TSP} = 344 \times A^{0.8} \times M^{-1.9} \times D^{-1.8}$	$EF_{TSP} = 0.00022 \times A^{1.5}$
PM_{10}	$EF_{PM10} = 0.52 \times 344 \times A^{0.8} \times M^{-1.9} \times D^{-1.8}$	$EF_{PM10} = 0.52 \times 0.00022 \times A^{1.5}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/blast EF_{PM10} is the PM_{10} size specific emission factor in kg/blast *A* is the area blasted (m²) *M* is the material moisture content (%) *D* is the depth of the blast holes (m)	Where: EF_{TSP} is the TSP size specific emission factor in kg/blast EF_{PM10} is the PM_{10} size specific emission factor in kg/blast *A* is the area blasted (m²)

The NPI emission estimation equation is from the fourth edition of AP-42 and is no longer supported by the US Environmental Protection Agency[168].

Figure 50 is a plot of the emission factors for PM_{10} for blasting showing the sensitivity to blast area for AP-42 and NPI emission factors and to moisture and blast depth for the NPI emission factors. The NPI provides no guidance on the ranges of validity of the variables and does not provide default values for the variables. The low, high and mid-range values shown in Figure 50 are based on the ranges and geometric means of moisture content and blasting depth contained in the fourth edition of AP-42. The ranges and geometric means of these variables are also shown in Table 79.

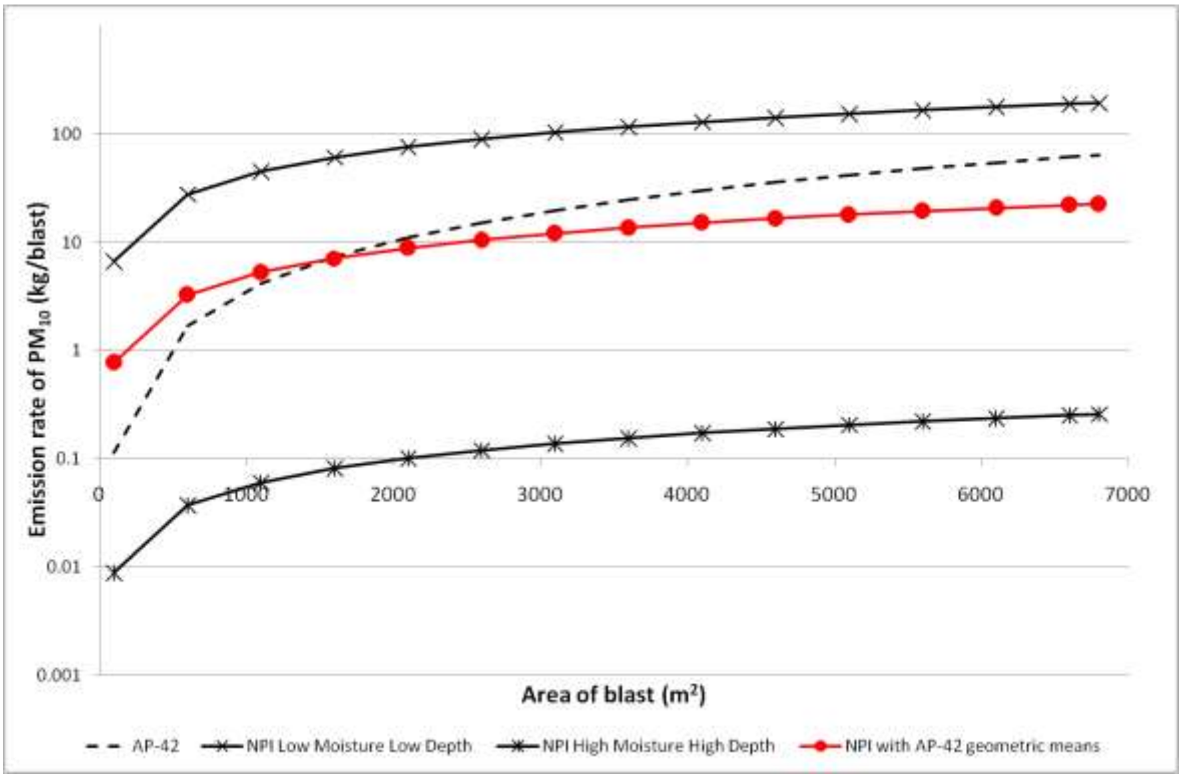

Figure 50 NPI and AP-42 PM_{10} emission factors for blasting and sensitivity to area blasted, moisture content and depth of blast

Table 79 Range and geometric means of variables for the NPI and AP-42 emission estimation equations for blasting

Parameter	NPI		AP-42	
	Range	Geometric mean	Range	Geometric mean
Moisture content (%)	7.2-38	17.2	-	-
Depth of blast holes (m)	6-41	7.9	-	-
Area blasted (m^2)	90-9,000	1,800	100-6,800	1,590
Note [1]Taken from AP-42 Fourth Edition[168]				

The NPI emission estimation equation for drilling provides an emission rate per hole drilled. In reality, the emission rate of particulate matter for drilling would also be dependent on the diameter of the hole, depth of the hole and the moisture content of the material[10]. The NPI emission estimation equation is equivalent to the AP-42 equation for TSP.

Table 80 NPI and AP-42 TSP and PM_{10} emission estimation equations for drilling overburden

Species	NPI	AP-42
TSP	$EF_{TSP} = 0.59$	$EF_{TSP} = 0.59$
PM_{10}	$EF_{PM10} = 0.31$	-
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/hole EF_{PM10} is the PM_{10} size specific emission factor in kg/hole	Where: EF_{TSP} is the TSP size specific emission factor in kg/hole

9.5.2 Blasting

The two key factors in minimising emissions of particulate matter from a blast are:

- Designing the blast
- Scheduling the blast (e.g. delaying the blast under unfavourable wind and atmospheric conditions[10])

In scheduling the blast a number of factors need to be considered, including wind and atmospheric conditions, duration the charge will remain in the ground should the blast be delayed (giving rise to fumes) and safety.

Blasting has been ranked as the fourth (as PM_{10}) and third (as $PM_{2.5}$) most significant activity for generating emissions of particulate matter and is also perceived by the public as a major source of emissions and as such this aspect of mining has been analysed in more depth than any other activity[169]. Best practice controls include the continuous design changes to be made to minimise emissions of particulate matter from operations and a suitably qualified blast designer to be involved[169].

Mattis[170] documents a Russian mining technique that avoids or minimises the need for traditional blasting activities. The technique involves the preparation of coal and hard overburden by treating the rock or coal with special aqueous solutions of surfactants and salts that are adsorbed at the inner pore surface of the rock, lowering its surface energy and altering its physical and mechanical properties[170]. Therefore no preliminary blasting activities are carried out with the technique. The testing conducted shows that the combined physical and chemical loosening of material:

- Reduces the need to move mining machinery around by 40%

- Increases excavator productivity by up to 30%
- Reduces the energy intensity of extraction by 20-35%
- Reduces the abrasiveness of the rock and coal by 30-40%

Using a combination of the new method and blasting to prepare hard rock for extraction reduces explosives consumption by 25-30% and cuts the amount of drilling required by up to 25%[171].

Table 81 summarises the control measures used for blasting.

Table 81 Best practice control measures to reduce particulate matter emissions from blasting

Control Measure		Effectiveness
Blasting	Design: Delay shot to avoid unfavourable weather conditions	Not quantified
	Design: Minimise area blasted	Not quantified

9.5.3 Drilling

Emissions of particulate matter from drilling can be controlled using wet and dry methods and these include:

- Wet suppression
  - Watering
- Dry collection
  - Fabric filters
  - Cyclones

The use of watering when drilling can be an effective control measure and efficiencies are dependent on the flow of watering and have been shown to range between 3.1% and 96.3%[142]. The watering system can be mounted onto the drill and is operated by the drill operator. The system is dependent on the moisture content of the material that is to be drilled.

A dry collection system is simply a system to collect particulate matter in an enclosure around where the drilling is taking place[142]. Fabric filters can reduce emissions of particulate matter by 99%[154]. Reed[172] documented a new approach to control emissions of particulate matter at the collector dump point for blast hole drills. The control was developed primarily to address occupational exposure for operators of this equipment; however, it is also effective in reducing total fugitive emissions of particulate matter. Reed[172] reports that creating a particulate matter collector shroud is a simple, yet very effective measure in reducing respirable particulate matter. The shroud is easy to fit and replace and is inexpensive requiring almost no maintenance[172]. The observed reduction in respirable particulate matter varied between 63% and 88%[172]. The reduction rates vary according to the meteorological conditions, particularly wind speed and direction[172].

The small drills used in surface mining typically use a dry collection system called a Cyclone in Australia and Rotoclone in the US[173]. A cyclone works by forcing the air to move rapidly in a curved trajectory and during this movement the denser particulates are separated from the air stream, drop out and are collected[174]. Although this collection system collects the majority of particulate matter (in mass terms) there is a significant amount of fine particulate matter that is not collected in this system[173]. Buonicore & Davis[175] reported efficiencies of PM_{10} capture of 80-90%. The US Bureau of Mines[173] documented an improved system for the Rotoclone in which water is injected in very small amounts to the Rotoclone exhaust to reduce the emissions of particulate matter from this activity. Principally this system was developed to remove fine particulate matter and the system proved very efficient. Monitoring was undertaken 10 feet downwind of the Rotoclone and the discharged showed a 90% reduction in total particulate matter emissions and a 92% reduction of respirable particulate matter emissions and the eradication of all visible emissions of particulate matter[173].

Table 82 summarises the control measures used for drilling.

Table 82 Best practice control measures to reduce particulate matter emissions from drilling

Control Measure		Effectiveness
Dry collection	Fabric filter Cyclone	99[154] 80-90[175]
Wet	Water injection	3 – 96[142], 70[10]

9.6 Draglines

Of all sources of particulate matter from coal mining activities in the GMR, draglines have been ranked number 8 in terms of emissions of TSP, number 10 in terms of emissions of PM_{10} and number 9 in terms of emissions of $PM_{2.5}$. Draglines have been estimated to contribute 1.9% of TSP, 1.5% of PM_{10} and 1.3% of $PM_{2.5}$ emissions from coal mines in the GMR.

Draglines are frequently used in the removal of blasted overburden from surface pit mining. The dragline consists of a large bucket which is controlled by a dragline operator using a pulley system of ropes. The bucket is lowered and dragged across the surface of the overburden to be excavated. The bucket is then swung to the in-pit dumping area where the overburden is dumped from the bucket. During this activity, there are three actions where emissions of particulate matter may arise:

- Pick up of the overburden material
- Loss of material from the bucket during the swing
- During the drop of the overburden material

The amount of particulate matter generated from these activities is dependent on local conditions such as, weather (wind speed, rainfall), drop height and moisture content of the material being excavated.

The NPI emission estimation equations for draglines are equivalent to AP-42 emission estimation equations[125].

Table 83 NPI and AP-42 TSP and PM_{10} emission estimation equations for draglines

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 0.0046 \times d^{1.1} \times M^{-0.3}$	$EF_{TSP} = 0.0046 \times d^{1.1} \times M^{-0.3}$
PM_{10}	$EF_{PM10} = 0.0022 \times d^{0.7} \times M^{-0.3}$	$EF_{PM10} = 0.75 \times 0.0029 \times d^{0.7} \times M^{-0.3}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/bcm EF_{PM10} is the PM_{10} size specific emission factor in kg/bcm d is the drop distance (m) M is the material moisture content (%)	Where: EF_{TSP} is the TSP size specific emission factor in kg/m³ EF_{PM10} is the PM_{10} size specific emission factor in kg/ m³ d is the drop distance (m) M is the material moisture content (%)

Figure 51 is a plot of the emission factors for PM_{10} for draglines showing the sensitivity to drop height and to moisture content for the NPI emission factors. The NPI suggests a drop height of 12 metres and moisture contents of 1% or 2% are reasonable for the Hunter Valley. The low, high and mid-range values shown in Figure 51 are based on the ranges and geometric means of moisture content and blasting depth contained in AP-42 (Table 84).

Table 84 NPI defaults and range and geometric means of variables for AP-42 emission estimation equations for draglines

Parameter	NPI defaults[10]	AP-42[125]	
		Range	Geometric mean
Moisture content (%)	1-2	0.2-16.3	3.2
Drop height (m)	12	1.5-30	8.6

Reducing the drop height from 30 metres to less than 5 metres will reduce total PM_{10} emissions by 72%. Increasing the moisture content of the material from 2% to 16.3% would reduce the PM_{10} emission rate by 53%.

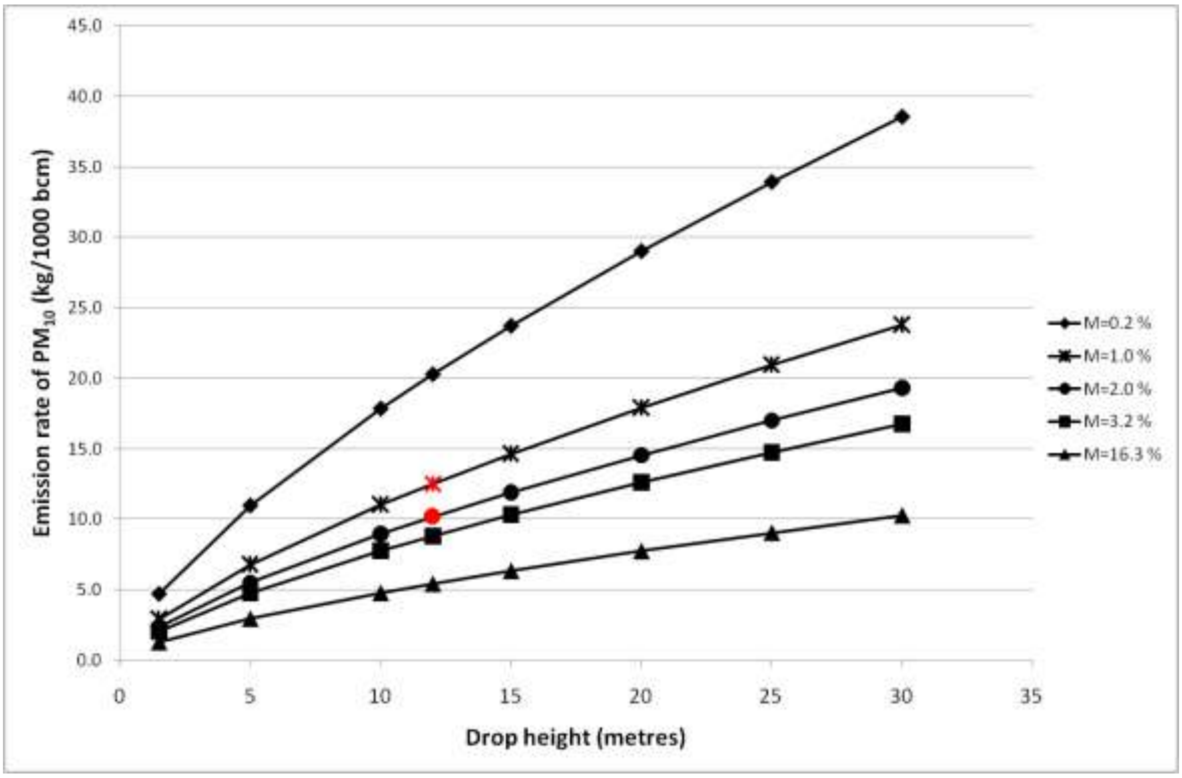

Figure 51 NPI and AP-42 PM_{10} emission factors for draglines and sensitivity to drop height and moisture content

BHP Billiton Mitsubishi Alliance (BMA) has developed a particulate matter suppression system that has been reported to be effective in reducing particulate matter emissions and has improved dragline productivity[176]. The particulate matter suppression system consists of a high water capacity, full circle irrigation spray[176].

There is a limitation to the amount of controls that can be placed on draglines due to the nature of the activity. Best practice techniques for the control of particulate matter emissions from draglines are:

- Minimise drop height
- Modify operations during adverse atmospheric and meteorological conditions
- Water sprays
- Eliminate side casting

Table 85 summarises the control measures used for dragline operations.

Table 85 Best practice control measures to reduce particulate matter emissions from draglines

Control measure		Effectiveness
Dragline	Minimise drop height	Reduce from 30 m to 5 m: 70%[a]
	Minimise drop height	Reduce from 10 m to 5 m: 40%[a]
	Modify activities in windy conditions	Unquantified
	Water application	50%[a]
	Minimise side casting	Unquantified
Note [a]Reduction due to reduced drop height and water have been inferred from the dragline emission estimation equation		

9.7 Loading and dumping overburden

Of all sources of particulate matter in coal mining activities in the GMR, trucks dumping overburden was ranked number 4 in terms of emissions of TSP, number 5 in terms of emissions of PM_{10} and number 6 in terms of emissions of $PM_{2.5}$. Trucks dumping overburden has been estimated to contribute 4.1% of PM_{10} emissions from coal mines in the GMR. Loaders dumping overburden ranked number 11 in terms of emissions of TSP, PM_{10} and $PM_{2.5}$. Loaders dumping overburden has been estimated to contribute 1.2% of PM_{10} emissions from coal mines in the GMR. A summary of rankings and proportional contributions to GMR emissions of particulate matter is included in Table 86.

Table 86 Contribution of trucks and loaders dumping overburden to GMR emissions of TSP, PM_{10} and $PM_{2.5}$

Activity	TSP			PM_{10}			$PM_{2.5}$		
	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)
Trucks (dumping overburden)	4	6,295	4.0	5	2,480	4.2	6	324	3.1
Loaders (overburden)	11	1,237	0.8	11	707	1.2	11	70	0.7

At truck and shovel mines, excavators or power shovels are used to excavate blasted overburden in the pit. The overburden is dumped into large haul trucks and transported to the waste emplacement and dumped or is dumped back into the pit.

To control emissions from trucks dumping the West Virginia Department of Environmental Protection recommends that where truck dumps have a drop height greater than 6 metres, a stacking tube or full enclosure of the dump should be used. The effect of this recommendation is to minimise the drop height of materials.

Other documents[146] suggest that the application of water can achieve a reduction in particulate emissions from truck dumping. The sensitivity of dragline emissions to drop height shows that increasing drop height would increase emissions significantly. It would be reasonable therefore, to conclude that minimising the drop height from excavator to truck and truck to ground would also be an effective mitigation measure.

Other approaches applied to draglines would also be relevant.

The NPI and AP-42 emission estimation equations for particulate matter emissions from dumping overburden by truck are shown in Table 87. The NPI emission factors for trucks dumping overburden are based on the NERDDC work[10] conducted in the Hunter Valley in the mid 1980s. The NPI argues that these emission factors are more representative of Australian mining operations and that the current AP-42 factors are too low.

Table 87 NPI and AP-42 TSP and PM_{10} emission estimation equations for dumping overburden from trucks

Species	NPI[10]	AP-42[177]
TSP	$EF_{TSP} = 0.012$	$EF_{TSP} = 0.74 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$
PM_{10}	$EF_{PM10} = 0.0043$	$EF_{PM10} = 0.35 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t U is the mean wind speed (m/s) M is the material moisture content (%)

The NPI and AP-42 emission estimation equations for particulate matter emissions from dumping overburden by excavator are shown in Table 88. The NPI emission estimation equation for excavators, shovels and front end loaders operating on overburden are equivalent to AP-42 emission estimation equations for aggregate handling and storage piles[177].

Table 88 NPI and AP-42 TSP and PM_{10} emission estimation equations for dumping overburden by front end loader, excavator or shovel

Species	NPI[10]	AP-42[177]
TSP	$EF_{TSP} = 0.74 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$	$EF_{TSP} = 0.74 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$
PM_{10}	$EF_{PM10} = 0.35 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$	$EF_{PM10} = 0.35 \times 0.0016 \times \left(\frac{U}{2.2}\right)^{1.3} \times \left(\frac{M}{2}\right)^{-1.4}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t U is the mean wind speed (m/s) M is the material moisture content (%)	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t U is the mean wind speed (m/s) M is the material moisture content (%)

Table 89 NPI defaults and range and geometric means of variables for AP-42 emission estimation equations for dumping overburden

Parameter	NPI defaults[10]	AP-42[177] Range[a]
Moisture content (%)	1-2	0.25-4.8
Wind speed (m/s)	3.6	0.6-6.7
Silt content (%)	-	0.44-19[b]
Note [a]Range provided in AP-42, but no geometric mean. [b]Silt content reported as being relevant for emission factor equation, although the parameter not included in the equation.		

The AP-42[125] also provides an emission factor equation for truck loading by power shovel (batch drop). The equation is for TSP and is as follows:

$$EF_{TSP} = 0.018$$

Where:

EF_{TSP} is the TSP size specific emission factor in kg/Mg

Figure 52 is a plot of the emission factors for PM_{10} for trucks and shovels dumping overburden showing the sensitivity to moisture content and average wind speed. The figure shows that the NPI emission factor for truck dumping and the AP-42 emission factor for truck loading by power shovel (batch drop) are at the upper bound of the other AP-42 emission factors. The ranges of average wind speed and moisture content are consistent with the AP-42 data.

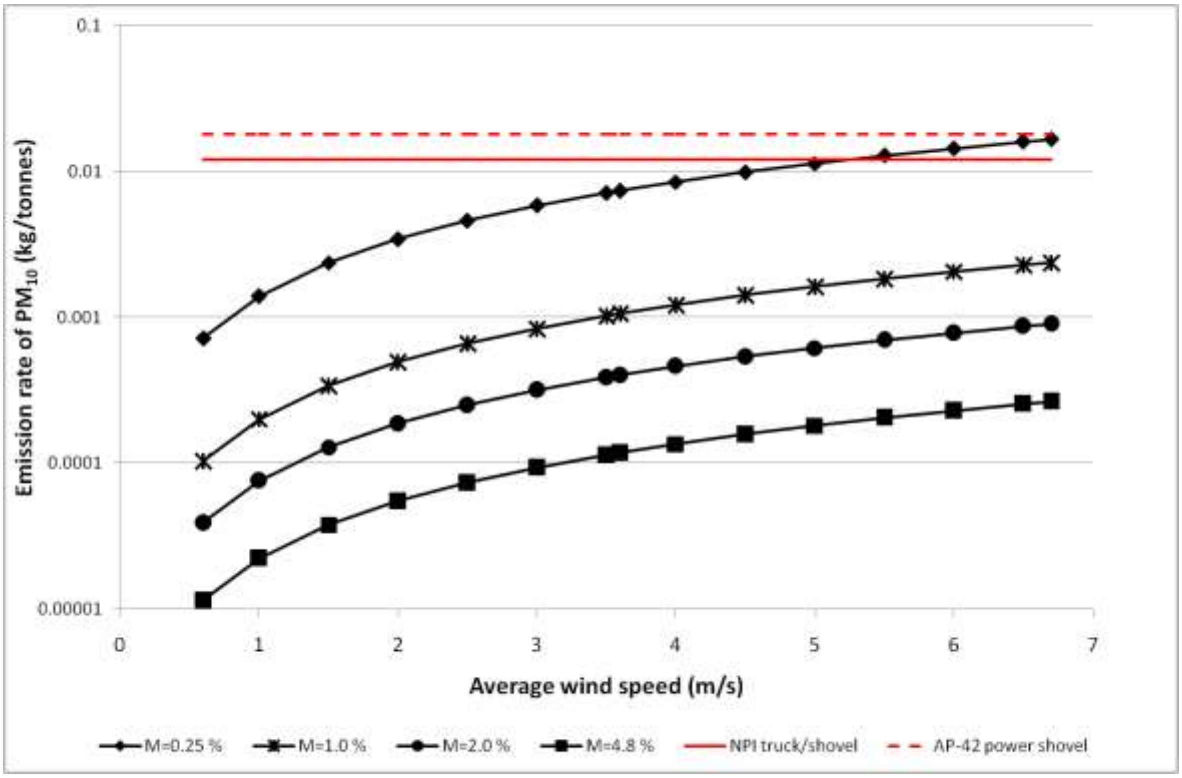

Figure 52 NPI and AP-42 PM_{10} emission factors for dumping overburden and sensitivity to moisture content and average wind speed

Reducing the drop height from 3 metres to less than 1.5 metres will reduce total PM_{10} emissions by 30%. Increasing the moisture content of the material from 1% to 2% would reduce the PM_{10} emission rate by 38%.

Best practice measures for minimising emissions from material dumping include:

- Use of water sprays or water carts with boom spray
- Cease or modify activities on dry windy days
- Minimise dump height

Table 90 summarises the control measures used for loading and dumping overburden.

Table 90 Best practice control measures to reduce particulate matter emissions from loading and dumping overburden

Control measure		Effectiveness
Excavator	Minimise drop height	Reduce from 3 m to 1.5 m: 30%[a]
Truck dumping	Minimise drop height	Reduce from 3 m to 1.5 m: 30%[a]
	Water application	50%[10]
	Modify activities in windy conditions	Unquantified

Note
[a] Reductions due to reduced drop heights have been inferred from the emission estimation equation for dropping material from a dragline and rounded down to the nearest 10%.

9.8 Loading and dumping ROM coal

Of all sources of particulate matter from coal mining activities in the GMR, loaders dumping coal was ranked number 7 in terms of emissions of TSP, number 6 in terms of emissions of PM_{10} and number 8 in terms of emissions of $PM_{2.5}$. Loaders dumping coal contribute 2.1% of total coal mining emissions of PM_{10} in the GMR. Trucks dumping coal ranked number 12 in terms of emissions of TSP, PM_{10} and $PM_{2.5}$. Trucks dumping coal contribute 0.7% to total coal mining emissions of PM_{10} in the GMR. A summary of rankings and proportional contributions to GMR emissions of particulate matter is included in Table 91.

Table 91 Contribution of trucks and loaders dumping coal to GMR emissions of TSP, PM_{10} and $PM_{2.5}$

Activity	TSP			PM_{10}			$PM_{2.5}$		
	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)	Rank	Rate (tpy)	Proportion (%)
Loaders (coal)	7	3,384	2.2	6	2,141	3.6	8	209	2.0
Trucks (dumping coal)	12	1,108	0.7	12	471	0.8	12	53	0.5

Emissions of particulate matter on the ROM pad are caused by dumping of coal on the pad, forming the coal into stockpiles and load-out of coal to the ROM bin. Emissions of particulate matter will also occur as a result of wind erosion of stockpiled coal on the ROM pad. Bulldozing coal is dealt with in Section 9.4 and wind erosion of stockpiled coal is dealt with in Section 9.3.3. The ROM pad is used to store coal as required prior to load-out into the coal processing plant. Coal may bypass the ROM stockpiles resulting in a reduction in emissions of particulate matter associated with dumping of coal and stockpile formation.

Loading coal into the ROM bin or truck produces particulate matter as a result of the turbulence induced by dumping coal, which may be enhanced in a cross-wind. Enclosure and application of water is the principal control measure used to control emissions of particulate matter from ROM bins[10]. Water may also be applied at the ROM pad to minimise dumping emissions.

The NPI and AP-42 emission estimation equations for particulate matter for trucks dumping coal are shown in Table 92.

Table 92 NPI and AP-42 TSP and PM_{10} emission estimation equations for dumping coal from trucks

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 0.01$	$EF_{TSP} = 0.58 \times M^{-1.2}$
PM_{10}	$EF_{PM10} = 0.0042$	$EF_{PM10} = 0.75 \times 0.0596 \times M^{-0.9}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t M is the material moisture content (%)

The NPI and AP-42 emission estimation equations for particulate matter from excavators dumping coal are shown in Table 93.

Table 93 NPI and AP-42 TSP and PM_{10} emission estimation equations for dumping coal from excavators

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 1.56 \times 0.0596 \times M^{-0.9}$	$EF_{TSP} = 0.58 \times M^{-1.2}$
PM_{10}	$EF_{PM10} = 0.75 \times 0.0596 \times M^{-0.9}$	$EF_{PM10} = 0.75 \times 0.0596 \times M^{-0.9}$
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t M is the material moisture content (%)	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t M is the material moisture content (%)

The NPI emission factors for trucks dumping coal are based on the NERDDC work[10] conducted in the Hunter Valley in the mid 1980s. The NPI argues that these emission factors are more representative of Australian mining operations and that the current AP-42 factors are too low. The NPI emission estimation equation for excavators, shovels and front end loaders operating on coal are equivalent to the AP-42 emission estimation equation for PM_{10} emissions from truck loading of coal[125]. However, the AP-42 emission estimation equation for TSP is different to the NPI emission estimation equation for excavators, shovels and front end loaders.

Table 94 is a comparison of NPI and AP-42 emission factors for TSP and PM_{10} for trucks and shovels dumping coal. The default NPI emission factor for trucks dumping coal is about 81% of the AP-42 factor calculated using the geometric mean of the moisture content. The default factor for PM_{10} emissions from dumping coal using a shovel, loader or excavator is 2.7 times higher than the AP-42 factor calculated using the geometric mean of the moisture content.

Table 94 Comparison of NPI and AP-42 emission factors for truck and shovel dumping coal

Activity	AP-42 Moisture data (%)		AP-42 using Geo mean for moisture (kg/t)		NPI default (kg/t)	
	Range	Geo mean	TSP	PM_{10}	TSP	PM_{10}
Truck dumping coal	6.6-38	17.8	0.019	0.0052	0.010	0.0042
Shovel, loader or excavator working on coal	6.6-38	17.8	0.019	0.0052	0.029	0.014

Figure 53 shows the sensitivity of the NPI and AP-42 emission estimation equations to moisture content of the coal. The default NPI emission factors for truck dumping coal and shovel, loader or excavator working on coal are also shown in the figure. Increasing the moisture content from the lower end of the range to the geometric mean will reduce emissions of PM_{10} by 59%.

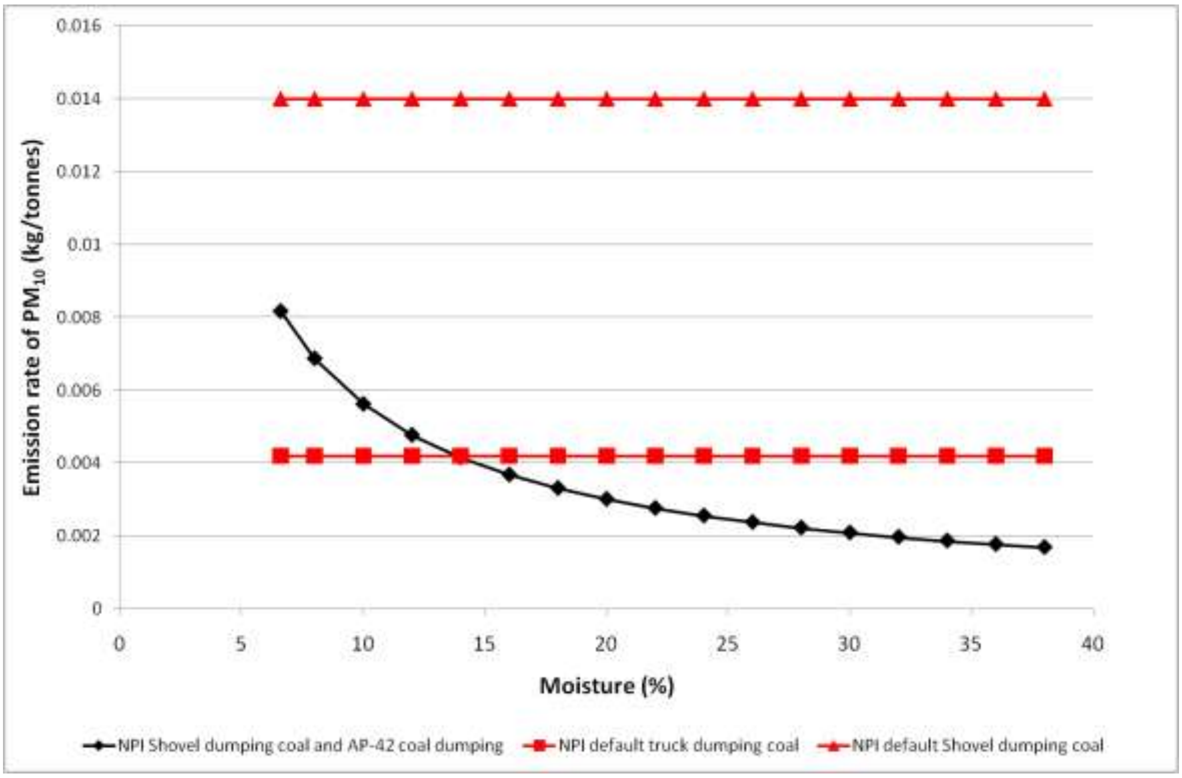

Figure 53 NPI and AP-42 PM_{10} emission factors for dumping coal and sensitivity to moisture content

Operational management and control of mining that ensures that coal bypasses the ROM pad will minimise potential emissions from stockpiled coal and multiple handling activities. There are no controls identified in the literature for reducing emissions from trucks dumping coal onto the ROM pad. Whereas particulate emissions from coal dumped into the ROM hopper can be effectively controlled.

Table 95 summarises the control measures used for the loading and dumping ROM coal.

Table 95 Best practice control measures to reduce particulate matter emissions from loading and dumping ROM coal

Control Measure		Effectiveness
Avoidance	Bypass ROM stockpiles	50% reduction in dumping emissions for coal bypassing ROM stockpile[a] Emissions associated with forming coal into stockpiles (e.g. by dozer push) would be reduced by 100% for bypassing coal
Truck or loader dumping coal	Minimise drop height	Reduce from 10 m to 5 m: 30%[b]
	Water sprays on ROM pad	50%[10]
Truck or loader dumping to ROM bin	Water sprays on ROM bin or sprays on ROM pad	50%[10]
	Three sided and roofed enclosure of ROM bin	70%[10]
	Three sided and roofed enclosure of ROM bin plus water sprays	85% by combining control factors from[10]
	Enclosure with control device	90-98%[165]

Note
[a] Reduction achieved because one dump required rather than two
[b] Reductions due to reduced drop heights have been inferred from the emission estimation equation for dropping material from a dragline.

9.9 Conveyors and transfers

Emissions of particulate matter from conveyors are not quantified in the CMED, the NPI or AP-42. However, transfer points between conveyors and from conveyors to stockpiles have been quantified in the CMED. Coal transfers contribute a relatively small proportion to GMR emissions of TSP (0.1%), PM_{10} (0.1%) and $PM_{2.5}$ (<0.1%). Transfers rank 18, 17 and 21, respectively for emissions of TSP, PM_{10} and $PM_{2.5}$ out of all coal mining activities.

In a detailed review of best practice and benchmarking study of the RG Tanna Coal Terminal in Gladstone, Connell Hatch found that the design of the conveyors and transfers within the material transport system has a large bearing upon their potential to emit particulate matter. Water application and wind shielding were the most important items in reducing the quantity of particulate matter emitted from coal whilst being transported by conveyor.

Water application up to the dust extinction moisture level (DEM) is an important basic premise to the reduction of particulate matter emissions. Surface addition of water at each point of coal disturbance (such as a transfer from one conveyor to another) reduces the emission of particulate matter.

To minimise the lift off of particulate matter from the conveyors, wind shielding and enclosure of the conveyors wherever possible is practiced at other sites.

The majority of other solutions to the particulate matter generated by the conveyor system are centred upon attention to detail for cleanup purposes. Several items were identified as being important such as: cleanup launders under conveyors, integrated control systems to prevent overloading of conveyors to prevent spillage, belt washing stations on heads of belts and transfer design and wind shielding.

Table 96 summarises the control measures used for conveyors and transfers.

Table 96 Best practice control measures to reduce particulate matter emissions from conveyors and transfers

Control Measure		Effectiveness
Conveyors	Application of water at transfers	50%[10]
	Wind shielding – roof or side wall	40%[10]
	Wind shielding – roof and side wall	70%[10]
	Belt cleaning and spillage minimisation	Not quantified
Transfers	Enclosure	70%[10]

9.10 Stacking and reclaiming product coal

Stacking and reclaiming product coal is not explicitly characterised in the CMED. Since product coal is in most circumstances, relatively wet during handling, emissions of particulate matter would be relatively small and would be a subset of coal dumping, bulldozing and transfers identified above.

Stacking coal on product stockpiles can produce emissions of particulate matter due to the turbulence induced by dropping coal from height particularly in circumstances where coal is dry and/or where coal has a high dustiness potential. Emissions of particulate matter are enhanced when there is a significant cross-wind present. Where coal is being stacked after washing, emissions of particulate matter are low so additional control is generally unnecessary.

The following measures are applied to minimise emissions of particulate matter from stacking:

- Bypass coal stockpile
- Variable height luffing stacker to allow drop height to be minimised and stacking to occur without dozer push
- Use of chutes or wind shields to shroud falling coal from static trippers
- Water application – boom tip sprays

Reclaiming coal on product stockpiles can produce emissions of particulate matter where substantial additional handling by loader or bulldozer are required to reclaim coal or where coal remains in stockpile for a period sufficient to allow substantial coal drainage and drying. Where coal is being reclaimed after washing, emissions of particulate matter may be low and additional amelioration may be unnecessary.

The following measures are applied to minimise emissions of particulate matter from reclaiming:

- Use of bucket-wheel, portal or bridge reclaimer
- Water application – boom tip sprays
- Reclaim tunnel with minimal mechanical disturbance
- Minimise residence time in stockpiles
- Coal moisture management

Table 97 summarises the control measures used for stacking and reclaiming coal.

Table 97 Best practice control measures to reduce particulate matter emissions from stacking and reclaiming product coal

Control Measure		Effectiveness
Avoidance	Bypass coal stockpiles	100% reduction in stacking emissions for coal bypassing stacker
Loading coal stockpiles	Variable height stack	25%[10]
	Boom tip water sprays	50%[10]
	Telescopic chute with water sprays	75%[10]
Unloading coal stockpiles	Bucket-wheel, portal or bridge reclaimer with water application	50%[10]

9.11 Train and truck load out and transportation

Of all sources of particulate matter in coal mining activities in the GMR, loading of trains with coal was ranked number 19 in terms of emissions of TSP, number 20 in terms of emissions of PM_{10} and number 22 in terms of emissions of $PM_{2.5}$. Loading trains with coal contributes less than 0.1% to overall coal mining emissions of TSP, PM_{10} and $PM_{2.5}$ in the GMR.

The NPI and AP-42 emission estimation equations for particulate matter from loading trains are shown in Table 98.

Table 98 NPI and AP-42 TSP and PM_{10} emission estimation equations for loading trains and trucks with coal

Species	NPI[10]	AP-42[125]
TSP	$EF_{TSP} = 0.0004$	$EF_{TSP} = 0.014$
PM_{10}	$EF_{PM10} = 0.00017$	-
Notes	Where: EF_{TSP} is the TSP size specific emission factor in kg/t EF_{PM10} is the PM_{10} size specific emission factor in kg/t	Where: EF_{TSP} is the TSP size specific emission factor in kg/t

The NPI emission factor is between the lower and upper bounds of the AP-42 emission factors for TSP.

Particulate matter occurs whilst coal is loaded into trains and trucks as a result of the air turbulence induced by dropping the coal from a height. Cross flow of wind can exacerbate emission of particulate matter. Spilled coal can also be a cause of particulate matter emissions due to wind erosion.

Emissions of particulate matter from train and truck load out facilities are low compared with other activities at mines as the majority of coal is relatively wet from washing and the activity is usually carried out within an enclosure.

Best practice measures to control emissions of particulate matter from truck and train loader are the use of volumetric loading from an overhead silo or bin with a telescopic chute with the entire activity enclosed within a building. Clam-shell or front-end loaders should be avoided where possible due to the potential for spillage during loading operations. Spilled coal can be a source of particulate matter emissions particularly as the coal dries and where it is deposited on tracks and trafficked areas can be pulverised to produce a very fine and easily eroded particulate matter.

Figure 54[178] shows a fully automated train loading facility with enclosure of the loading point.

Figure 54 Photograph of a train loading facility

The off-site transportation of the coal via rail can give rise to localised impacts on levels of particulate matter. Queensland Rail has undertaken an extensive study into fugitive emissions of particulate matter from coal trains. Emissions of particulate matter are mainly caused by wheel action on the rails, wagon-induced turbulence acting on dust-supporting ground surfaces and windblown particulate matter from loads. Sources of particulate matter emissions from trains are:

- The coal surface of loaded wagons
- Leakage of coal from doors of loaded wagons
- Wind erosion of spilled coal in the corridor
- Leakage of residual coal from doors of unloaded wagons

Best practice measures to control emissions of particulate matter from rail corridors include[179]:

- Use of profilers to manage overloading or underloading of wagons
- Maintain a consistent profile. (Loading via front-end loaders and clam shells produces uneven loads that are susceptible to spillage and reduce the effectiveness of suppressants.)
- Maintaining the 100 mm freeboard around the edge of the wagon
- Application of a suppressant to the surface of the coal profile
- Removing parasitic coal from the surface of the wagons before leaving the mine site
- Covering load (e.g. tarpaulins or lid)
- Wagon wheel wash

There are a number of suppressants available, however the effectiveness of each to minimise lift-off depends on the properties of the coal and the individual suppressant[179].

Best practice measures to control emissions of particulate matter from trucks include:

- Limit load size to ensure coal is not above the level of the sidewalls
- Maintain a consistent profile
- Use bedliners to minimise seepage and spillage from bottom dumping trucks
- Covering load with a tarpaulin
- Utilise a truck wheel wash ensuring that truck is clean and free of loose material

10. NSW Techniques for Controlling Particulate Matter Emissions from Coal Mining

In this section, current techniques for controlling particulate matter emissions from coal mines in the GMR have been researched by considering:

- The Coal Mines Emission Database (CMED) developed by OEH from its industrial survey conducted in 2009.
- An internet survey of GMR mines in July – August 2010. Non-responders were re-surveyed in February – March 2011.
- Information sourced during site visits to thirteen mines in the Hunter and Newcastle coalfields.
- Documents published by the coal mines such as: Annual Environment Management Reports (AEMR), Environmental Management Plans (EMP) and Environmental Management Systems (EMS).
- Conditions of Approval and Environment Protection Licences (EPL).

A metric has been developed to rank, in relative terms, the progress towards best practice that has been achieved at GMR coal mines. The metric has been solely based on data provided by EPA licensees in response to the OEH industrial survey conducted in 2009 and contained within CMED. The metric, hereafter, is referred to as the particulate matter emission control metric.

10.1 Methodology

The existing practices adopted to manage particulate matter emissions from coal mining activities in the GMR have been identified through the following work:

- A review of data contained in OEH's CMED.
- Internet surveys.
- Site visit to thirteen coal mines in the Hunter Valley and Newcastle Coalfields.
- Review of NPI data for 2008-09 reporting year.
- Review of Annual Environmental Management Reports (AEMR), Environmental Management Systems (EMS), Environmental Management Plans (EMP) and Environment Protection Licences (EPL).

This information has been consolidated into the following sections.

Letters were sent to 69 licensees in the GMR requesting that they participate in this study and requesting disaggregated NPI data and other documents. A copy of the OEH letter that was sent to each mine is included at Appendix C.

10.1.1 Coal Mines Emission Database

In September 2009, OEH wrote to all EPA licensees including all coal mines in the GMR and requested information by Notice under Section 191 of the POEO Act (Appendix B). The Notice required licensees to complete a questionnaire that included the provision of the following information:

- Details of the operation
- Operating schedule
- Major materials and products

- Air emissions sources
- Fuel combustion
- Fugitive emissions from valves seals
- On-site vehicles
- Materials handling
- Stockpiles and exposed areas
- NPI emissions of particulate matter
- Process flow diagram

OEH provided Katestone Environmental with a database of disaggregated particulate matter emissions for coal mining activities in the GMR. The Coal Mines Emission Database (CMED) is a subset of the information collected for the GMR air emissions inventory.

10.1.2 Internet survey: July-August 2010

On 8 July 2010, sixty nine letters were sent out to coal mines in the GMR. Twenty six complete responses to the survey were received. The survey consisted of thirty questions covering the following:

- Coal produced
- Type of coal mining activity
- For open-cut mines:
  - Mining method for coal and overburden extraction
  - Management of particulate matter emissions from draglines, blasting and exposed materials
- For all activities:
  - Coal and overburden transport methods
  - Management of particulate matter emissions from unloading trucks, haul roads and conveyors
  - Management of particulate matter emissions from ROM and product stockpiles
  - Management of particulate matter emissions from CHPP, dry processing of coal, wind erosion, tailings dams and truck and train loading

A copy of the Katestone Environmental letter and internet survey is included as Appendix D.

10.1.3 Internet survey: February – March 2011

The final draft report of this benchmarking study was published on the OEH website (http://www.environment.nsw.gov.au/air/coalminingNSW.htm) on 23 December 2010 and comments were requested by 7 February 2011. A number of mines that did not participate in the survey conducted in July and August 2010, requested that they be given the opportunity to complete the survey. On 22 February 2011, the survey was reissued to those mining companies that had not completed the survey. An additional 33 responses were received.

A copy of the Katestone Environmental letter and internet survey is included as Appendix D.

10.1.4 Coal mine site visits

The following criteria were used to identify the subset of mines to be initially considered for the site visits:

- Open-cut (or combination of open-cut and underground) to provide the broadest range of issues
- Located in the Hunter Valley to provide for most efficient timing of visits
- Relative proximity to sensitive land-use
- Population density and evidence of complaints
- Use of dragline and truck and shovel

Of these mines, the top fifteen mines with respect to production rate and PM_{10} emission rate were identified. Additionally, the relative PM_{10} emission rate was calculated (i.e. the emission rate of PM_{10} per tonne of coal produced) and used to identify mines with low and high relative PM_{10} emission rates. Preliminary information from the review of current NSW management practices identified a number of mines of particular interest. Relative proximity of mines to residential areas was also considered. Using the nominated criteria, nineteen mines were identified and as a result of personnel availability during the two weeks of visits, arrangements were able to be made with 13 of those mines for inspections.

The following sites were visited during the study:

- Hunter Valley Operations
- Mt Arthur North Coal Mine
- Saxonvale Colliery Holding
- Warkworth Coal Mine/Mount Thorley Operations
- Mt Owen Coal Mine
- Wambo Coal Pty Ltd
- Liddell Coal Operations
- Bengalla Mine
- Ravensworth/Narama Mine
- Muswellbrook Colliery Holding
- Cumnock No. 1 Colliery
- Glendell Mine
- Donaldson Coal Pty Ltd

The objectives of the visits were as follows:

- Observe and document air quality management and mitigation measures implemented at each site
- Focus of observations was on major sources of particulate matter:
    - Unpaved roads and haul trucks
    - Wind erosion of overburden and exposed areas
    - Blasting
    - ROM pad
    - Dragline and overburden handling
- Develop an understanding, through discussion with relevant site personnel, the effectiveness of particulate matter mitigation strategies and the site constraints to reducing emissions

10.1.5 Review of AEMR, EMS, EMP and EPL documents

Relevant documents were obtained for each facility as a result of the written request for information and from the websites of some facilities. EPLs for all activities were obtained from OEH's website. All relevant documents have been reviewed and details of management practices and monitoring data have been compiled. Forty eight AEMRs have been obtained and details of particulate matter management activities have been included in this study. In some cases, where AEMR were not available, EMP or EMS have been used. Minimal information was available for five mines.

This information has been summarised in the following sections.

10.2 Results of internet survey

Responses representing fifty nine facilities were received during the two survey periods. The results of the surveys are summarised in the following sections. Survey respondents represented 93% of coal production in the GMR and 91% of estimated PM_{10} emissions using the CMED. The data from the surveys has been used to supplement the information obtained about GMR mines and this information is presented in the following sections. Responses to each survey question are summarised at Appendix E.

Of the fifty nine respondents, 41% represent underground mining activities and 41% open-cut mining activities (Figure 55). Fifteen percent of respondents conduct no mining, but represent either processing plants or former mines under rehabilitation or care and maintenance.

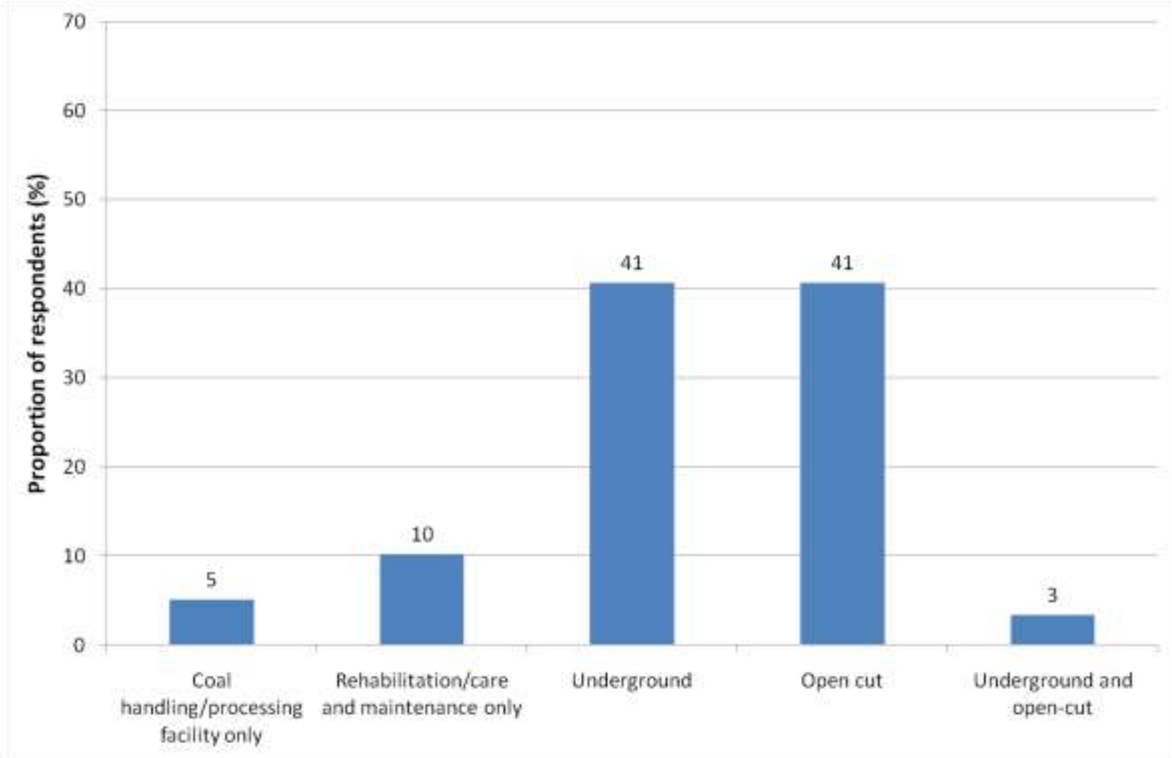

Figure 55 Survey response: type of coal produced

Of the mines that responded to the survey, the majority (59%) produce thermal coal of either low or high ash content (Figure 56). High ash thermal coal has ash content from 15-30% whilst low ash thermal coal has ash content that is less than 15%[180]. Twenty six percent produce coking coal. The other category includes mines producing soft coking coals and mines that produce multiple products for export and local markets.

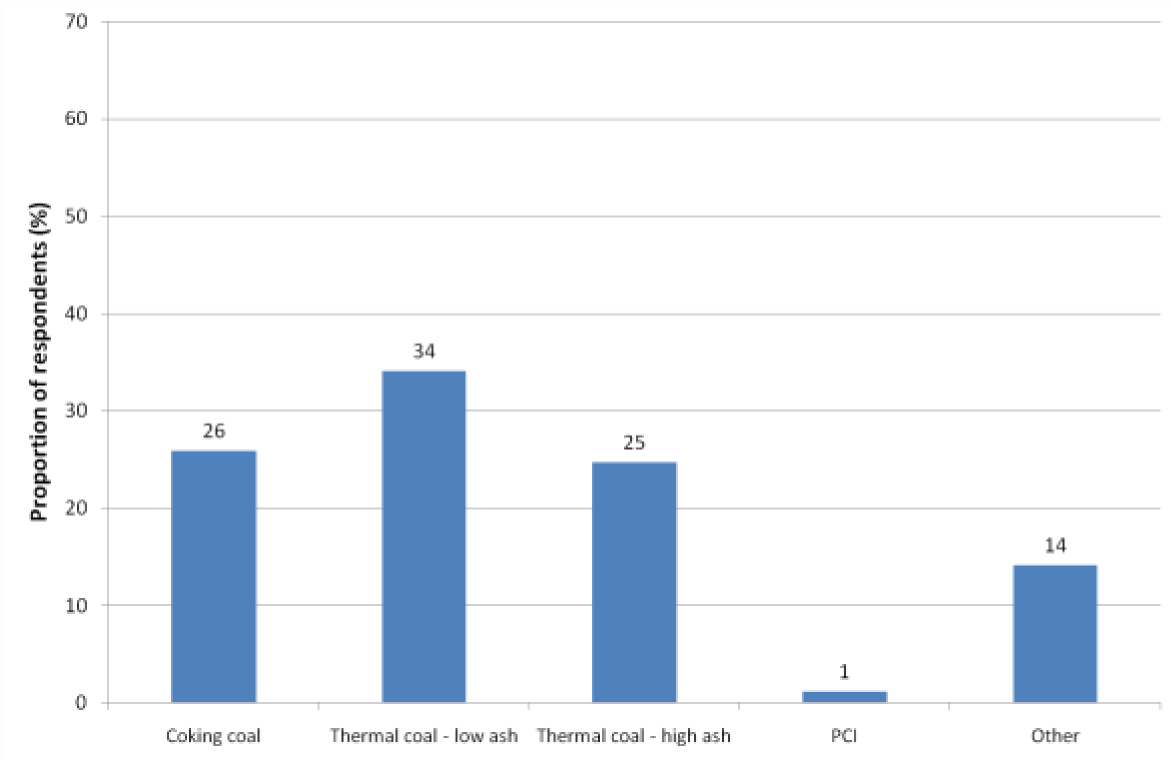

Figure 56 Survey response: type of coal produced

10.3 Particulate matter emission control metric

A particulate matter emission control metric was developed to quantify the progress of mines towards achieving best practice in control of emissions of particulate matter. The metric has been solely based on data provided by EPA licensees in response to the OEH industrial survey conducted in 2009 and contained within CMED. For an individual source of particulate matter emissions the source metric is calculated as follows:

$$M_i = \frac{CF_i}{CF_{i-B}} \times 100$$

Where:

M_i is the metric for source i
CF_i is the current control factor for source i
CF_{i-B} is the best practice control factor for source i

The combined metric for a mine is the sum of metrics calculated for each individual source weighted by the contribution of that uncontrolled source to the mine's total uncontrolled emission rate. For a mine with best practice the score would be 100. To achieve a high score, a mine must score close to 100 for the emission sources that represent the majority of emissions.

For a mine the combined metric is calculated as an uncontrolled emission weighted sum of the individual source metrics as follows:

$$M_m = \sum_{i=1}^{n} \frac{E_{i,m}}{E_m} \times \frac{CF_{i,m}}{CF_{i-B}} \times 100$$

Where:

M_m is the metric for mine m.
$E_{i,m}$ is the uncontrolled source emission rate for source i at mine m.
E_m is the total uncontrolled emission rate of all sources at mine m:

$$E_m = \sum_{i=1}^{n} E_{i,m}$$

$CF_{i,m}$ is the current control factor for source i at mine m
$CF_{i\text{-}B}$ is the best practice control factor for source i

For the GMR, a combined metric representing the progress towards achieving best practice across all mines was calculated from the metric for each individual mine as follows:

$$M_{GMR} = \sum_{m=1}^{n} M_m \times \frac{E_m}{E_{GMR}}$$

Where:

M_{GMR} is the metric for the entire GMR.
M_m is the metric for mine m.
E_m is the total emission rate of all sources at mine m
E_{GMR} is the sum of the uncontrolled emissions from all mines in the GMR i.e.

$$E_{GMR} = \sum_{m=1}^{n} E_m$$

An example of this calculation is shown in Table 99. In the example, Mine C is achieving best practice for emission source 1., but is below best practice for sources 2 and 3. The metric for Mine A is 55, for Mine B is 62 and for Mine C is 74, indicating that Mine C is providing the best level of emission control for particulate emissions. Emission source 1 is controlled to the greatest degree of all the sources with a combined source metric of 85. Emission source 2 is controlled to the lowest extent. The metric for all three mines combined is 67.

Table 99 Example calculation of the particulate matter emission control metric for three mines each with three emission sources

Mine	Current control factor for each source (CF_i)			Uncontrolled source emission rate for each source (tonnes/year)				Metric (M_i)			
	CF1	**CF2**	**CF3**	**E1**	**E2**	**E3**	**Sum (E_m)**	**M1**	**M2**	**M3**	**Mine metric (M_m)**
A	0.2	0.25	0.85	20	60	20	100	29	50	94	**55**
B	0.5	0.1	0.75	33	16.5	16.5	66	71	20	83	**62**
C	0.7	0.1	0.5	104	20.8	83.2	208	100	20	56	**74**
Sum				157	97.3	119.7	374				
Source metric								**85**	**38**	**66**	
Best Practice (CF_{i-B})	**0.7**	**0.5**	**0.9**								

Combined metrics have been calculated using a consistent methodology to that described above for mining activities. These metrics are presented in the following sections.

10.4 Identification of existing management practices

10.4.1 Haul roads

Of all sources of particulate matter from coal mining activities in the GMR, wheel generated emissions, which is mainly generated by trucks travelling on unsealed haul roads, has been ranked number 1 in terms of emissions of TSP and PM_{10} and number 2 in terms of emissions of $PM_{2.5}$. Haul roads have been estimated to contribute 52.4% of TSP, 39.1% of PM_{10} and 22.6% of $PM_{2.5}$ emissions from coal mines in the GMR.

The methods used to minimise emissions of particulate matter from haul roads based on information contained in AEMR, EMP and from site visits are summarised in Table 100 for underground mines and Table 101 for open-cut mines and combined open-cut and underground mines. Measures for minimising emissions of particulate matter from unpaved haul roads are:

- Watering;
- Grading;
- Well-defined haul routes;
- Speed limits to 40 km per hour; and/or
- The use of suppressants.

The data indicates that 89% of underground mines and 96% of open-cut mines use either fixed sprays or water carts to control emissions of particulate matter from haul roads. The majority of mines that were visited indicated that haul roads were watered on a consistent routine basis under normal weather conditions and that, under adverse conditions, visible particulate matter above the deck, wheels or tray of the haul trucks was used as a trigger for the application of additional watering. At a number of mines that were visited, haul truck drivers were instrumental in identifying problematic conditions and ensuring that water was applied to roads. However, the degree of diligence of watering activities could not be determined for each mine from the available information. Hence, the fact that watering is implemented may not mean that emissions are minimised as far as is practicable.

Approximately 74% of underground mines and 64% of open-cut mines use speed restrictions to control emissions of particulate matter from unpaved haul roads.

Table 100 Management of particulate matter from haul roads in the GMR - underground mines

Coal Mine	Covered Product Trucks	Haul Road Watering	Road sweeping	Road Grading	Permanent sealing site roads	Maintain all sealed roads	Minimise haul distances	Chemical dust suppressant on unsealed roads	Well defined haul routes	Speed limits on haul roads	Watering during peak activity periods (shift changes)	Vegetating obsolete haul roads	Truck wash
Abel Underground Mine		✓			✓		✓			✓			
Airly Coal Project		✓								✓	✓		
Angus Place Colliery		✓			✓					✓			
Appin Coal Mine		✓	✓	✓	✓			✓					
Austar Coal Mine		✓		✓						✓			
Awaba Colliery		✓	✓		✓		✓			✓			
Baal Bone Colliery		✓											
Chain valley Colliery	✓	✓	✓		✓					✓			
Charbon Coal Pty Ltd		✓							✓	✓			
Clarence Colliery			✓										
Dendrobium Mine		✓	✓		✓					✓			
Glennies Creek Colliery	✓							✓		✓			✓
Mandalong Mine and Cooranbong Colliery	✓												
Mannering Colliery		✓	✓							✓			
Metropolitan Colliery	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓
Myuna Colliery		✓	✓		✓					✓			
Newstan Colliery		✓		✓				✓		✓			
NRE No 1 Colliery		✓		✓	✓			✓		✓			✓
NRE Wongawilli Colliery		✓			✓					✓			
Ravensworth Underground mine		✓		✓	✓			✓					
Richmond Main East		✓		✓	✓					✓			
Springvale Colliery	✓	✓			✓					✓			
Tahmoor Colliery		✓			✓			✓					
Tasman Coal mine		✓			✓					✓			
United Colliery		✓											
West Wallsend Colliery		✓			✓					✓			
Westcliff and Northcliff Collieries	✓	✓		✓				✓		✓			✓
Proportion of total (%)	22	89	26	30	59	4	11	30	7	74	4	4	15

Table 101 Management of particulate matter from haul roads in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Covered Product Trucks	Haul Road Watering	Road sweeping	Road Grading	Permanent sealing site roads	Dust Shaker Grid[a]	Maintain all sealed roads	Minimise haul distances	Chemical dust suppressant on unsealed roads	Well defined haul routes	Speed limits on haul roads	Watering during peak activity periods (shift changes)	Vegetating obsolete haul roads	Fewer larger trucks
Ashton Coal Mine		✓		✓				✓		✓	✓			
Bengalla		✓			✓			✓			✓	✓	✓	
Bloomfield Colliery		✓		✓	✓		✓	✓		✓	✓	✓	✓	
Camberwell (Integra Coal Open-cut)		✓												
Cullen Valley Mine	✓	✓		✓		✓	✓				✓			
Cumnock No.1 Colliery		✓		✓										
Donaldson Coal Mine		✓		✓	✓			✓			✓			
Drayton Coal Mine		✓		✓							✓			
Glendell Mine, Mt Owen Mine, Ravensworth East		✓		✓					✓		✓			
Hunter Valley Operations		✓			✓			✓			✓	✓	✓	
Ivanhoe No.2 Colliery		✓												
Liddell Coal Operations		✓		✓						✓	✓			
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)		✓							✓	✓	✓			
Moolarben Coal Mine		✓		✓						✓	✓			
Mount Arthur Coal Mine		✓		✓					✓		✓			
Mount Thorley Warkworth Operations		✓			✓			✓			✓	✓	✓	
Muswellbrook Colliery Holding		✓		✓	✓					✓			✓	
Pine Dale Mine														
Ravensworth Narama		✓												
Rix's Creek Colliery Holding		✓												
Saxonvale Colliery Holding		✓		✓						✓	✓			
The Invincible Mine	✓	✓												
Wambo Coal	NA	✓	✓							✓	✓			
Westside Mine		✓			✓					✓				
Wilpinjong Coal Pty Ltd	NA	✓		✓				✓		✓	✓		✓	✓
Proportion of total (%)	10	96	4	52	28	4	8	28	12	40	64	16	24	4

Note
[a] Dust shaker grid or rumble strips are used to remove loose material from a vehicle by vibration as the vehicle travels across the grid or strip.

The individual source metrics for haul roads, which are presented in Table 102 assume best practice control factors of 84% (i.e. the use of suppressant) and 50% (i.e. soil is naturally or artificially moist), respectively, for haul roads and graders. Table 102 details the current control factors that are in the CMED for each mine in the GMR and the individual source metric for each mine for controlling emissions from unpaved haul roads.

Table 102 Current control factor for haul roads in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Haul roads		Graders	
	Current control	Source metric	Current control	Source metric
Best practice - suppressant	**0.84**	**100%**	**0.5**	**100**
CUMNOCK NO. 1 COLLIERY	0.50	60%	NC	NC
BAYSWATER COLLIERY	-	-	-	-
MANNERING COLLIERY	-	-	-	-
MANDALONG MINE AND COORANBONG COLLIERY	-	-	-	-
MYUNA COLLIERY	-	-	-	-
BLOOMFIELD COLLIERY	0.75	89%	NC	NC
AUSTAR COAL MINE	-	-	NC	NC
AWABA COLLIERY	-	-	-	-
ANGUS PLACE COLLIERY	-	-	-	-
CHARBON COAL PTY LIMITED	0.50	60%	NC	NC
WAMBO COAL PTY LTD	0.50	60%	NC	NC
SAXONVALE COLLIERY HOLDING	0.50	60%	NC	NC
BERRIMA COLLIERY	-	-	-	-
IVANHOE NO.2 COLLIERY	-	-	-	-
HUNTER VALLEY OPERATIONS	0.75	89%	-	-
MUSWELLBROOK COLLIERY HOLDING	0.50	60%	NC	NC
CLARENCE COLLIERY	0.50	60%	-	-
APPIN COLLIERY	-	-	-	-
BAAL BONE COLLIERY	0.50	60%	-	-
METROPOLITAN COLLIERY	0.75	89%	-	-
NRE WONGAWILLI COLLIERY	0.75	89%	-	-
DRAYTON COAL MINE	0.50	60%	NC	NC
WEST WALLSEND COLLIERY	-	-	-	-
WARKWORTH COAL MINE	0.75	89%	NC	NC
TAHMOOR COLLIERY	0.50	60%	-	-
CHAIN VALLEY COLLIERY	-	-	-	-
MOUNT THORLEY OPERATIONS	-	-	-	-
LIDDELL COAL OPERATIONS	0.75	89%	0.50	100%
WESTCLIFF AND NORTHCLIFF COLLIERIES	-	-	-	-
RAVENSWORTH/NARAMA MINE	0.50	60%	NC	NC
UNITED COLLIERY	0.50	60%	-	-
DENDROBIUM MINE	-	-	-	-
CAMBERWELL COAL MINE	0.50	60%	NC	NC
RIX'S CREEK COLLIERY	0.75	89%	NC	NC
SPRINGVALE COLLIERY	-	-	-	-
WESTSIDE MINE	0.50	60%	0.43	88%
MT OWEN COAL MINE	0.50	60%	0.50	100%
PINE DALE MINE	0.50	60%	NC	NC
BENGALLA MINE	0.75	89%	NC	NC
GLENNIES CREEK COLLIERY	0.50	60%	-	-
RAVENSWORTH UNDERGROUND MINE	0.50	60%	NC	NC
CULLEN VALLEY MINE	0.50	60%	NC	NC
RAVENSWORTH EAST MINE	0.75	89%	0.50	100%
DONALDSON COAL PTY LTD	0.50	60%	NC	NC
MT ARTHUR NORTH COAL MINE	0.75	89%	-	-
ASHTON COAL MINE	0.75	89%	NC	NC
NRE NO 1 COLLIERY	-	-	-	-
NEWSTAN COLLIERY	0.50	60%	-	-
MACQUARIE COAL PREPARATION PLANT	0.50	60%	0.50	100%
THE INVINCIBLE COLLIERY	0.50	60%	NC	NC
WILPINJONG COAL PTY LTD	0.50	60%	NC	NC
TASMAN COAL MINE	-	-	-	-

Mine	Haul roads		Graders	
	Current control	Source metric	Current control	Source metric
GLENDELL MINE	0.75	89%	NC	NC
ABEL UNDERGROUND MINE	-	-	-	-
XSTRATA MANGOOLLA (ANVIL HILL MINE)	-	-	-	-
RICHMOND MAIN EAST	-	-	-	-
Note NC means no controls "–" means no emissions from this source				

The combined particulate matter emission control metric for wheel generated emissions from haul roads at coal mines in the GMR is 77.9 out of 100. This indicates that most of the mines that have a significant contribution to particulate matter emissions from haul roads have stated that they are applying Level 2 watering. The combined particulate matter emission control metric for graders at coal mines in the GMR is 31.1 out of 100.

10.4.2 Wind erosion

Of all sources of particulate matter from coal mining activities in the GMR, wind erosion of overburden, was ranked number 2 in terms of emissions of TSP and PM_{10} and number 1 in terms of emissions of $PM_{2.5}$. Wind erosion of exposed areas and coal stockpiles also ranked highly. Wind erosion has been estimated to contribute 22.5% of TSP, 32.5% of PM_{10} and 37.8% of $PM_{2.5}$ emissions from coal mines in the GMR.

The methods used to minimise emissions of particulate matter associated with wind erosion of cleared areas and overburden and coal stockpiles are summarised in Table 103 for underground mines and Table 104 for open-cut mines and combined open-cut and underground mines. Current measures for minimising emissions of particulate matter from wind erosion are:

- Watering exposed areas
- Topsoil stripping when moisture is elevated but not sodden
- Minimising the area of disturbance
- Progressive rehabilitation
- Suppressant on stockpiles and exposed areas
- Long term stockpiles revegetated
- Stockpile moisture content measured and controlled
- Wind barriers

The data indicates that the majority (78%) of underground mines use watering to control emissions of particulate from cleared areas. At open-cut mines and combined underground and open-cut mines, watering (92%) and limiting areas of disturbance (84%) are the major techniques that are used to minimise emissions associated with wind erosion. Sixty five percent of mines use water applied by fixed sprays (Figure 57[181]) or by water cart to manage particulate matter emissions generated by wind erosion.

One mine was identified as using suppressants to manage emissions from ROM stockpiles.

Table 103 Management of particulate matter from wind erosion in the GMR - underground mines

Coal Mine	Water exposed areas/active areas	Topsoil stripping when moisture is elevated but not sodden	Minimise area of disturbance	Chemical dust suppressants	Stockpile moisture content measured and controlled	Wind barriers	Suppressant on ROM stockpiles
Abel Underground Mine	✓		✓				
Airly Coal Project							
Angus Place Colliery	✓						
Appin Coal Mine	✓			✓			
Austar Coal Mine	✓					✓	
Awaba Colliery	✓						
Baal Bone Colliery	✓						
Chain valley Colliery	✓						
Charbon Coal Pty Ltd		✓	✓				
Clarence Colliery							
Dendrobium Mine	✓				✓		
Glennies Creek Colliery	✓		✓		✓		
Mandalong Mine and Cooranbong Colliery	✓						
Mannering Colliery	✓						
Metropolitan Colliery	✓		✓				
Myuna Colliery	✓						
Newstan Colliery	✓						
NRE No 1 Colliery	✓						
NRE Wongawilli Colliery							✓
Ravensworth Underground mine	✓		✓	✓			
Richmond Main East	✓						
Springvale Colliery	✓						
Tahmoor Colliery	✓						
Tasman Coal mine							
United Colliery							
West Wallsend Colliery	✓						
Westcliff and Northcliff Collieries	✓						
Proportion of total (%)	78	4	19	7	7	4	4

Table 104 Management of particulate matter from wind erosion in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Water exposed areas/active areas	Topsoil stripping when moisture is elevated but not sodden	Minimise area of disturbance	Chemical dust suppressants	Stockpile moisture content measured and controlled	Wind barriers	Water application by fixed sprays or water cart on ROM pad	Suppressant on ROM stockpiles
Ashton Coal Mine	✓		✓				✓	
Bengalla	✓	✓	✓			✓	✓	
Bloomfield Colliery	✓		✓				✓	
Camberwell (Integra Coal Open Cut)	✓	✓	✓				✓	
Cullen Valley Mine	✓	✓						
Cumnock No. 1 Colliery	✓	✓	✓					
Donaldson Coal Mine	✓		✓				✓	
Drayton Coal Mine	✓		✓				✓	
Glendell Mine, Mt Owen Mine, Ravensworth East	✓		✓	✓				
Hunter Valley Operations	✓	✓	✓	✓		✓	✓	
Ivanhoe No.2 Colliery	✓		✓					
Liddell Coal Operations	✓	✓		✓			✓	
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓		✓	✓				
Moolarben Coal Mine	✓		✓				✓	
Mount Arthur Coal Mine	✓		✓				✓	
Mount Thorley Warkworth Operations	✓	✓	✓				✓	
Muswellbrook Collier Holding	✓		✓				✓	
Pine Dale Mine								
Ravensworth Narama	✓	✓	✓					
Rix's Creek Colliery Holding							✓	
Saxonvale Colliery Holding	✓	✓	✓				✓	
The Invincible Mine	✓		✓			✓	✓	
Wambo Coal	✓		✓			✓		
Westside Mine	✓		✓				✓	
Wilpinjong Coal Pty Ltd	✓		✓					
Proportion of total (%)	92	36	84	16	0	16	64	0

Figure 57 Stockpile sprays

Progressive rehabilitation was found to be a best practice measure for minimising emissions of particulate matter associated with wind erosion. Table 105 and Table 106 provide information on aspects of rehabilitation noted in the available information. The development of site and industry wide benchmarks and key performance indicators and the annual reporting against the key performance indicators would bolster the use of rehabilitation as a best practice measure to control particulate emissions. It was noted in the review of mine information that some mines already use the extent of rehabilitation achieved in a year as a key performance indicator.

Use of hydraulic mulch and aerial seeding has been found to be effective in establishing a vegetative cover in a relatively short period of time (six weeks) under favourable weather conditions. Hydraulic mulch also provides an immediate sealing of the surface material that will minimise the emissions of particulate matter until the vegetative cover takes hold. The study found information to suggest that one of the underground mines and six open-cut mines have used hydraulic mulch. Other mines indicated an interest in using hydraulic mulch in the future.

Discussions with site personnel suggest that at least five mines have successfully used aerial seeding to assist in rehabilitation.

Table 105 Management of particulate matter using rehabilitation in the GMR - underground mines

Coal Mine	Progressive rehabilitation	Seeding topsoil	Use of ameliorants to improve soil	Hydraulic mulch seeding	Use of Organic Growth Medium (OGM)	Rehabilitation Strategy
Abel Underground Mine						
Airly Coal Project				✓		
Angus Place Colliery						
Appin Coal Mine						
Austar Coal Mine						
Awaba Colliery						
Baal Bone Colliery						
Chain valley Colliery						
Charbon Coal Pty Ltd						
Clarence Colliery						
Dendrobium Mine						
Glennies Creek Colliery	✓					
Mandalong Mine and Cooranbong Colliery	✓					✓
Mannering Colliery						
Metropolitan Colliery						
Myuna Colliery						
Newstan Colliery	✓	✓				
NRE No 1 Colliery						
NRE Wongawilli Colliery						
Ravensworth Underground mine						
Richmond Main East						
Springvale Colliery	✓					
Tahmoor Colliery	✓					
Tasman Coal mine						
United Colliery						✓
West Wallsend Colliery						
Westcliff and Northcliff Collieries						
Proportion of total (%)	19	4	0	4	0	7

Table 106 Management of particulate matter using rehabilitation in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Progressive rehabilitation	Seeding topsoil	Use of ameliorants to improve soil	Hydraulic mulch seeding	Use of Organic Growth Medium (OGM)	Rehabilitation Strategy
Ashton Coal Mine	✓	✓	✓		✓	✓
Bengalla	✓	✓	✓	✓		✓
Bloomfield Colliery	✓				✓	
Camberwell (Integra Coal Open Cut)	✓					
Cullen Valley Mine	✓	✓				
Cumnock No1 Colliery	✓	✓	✓	✓		
Donaldson Coal Mine	✓					
Drayton Coal Mine	✓					
Glendell Mine, Mt Owen Mine, Ravensworth East	✓	✓	✓	✓		✓
Hunter Valley Operations	✓		✓		✓	✓
Ivanhoe No.2 Colliery	✓					
Liddell Coal Operations	✓	✓	✓			
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓	✓				
Moolarben Coal Mine	✓					
Mount Arthur Coal Mine	✓	✓				
Mount Thorley Warkworth Operations	✓		✓	✓	✓	✓
Muswellbrook Colliery Holding	✓	✓				✓
Pine Dale Mine						
Ravensworth Narama	✓	✓	✓	✓		
Rix's Creek Colliery Holding						
Saxonvale Colliery Holding	✓	✓				
The Invincible Mine						
Wambo Coal	✓	✓	✓	✓		
Westside Mine	✓					
Wilpinjong Coal Pty Ltd						
Proportion of total (%)	84	48	36	24	16	24

The individual source metrics for coal stockpiles, overburden stockpiles and other exposed areas, which are presented in Table 107 assume best practice control factors of 75% (i.e. wind screens, wind fences or erect three-sided enclosure around storage piles), 80% (i.e. fencing, bunding, shelterbelts or in-pit dump) and 99% (i.e. rehabilitation or revegetation), respectively. Table 107 details the current control factors that are in the CMED for each mine in the GMR and the individual source metric for each mine for controlling emissions from exposed areas, overburden and coal stockpiles.

Table 107 Current control factor for wind erosion of exposed areas, coal stockpiles and overburden in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Exposed areas		Coal stockpiles		Overburden	
	Current control	Source metric	Current control	Source metric	Current control	Source metric
Best practice - various	**0.99**	**100**	**0.75**	**100**	**0.8**	**100**
CUMNOCK NO. 1 COLLIERY	-	-	0.50	67%	0.02	2%
BAYSWATER COLLIERY	-	-	0.50	67%	0.23	23%
MANNERING COLLIERY	-	-	NC	NC	-	-
MANDALONG MINE AND COORANBONG COLLIERY	-	-	NC	NC	-	-
MYUNA COLLIERY	-	-	0.95	100%	-	-
BLOOMFIELD COLLIERY	-	-	0.50	67%	0.80	100%
AUSTAR COAL MINE	-	-	0.50	67%	0.50	91%
AWABA COLLIERY	-	-	NC	NC	-	-
ANGUS PLACE COLLIERY	-	-	NC	NC	-	-
CHARBON COAL PTY LIMITED	NC	NC	0.50	67%	-	-
WAMBO COAL PTY LTD	0.90	91%	0.50	67%	-	-
SAXONVALE COLLIERY HOLDING	-	-	0.50	67%	NC	NC
BERRIMA COLLIERY	-	-	0.50	67%	-	-
IVANHOE NO.2 COLLIERY	-	-	-	-	NC	NC
HUNTER VALLEY OPERATIONS	-	-	0.00	0%	NC	NC
MUSWELLBROOK COLLIERY HOLDING	-	-	NC	NC	0.39	70%
CLARENCE COLLIERY	NC	NC	0.50	67%	-	-
APPIN COLLIERY	-	-	0.50	67%	-	-
BAAL BONE COLLIERY	0.50	51%	NC	NC	0.50	91%
METROPOLITAN COLLIERY	-	-	0.50	67%	-	-
NRE WONGAWILLI COLLIERY	-	-	0.50	67%	-	-
DRAYTON COAL MINE	-	-	0.50	67%	0.80	100%
WEST WALLSEND COLLIERY	-	-	0.50	67%	-	-
WARKWORTH COAL MINE	-	-	0.50	67%	0.99	100%
TAHMOOR COLLIERY	-	-	0.41	55%	0.50	91%
CHAIN VALLEY COLLIERY	-	-	0.50	67%	-	-
MOUNT THORLEY OPERATIONS	NC	NC	0.50	67%	NC	NC
LIDDELL COAL OPERATIONS	-	-	0.28	37%	NC	NC
WESTCLIFF AND NORTHCLIFF COLLIERIES	-	-	0.50	67%	-	-
RAVENSWORTH/NARAMA MINE	-	-	NC	NC	0.46	100%
UNITED COLLIERY	-	-	0.50	67%	-	-
DENDROBIUM MINE	-	-	0.50	67%	-	-
CAMBERWELL COAL MINE	0.40	61%	0.59	78%	0.99	100%
RIX'S CREEK COLLIERY	-	-	0.50	67%	0.80	100%
SPRINGVALE COLLIERY	-	-	0.50	67%	NC	NC
WESTSIDE MINE	-	-	NC	NC	NC	NC
MT OWEN COAL MINE	-	-	NC	NC	NC	NC
PINE DALE MINE	-	-	0.50	67%	-	-
BENGALLA MINE	0.50	51%	0.50	67%	-	-
GLENNIES CREEK COLLIERY	0.99	71%	0.50	67%	-	-
RAVENSWORTH UNDERGROUND MINE	-	-	NC	NC	0.75	100%
CULLEN VALLEY MINE	-	-	0.50	67%	0.07	12%
RAVENSWORTH EAST MINE	-	-	NC	NC	0.50	91%
DONALDSON COAL PTY LTD	0.60	74%	0.25	33%	-	-
MT ARTHUR NORTH COAL MINE	-	-	0.50	67%	0.24	24%
ASHTON COAL MINE	NC	NC	0.50	67%	0.99	100%
NRE NO 1 COLLIERY	-	-	0.50	67%	-	-
NEWSTAN COLLIERY	-	-	0.50	67%	-	-
MACQUARIE COAL PREPARATION PLANT	-	-	0.50	67%	-	-
THE INVINCIBLE COLLIERY	-	-	0.50	67%	0.07	12%
WILPINJONG COAL PTY LTD	-	-	0.27	36%	0.99	100%
TASMAN COAL MINE	NC	NC	0.50	67%	-	-

Mine	Exposed areas		Coal stockpiles		Overburden	
GLENDELL MINE	-	-	-	-	0.50	91%
ABEL UNDERGROUND MINE	NC	NC	0.50	67%	-	-
XSTRATA MANGOOLLA (ANVIL HILL MINE)	-	-	-	-	0.50	91%
RICHMOND MAIN EAST	-	-	-	-	0.50	91%
Note NC means no controls " – " means no emissions from this source						

Table 108 shows the combined particulate matter emission control metrics for wind erosion sources at coal mines in the GMR. The table shows that a moderate level of control is applied to wind erosion sources.

Table 108 Combined particulate matter emission control metric for GMR wind erosion sources

Wind erosion source	Combined metric for GMR mines
Exposed areas	63
Coal stockpiles	51
Overburden	54

10.4.3 Bulldozing

Of all sources of particulate matter from coal mining activities in the GMR, bulldozing was ranked number 3 in terms of emissions of TSP and PM_{10} and number 4 in terms of emissions of $PM_{2.5}$. Bulldozing has been estimated to contribute 9.1% of TSP, 8.3% of PM_{10} and 8.6% of $PM_{2.5}$ emissions from coal mines in the GMR.

The review of current practices identified no specific measures are implemented to control emissions of particulate matter associated with bulldozing at coal mines in the GMR.

The individual source metrics for bulldozing coal and overburden, which are presented in Table 109, assume a best practice control factor of 50% (i.e. use of water to keep travel routes and materials moist). Table 109 details the current control factors that are shown in the CMED for each mine in the GMR and the individual source metric for each mine for controlling emissions from bulldozers.

Table 109 Current control factor for bulldozing coal and overburden in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Bulldozing coal		Bulldozing overburden	
	Current control	Source metric	Current control	Source metric
Best practice	**0.5**	**100**	**0.5**	**100**
CUMNOCK NO. 1 COLLIERY	NC	NC	NC	NC
BAYSWATER COLLIERY	NC	NC	NC	NC
MANNERING COLLIERY	-	-	-	-
MANDALONG MINE AND COORANBONG COLLIERY	NC	NC	-	-
MYUNA COLLIERY	-	-	-	-
BLOOMFIELD COLLIERY	NC	NC	NC	NC
AUSTAR COAL MINE	NC	NC	-	-
AWABA COLLIERY	-	-	-	-
ANGUS PLACE COLLIERY	NC	NC	-	-
CHARBON COAL PTY LIMITED	NC	NC	NC	NC
WAMBO COAL PTY LTD	NC	NC	NC	NC
SAXONVALE COLLIERY HOLDING	NC	NC	NC	NC
BERRIMA COLLIERY	-	-	-	-

Mine	Bulldozing coal		Bulldozing overburden	
IVANHOE NO.2 COLLIERY	-	-	-	-
HUNTER VALLEY OPERATIONS	NC	NC	NC	NC
MUSWELLBROOK COLLIERY HOLDING	NC	NC	NC	NC
CLARENCE COLLIERY	NC	NC	-	-
APPIN COLLIERY	-	-	-	-
BAAL BONE COLLIERY	NC	NC	-	-
METROPOLITAN COLLIERY	-	-	-	-
NRE WONGAWILLI COLLIERY	NC	NC	-	-
DRAYTON COAL MINE	NC	NC	NC	NC
WEST WALLSEND COLLIERY	-	-	-	-
WARKWORTH COAL MINE	NC	NC	NC	NC
TAHMOOR COLLIERY	NC	NC	-	-
CHAIN VALLEY COLLIERY	-	-	-	-
MOUNT THORLEY OPERATIONS	-	-	-	-
LIDDELL COAL OPERATIONS	NC	NC	NC	NC
WESTCLIFF AND NORTHCLIFF COLLIERIES	NC	NC	-	-
RAVENSWORTH/NARAMA MINE	NC	NC	NC	NC
UNITED COLLIERY	NC	NC	-	-
DENDROBIUM MINE	NC	NC	-	-
CAMBERWELL COAL MINE	NC	NC	NC	NC
RIX'S CREEK COLLIERY	NC	NC	NC	NC
SPRINGVALE COLLIERY	NC	NC	NC	NC
WESTSIDE MINE	NC	NC	NC	NC
MT OWEN COAL MINE	NC	NC	NC	NC
PINE DALE MINE	NC	NC	NC	NC
BENGALLA MINE	NC	NC	-	-
GLENNIES CREEK COLLIERY	NC	NC	-	-
RAVENSWORTH UNDERGROUND MINE	-	-	-	-
CULLEN VALLEY MINE	NC	NC	NC	NC
RAVENSWORTH EAST MINE	NC	NC	NC	NC
DONALDSON COAL PTY LTD	NC	NC	NC	NC
MT ARTHUR NORTH COAL MINE	NC	NC	NC	NC
ASHTON COAL MINE	NC	NC	NC	NC
NRE NO 1 COLLIERY	NC	NC	-	-
NEWSTAN COLLIERY	NC	NC	-	-
MACQUARIE COAL PREPARATION PLANT	NC	NC	-	-
THE INVINCIBLE COLLIERY	NC	NC	NC	NC
WILPINJONG COAL PTY LTD	NC	NC	NC	NC
TASMAN COAL MINE	-	-	-	-
GLENDELL MINE	NC	NC	NC	NC
ABEL UNDERGROUND MINE	-	-	-	-
XSTRATA MANGOOLLA (ANVIL HILL MINE)	-	-	-	-
RICHMOND MAIN EAST	-	-	NC	NC
Note NC means no controls " – " means no emissions from this source				

Table 109 shows that the metric representing the current level of control of particulate matter emissions from bulldozing is 0 out of 100.

10.4.4 Blasting and drilling

Of all sources of particulate matter in coal mining activities in the GMR, blasting was ranked number 5 in terms of emissions of TSP, number 4 in terms of emissions of PM_{10} and number 3 in terms of emissions of $PM_{2.5}$. Blasting has been estimated to contribute 3.5% of TSP, 5.6% of PM_{10} and 20.6% of $PM_{2.5}$ emissions from coal mines in the GMR. Drilling was ranked number 15 in terms of emissions of TSP and PM_{10} and number 17 in terms of emissions of $PM_{2.5}$. Drilling has been estimated to contribute 0.2% of TSP, 0.3% of PM_{10} and 0.1% of $PM_{2.5}$ emissions from coal mines in the GMR.

The methods used to minimise emissions of particulate matter associated with blasting in the GMR are summarised in Table 110 for open-cut mines and combined open-cut and underground mines. The data indicates that the majority (96%) restrict blasting to daytime hours only. In most cases this is required under a condition of approval or an EPL condition.

Most mines (91%) also restrict blasting to times of favourable weather conditions. Unfavourable weather conditions are usually defined as times when the wind would direct particulate matter produced by the blast towards a sensitive location. Some mines also avoid blasting when there are strong winds (>10 m/s) to avoid excessive production of particulate matter. Most mines avoid blasting at times when meteorological conditions are likely to be conducive to noise propagation (e.g. stable atmospheric conditions), which corresponds to conditions when dispersion of pollutants is not favoured.

Table 110 Management of particulate matter from blasting in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	No Blasting during adverse weather conditions	Blast during day only	Advise local residents of blasting times	Gravel stemming blast holes	Blast protocol	Coordination with surrounding mines
Ashton Coal Mine	✓	✓	✓	✓	✓	
Bengalla	✓	✓	✓	✓	✓	
Bloomfield Colliery	✓	✓		✓		
Camberwell (Integra Coal Open Cut)	✓	✓	✓	✓		
Cullen Valley Mine	✓	✓	✓		✓	
Cumnock No1 Colliery And Ravensworth	✓		✓			
Donaldson Coal Mine	✓	✓	✓			
Drayton Coal Mine	✓	✓		✓		
Glendell Mine, Mt Owen Mine, Ravensworth East	✓	✓			✓	
Hunter Valley Operations	✓	✓	✓	✓	✓	
Ivanhoe No.2 Colliery	No blasting occurs					
Liddell Coal Operations	✓	✓	✓			
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓				✓	
Moolarben Coal Mine	✓	✓				
Mount Arthur Coal Mine	✓	✓	✓			
Mount Thorley Warkworth Operations	✓	✓	✓	✓	✓	
Muswellbrook Collier Holding	✓	✓	✓	✓	✓	
Pine Dale Mine		✓				
Ravensworth Narama	✓	✓	✓			
Rix's Creek Colliery Holding	✓	✓				
Saxonvale Colliery Holding	✓	✓				

Coal Mine	No Blasting during adverse weather conditions	Blast during day only	Advise local residents of blasting times	Gravel stemming blast holes	Blast protocol	Coordination with surrounding mines
The Invincible Mine		✓		✓		
Wambo Coal	✓	✓		✓		
Westside Mine		✓				
Wilpinjong Coal Pty Ltd	✓	✓	✓			✓
Proportion of total (%)	91	96	57	43	35	4

The methods used to minimise emissions of particulate matter from drilling in the GMR are summarised in Table 111 for open-cut mines and combined open-cut and underground mines. The data indicates that 58% control emissions using water sprays and 63% have curtains. A total of 75% use either dust curtains or water sprays to manage emissions of particulate matter.

Notwithstanding this, visible emissions of particulate matter from drilling equipment were noted at a number of the mines visited during this study. This indicated that emissions may not always be well-controlled despite the availability of effective mitigation techniques.

Table 111 Management of particulate matter from drilling in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Drill rigs have dust curtains	Water sprays on the drill	Fabric filters on the drill	No drilling in adverse weather	Drill area moistened
Ashton Coal Mine	✓	✓		✓	✓
Bengalla	✓	✓			✓
Bloomfield Colliery	✓		✓		
Camberwell (Integra Coal Open Cut)	✓	✓			
Cullen Valley Mine					
Cumnock No1 Colliery	✓			✓	
Donaldson Coal Mine					
Drayton Coal Mine	✓				
Glendell Mine, Mt Owen Mine, Ravensworth East	✓	✓			
Hunter Valley Operations	✓	✓			
Liddell Coal Operations	✓	✓			✓
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)		✓			

Coal Mine	Drill rigs have dust curtains	Water sprays on the drill	Fabric filters on the drill	No drilling in adverse weather	Drill area moistened
Moolarben Coal Mine					
Mount Arthur Coal Mine	✓	✓			
Mount Thorley Warkworth Operations	✓	✓			
Muswellbrook Collier Holding	✓	✓		✓	✓
Pine Dale Mine					
Ravensworth Narama	✓			✓	
Rix's Creek Colliery Holding					
Saxonvale Colliery Holding	✓	✓			✓
The Invincible Mine	✓	✓			
Wambo Coal		✓			
Westside Mine		✓			
Wilpinjong Coal Pty Ltd					
Proportion of total (%)	63	58	4	17	21

The individual source metrics for blasting and drilling, which are presented in Table 112, assume a best practice control factor of 99% (i.e. enclosure with fabric filter). The use of blast design and timing was assumed to be best practice for blasting, but the reduction in emissions associated with this approach to management could not be quantified. Table 112 details the current control factors that are in the CMED for each mine in the GMR and the individual source metric for each mine for controlling emissions from blasting and drilling.

Table 112 Current control factor for blasting and drilling in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Blasting		Drilling	
	Current control	Source metric	Current control	Source metric
Best practice	**NQ**	**100**	**0.99**	**100**
CUMNOCK NO. 1 COLLIERY	NC	NC	NC	NC
BAYSWATER COLLIERY	-	-	-	-
MANNERING COLLIERY	-	-	-	-
MANDALONG MINE AND COORANBONG COLLIERY	-	-	-	-
MYUNA COLLIERY	-	-	-	-
BLOOMFIELD COLLIERY	NC	NC	NC	NC
AUSTAR COAL MINE	-	-	-	-
AWABA COLLIERY	-	-	-	-
ANGUS PLACE COLLIERY	-	-	-	-
CHARBON COAL PTY LIMITED	-	-	-	-
WAMBO COAL PTY LTD	NC	NC	0.70	70%
SAXONVALE COLLIERY HOLDING	NC	NC	NC	NC
BERRIMA COLLIERY	-	-	-	-
IVANHOE NO.2 COLLIERY	-	-	-	-
HUNTER VALLEY OPERATIONS	NC	NC	NC	NC
MUSWELLBROOK COLLIERY HOLDING	NC	NC	0.70	70%

Mine	Blasting		Drilling	
	Current control	Source metric	Current control	Source metric
CLARENCE COLLIERY	-	-	-	-
APPIN COLLIERY	-	-	-	-
BAAL BONE COLLIERY	-	-	-	-
METROPOLITAN COLLIERY	-	-	-	-
NRE WONGAWILLI COLLIERY	-	-	-	-
DRAYTON COAL MINE	NC	NC	NC	NC
WEST WALLSEND COLLIERY	-	-	-	-
WARKWORTH COAL MINE	NC	NC	NC	NC
TAHMOOR COLLIERY	-	-	-	-
CHAIN VALLEY COLLIERY	-	-	-	-
MOUNT THORLEY OPERATIONS	-	-	-	-
LIDDELL COAL OPERATIONS	NC	NC	NC	NC
WESTCLIFF AND NORTHCLIFF COLLIERIES	-	-	-	-
RAVENSWORTH/NARAMA MINE	NC	NC	NC	NC
UNITED COLLIERY	-	-	-	-
DENDROBIUM MINE	-	-	-	-
CAMBERWELL COAL MINE	NC	NC	0.75	75%
RIX'S CREEK COLLIERY	NC	NC	NC	NC
SPRINGVALE COLLIERY	-	-	-	-
WESTSIDE MINE	NC	NC	NC	NC
MT OWEN COAL MINE	NC	NC	0.70	70%
PINE DALE MINE	NC	NC	0.70	70%
BENGALLA MINE	NC	NC	NC	NC
GLENNIES CREEK COLLIERY	-	-	-	-
RAVENSWORTH UNDERGROUND MINE	-	-	-	-
CULLEN VALLEY MINE	NC	NC	NC	NC
RAVENSWORTH EAST MINE	NC	NC	0.70	70%
DONALDSON COAL PTY LTD	NC	NC	0.85	85%
MT ARTHUR NORTH COAL MINE	-	-	-	-
ASHTON COAL MINE	NC	NC	0.70	70%
NRE NO 1 COLLIERY	-	-	-	-
NEWSTAN COLLIERY	-	-	-	-
MACQUARIE COAL PREPARATION PLANT	-	-	-	-
THE INVINCIBLE COLLIERY	NC	NC	NC	NC
WILPINJONG COAL PTY LTD	NC	NC	NC	NC
TASMAN COAL MINE	-	-	-	-
GLENDELL MINE	NC	NC	NC	NC
ABEL UNDERGROUND MINE	-	-	-	-
XSTRATA MANGOOLLA (ANVIL HILL MINE)	-	-	-	-
RICHMOND MAIN EAST	-	-	-	-
Note NQ means best practice emission control factor not quantified NC means no controls “ – “ means no emissions from this source				

No best practice control factor could be quantified for blasting and no control factor is specified in the CMED for mines that conduct blasting. However, Table 110 shows that elements of best practice have been adopted at many mines and so this has been recognised in the calculation of the metric for blasting.

The combined particulate matter emission control metric for blasting at coal mines in the GMR cannot be estimated. The combined particulate matter emission control metric for drilling at coal mines in the GMR has been estimated to be 70.7 out of 100.

10.4.5 Draglines

Of all sources of particulate matter from coal mining activities in the GMR, draglines have been ranked number 8 in terms of emissions of TSP, number 10 in terms of emissions of PM_{10} and number 9 in terms of emissions of $PM_{2.5}$. Draglines have been estimated to contribute 1.9% of TSP, 1.6% of PM_{10} and 1.3% of $PM_{2.5}$ emissions from coal mines in the GMR.

There are seven open-cut coal mines in the GMR that use draglines, these are all located in the Hunter Coalfield, namely:

- Bengalla Mine
- Drayton Coal Mine
- Hunter Valley Operations
- Ravensworth/Narama Mine
- Rix's Creek Colliery
- Saxonvale Colliery Holding
- Warkworth Coal Mine

The methods used to minimise emissions of particulate matter from these draglines based on information contained in AEMR, EMP and from site visits are summarised in Table 113. Best practice for controlling particulate matter from draglines is the minimisation of drop height, careful placement of overburden on overburden piles and the suspension of operations when weather conditions are causing excessive visible emissions. The available data suggests that at least six of the seven mines (86%) minimise drop heights and suspend operations if weather conditions result in excessive particulate matter emissions. The information contained in the CMED for a subset of these mines indicates that the drop heights are minimised to between 6 and 12 metres. Six metres has been taken to be equivalent to best practice.

Observations from the site visits and discussions with mine personnel suggest that whilst the majority of coal mines actively work towards the minimisation of particulate matter from draglines through the use of good operating practices, such as minimising drop heights and careful placement of materials, emissions are still dependent on the skills of the operator. Most mines also indicated that the minimisation of particulate matter emissions was included in training of dragline operators and in standard operating procedures indicating that training and awareness may not be the entire solution to managing emissions.

Table 113 Management of particulate matter from draglines in the GMR

Coal Mine	Minimise drop height	Place material on overburden piles in a manner that minimises emissions	Suspend operations if weather conditions cause excessive visible emissions
Bengalla	✓		✓
Drayton Coal Mine	✓		✓
Hunter Valley Operations	✓		✓
Ravensworth/Narama Mine	✓		✓
Rix's Creek Colliery			
Mount Thorley Warkworth Operations	✓		✓
Saxonvale Colliery Holding	✓	✓	✓
Proportion of total (%)	**86**	**14**	**86**

In addition to training, any performance indicators that are used to manage production should take account of the need for minimisation of emissions from dragline operations.

Given the earlier comments about the potential for a wind tunnel to form in the open-cut mining void, coal mines should not be overly reliant on pit ventilation to minimise emissions. Furthermore, pit retention of particulate matter is only estimated to reduce uncontrolled emissions of PM_{10} by 5%. This control efficiency would be expected to be even less for smaller particles such as $PM_{2.5}$.

The individual source metrics for draglines assume a best practice control factor of 57% (i.e. minimise drop height). The combined particulate matter emission control metric for draglines at coal mines in the GMR has been estimated to be 93.4 out of 100.

10.4.6 Loading and dumping overburden

Of all sources of particulate matter from coal mining activities in the GMR, trucks dumping overburden was ranked number 4 in terms of emissions of TSP, number 5 in terms of emissions of PM_{10} and number 6 in terms of emissions of $PM_{2.5}$. Trucks dumping overburden has been estimated to contribute 4.2% of PM_{10} emissions from coal mines in the GMR. Loaders dumping overburden ranked number 11 in terms of emissions of TSP, PM_{10} and $PM_{2.5}$. Loaders dumping overburden has been estimated to contribute 1.2% of PM_{10} emissions from coal mines in the GMR.

The following practices are currently adopted:

- Water application by fixed sprays or water cart
- The minimisation of drop heights
- Suspension or modification of high risk activities under adverse weather conditions

The measures adopted at GMR mines are shown in Table 114 for open-cut mines and combined underground and open-cut mines. At least 92% of open-cut mines were found to utilise water application by fixed sprays or water cart. Fifty six percent of open-cut mines were found to suspend or modify high risk activities under adverse weather conditions.

During the site visits, it was evident that some mines dump material into the pit over the highwall. Such practices were stated to be suspended during adverse weather conditions. However, given the potential for dropping materials from a height to cause elevated emissions, this practice should be eliminated.

Table 114 Management of particulate matter from loading and dumping overburden in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Water sprays or boom spray on water cart	Automatic water sprays	Minimise drop height	Suspension or modification of operations during adverse weather	No dumping on high emplacements in strong winds
Ashton Coal Mine	✓		✓	✓	✓
Bengalla	✓	✓		✓	✓
Bloomfield Colliery	✓				
Camberwell (Integra Coal Open Cut)	✓				
Cullen Valley Mine	✓	✓			
Cumnock No1 Colliery	✓		✓		
Donaldson Coal Mine	✓				
Drayton Coal Mine	✓		✓		
Glendell Mine, Mt Owen Mine, Ravensworth East	✓	✓		✓	✓
Hunter Valley Operations	✓	✓			
Ivanhoe No.2 Colliery	✓	✓	✓	✓	
Liddell Coal Operations	✓	✓	✓	✓	
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓			✓	
Moolarben Coal Mine	✓			✓	
Mount Arthur Coal Mine	✓			✓	
Mount Thorley Warkworth Operations	✓	✓	✓		
Muswellbrook Colliery Holding		✓		✓	
Pine Dale Mine					
Ravensworth Narama	✓		✓	✓	
Rix's Creek Colliery Holding	✓				
Saxonvale Colliery Holding	✓		✓	✓	
The Invincible Mine	✓		✓	✓	
Wambo Coal	✓			✓	
Westside Mine	✓			✓	
Wilpinjong Coal Pty Ltd	✓				
Proportion of total (%)	92	32	36	56	12

The individual source metrics for loading and dumping overburden, which are presented in Table 115, assume a best practice control factor of 50% (i.e. water application). The modification of activities in windy conditions was also assumed to be best practice for loading and dumping overburden, but the reduction in emissions associated with this approach to management could not be quantified. Table 115 details the current control factors that are in the CMED for each mine in the GMR and the individual source metric for each mine for controlling emissions from loading and dumping overburden.

Table 115 Current control factor for loading and dumping overburden in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Loaders (overburden)		Trucks (dumping overburden)	
	Current control	Source metric	Current control	Source metric
Best practice	**0.5**	**100**	**0.5**	**100**
CUMNOCK NO. 1 COLLIERY	NC	NC	NC	NC
BAYSWATER COLLIERY	NC	NC	NC	NC
MANNERING COLLIERY	-	-	-	-
MANDALONG MINE AND COORANBONG COLLIERY	-	-	-	-
MYUNA COLLIERY	-	-	-	-
BLOOMFIELD COLLIERY	NC	NC	NC	NC
AUSTAR COAL MINE	-	-	-	-
AWABA COLLIERY	-	-	-	-
ANGUS PLACE COLLIERY	-	-	-	-
CHARBON COAL PTY LIMITED	-	-	NC	NC
WAMBO COAL PTY LTD	NC	NC	-	-
SAXONVALE COLLIERY HOLDING	NC	NC	NC	NC
BERRIMA COLLIERY	-	-	-	-
IVANHOE NO.2 COLLIERY	-	-	-	-
HUNTER VALLEY OPERATIONS	NC	NC	NC	NC
MUSWELLBROOK COLLIERY HOLDING	NC	NC	NC	NC
CLARENCE COLLIERY	-	-	-	-
APPIN COLLIERY	-	-	-	-
BAAL BONE COLLIERY	-	-	-	-
METROPOLITAN COLLIERY	-	-	-	-
NRE WONGAWILLI COLLIERY	-	-	-	-
DRAYTON COAL MINE	NC	NC	NC	NC
WEST WALLSEND COLLIERY	-	-	-	-
WARKWORTH COAL MINE	NC	NC	NC	NC
TAHMOOR COLLIERY	-	-	-	-
CHAIN VALLEY COLLIERY	-	-	-	-
MOUNT THORLEY OPERATIONS	-	-	-	-
LIDDELL COAL OPERATIONS	NC	NC	-	-
WESTCLIFF AND NORTHCLIFF COLLIERIES	-	-	-	-
RAVENSWORTH/NARAMA MINE	NC	NC	NC	NC
UNITED COLLIERY	-	-	-	-
DENDROBIUM MINE	-	-	-	-
CAMBERWELL COAL MINE	NC	NC	NC	NC
RIX'S CREEK COLLIERY	NC	NC	NC	NC
SPRINGVALE COLLIERY	NC	NC	NC	NC
WESTSIDE MINE	NC	NC	NC	NC
MT OWEN COAL MINE	NC	NC	-	-
PINE DALE MINE	NC	NC	NC	NC
BENGALLA MINE	NC	NC	NC	NC
GLENNIES CREEK COLLIERY	-	-	-	-
RAVENSWORTH UNDERGROUND MINE	-	-	-	-
CULLEN VALLEY MINE	NC	NC	NC	NC
RAVENSWORTH EAST MINE	NC	NC	NC	NC
DONALDSON COAL PTY LTD	NC	NC	NC	NC
MT ARTHUR NORTH COAL MINE	NC	NC	NC	NC
ASHTON COAL MINE	NC	NC	NC	NC
NRE NO 1 COLLIERY	-	-	-	-
NEWSTAN COLLIERY	-	-	-	-
MACQUARIE COAL PREPARATION PLANT	-	-	-	-
THE INVINCIBLE COLLIERY	NC	NC	NC	NC
WILPINJONG COAL PTY LTD	NC	NC	NC	NC
TASMAN COAL MINE	-	-	-	-
GLENDELL MINE	NC	NC	NC	NC
ABEL UNDERGROUND MINE	-	-	-	-

Mine	Loaders (overburden)		Trucks (dumping overburden)	
	Current control	Source metric	Current control	Source metric
XSTRATA MANGOOLLA (ANVIL HILL MINE)	NC	NC	-	-
RICHMOND MAIN EAST	NC	NC	-	-
Note NQ means best practice emission control factor not quantified NC means no controls " – " means no emissions from this source				

The combined particulate matter emission control metric for dumping overburden from loader or truck at coal mines in the GMR has been estimated to be 0 out of 100. This outcome is inconsistent with the outcomes of the review of AEMR, EMS, EMP and EPL shown in Table 114 that indicated a moderate level of controls on overburden dumping.

10.4.7 Loading and dumping ROM coal

Of all sources of particulate matter from coal mining activities in the GMR, loaders dumping coal was ranked number 7 in terms of emissions of TSP, number 6 in terms of emissions of PM_{10} and number 8 in terms of emissions of $PM_{2.5}$. Loaders dumping coal contribute 3.6% of total coal mining emissions of PM_{10} in the GMR. Trucks dumping coal ranked number 12 in terms of emissions of TSP, PM_{10} and $PM_{2.5}$. Trucks dumping coal contribute 0.8% to total coal mining emissions of PM_{10} in the GMR.

The key sources of particulate matter at the ROM pad are trucks and loaders dumping into the ROM hopper and onto the ROM pad. Current practice for the management of particulate matter emissions from the ROM pad are the combined use of water sprays and enclosure of the ROM hopper. Such an enclosure ensures that the water sprays remain effective with moderate to strong winds.

Most of the mines that were visited during this study aimed to minimise the amount of material that was stockpiled on the ROM pad, with coal being dumped directly into the ROM bin whenever possible. The ROM pad was used primarily when there was a break-down in the processing plant or when the coal coming from the pit was out-of-specification with the requirements of the processing plant.

The practice of dumping directly into the ROM hopper avoids particulate emissions associated with double handling of coal and reduces the potential that the coal will dry-out on the pad and be subject to wind erosion.

The measures adopted at GMR mines are shown in Table 116 for open-cut mines and combined underground and open-cut mines. Three mines (13%) were found that utilise both elements of best practice to minimise emissions associated with loading coal to the ROM hoppers (Figure 58[182]). Most ROM hoppers (83%) use water sprays activated by the movement of the truck into the dumping area to minimise particulate emissions as the coal falls into the hopper. Sixty seven percent of mines use water applied by fixed sprays or by water cart to manage particulate matter emissions generated by coal dumping.

Table 116 Management of particulate matter from ROM pad in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Automatic water sprays whilst dumping into ROM hopper	ROM hopper enclosure of three sides and a roof	Water application by fixed sprays or water cart on ROM pad	Enclosure with fabric filter
Ashton Coal Mine	✓	✓	✓	
Bengalla	✓	✓	✓	
Bloomfield Colliery			✓	
Camberwell (Integra Coal Open Cut)	✓		✓	
Cullen Valley Mine	✓			
Cumnock No1 Colliery	✓			
Donaldson Coal Mine			✓	
Drayton Coal Mine	✓		✓	
Glendell Mine, Mt Owen Mine, Ravensworth East	✓			
Hunter Valley Operations	✓		✓	
Liddell Coal Operations	✓		✓	
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓			
Moolarben Coal Mine	✓		✓	
Mount Arthur Coal Mine	✓	✓	✓	
Mount Thorley Warkworth Operations	✓		✓	
Muswellbrook Colliery Holding	✓		✓	
Pine Dale Mine				
Ravensworth Narama	✓			
Rix's Creek Colliery Holding	✓		✓	
Saxonvale Colliery Holding	✓		✓	
The Invincible Mine	✓		✓	
Wambo Coal	✓			
Westside Mine			✓	
Wilpinjong Coal Pty Ltd	✓			
Proportion of total (%)	83	13	67	0

Figure 58 ROM hopper with enclosure

The individual source metrics for coal loading and dumping at the ROM pad and ROM hopper, which are presented in Table 117 and Table 118 assume best practice control factors of 50% (i.e. water sprays on ROM pad) and 98% (i.e. enclosure of the ROM hopper with a control device), respectively. Table 117 and Table 118 detail the current control factors that are in the CMED for each mine in the GMR and the individual source metric for each mine for controlling emissions from coal loading and dumping at the ROM pad and ROM hopper.

Table 117 Current control factor for loading coal in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Loaders (coal)		Loading stockpiles (coal)	
	Current control	Source metric	Current control	Source metric
Best practice	**0.5**	**100**	**0.5**	**100**
CUMNOCK NO. 1 COLLIERY	NC	NC	0.63	100%
BAYSWATER COLLIERY	NC	NC	-	-
MANNERING COLLIERY	-	-	NC	NC
MANDALONG MINE AND COORANBONG COLLIERY	-	-	0.50	100%
MYUNA COLLIERY	-	-	-	-
BLOOMFIELD COLLIERY	NC	NC	NC	NC
AUSTAR COAL MINE	0.42	83%	0.50	100%
AWABA COLLIERY	NC	NC	NC	NC
ANGUS PLACE COLLIERY	NC	NC	-	-
CHARBON COAL PTY LIMITED	NC	NC	NC	NC
WAMBO COAL PTY LTD	NC	NC	-	-
SAXONVALE COLLIERY HOLDING	NC	NC	NC	NC
BERRIMA COLLIERY	NC	NC	-	-

Mine	Loaders (coal)		Loading stockpiles (coal)	
	Current control	Source metric	Current control	Source metric
IVANHOE NO.2 COLLIERY	-	-	-	-
HUNTER VALLEY OPERATIONS	0.12	24%	NC	NC
MUSWELLBROOK COLLIERY HOLDING	NC	NC	NC	NC
CLARENCE COLLIERY	-	-	0.50	100%
APPIN COLLIERY	-	-	-	-
BAAL BONE COLLIERY	NC	NC	0.50	100%
METROPOLITAN COLLIERY	NC	NC	NC	NC
NRE WONGAWILLI COLLIERY	NC	NC	NC	NC
DRAYTON COAL MINE	NC	NC	NC	NC
WEST WALLSEND COLLIERY	NC	NC	NC	NC
WARKWORTH COAL MINE	0.11	22%	0.50	100%
TAHMOOR COLLIERY	0.09	17%	-	-
CHAIN VALLEY COLLIERY	NC	NC	NC	NC
MOUNT THORLEY OPERATIONS	0.26	52%	NC	NC
LIDDELL COAL OPERATIONS	NC	NC	-	-
WESTCLIFF AND NORTHCLIFF COLLIERIES	NC	NC	0.50	100%
RAVENSWORTH/NARAMA MINE	NC	NC	-	-
UNITED COLLIERY	0.50	100%	0.25	50%
DENDROBIUM MINE	-	-	0.50	100%
CAMBERWELL COAL MINE	NC	NC	0.70	100%
RIX'S CREEK COLLIERY	NC	NC	NC	NC
SPRINGVALE COLLIERY	-	-	NC	NC
WESTSIDE MINE	NC	NC	-	-
MT OWEN COAL MINE	NC	NC	NC	NC
PINE DALE MINE	0.17	33%	-	-
BENGALLA MINE	NC	NC	NC	NC
GLENNIES CREEK COLLIERY	NC	NC	0.50	100%
RAVENSWORTH UNDERGROUND MINE	-	-	0.70	100%
CULLEN VALLEY MINE	NC	NC	NC	NC
RAVENSWORTH EAST MINE	NC	NC	NC	NC
DONALDSON COAL PTY LTD	NC	NC	-	-
MT ARTHUR NORTH COAL MINE	NC	NC	-	-
ASHTON COAL MINE	0.25	50%	0.50	100%
NRE NO 1 COLLIERY	NC	NC	0.50	100%
NEWSTAN COLLIERY	NC	NC	NC	NC
MACQUARIE COAL PREPARATION PLANT	0.70	100%	0.36	72%
THE INVINCIBLE COLLIERY	NC	NC	NC	NC
WILPINJONG COAL PTY LTD	NC	NC	NC	NC
TASMAN COAL MINE	NC	NC	NC	NC
GLENDELL MINE	NC	NC	-	-
ABEL UNDERGROUND MINE	NC	NC	NC	NC
XSTRATA MANGOOLLA (ANVIL HILL MINE)	-	-	-	-
RICHMOND MAIN EAST	-	-	-	-

Note
NQ means best practice emission control factor not quantified
NC means no controls
" – " means no emissions from this source

Table 118 Current control factor for dumping coal in the Coal Mines Emission Database for GMR coal mines and particulate matter emission control metrics

Mine	Trucks (dumping coal)		Dumping coal into ROM hopper	
	Current control	Source metric	Current control	Source metric
Best practice	**0.5**	**100**	**0.98**	**100**
CUMNOCK NO. 1 COLLIERY	-	-	0.70	71%
BAYSWATER COLLIERY	-	-	0.50	51%
MANNERING COLLIERY	-	-	-	-
MANDALONG MINE AND COORANBONG COLLIERY	-	-	-	-
MYUNA COLLIERY	-	-	-	-
BLOOMFIELD COLLIERY	-	-	NC	NC
AUSTAR COAL MINE	NC	NC	-	-
AWABA COLLIERY	-	-	-	-
ANGUS PLACE COLLIERY	-	-	-	-
CHARBON COAL PTY LIMITED	-	-	NC	NC
WAMBO COAL PTY LTD	-	-	-	-
SAXONVALE COLLIERY HOLDING	-	-	NC	NC
BERRIMA COLLIERY	-	-	NC	NC
IVANHOE NO.2 COLLIERY	-	-	-	-
HUNTER VALLEY OPERATIONS	-	-	NC	NC
MUSWELLBROOK COLLIERY HOLDING	NC	NC	0.50	51%
CLARENCE COLLIERY	-	-	-	-
APPIN COLLIERY	-	-	0.70	71%
BAAL BONE COLLIERY	NC	NC	-	-
METROPOLITAN COLLIERY	-	-	-	-
NRE WONGAWILLI COLLIERY	-	-	-	-
DRAYTON COAL MINE	NC	NC	NC	NC
WEST WALLSEND COLLIERY	-	-	-	-
WARKWORTH COAL MINE	-	-	NC	NC
TAHMOOR COLLIERY	-	-	NC	NC
CHAIN VALLEY COLLIERY	-	-	-	-
MOUNT THORLEY OPERATIONS	-	-	-	-
LIDDELL COAL OPERATIONS	-	-	0.50	32%
WESTCLIFF AND NORTHCLIFF COLLIERIES	-	-	0.60	60%
RAVENSWORTH/NARAMA MINE	-	-	0.57	58%
UNITED COLLIERY	-	-	0.70	60%
DENDROBIUM MINE	-	-	-	-
CAMBERWELL COAL MINE	NC	NC	0.50	51%
RIX'S CREEK COLLIERY	-	-	NC	NC
SPRINGVALE COLLIERY	-	-	NC	NC
WESTSIDE MINE	-	-	-	-
MT OWEN COAL MINE	-	-	NC	NC
PINE DALE MINE	-	-	NC	NC
BENGALLA MINE	-	-	NC	NC
GLENNIES CREEK COLLIERY	-	-	NC	NC
RAVENSWORTH UNDERGROUND MINE	-	-	-	-
CULLEN VALLEY MINE	-	-	NC	NC
RAVENSWORTH EAST MINE	-	-	NC	NC
DONALDSON COAL PTY LTD	-	-	-	-
MT ARTHUR NORTH COAL MINE	-	-	0.50	51%
ASHTON COAL MINE	NC	NC	0.50	51%
NRE NO 1 COLLIERY	-	-	-	-
NEWSTAN COLLIERY	-	-	NC	NC
MACQUARIE COAL PREPARATION PLANT	-	-	0.70	71%
THE INVINCIBLE COLLIERY	-	-	NC	NC
WILPINJONG COAL PTY LTD	NC	NC	NC	NC
TASMAN COAL MINE	-	-	-	-
GLENDELL MINE	-	-	-	-
ABEL UNDERGROUND MINE	-	-	-	-

Mine	Trucks (dumping coal)		Dumping coal into ROM hopper	
	Current control	Source metric	Current control	Source metric
XSTRATA MANGOOLLA (ANVIL HILL MINE)	-	-	-	-
RICHMOND MAIN EAST	-	-	-	-
Note NQ means best practice emission control factor not quantified NC means no controls " – " means no emissions from this source				

Table 119 shows the combined particulate matter emission control metrics for coal dumping sources at the ROM pad for coal mines in the GMR. The table shows that a low level of control is applied to coal dumping sources. This outcome is inconsistent with the outcomes of the review of AEMR, EMS, EMP and EPL shown in Table 116, which indicated a moderate level of control on ROM hoppers.

Table 119 Combined particulate matter emission control metrics for GMR coal dumping sources

Wind erosion source	Combined metric for GMR mines
Loaders (coal)	14.9
Loading stockpiles (coal)	27.1
Trucks (dumping coal)	0.0
Dumping coal into ROM hopper	24.2

10.4.8 Conveyors and transfers

Emissions of particulate matter from conveyors are not quantified in the CMED and emission factors are not available in the NPI handbook or AP-42. However, transfer points between conveyors and from conveyors to stockpiles have been quantified in the CMED. Coal transfers contribute a relatively small amount to GMR emissions of TSP (0.1%), PM_{10} (0.1%) and $PM_{2.5}$ (<0.1%).

At GMR mines, conveyors are generally used to transport coal from the ROM hopper to the processing plant and from the processing plant to the product stockpiles. Some mines utilise common processing plants and so, conveyor lengths can be extensive with many transfer points.

Best practice measures for minimising emissions of particulate matter from conveyors and transfers are:

- The use of wind shielding on conveyor sides;
- Water sprays at conveyor transfers;
- Enclosure of transfer points; and
- Soft-loading chutes.

The measures adopted at GMR mines are shown in Table 120 for underground mines and Table 121 for open-cut mines and combined underground and open-cut mines. Three open-cut mines (12%) were found that utilise all of these measures. No underground mines were found that utilise all of the measures. A third of underground and 40% of open-cut mines were found to utilise four of the five elements. Seventy eight percent of underground mines and 68% of open-cut mines were found to use one aspect of best practice.

Table 120 Management of particulate matter from conveyors and transfers in the GMR - underground mines

Coal Mine	Conveyor wind shielding - roof	Conveyor wind shielding - one or two sides	Water sprays at transfers	Enclosed transfers	Soft-loading chutes
Abel Underground Mine	✓				
Airly Coal Project					
Angus Place Colliery	✓	✓	✓		
Appin Coal Mine	✓	✓		✓	
Austar Coal Mine	✓	✓	✓	✓	
Awaba Colliery	✓	✓	✓	✓	
Baal Bone Colliery			✓		
Chain valley Colliery	✓	✓	✓	✓	
Charbon Coal Pty Ltd					
Clarence Colliery	✓				
Dendrobium Mine	✓	✓	✓	✓	
Glennies Creek Colliery					
Mandalong Mine and Cooranbong Colliery	✓	✓	✓	✓	
Mannering Colliery	✓	✓	✓		
Metropolitan Colliery	✓		✓	✓	
Myuna Colliery	✓	✓	✓	✓	
Newstan Colliery	✓	✓	✓		✓
NRE No 1 Colliery		✓	✓	✓	
NRE Wongawilli Colliery	✓		✓	✓	
Ravensworth Underground mine	✓		✓	✓	✓
Richmond Main East					
Springvale Colliery	✓	✓		✓	
Tahmoor Colliery	✓	✓	✓	✓	
Tasman Coal mine	✓				
United Colliery					
West Wallsend Colliery	✓		✓	✓	
Westcliff and Northcliff Collieries					
Proportion of total (%)	70	48	59	52	7

Table 121 Management of particulate matter from conveyors and transfers in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Conveyor wind shielding - roof	Conveyor wind shielding - one or two sides	Waters prays at transfers	Enclosed transfers	Soft-loading chutes
Ashton Coal Mine	✓	✓	✓	✓	
Bengalla	✓	✓	✓	✓	✓
Bloomfield Colliery	✓		✓	✓	✓
Camberwell (Integra Coal Open Cut)			✓		
Cullen Valley Mine			✓		
Cumnock No1 Colliery			✓		
Donaldson Coal Mine					
Drayton Coal Mine			✓	✓	
Glendell Mine, Mt Owen Mine, Ravensworth East	✓	✓	✓	✓	
Hunter Valley Operations	✓	✓		✓	
Ivanhoe No.2 Colliery					
Liddell Coal Operations	✓	✓	✓	✓	
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓	✓	✓	✓	
Moolarben Coal Mine					
Mount Arthur Coal Mine	✓	✓	✓	✓	✓
Mount Thorley Warkworth Operations					
Muswellbrook Colliery Holding	✓	✓	✓	✓	
Pine Dale Mine					
Ravensworth Narama					
Rix's Creek Colliery Holding					
Saxonvale Colliery Holding	✓	✓	✓	✓	
The Invincible Mine			✓		
Wambo Coal			✓		
Westside Mine	✓	✓	✓	✓	
Wilpinjong Coal Pty Ltd					
Proportion of total (%)	44	40	64	48	12

Since these emission sources are not explicitly represented in the database and are not a substantial source of emissions, metrics have not been presented.

10.4.9 Stacking and reclaiming product coal

Stacking and reclaiming product coal is not explicitly characterised in the CMED. Since product coal is in most circumstances, relatively wet during handling, emissions of particulate matter would be relatively small and would be a subset of the coal dumping, bulldozing and transfers identified above.

Current practices have been identified to be:

- Water application by fixed sprays or water cart
- The minimisation of drop heights
- Suspension or modification of high risk activities under adverse weather conditions
- Variable height stacker
- Bucket wheel, portal or bridge reclaimer
- Active site area cleaned regularly
- Coal sizer ventilated through filter
- Dust extractor system at CHPP

The measures adopted at GMR mines are shown in Table 122 for underground mines and Table 123 for open-cut mines and combined underground and open-cut mines. At least 78% of underground mines and 88% of open-cut mines were found to utilise water application by fixed sprays or water cart.

Twelve percent of all open-cut mines were found to use variable height stackers and 12%, bucket wheel, portal or bridge reclaimers.

Table 122 Management of particulate matter from materials handling in the GMR - underground mines

Coal Mine	Water sprays or boom spray on water cart	Active site area cleaned regularly	Coal sizer ventilated through filter	Variable height stacker or tripper with chute/windshield	Bucket wheel, portal or bridge reclaimer	Dust extractor system at CHPP
Abel Underground Mine	✓					
Airly Coal Project	✓			✓		
Angus Place Colliery	✓					
Appin Coal Mine	✓					
Austar Coal Mine	✓					
Awaba Colliery						
Baal Bone Colliery						
Chain valley Colliery	✓					
Charbon Coal Pty Ltd	✓					
Clarence Colliery	✓					
Dendrobium Mine	✓		✓			
Glennies Creek Colliery	✓		✓			
Mandalong Mine and Cooranbong Colliery	✓					
Mannering Colliery	✓					
Metropolitan Colliery	✓	✓				
Myuna Colliery	✓	✓				
Newstan Colliery	✓	✓				
NRE No 1 Colliery	✓					
NRE Wongawilli Colliery						
Ravensworth Underground mine	✓	✓				

Coal Mine	Water sprays or boom spray on water cart	Active site area cleaned regularly	Coal sizer ventilated through filter	Variable height stacker or tripper with chute/windshield	Bucket wheel, portal or bridge reclaimer	Dust extractor system at CHPP
Richmond Main East	✓					
Springvale Colliery						
Tahmoor Colliery	✓					
Tasman Coal mine						
United Colliery						
West Wallsend Colliery	✓	✓		✓	✓	
Westcliff and Northcliff Collieries	✓					✓
Proportion of total (%)	78	19	7	7	4	4

Table 123 Management of particulate matter from materials handling in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Water sprays or boom spray on water cart	Active site area cleaned regularly	Coal sizer ventilated through filter	Variable height stacker or tripper with chute/windshield	Bucket wheel, portal or bridge reclaimer	Dust extractor system at CHPP
Ashton Coal Mine	✓					
Bengalla	✓			✓	✓	
Bloomfield Colliery	✓					
Camberwell (Integra Coal Open Cut)	✓					
Cullen Valley Mine	✓	✓				
Cumnock No1 Colliery	✓					
Donaldson Coal Mine	✓					
Drayton Coal Mine	✓			✓	✓	
Glendell Mine, Mt Owen Mine, Ravensworth East	✓					
Hunter Valley Operations	✓					
Ivanhoe No.2 Colliery	✓					
Liddell Coal Operations	✓					
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓					
Moolarben Coal Mine						
Mount Arthur Coal Mine	✓					

Coal Mine	Water sprays or boom spray on water cart	Active site area cleaned regularly	Coal sizer ventilated through filter	Variable height stacker or tripper with chute/windshield	Bucket wheel, portal or bridge reclaimer	Dust extractor system at CHPP
Mount Thorley Warkworth Operations	✓			✓	✓	
Muswellbrook Colliery Holding						
Pine Dale Mine						
Ravensworth Narama	✓					
Rix's Creek Colliery Holding	✓					
Saxonvale Colliery Holding	✓	✓				
The Invincible Mine	✓					
Wambo Coal	✓		✓			
Westside Mine	✓					
Wilpinjong Coal Pty Ltd	✓					
Proportion of total (%)	88	8	4	12	12	0

Since these emission sources are not explicitly represented in the database and are not a substantial source of emissions, metrics have not been presented.

10.5 Summary of particulate matter emission control metrics

Particulate matter emission control metrics have been calculated from the Coal Mines Emission Database (CMED) for all sources of particulate matter at GMR coal mines. The metrics have been expressed as a combined metric for each coalfield and for the GMR as a whole in Table 124.

Note that the combined metrics for each coalfield are the sum of the metrics for each emission source within each coalfield weighted by the relative contribution of each source to the total uncontrolled emissions within each coalfield. Similarly, the combined metric for the GMR is sum of the metrics for each emission source within the GMR weighted by the relative contribution of each source to the total uncontrolled GMR emissions. Hence, the combined GMR metric is not a simple average of the combined metrics for each of the coalfields.

The metrics show that the Hunter and Newcastle coalfields have a similar level of particulate matter emissions control as an aggregate of all sources of emissions. A moderate level of progress towards best practice has been achieved. Whilst lower combined metrics are evident in the Southern and Western coalfields, the relatively low contribution of these coalfields to the overall emissions into the GMR airshed mean that the combined GMR metric is marginally lower than the Hunter and Newcastle coalfield metrics.

Table 124 Combined particulate matter emission control metrics by coalfield and GMR

Coal field	Combined particulate matter emission control metric (/100)	
	Range	Weighted sum
HUNTER	0.0-93.7	63.2
NEWCASTLE	0.0-92.2	67.0
SOUTHERN	0.0-87.8	46.5
WESTERN	0.0-66.3	51.4
GMR Total	0.0-93.7	62.8

11. Air Quality Management Tools

This section provides details of air quality management tools that are used to control emissions of particulate matter from coal mines. The current practices adopted by coal mines in the GMR are detailed.

An Air Quality Management Plan (AQMP) is an essential part of controlling emissions of particulate matter. Measures to minimise the potential impact of fugitive particulate matter emissions must recognise all potential sources and have strategies in place to mitigate any unnecessary emissions and adverse impacts that the proposed activities may have on the health and amenity of the surrounding community. An AQMP should have both proactive and reactive components.

An AQMP for a coal mine should contain as a minimum the following elements:

- Environmental Criteria
- Mission statement
- Particulate matter management strategy consisting of:
    - Objectives and targets
    - Particulate matter risk assessment
    - Particulate matter suppression improvement plan
- Monitoring requirements including assignment of responsibility
- Communication strategy
- System and performance review for continuous improvement

11.1 Identify environmental criteria

Identify environmental criteria that can be used to measure the extent of impacts from emissions of particulate matter. The environmental criteria should note the:

- Particle size
- Averaging time
- Concentration
- Frequency of allowable exceedances

Environmental criteria for an AQMP may not directly correlate to regulatory criteria. For example, the premises may operate several air quality monitors that measure and report ambient levels of particulate matter at 10 minute time intervals. It may be useful for the AQMP to identify alarm levels based on short term time intervals in order to effectively manage air quality impacts. Therefore, environmental criteria would need to be developed that are not necessarily consistent with regulatory criteria but improve the mine's ability for achieving them.

11.2 Mission statement

Provide a mission statement for the operation of the premises. The mission statement for a particulate matter management plan for a coal mine should encompass the need for continuous improvement in terms of reducing fugitive particulate matter generated by activities at the coal mine and outline why continuous improvement is important for the organisation.

11.3 Develop particulate matter management strategy

11.3.1 Set objectives and targets

Within the Particulate Matter Management Strategy, the operator should set objectives and targets to meet over the reporting period taking into consideration the following aspects:

- environmental risks identified in the particulate matter risk register
- legal non-compliance issues
- audit findings and corrective actions
- stakeholder complaints and views
- technological options
- financial, operational and business requirements

11.3.2 Particulate matter risk assessment

The particulate matter risk assessment should:

- identify all potential particulate matter emission sources
- magnitude of emission source and range of potential emission significance
- potential impact area under the range of meteorological conditions likely at the site
- probability of occurrence
- consequence of occurrence
- existing controls of each source, including physical controls, behavioural controls and procedural controls

11.3.3 Particulate matter suppression improvement plan

The particulate matter suppression improvement plan should outline actions to meet endorsed objectives and targets and address high risk areas identified in the particulate matter risk register.

11.4 Monitoring requirements

The broad aim of the monitoring programme is to provide a quantitative measurement of how the operator is performing against the Objectives and Targets set out in the Particulate Matter Management Plan. Secondary aims of the monitoring network are to:

- Determine long-term trends in ambient particulate matter levels.
- Determine TSP, PM_{10} and $PM_{2.5}$ concentrations at representative locations surrounding the facility.
- Provide scientific data for the community.

It is important to note that monitoring requirements for informing an AQMP do not necessarily have to align with regulatory monitoring requirements. For example, light scattering techniques that are correlated to particulate matter levels could be used to inform the Particulate Matter Management Plan (e.g. opacity meters used to measure haul road particulate matter to inform road watering, surface treatment response etc.).

11.5 Responsibilities

The Particulate Matter Management Plan should outline all responsibilities in regards to particulate matter management for all employees (including contractors) of the operator.

11.6 Communication strategies

Both internal (e.g. training and induction, exceedance reporting, incidence reporting) and external (e.g. annual reporting, exceedance analysis, complaint analysis, internet reporting for community) communication strategies in relation to particulate matter management are to be outlined in the Particulate Matter Management Plan.

11.7 System and performance review

A review of the Air Quality Management Plan should be conducted on an annual basis as a minimum. The review should take into account the following:

- Suitability of the mission statement
- The extent to which objectives and targets have been met
- Air quality concerns or complaints from external stakeholders
- General particulate matter performance based on monitoring results
- Periodic environmental audit findings
- Periodic reviews of particulate matter control trials and investigations
- Changing circumstances such as urban encroachment, changing location and orientation of mining operations, developments in legal and other requirements
- Annual external review of particulate matter management practices and particulate matter monitoring results

The results of the review are to feed back into the Air Quality Management Plan with the objective to drive continuous improvement in performance.

11.8 Proactive and reactive components of a management plan

Proactive components of a management plan could include:

- Training, tool-box talks, implementation of particulate matter minimisation into standard operating procedure
- Local activity-based observations of particulate matter (or opacity) and feedback to mine management
- Continuous real time monitoring of meteorological conditions that feed into operational planning
- Continuous real time monitoring of particulate matter concentrations at sensitive receptors that feed into operational planning
- Use of a forecasting system to assist in anticipating adverse meteorological conditions that may give rise to emissions of particulate matter and implementation of operational changes and improved mitigation to avoid adverse impacts. e.g. plan activities that include land clearing, blasting etc.
- Adaptive management strategies such as reduction in extraction rates of operations when meteorological monitoring suggests adverse wind conditions or monitoring of particulate matter at sensitive receptors indicates levels are near to exceeding air quality criteria
- Scheduling of activities based on the outcomes of the real time monitoring, forecasting and adaptive management strategies

Reactive components of a management plan could include:

- Implementation of additional mitigation measures when wind conditions become adverse, such as ceasing operations, reducing activity rates or covering equipment, application of suppressants
- Trigger points for management decisions based on measurements of wind conditions and/or monitoring of particulate matter at sensitive receptors when levels are near exceeding air quality criteria

The objective of any monitoring undertaken must be clear in order to design a monitoring program that is effective and useful. Table 125 outlines considerations for monitoring conducted under an AQMP.

Table 125 Air quality monitoring considerations

Consideration	Baseline monitoring	Compliance monitoring	Real time management
Purpose	To gather site-specific information on existing air quality	To determine compliance against a set air quality criteria	To provide early indication of impacts. Data needs to feed into management plan for the mine. i.e. affects where and how activities are occurring
Monitoring requirements	Minimum 1 year	As required by licence or approval conditions	Short-term (10-minute)
Location	At a residence	At a residence	At boundary of mine and/or at a residence
Method	Monitor to be sited and operated in accordance with standards	Monitor to be sited and operated in accordance with standards	Not critical to be sited and operated in accordance with standards
Comments	Need to confirm specific monitoring requirements (i.e. monitoring interval require and pollutants)	Need to confirm specific monitoring requirements (i.e. monitoring interval require and pollutants)	Weather station (measuring wind speed and wind direction as a minimum) will need to be co-located with pollution monitor

11.9 Current practices in the GMR

Proactive and reactive management tools were found to be best practice for reducing emissions of particulate matter from open-cut coal mines. Such tools could also be applied to surface activities of underground mines. However, the nature of the surface facilities of an underground mine being compact and hence more easily managed than that of an open-cut mine, mean that proactive and reactive strategies are less critical for underground mines. Best practice for underground mines consists of meteorological monitoring and monitoring ambient concentrations of particulate matter.

A summary of information collected relating to air quality management tools used at underground and open-cut mines in the GMR is presented in Table 126 and Table 127, respectively.

Considering the underground mines, 41% monitor meteorological conditions and 33% monitor concentrations of particulates using high volume air samplers. At least 78% of underground mines measure the potential nuisance impact of particulate matter emissions using dust deposition gauges.

Of the open-cut mines, 84% monitor meteorological conditions and 48% monitor using a TEOM or other continuous particulate monitoring technique. Forty eight percent modify or cease activities on dry or windy days based on consideration of monitoring data. At least three mines have continuous particulate matter monitoring data available in the control room with alarms to alert operators when trigger levels are being exceeded.

A number of mines use a forecasting system and inversion tower data to predict the potential for strong inversions for scheduling blasts to avoid noise impacts. Three mines were identified that adopt similar proactive approaches for management of particulate matter emissions.

Table 126 Air quality management tools in the GMR - underground mines

Coal Mine	Meteorological monitoring	Dust deposition gauges	TEOMs	HVAS	Directional gauge	Continuous, non-standard particulate measurement method	GPS in trucks aid dust controls	SMS alarm system during high winds	Ceasing or modifying activities on dry windy days considering monitoring information
Abel Underground Mine	✓	✓		✓		✓			
Airly Coal Project	✓	✓							
Angus Place Colliery	✓	✓		✓					
Appin Coal Mine		✓							
Austar Coal Mine									
Awaba Colliery		✓							
Baal Bone Colliery		✓							
Chain valley Colliery									
Charbon Coal Pty Ltd									
Clarence Colliery	✓	✓		✓					
Dendrobium Mine	✓	✓		✓					
Glennies Creek Colliery	✓	✓		✓					
Mandalong Mine and Cooranbong Colliery	✓	✓							
Mannering Colliery		✓							
Metropolitan Colliery		✓		✓					
Myuna Colliery		✓							
Newstan Colliery	✓	✓		✓					
NRE No 1 Colliery		✓							
NRE Wongawilli Colliery		✓							
Ravensworth Underground mine		✓		✓					
Richmond Main East									
Springvale Colliery	✓	✓							
Tahmoor Colliery		✓							
Tasman Coal mine	✓	✓		✓					
United Colliery									
West Wallsend Colliery	✓								
Westcliff and Northcliff Collieries		✓							
Proportion of total (%)	41	78	0	33	0	4	0	0	0

Table 127 Air quality management tools in the GMR - open-cut mines and combined open-cut and underground mines

Coal Mine	Meteorological monitoring	Dust deposition gauges	TEOMs	HVAS	Directional gauge	Continuous, non-standard particulate measurement method	GPS in trucks aid dust controls	SMS alarm system during high winds	Ceasing or modifying activities on dry windy days considering monitoring information
Ashton Coal Mine	✓	✓	✓	✓					✓
Bengalla	✓	✓	✓	✓		✓		✓	✓
Bloomfield Colliery									
Camberwell (Integra Coal Open Cut)	✓	✓		✓					✓
Cullen Valley Mine	✓	✓		✓					
Cumnock No1 Colliery	✓	✓		✓	✓				✓
Donaldson Coal Mine	✓	✓		✓		✓			
Drayton Coal Mine	✓	✓			✓				
Glendell Mine, Mt Owen Mine, Ravensworth East	✓	✓	✓	✓					✓
Hunter Valley Operations	✓	✓	✓	✓				✓	✓
Ivanhoe No.2 Colliery		✓							
Liddell Coal Operations	✓	✓		✓					
Mangoola (Anvil Hill) (UNDER CONSTRUCTION)	✓	✓		✓					✓
Moolarben Coal Mine	✓	✓	✓	✓					
Mount Arthur Coal Mine	✓	✓	✓	✓			✓	✓	✓
Mount Thorley Warkworth Operations	✓	✓	✓	✓		✓		✓	✓
Muswellbrook Colliery Holding	✓	✓	✓	✓					
Pine Dale Mine									
Ravensworth Narama	✓	✓		✓	✓				✓
Rix's Creek Colliery Holding									
Saxonvale Colliery Holding	✓	✓		✓	✓				
The Invincible Mine	✓	✓		✓					✓
Wambo Coal	✓	✓	✓	✓					✓
Westside Mine	✓	✓		✓					
Wilpinjong Coal Pty Ltd	✓	✓	✓	✓					
Proportion of total (%)	84	88	40	80	16	12	4	16	48

12. Estimated Costs of Controlling Particulate Matter Emissions from NSW Coal Mines

12.1 Overview

The costs associated with a range of best practice measures to control emissions of particulate matter have been estimated for a number of activities and emission sources, both individually by activity and in aggregate for the GMR.

Information on the effectiveness of existing controls on emissions of particulate matter from GMR coal mines has been taken from the Coal Mines Emission Database (CMED). The cost of best practice measures that is detailed in the following sections has been combined with the uncontrolled emissions data from the CMED and the benefits detailed in Section 9 to quantify the total cost and benefits of implementing best practice emission controls at GMR coal mines.

Costs and benefits of implementing best practice measures have been estimated for the following activities and emission sources that represent the majority of emissions from coal mines into the GMR airshed:

- Unpaved haul roads
- Wind erosion from overburden, coal stockpiles and other exposed areas
- Trucks and loaders dumping coal to the ROM hopper
- Trucks dumping coal to the ROM pad
- Drilling
- Graders
- Draglines
- Trucks and loaders dumping overburden
- Bulldozers working on coal and overburden

In the following analysis, the estimated cost of any major capital purchases that are associated with each best practice control measure have been annualised over a 10 year period. The cost and effectiveness of each of the best practice control measures was determined assuming that the best practice control measure replaces the current control measure. In a small number of cases, the current control measure for a particular activity at a particular mine that is recorded in the Coal Mines Emission Database was greater than the control measure that was determined to be best practice. In these cases the current control measure was assumed to remain in place and no additional cost was determined.

Where possible and relevant, the cost of existing equipment was accounted for in the estimation of the cost of the best practice control measures. Additional costs relevant to the best practice control measures take into account the operating costs of the current control and assume that these will no longer be an ongoing cost.

In Section 10.3, the particulate matter emission control metric was defined to measure the progress towards implementation of best practice control measures at mines in the GMR. The particulate matter emission control metric has been presented in the following sections to provide in indication of the existing level of controls of particulate emissions. Where relevant, costs were estimated based on the assumptions discussed in Section 12.3. The costs of the best practice control measures are compared with the costs of the existing control measures and the incremental costs to upgrade to best practice control measures are also presented.

12.2 Limitations

In reading the information contained in the following sections, the following limitations in the study should be noted:

- Particulate matter emission rates and the effectiveness of existing control measures and best practice control measures have been based on the information developed in this project and the information contained in the CMED. Where data were missing, an average value based on all current information was used.
- Cost and benefits of the application of best practice control measures to the different mine activities are based on generalised assumptions about mine activities, costs and effectiveness of those control measures. The actual costs and effectiveness will be dependent on a number of site specific variables that need to be evaluated on a case by case basis.
- The cost of each best practice control measure has been evaluated separately and independently of current control measures and other possible best practice control measures to provide an upper bound estimate of costs. In most circumstances, the effectiveness of a combination of control measures will be equal to or more effective than the effectiveness of individual control measures operating in isolation.

12.3 Input data and assumptions

12.3.1 Watering

Watering is one of the most common and effective ways of reducing particulate matter emissions from a number of coal mining activities. Diligent application of water has been identified as a best practice measure for many activities that emit particulate matter. Emissions of particulate matter have been demonstrated to be reduced by between 50% and 75%[10] depending on the application and the rate of water use.

The cost and potential reduction in particulate matter emissions using watering as a control measure on a number of mine activities has been estimated. Throughout this study, Level 1 watering represents the application of 2 litres of water per square metre per hour (2 L/m^2/hour) and Level 2 watering is the application of >2 L/m^2/hour. The cost of water has been estimated to be $1.70 per kL[183]. It is worth noting that most of the coal mines in the Hunter Valley that were visited during this study had excess water available through pre-drainage of old mine workings, the collection of stormwater in mine voids and wastewater from coal processing. Hence, applying the above cost for water is conservative and will overestimate the cost of this control measure.

The costs associated with increasing the amount of water were quantified by taking into account additional resources required to achieve the watering level and operating costs. These include additional volume of water and truck operating costs (including fuel consumption and wages), which are assumed to be directly proportional to the amount of additional watering required (i.e. per square metre). Mines with Level 1 watering were assumed to increase watering to Level 2 watering, simply by doubling the watering rate.

For haul roads and graders, the amount of water required for each mine is based on the vehicle kilometers travelled (VKT) by each water truck on unpaved roads and a typical haul road width of 30 metres. Diesel costs are based on the diesel consumption rates contained in the CMED and a cost of $1.17 per litre[184]. Wages for the additional labour required to make the additional number of trips are based on the total operating hours for each truck, using a standard of $50 per hour, inclusive of all service-related benefits such as allowances, superannuation expenses, and other miscellaneous benefits (Richard Hoskings, Managing Director, The Minserve Group Pty Ltd, pers. comm.).

Where required, the costs of buying, maintaining and operating additional trucks were also included. Additional trucks were used where the demand on the current fleet could not be doubled, such as where the existing water truck is operating more than 12 hours per day. Doubling this would mean that the water truck would need to operate for more than 24 hours per day.

The implementation of watering to reduce emissions due to wind erosion is dependent on the surface area, frequency, and the operational costs. On days when the rainfall exceeds 0.25 mm, watering is not applied.

While watering is a relatively inexpensive and accessible form of emissions control, the benefits are short-term and water needs to be applied consistently and regularly.

12.3.2 Chemical suppressant

Chemical suppressants can provide a longer term and more durable reduction in emissions of particulate matter. Suppressants can be in the form of wetting agents, binding/agglomerating agents or crusting agents.

Wetting agents are surfactant formulations that are soluble in water. Wetting agents reduce the surface tension of water, thus improving its ability to wet and agglomerate fine particles. Binding or agglomerating agents, on the other hand, provide a longer-term or residual control than water as these absorb and maintain surface moisture to keep the erodible material wet. These are also used when using water-based technologies are impractical. Chemical suppressants can also be in the form of crusting agents, which are essentially binding agents used for long-term surface stabilisation. Viscosity modifiers may be added to affect the rate and degree of liquid penetration into the bulk solid surface.

While the cost of chemicals varies, a standard cost of $0.14 per square metre (L. Xavier, Vital Chemical Pty Ltd, 25 June 2010, pers. comm.) is used in this study. Mine water trucks are assumed to apply suppressant every two weeks (L. Xavier, Vital Chemical Pty Ltd, 25 June 2010, pers. comm.) travelling at a speed of 5 km/hr (conservatively estimated from CMED). Since the application of water serves to reactivate the suppressants, the cost of periodic watering is also included in the cost estimation for this control method.

12.3.3 Rehabilitation

Rehabilitation is one of the most common and effective control measures for reducing emissions of particulate matter from exposed areas prone to wind erosion. It is usually conducted by a rehabilitation expert and involves reshaping the land using small bulldozers and other equipment to spread stockpiled topsoil and reseed it.

While effective, rehabilitation is not always a practical solution. For example, rehabilitation is not applied to mine areas where activities are still expected to take place. In addition to this, the effects of rehabilitation are not immediate and continuously progress from seeding to full development over the area to be vegetated. Depending on the type of plants, this process could take up to a few years.

The reduction in the emission rate of particulate matter was assumed to be constant. The maximum reduction in particulate matter emissions (i.e. 99%[10]) is assumed from the time the area is rehabilitated with an estimated cost of $10,000 per hectare[185].

12.3.4 Hydraulic mulch seeding

Hydraulic mulch seeding, also known as hydro-seeding, hydro-mulch or spray-on grass, is another form of rehabilitation. The process allows the spreading of seed, mulch and fertiliser in one application. Hydraulic mulch seeding can use almost any seed including native species, trees and shrubs. A range of ingredients in various combinations, including wood fibre, hemp, paper pulp, sugar cane mulch and other natural and artificial fibres can be used as mulch. All the materials are mixed in tanks onsite and sprayed as slurry over areas to be re-vegetated directly from the truck (up to 30 metres) or through hoses (over 100 metres).

The estimated cost of applying hydraulic mulch seeding as an alternative means of rehabilitation is about three times greater than conventional seeding ($30,000 per hectare) (Amy Harburg, Bengalla Mine, 30 July 2010 pers. comm.). The expected benefit in reduction of particulate matter emissions due to wind erosion is 99%[10], the same as for conventional rehabilitation. However, hydraulic mulch seeding provides a more flexible control measure than rehabilitation. The benefit of hydraulic mulch seeding is immediate, as the binder cures within a few hours and sets to form a stable, porous matrix, protecting the surface from erosion until vegetation is established. Applying the mulch in water helps it conform to irregularities in the ground, providing close soil contact and erosion protection.

12.3.5 Enclosures and windbreaks

Enclosures and windbreaks around areas where activities produce a large volume of particulate matter can control emissions by 70%[150]. Windbreaks slow the speed of the wind as it passes over the erodible surface. The best windbreaks produce a zone behind the windbreak that reduces the incident wind to a quarter of its speed. For a 15 metre high windbreak this zone will extend about 70 metres downwind. From 70 metres to 150 metres the wind speed will increase up to about half that of the incident wind. The windbreak loses its effectiveness beyond about 150 metres.

Natural windbreaks, such as trees and shrubs which are planted to provide shelter from the wind, are used to prevent wind erosion and also provide improved amenity. However, these do not provide the immediate impact and flexibility that man-made windbreaks can provide.

To estimate costs, the related capital expenditure and ongoing maintenance for a non-metallic screening material was approximated based on the size of the area to be enclosed. All areas were assumed to be square for the purpose of determining the size of the windbreak. The cost per lineal metre was based on the costs estimated by Connell Hatch for the RG Tanna Coal Terminal[153], with an estimated cost of $10M for a 4 km long enclosure and an ongoing annual operating cost of 7% of the capital cost.

The estimated cost of this enclosure is based on a shade-cloth type of material. To estimate the cost of a metal fabricated enclosure for the ROM hopper, the cost per lineal metre was multiplied by five[153].

12.3.6 Conveyors

Trucks travelling on unpaved roads carrying coal and overburden are the major source of particulate matter emissions at coal mines. The cost associated with using an alternative transport method has been estimated and the potential reduction in particulate matter emissions has been quantified.

Conveyors have significantly lower emission rates of particulate matter than haul trucks travelling on unpaved roads. However, conveyors are semi-permanent or permanent fixtures that are not as easy to move as haul roads with the progression of the pit. Conveyors also require a higher initial capital outlay than do haul trucks. To provide a case study of the use of conveyors, half of the haul road from the pit to the ROM pad or overburden dump was assumed to be converted to conveyors.

The length of the haul road has been calculated from the information contained in the CMED, including the haul truck capacity, VKT of each haul truck, and the mass of ROM coal and overburden transported. The number of trips per day for each haul truck is based on the apportionment of the annual load transported (ROM and overburden) and the capacity. The cost of a conveyor is estimated at $4,000 per metre (pers. comm. Richard Hoskings, Managing Director, The Minserve Group Pty Ltd).

Emissions of particulate matter were assumed to be reduced by 95% (see Section 9.2) when transporting ROM coal by conveyor. Emissions from transporting overburden and ROM coal by haul trucks on the remaining length of the haul road were added to this.

12.3.7 Haul trucks and equipment

Particulate matter emissions are proportional to the vehicle kilometres travelled (VKT) by haul trucks (i.e. lower VKT will result in a lower emission rate of particulate matter). Using larger capacity haul trucks can reduce the number of trips required to transport the same amount of material. Therefore, overall emissions can be reduced by replacing smaller capacity trucks with larger ones.

Data on the current fleet of haul trucks for each mine are contained in the CMED. In this scenario, trucks with less than 90 tonne capacity are replaced with the CAT 777, with a capacity of 90 tonnes and an estimated cost of $2M (Matt Wood, Hastings Deering (Australia) Ltd, 25 August 2010, pers. comm.). Trucks with capacities from 90 tonnes to 190 tonnes are replaced with the LIEBHERR T282, which has the largest capacity in the current vehicle inventory and an estimated cost of $5M. Trucks that have capacities greater than 190 tonnes are assumed to remain the same.

The reduced number of haul trucks required to transport the same amount of material is calculated as a direct proportion of the replacement truck's and the original truck's capacities. The hours of operation of each truck in the fleet were assumed to remain the same.

The estimated costs associated with using larger capacity haul trucks is assumed to be the difference between the total purchase price of the new fleet compared to the existing fleet. Truck costs are detailed in Table 128. Table 128 also shows the annual operating costs of trucks used in this assessment. Prices for Caterpillar equipment are based on data supplied by Hastings Deering (Australia) Ltd (Matt Wood, Hastings Deering (Australia) Ltd, 25 August 2010 and 20 September 2010 pers. comm.). Data for trucks by other manufacturers are interpolated from known truck costs (Table 128) and assumed to be proportional to the engine size.

Table 128 Estimated purchase and operating costs of haul trucks and equipment

Truck	Purchase Cost	Annual Operating Cost
CAT 769[a]	$1,706,204	$18,636
CAT 773[a]	$1,200,000	$18,910
CAT 777[b]	$1,924,789	$20,632
CAT 789[b]	$3,218,382	$41,226
EUCLID R100	$1,200,000	$18,910
FORD LN9000	$1,706,204	$18,636
KOMATSU HD 785-3	$1,200,000	$18,910
VOLVO F724	$1,706,204	$18,636
Unidentified Water Truck	$1,849,875	$23,663

Note:
[a] Price estimated based on similarity in engine size to the Euclid water truck with a known price of $1,200,000
[b] Purchase and Operational Cost provided by Hastings Deering

Wheel-generated emissions of particulate matter not attributed to haul trucks are relatively small and were assumed to remain the same.

12.3.8 Fabric filters – ROM hopper and drilling

Fabric filters can reduce the emission rate of particulate matter by 99%[154]. The source of emissions needs to be effectively enclosed so that particulate matter can be entrained in a stream of air and passed through the fabric filter. Bags have been assumed to be cleaned using mechanical shakers.

Costs for the use of fabric filters to reduce emissions of particulate matter from drilling and dumping into the ROM hoppers have been estimated using the information contained in AirControlNet[186]. The highest value in the range of US$303 (1998 dollar value) per tonne reduction of PM_{10} emissions has been used. The net present value to 2010 was calculated assuming an inflation rate of 4% amortised quarterly.

12.4 Application of best practice controls by source or activity

12.4.1 Haul roads

While not all mines included in the assessment emit substantial amounts of particulate matter from haul trucks travelling on unpaved roads, for 36 mines this is the most significant source of TSP (53%) and PM_{10} (39%) emissions and the second largest source of emissions of $PM_{2.5}$ (23%). All mines in the GMR implement watering controls using water trucks. Twenty-four mines employ Level 1 watering (2 L/m²/hour) and, hence, achieve a 50% control of emissions. The remaining twelve mines use Level 2 watering (greater than 2 L/m²/hour) and achieve 75% control of emissions.

Emissions due to vehicles travelling on unpaved roads can be minimised by implementing watering controls, applying suppressant, alternative transport methods (such as conveyors) or by reducing the number of trips required to transport material through the use of larger trucks. The costs associated with each of these control measures have been estimated and are represented in Figure 59, where current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity). The cost per tonne of particulate matter reduced is shown at the top of each stacked column.

Figure 59 shows that the particulate matter generated by haul trucks travelling on unpaved roads is almost equivalent to the emissions from all other activities at GMR coal mines. Hence, a significant reduction in wheel-generated particulate matter will also significantly reduce aggregate GMR coal mine emissions.

Figure 59 also shows that the greatest reduction in emissions would be achieved by the application of suppressants in conjunction with level 2 watering. A slightly smaller reduction would be achieved by the conversion of half of the haul roads to conveyors at less than half the cost.

The most cost-effective control measure would be the replacement of the current fleet with larger-capacity vehicles, which is shown not to incur any additional costs, but instead produces a significant cost saving due to the reduction in the number of vehicles required to be purchased, as well as reduced operating costs. Total emission reduction for this control measure is comparable to implementing Level 2 Watering, but less than employing alternative methods of transportation.

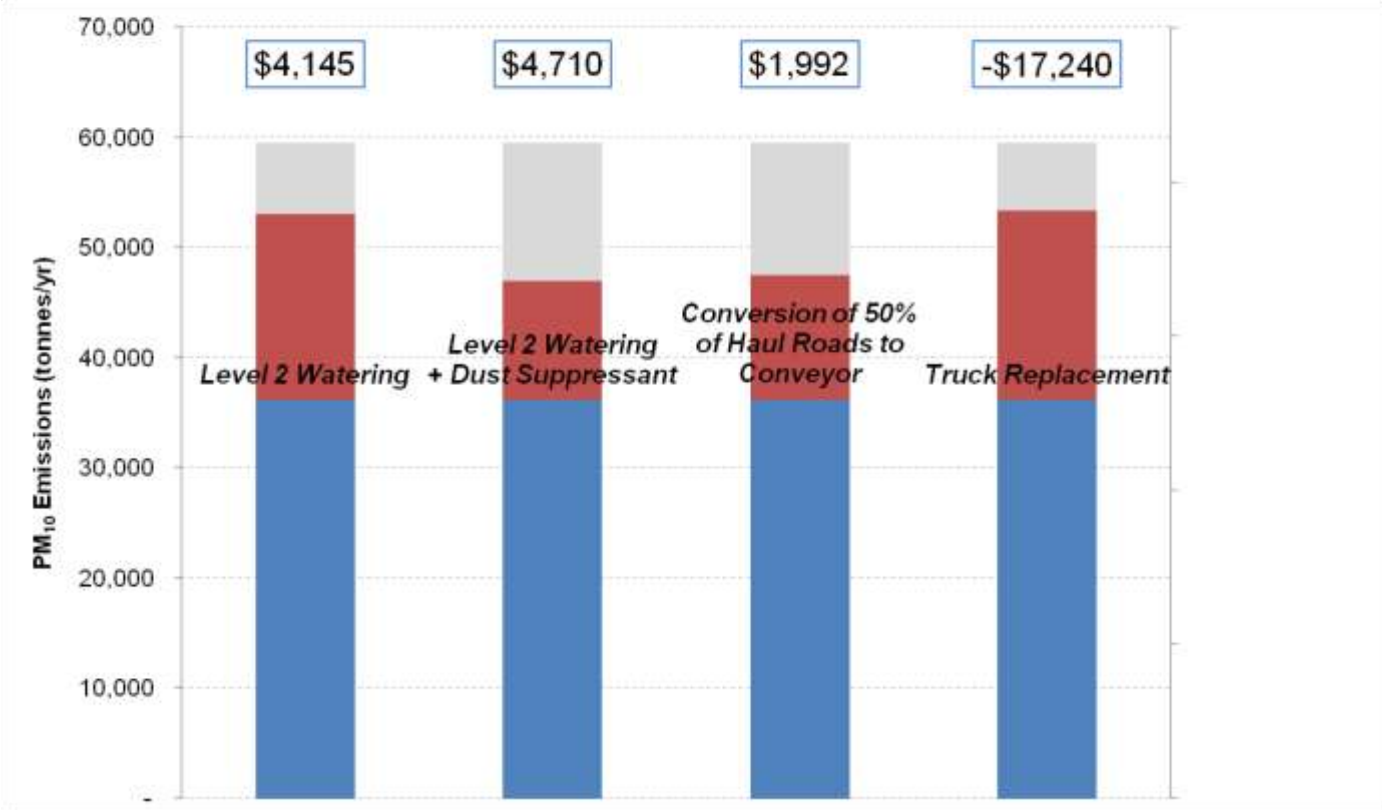

Figure 59 Reduction in emissions and associated costs (per tonne) to implement control options on haul roads

12.4.2 Wind erosion

Exposed areas are prone to wind erosion. The CMED categorises these areas as overburden dumps, coal stockpiles or other exposed areas.

12.4.2.1 Overburden emplacements

Within the GMR, wind erosion of overburden dumps is a significant source of particulate matter emissions from coal mines. There are 30 mines that have wind erosion emissions, contributing 27% to the total GMR emissions of PM_{10}. The number of mines implementing control measures is presented in Table 129. Mines implementing more than one control are counted separately in the table. There are 7 mines where the CMED records no control measures, while 23 mines in the GMR are recorded as implementing at least one or a combination of control measures.

Table 129 Control measures for mines with overburden emplacement emissions

Control Measure	Reduction (%)	Number of mines
Full Rehabilitation	99	11
Partial rehabilitation	varies	7
Enclosure	70	1
Level 2 Watering	75	2
Level 1 Watering	50	11
No Control	0	7

Emissions of particulate matter associated with wind erosion of overburden dumps can be reduced by rehabilitation, watering or by enclosing the exposed areas. The methodology used to estimate the costs and the reduction in emissions for the implementation of Level 1 and Level 2 watering are discussed in detail in Section 12.3.1. Estimation of the costs and emissions for rehabilitation and enclosures are discussed in Sections 12.3.3 and 12.3.5, respectively. The results of these assessments are presented in Figure 60, where current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity).

Rehabilitation of 80% of the exposed areas show the highest level of reduction, with a cost per tonne reduction in the lower range of the costs of all the control measures considered.

Figure 60 Reduction in emissions and associated costs (per tonne) to implement control options on overburden emplacements

12.4.2.2 Coal stockpiles

Wind erosion of coal stockpiles contributes approximately 2% of emissions to the aggregate GMR coal mine emissions of PM_{10}. Table 130 presents the current control measures implemented by the mines to mitigate emissions associated with wind erosion of coal stockpiles. There are 52 mines in the CMED that emit PM_{10} from coal stockpiles, with most of the mines implementing some form of emissions control to reduce the emissions, the most common of which is Level 1 watering, which is implemented by 38 mines.

Table 130 Control measures for mines with coal stockpile emissions

Control Measure	Reduction (%)	Number of mines
Suppressant	95	1
Enclosure	70	2
Level 1 Watering	50	38
Unidentified Control (25% Reduction)	25	2
No Control	0	11

Costs and associated reductions in emissions were estimated for the application of suppressants, Level 1 and Level 2 watering, and the construction of an enclosure. The methodology used to estimate the costs and emissions are discussed in more detail in Section 12.2. The results are presented in Figure 61, showing that the application of chemical suppressants significantly reduces the emissions at a cost of approximately \$29,000 per tonne of PM_{10}. Current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity).

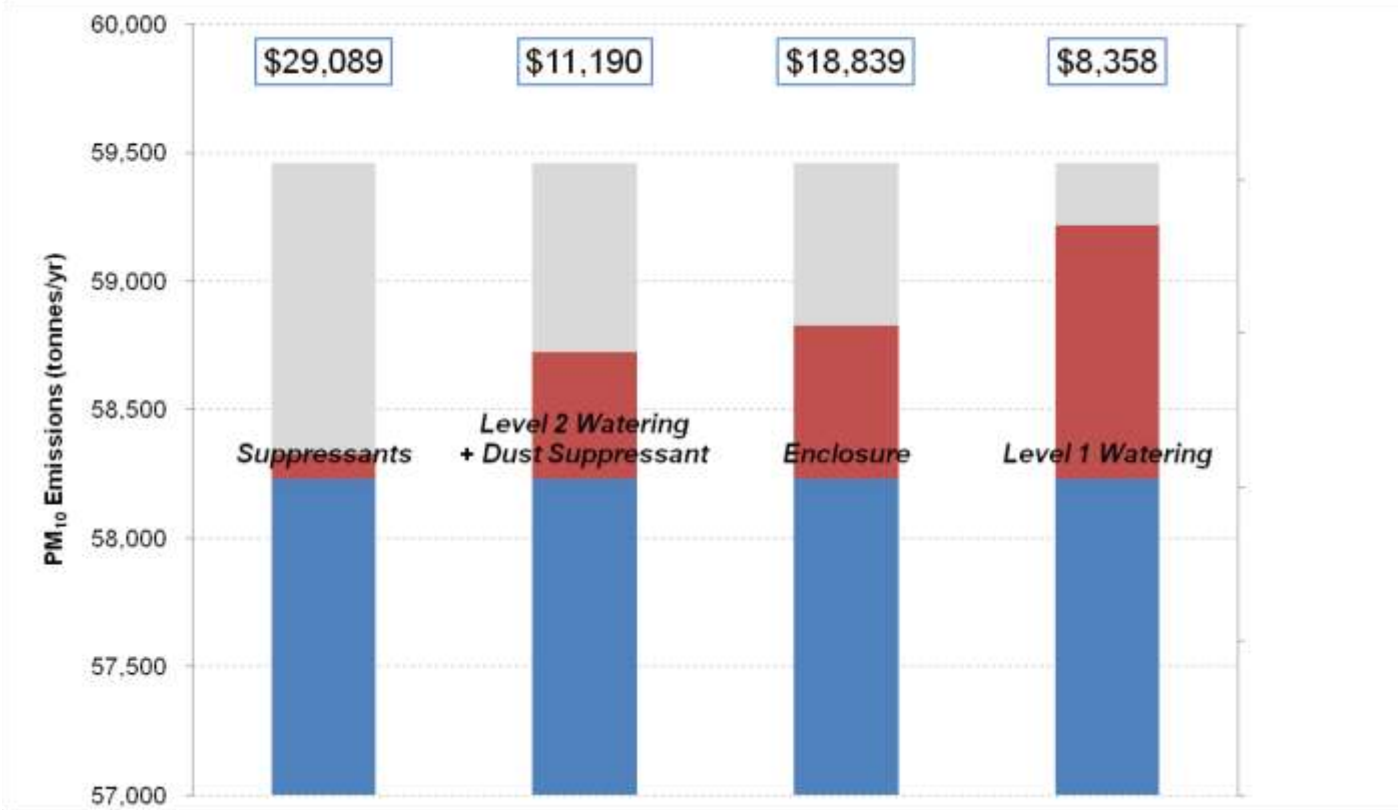

Figure 61 Reduction in emissions and associated costs (per tonne) to implement control options on coal stockpiles

12.4.2.3 Exposed areas

Twelve mines in the GMR have reported emissions associated with wind erosion from exposed areas. Wind erosion of these areas is a function of the size of the exposed area, silt content, number of rainfall days and frequency of wind speeds greater than 5.4 m/s. Table 131 presents the control measures implemented by the mines to mitigate emissions from wind erosion of exposed areas.

Table 131 Control measures for mines with exposed area emissions

Control Measure	Reduction (%)	Number of mines
Partial Rehabilitation	Varies	3
Enclosure	70	2
Level 1 Watering	50	2
No Control	0	6

The methodology used to estimate the costs and emissions are discussed in Section 12.2. The results are shown in Figure 62, showing an estimated saving of $2,000 by the implementation of full rehabilitation in place of current control measures, namely watering. Current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity).

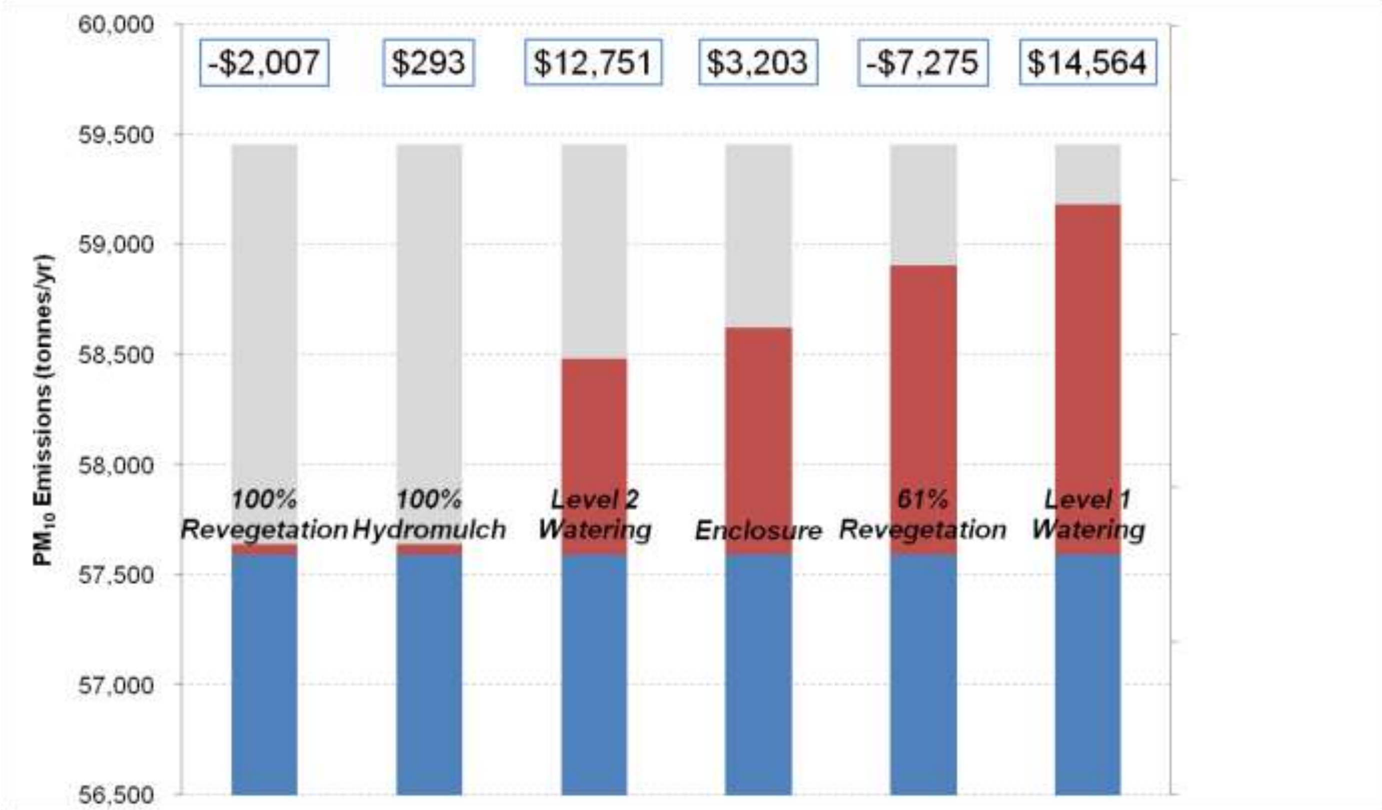

Figure 62 Reduction in emissions and associated costs (per tonne) to implement control options on exposed areas

12.4.3 Bulldozers

Bulldozing activities contribute approximately 8.5% of the total PM_{10} emissions in the GMR. Almost 5% of GMR emissions can be attributed to bulldozing coal at 41 mines. More than 3.5% of GMR emissions can be attributed to bulldozing overburden at 27 mines. The CMED indicates that none of the mines in the GMR implement control measures to minimise emissions due to bulldozing.

The application of watering during bulldozing activities can reduce the emissions by 50%. The cost required to implement this is based on the total hours of operation of the dozers in the coal mining vehicle database. The proportion to which the dozers are used on coal or overburden is based on each mine's ROM coal and overburden. The cost of water is calculated by assuming that a water truck with a capacity of 75,000L operates in conjunction with the bulldozers.

The reduction in emissions by implementing watering to bulldozing activities is shown in Figure 63 and Figure 64. The figures show that the cost per tonne of PM_{10} reduced by implementing watering is lower for bulldozers operating on coal and, is overall, more effective in reducing emissions.

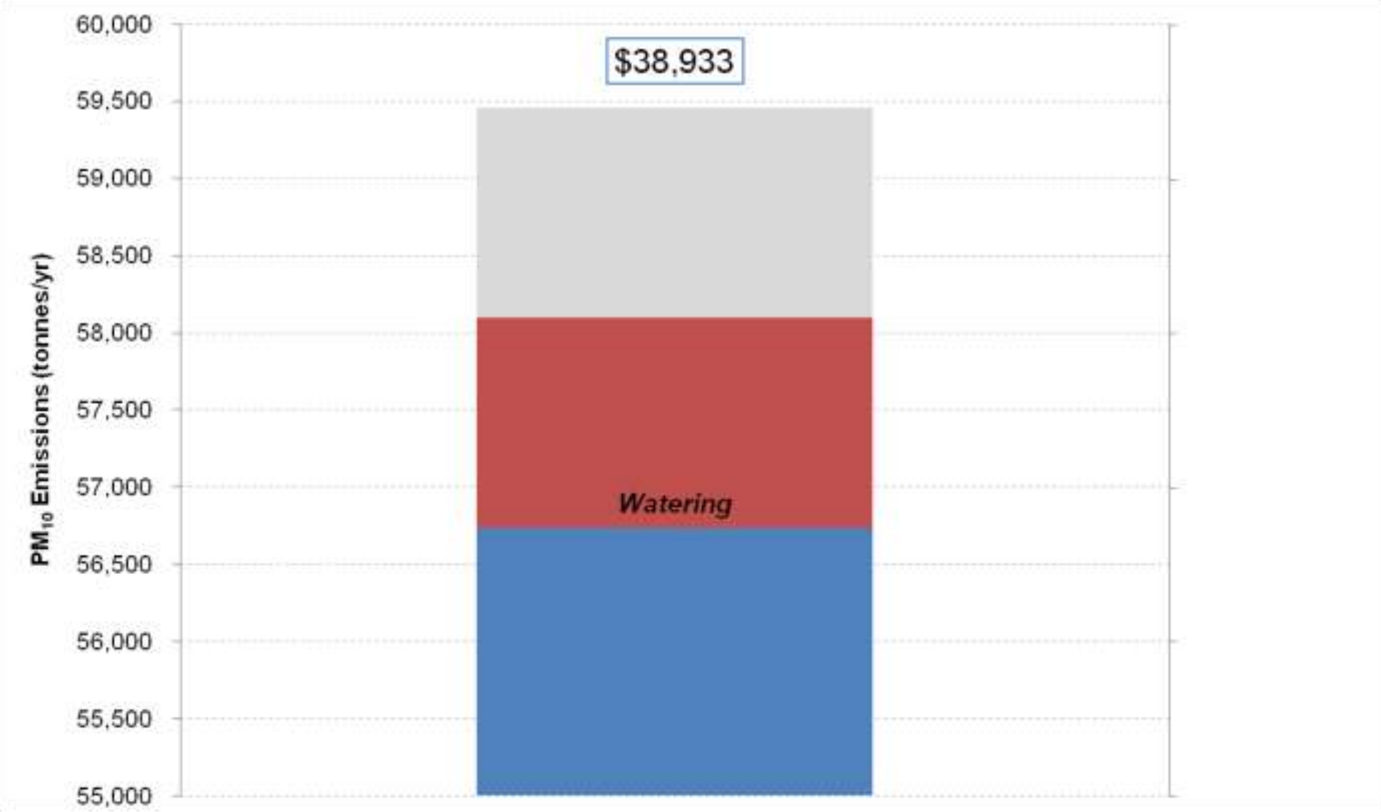

Figure 63 Reduction in emissions and associated costs (per tonne) to implement watering on bulldozing coal

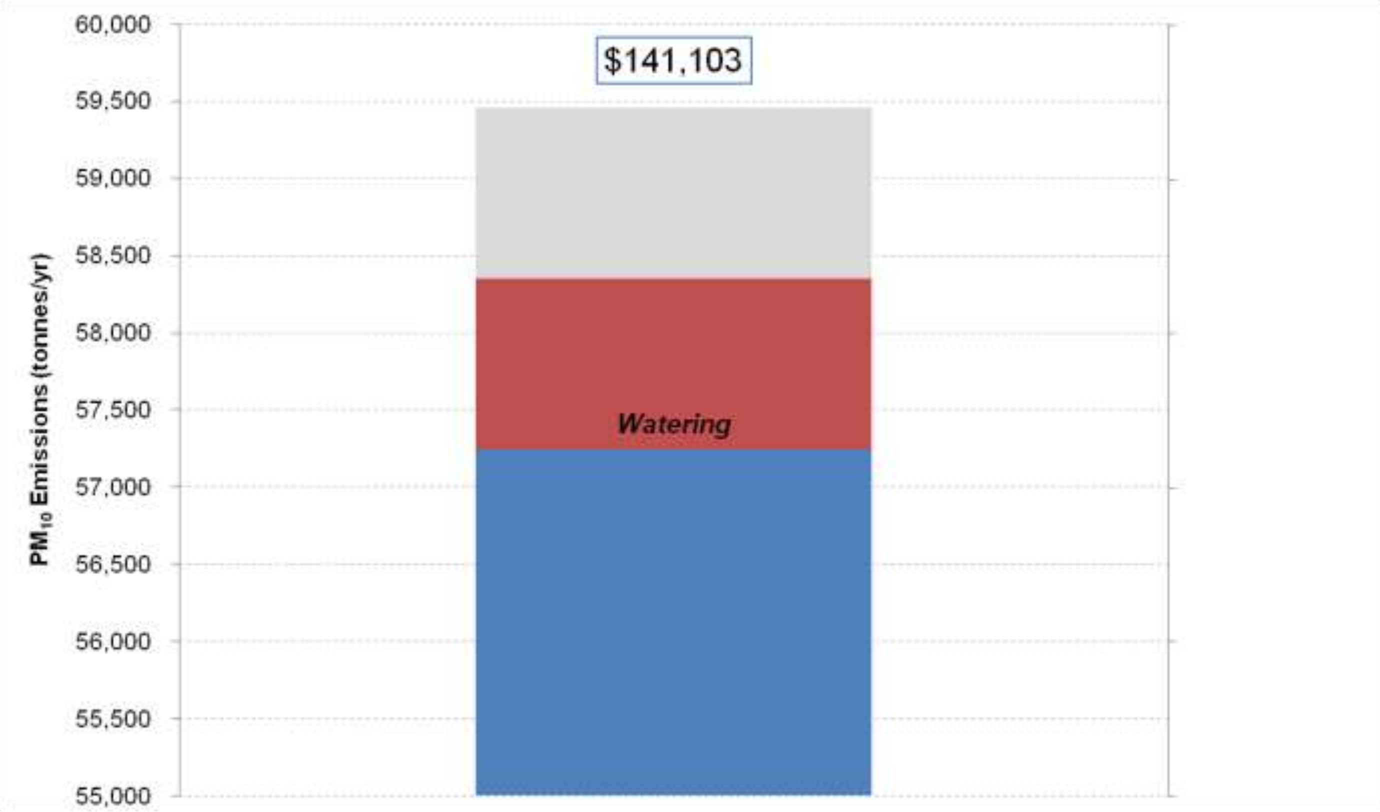

Figure 64 Reduction in emissions and associated costs (per tonne) to implement watering on bulldozing overburden

12.4.4 Trucks dumping coal to the ROM hopper

Trucks dumping coal to the ROM hopper contribute less than 1% to the total emissions of PM_{10} from coal mines in the GMR. The number of mines implementing control measures is shown in Table 132, with most of the mines not implementing any form of control measure to minimise emissions. The costs and reductions in emissions achieved by the use of enclosure and fabric filters, water sprays and enclosure, and water sprays alone were estimated.

Table 132 Control measures for mines with emissions from trucks dumping coal to the ROM hopper

Control Measure	Reduction (%)	Number of mines
Unidentified Control (75% reduction)	75	1
Water Sprays + Enclosure	70	6
Water Sprays	50	6
No Control	0	20

The ROM hopper is assumed to be a 9m x 3m area, and the enclosure required is estimated to be double this size. Structural costs for the enclosure and water sprays take into account the existing structures. Water sprays were estimated to cost $200,000, and the enclosures are estimated based on the discussion in Section 12.3.5.

The water sprays are assumed to be activated for 2 minutes while the trucks are dumping the coal at a rate of 2 $L/m^2/hr$ for each dump. The total number of trips is based on data provided in the CMED.

Costs and the reduction in emissions are shown in Figure 65 where current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity). The use of a fabric filter and enclosing the ROM hopper is estimated to reduce the emissions by 99% at a cost of almost $6,000 per tonne reduction of PM_{10} emissions.

Figure 65 Reduction in emissions and associated costs (per tonne) to implement control options on trucks dumping coal at the ROM hopper

12.4.5 Graders

Grading is conducted at 26 mines in the GMR. Grading is estimated in the CMED to contribute less than 1% to coal mining emissions of PM_{10}. The number of mines implementing control measures is shown in Table 133, with most of the mines not implementing any form of control measure.

Table 133 Control measures for mines with grader emissions

Control Measure	Reduction (%)	Number of mines
Level 1 Watering	50	5
No Control	0	21

Costs and the reduction in emissions achieved by implementing Level 1 and Level 2 watering are shown in Figure 66, where current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity). The costs are estimated based on the data in the activity data in the CMED, where the hours of operation are used to calculate the amount of water required. Level 1 watering reduces the emissions at a lower cost than Level 2 watering.

Figure 66 Reduction in emissions and associated costs (per tonne) to implement control options on grading

12.4.6 Drilling

Drilling produces less than 1% to the total PM_{10} emissions from coal mining in the GMR and is conducted by 23 coal mines. The number of coal mines that implement control measures to reduce drilling emissions based on the CMED are shown inTable 134, with most of the mines not implementing control measures.

Table 134 Control measures for mines with drilling emissions

Control Measure	Reduction (%)	Number of mines
Unidentified Control (85% reduction)	85	1
Level 2 Watering	75	1
Enclosure	70	7
No Control	0	14

Costs and the reduction in emissions by the implementation of controls are shown in Figure 67, where current emissions are the sum of the grey area (emission reduction for the subject activity), red area (emission remaining for the subject activity) and dark blue area (emission from activities other than the subject activity). The drilling area is assumed to be 2m x 1m area, and costs for the enclosure estimated based on this. The cost of the fabric filter is estimated using the method described in Section 12.3.8.

The use of fabric filters reduces the emissions by 99%. On a cost per tonne basis, the costs associated with implementing control measured to minimise emissions from drilling are significantly lower than other activities.

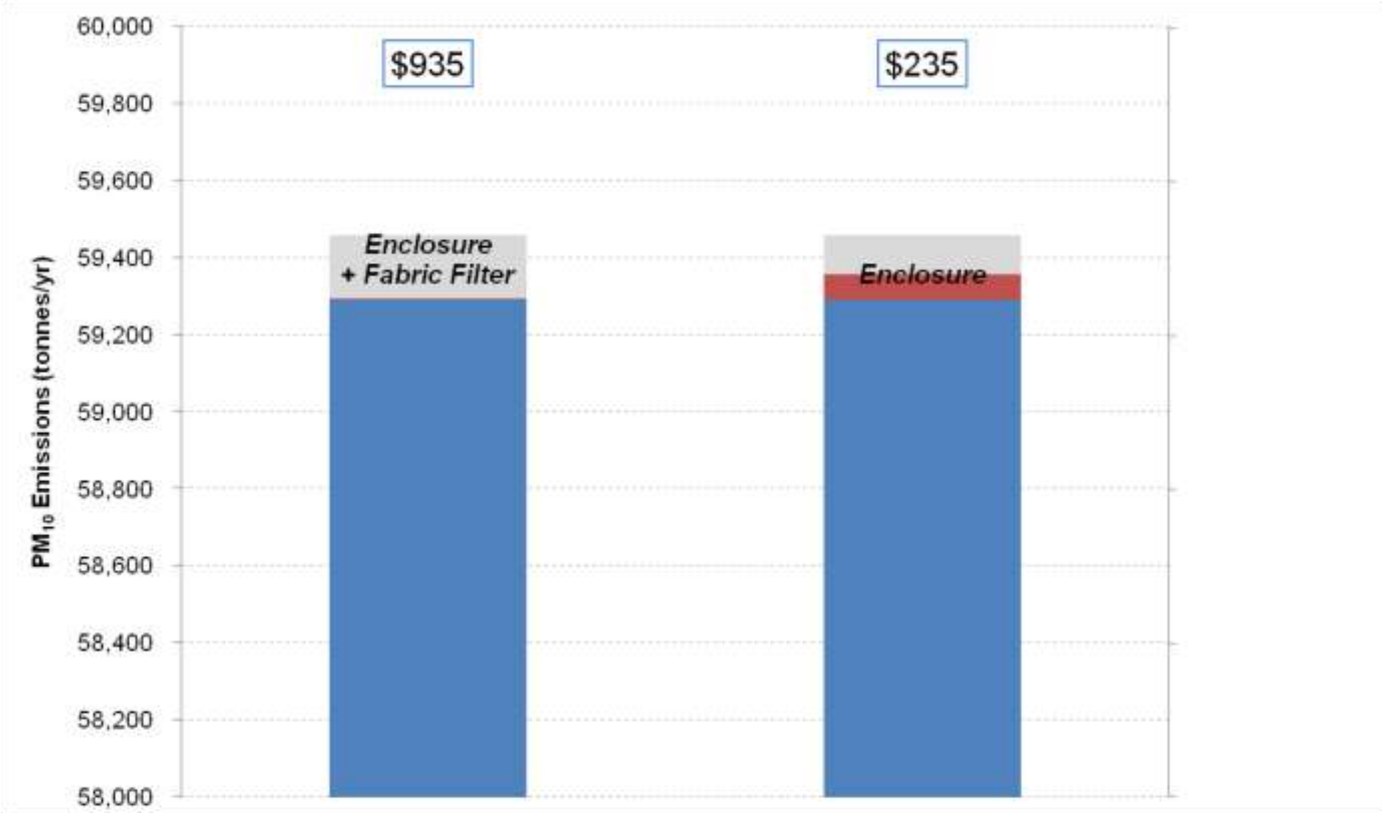

Figure 67 Reduction in emissions and associated costs (per tonne) to implement control options on drilling

12.4.7 No cost emission reductions

The implementation of best practice control measures for a number of mine activities were evaluated as having no cost. These are shown in Table 135 and Figure 68. Trucks dumping overburden contribute over 4% of the total PM_{10} emissions in the GMR. However, none of the mines are implementing control measures to minimise emissions. Minimising the drop height to 1.5 metres has been estimated to reduce the emissions by 70%.

The other activities listed in Table 135 currently contribute less than 1% of the total PM_{10} emissions in the GMR, with some of the mines implementing control measures to minimise emissions. However, emissions can be further reduced by the implementation of the control measures listed.

Table 135 No cost emission reductions, reduction in emissions to implement best practice control measures

Activity	Best Practice Control Option	Source Metric	Current Emissions (tonnes/year)	Reduced Emissions (tonnes/year)
Trucks (dumping overburden)	Minimise drop height	0%	2,512	776
Loaders (coal)	Watering	15%	2,198	1,008
Unloading from stockpiles (coal)	Watering	39%	1,092	407
Dragline (Other)	Minimise drop height	93%	924	74
Loading stockpiles (coal)	Watering	27%	245	102
Material transfer (coal)	Enclosure	70%	37	15
Loading trains (coal)	Level 2 Watering	29%	15	10

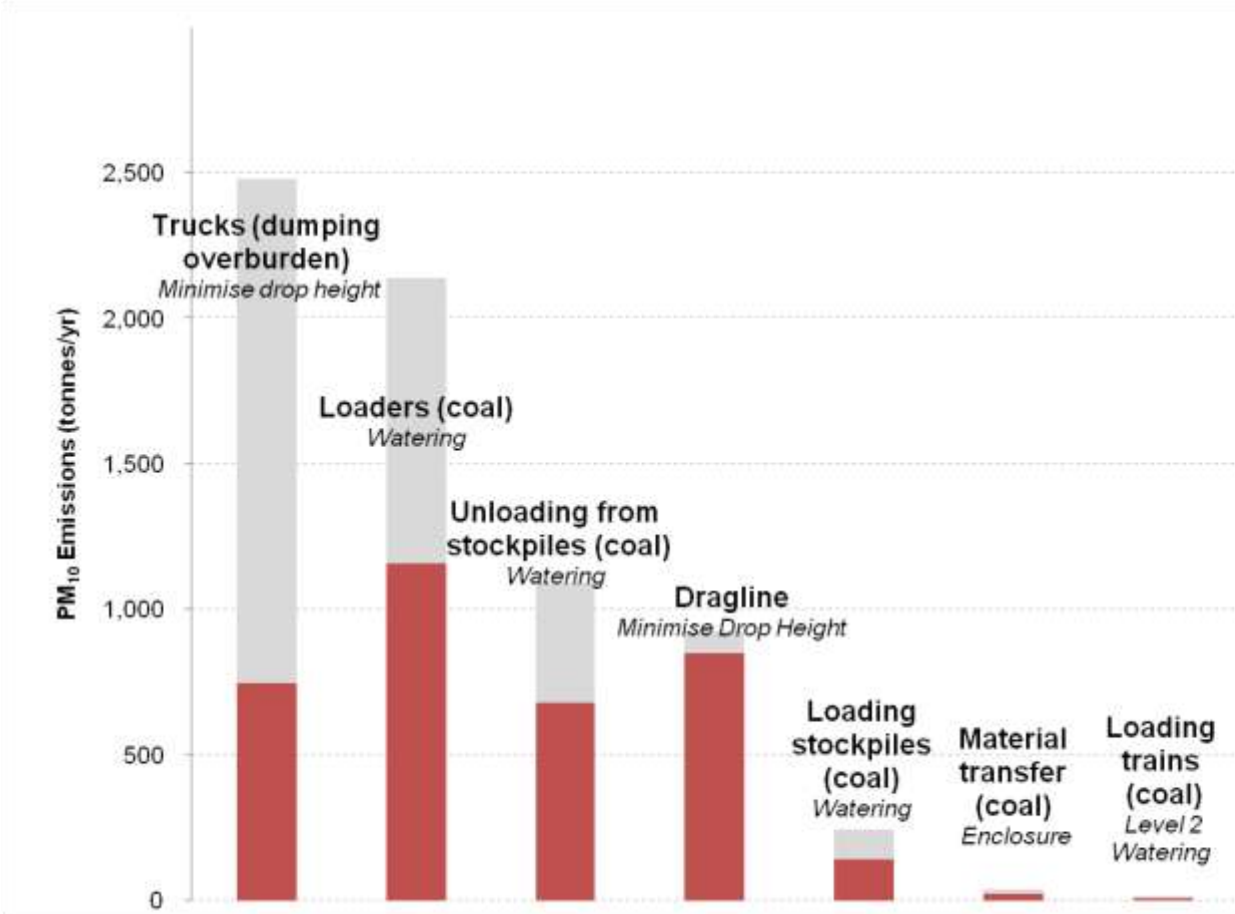

Figure 68 No cost emission reductions, reduction in emissions to implement best practice control measures

12.4.8 Emission reductions not assessed

Mine activities where no control measures were evaluated are summarised below:

- Blasting
- Coal crushing (controlled wet suppression)
- Internal Combustion Engine (Diesel, P>450kW)
- Scrapers (overburden)
- Internal Combustion Engine (Diesel, P<450kW)
- Flares (natural gas, coal seam methane, landfill gas)
- Screening

- Material transfer (overburden)
- Boiler (Natural gas, Residential (<0.3 GJ/h))

Apart from blasting, the activities mentioned contribute less than 0.2% of emissions of PM_{10} in the GMR. For these activities, mines were assumed to be operating at best practice and no further reduction to emissions was assessed. These activities were not included in calculating the mine metrics.

While the current level of reduction in emissions due to blasting is difficult to quantify from the database, Table 110 shows that many mines currently implement measures to control the emissions from blasting. Emissions from blasting activities contribute almost 6% to the current emissions in the GMR. Emissions from blasting may be further reduced by greater adoption of practices such as minimising the blast area and delaying blasting when conditions are unfavourable.

12.4.9 Summary by source or activity

Emissions and costing information for the implementation of best practice control measures for seven key activities are summarised in Table 136. Table 136 shows that implementing best practice on exposed areas reduces the aggregate costs compared with the current control measures. However, this will only reduce the current emissions by 3%. A significant reduction in the emissions is achieved by implementing best practice control measures to the two biggest sources of emissions in the GMR (wheel generated particulate matter from unpaved haul roads and wind erosion of overburden emplacements). The table also shows that the most cost-effective implementation of control measures will reduce the emissions by a significantly higher rate than the more expensive options.

Table 136 Cumulative cost and reduction by the implementation of best practice control measures

Source	Costs			Reduction in emissions		
	Total Cost	Cumulative cost	Cost per tonne of PM_{10} reduced	Emission rate (tonnes/year)	Cumulative reduction (tonnes/year)	Cumulative (%)
Exposed area (wind erosion)	-$3,645,902	-$3,645,902	-$2,007	1,816	1,816	3%
Drilling	$153,078	-$3,492,824	$935	164	1,980	3%
Wind Erosion (overburden)	$20,424,971	$16,932,148	$1,761	11,596	13,577	23%
Unpaved roads	$58,898,874	$75,831,022	$4,710	12,495	26072	44%
Trucks (dumping coal) - ROM Hopper	$2,275,271	$78,106,292	$5,812	391	26463	45%
Wind Erosion (coal)	$32,801,897	$110,908,189	$29,089	1,128	27591	46%
Bulldozers (coal)	$53,032,907	$163,941,097	$38,933	1,362	28953	49%
Bulldozers (overburden)	$156,240,732	$320,181,829	$141,103	1,107	30060	51%
Graders	$20,239,481	$340,421,310	$287,641	70	30131	51%

Including only those control measures that cost less than $40,000 per tonne of PM_{10} reduced, the cost of implementing best practice particulate emission controls in GMR coal mines was estimated to be $164M per year. The application of these best practice particulate emission controls was estimated to produce a 49% reduction in overall emissions of PM_{10}.

12.5 Aggregated costs by activity and premises for the GMR

Table 137 shows the current emission rates of PM_{10} and particulate matter emission control metrics for various sources of particulate matter at GMR coal mines, as well as the resultant emissions and reduction in emissions of PM_{10} achieved by the implementation of best practice control measures. As shown in Table 137, a significant portion of the current emissions can be reduced by the implementation of chemical suppressants to haul roads and rehabilitation of 81% of overburden emplacements.

This is also graphically represented in Figure 69, showing the relevant costs per tonne reduction of emissions for each activity where possible.

Emissions and costs to implement best practice control measures for the individual mines are presented in Table 138 and Figure 70, showing the significant reduction in emissions can be achieved by the implementation of best practice control measures to significant sources of PM_{10} emissions in the GMR.

Table 137 Current emissions of PM_{10} by coal mining activity in the GMR and estimated emissions after the implementation of best practice control measures and the estimated cost of implementing best practice

Activity	Current		Best practice				
	PM_{10} emissions (tonnes/yr)	Combined Source Metric	Best practice control options	PM_{10} emissions (tonnes/yr)	Reduction (tonnes/yr)	Cost	Cost per tonne of PM_{10} reduced
Unpaved roads - coal mines	23,272	78%	Chemical Suppressant + Level 2 Watering	10,777	12,495	$58,898,874	$4,710
Wind Erosion (overburden)	16,246	50%	81% Rehabilitation	4,649	11,596	$20,424,971	$1,761
Blasting[a]	3,329	0%	Minimise Blast Area	3,329	0		
Bulldozers (coal)	2,724	0%	Watering	1,362	1,362	$53,032,907	$38,933
Trucks (dumping overburden)[a]	2,480	0%	Minimise drop height	746	1,734		
Bulldozers (overburden)	2,215	0%	Watering	1,107	1,107	$156,240,732	$141,103
Loaders (coal)[b]	2,141	15%	Watering	1,156	985		
Exposed area (wind erosion)	1,866	63%	100% Rehabilitation	50	1,816	-$3,645,902	-$2,007
Wind Erosion (coal)	1,227	40%	Chemical Suppressant	99	1,128	$32,801,897	$29,089
Unloading from stockpiles (coal)[b]	1,092	39%	Watering	677	415		
Dragline (Other)[a]	924	93%	Minimise Drop Height	850	74		
Loaders (overburden)[d]	707	0%	No Controls Assessed	707	0		
ROM hopper	397	24%	Fabric Filter + Enclosure	5	391	$2,275,271	$5,812
Loading stockpiles (coal)[b]	245	27%	Level 1 Watering	140	104		
Graders	172	31%	Level 1 Watering	102	70	$20,239,481	$287,641
Drilling	166	22%	Fabric Filter and Enclosure	2	164	$153,078	$935
Coal crushing (controlled wet suppression)[c]	75	0%	Minimise drop height	75	0		
Material transfer (coal)[b]	40	100%	No Controls Assessed	40	0		
Internal Combustion Engine (Diesel, P>450kW)[c]	37	70%	Enclosure	22	15		
Scrapers (overburden)[c]	34	100%	No Controls Assessed	34	0		
Trucks (dumping coal)	32	100%	No Controls Assessed	32	0		
Internal Combustion Engine (Diesel, P<450kW)[c]	15	100%	No Controls Assessed	15	0		
Loading trains (coal)[b]	15	29%	Level 2 Watering	5	10		
Flares (natural gas, csm, lfg)[c]	7	100%	No Controls Assessed	7	0		
Screening[c]	0	100%	No Controls Assessed	0	0		
Material transfer (overburden)[c]	0	100%	No Controls Assessed	0	0		
Boiler (Natural gas, Residential (<0.3 GJ/h))[c]	0	100%	No Controls Assessed	0	0		
Grand total	59,460			25,989	33,468	$340,421,310	

Note:
[a] No direct costs associated with implementation of best practice control measure.
[b] Costs are not assessed. The highest available level of control within the data is assumed to be best practice.
[c] No controls are assumed to be available or best practice assumed to be in place.
[d] Controls are assumed to be available, no credit given to the mines.

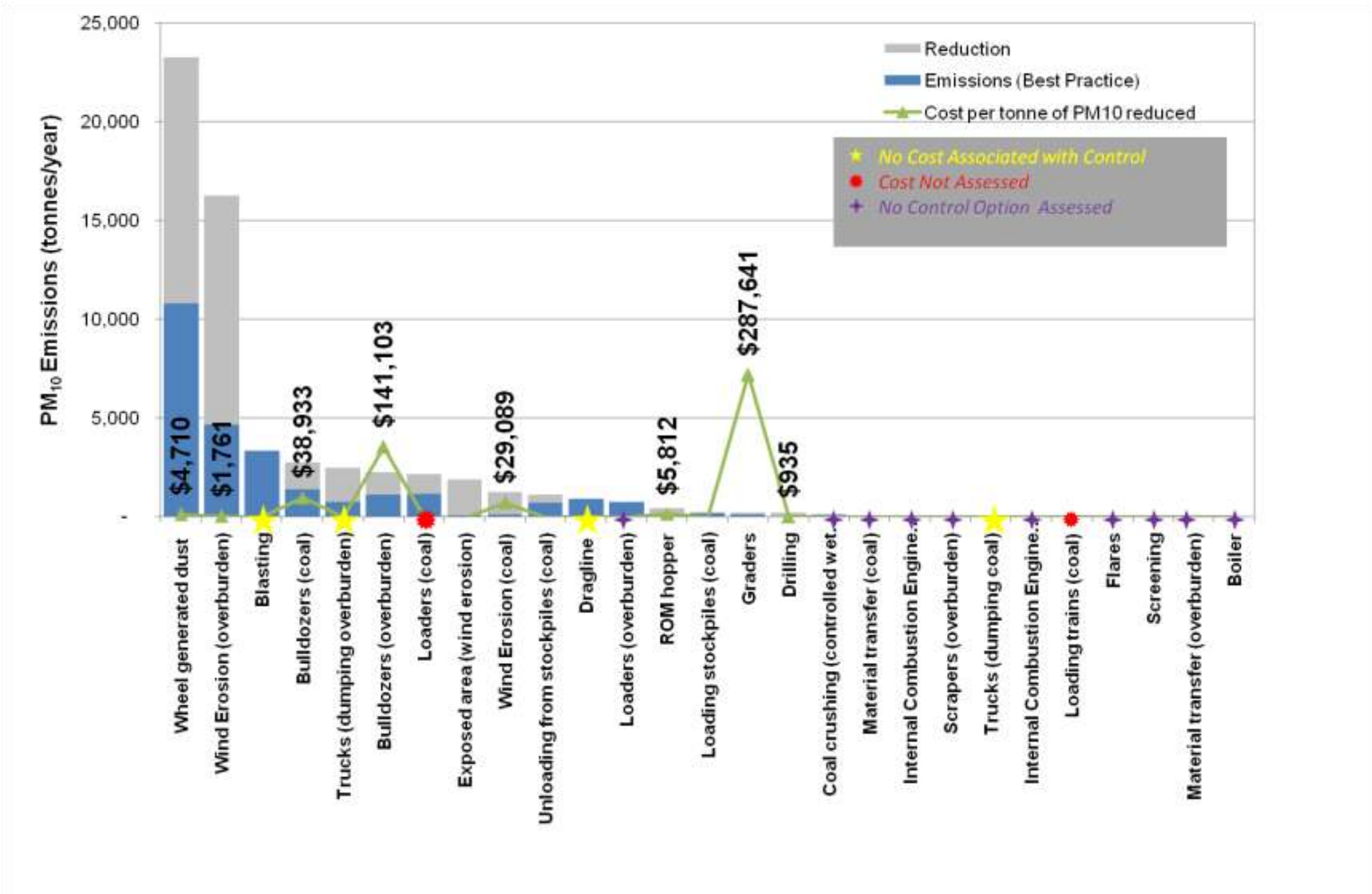

Figure 69 Reduction in PM_{10} emissions and associated costs (per tonne) to implement control options by mine activity

Table 138 Current emissions of PM_{10} by coal mine in the GMR and estimated emissions after the implementation of best practice control measures and the estimated cost of implementing best practice

Activity	Current		Best Practice			
	PM_{10} emissions (tonnes/yr)	Source Metric	PM_{10} emissions (tonnes/yr)	Reduction (tonnes/yr)	Cost to implement	Cost per tonne of PM_{10} reduced
HUNTER VALLEY OPERATIONS	11,633	51%	4,564	7,069	$38,407,787	$5,433
MT ARTHUR NORTH COAL MINE	7,524	71%	3,373	4,151	$44,389,466	$10,693
SAXONVALE COLLIERY HOLDING	4,653	54%	2,096	2,557	$17,071,653	$6,676
WARKWORTH COAL MINE	3,494	94%	2,071	1,423	$21,831,420	$15,337
MT OWEN COAL MINE	2,859	51%	1,142	1,717	$12,641,210	$7,364
CAMBERWELL COAL MINE	2,727	49%	910	1,817	$21,616,534	$11,897
LIDDELL COAL OPERATIONS	2,660	53%	1,102	1,558	$4,814,914	$3,090
DRAYTON COAL MINE	2,497	67%	1,202	1,295	$27,629,709	$21,328
WAMBO COAL PTY LTD	2,166	67%	825	1,341	$12,647,437	$9,434
BENGALLA MINE	2,098	73%	942	1,156	$4,329,712	$3,747
MOUNT THORLEY OPERATIONS	1,958	3%	429	1,529	$1,936,992	$1,267
RAVENSWORTH/NARAMA MINE	1,816	58%	842	974	$6,643,232	$6,819
WILPINJONG COAL PTY LTD	1,757	58%	776	981	$23,018,174	$23,473
RAVENSWORTH EAST MINE	1,704	61%	906	798	$7,713,872	$9,668
MUSWELLBROOK COLLIERY HOLDING	1,274	50%	635	639	$9,669,461	$15,138
CUMNOCK NO. 1 COLLIERY	1,120	51%	384	736	$5,826,841	$7,914
ASHTON COAL MINE	1,095	65%	522	573	$8,982,718	$15,671
GLENDELL MINE	1,063	59%	568	495	$4,625,755	$9,338
RIX'S CREEK COLLIERY	833	94%	685	148	$5,331,295	$36,008
DONALDSON COAL PTY LTD	596	52%	196	400	$3,370,748	$8,434
BLOOMFIELD COLLIERY	505	92%	404	101	$4,405,657	$43,580
WESTSIDE MINE	415	33%	157	257	$2,918,797	$11,337
WESTCLIFF AND NORTHCLIFF COLLIERIES	268	49%	151	117	$3,903,177	$33,317
BAAL BONE COLLIERY	268	44%	58	210	$2,633,866	$12,520
CULLEN VALLEY MINE	248	39%	98	149	$3,788,083	$25,350
BAYSWATER COLLIERY	234	25%	70	164	$3,436,392	$21,007
NEWSTAN COLLIERY	204	38%	88	116	$2,101,702	$18,111
PINE DALE MINE	204	57%	83	120	$3,611,796	$30,009
RAVENSWORTH UNDERGROUND MINE	204	77%	88	115	$3,209,467	$27,859
THE INVINCIBLE COLLIERY	157	35%	58	99	$3,647,879	$36,690
UNITED COLLIERY	155	66%	82	73	$2,053,087	$28,130
MACQUARIE COAL PREPARATION PLANT	140	66%	41	98	$4,013,292	$40,780
SPRINGVALE COLLIERY	110	5%	42	68	$952,049	$13,971
GLENNIES CREEK COLLIERY	98	78%	37	61	$1,770,822	$29,266

Activity	Current		Best Practice			
	PM_{10} emissions (tonnes/yr)	Source Metric	PM_{10} emissions (tonnes/yr)	Reduction (tonnes/yr)	Cost to implement	Cost per tonne of PM_{10} reduced
TAHMOOR COLLIERY	97	49%	36	61	$4,026,793	$66,379
CHARBON COAL PTY LIMITED	80	45%	22	58	$3,767,065	$64,504
CLARENCE COLLIERY	80	66%	48	32	$2,603,810	$82,368
AUSTAR COAL MINE	79	64%	38	41	$281,020	$6,790
MANDALONG MINE AND COORANBONG COLLIERY	71	67%	52	19	$182,645	$9,544
DENDROBIUM MINE	49	62%	36	14	$883,478	$64,440
ANGUS PLACE COLLIERY	44	0%	21	23	$1,306,270	$56,563
METROPOLITAN COLLIERY	39	8%	19	20	$606,671	$30,830
WEST WALLSEND COLLIERY	31	3%	16	15	$15,199	$1,011
TASMAN COAL MINE	31	2%	7	24	$32,457	$1,370
NRE NO 1 COLLIERY	21	39%	13	8	$373,072	$47,006
ABEL UNDERGROUND MINE	20	8%	13	7	$32,379	$4,541
APPIN COLLIERY	20	88%	15	5	$27,238	$5,629
NRE WONGAWILLI COLLIERY	16	23%	7	9	$1,121,820	$125,809
AWABA COLLIERY	16	0%	8	8	$15,411	$1,925
MANNERING COLLIERY	10	0%	5	6	$39,260	$6,923
CHAIN VALLEY COLLIERY	8	19%	3	5	$44,127	$8,941
RICHMOND MAIN EAST	5	0%	3	3	$72,416	$27,120
BERRIMA COLLIERY	4	37%	1	3	$44,324	$16,347
IVANHOE NO.2 COLLIERY	1	0%	0	1	$920	$1,325
MYUNA COLLIERY	1	37%	0	0	$0	$0
XSTRATA MANGOOLLA (ANVIL HILL MINE)	0	63%	0	0	-$61	-$897

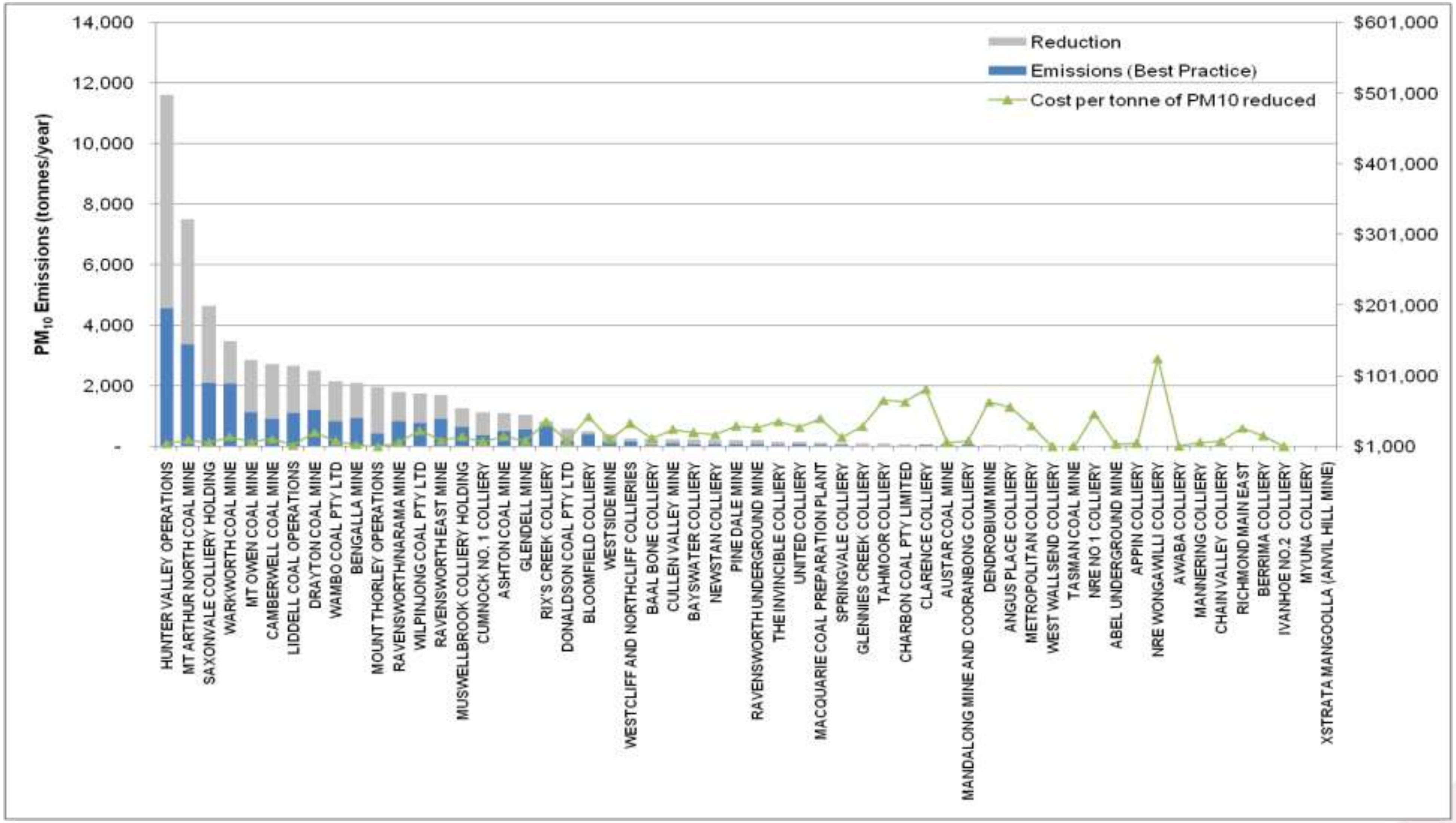

Figure 70 Reduction in PM_{10} emissions and associated costs (per tonne) to implement best practice control measures by coal mine

12.6 Summary of cost effectiveness analysis

Table 139 provides a summary of the costs and benefits of implementing best practice particulate control measures in GMR coal mines. The table shows that:

Haul roads:

- The greatest reduction in emissions would be achieved by the application of suppressants to haul roads, which will reduce the current emissions by 21%. The cost for this is $59M per year.
- A similar reduction in emissions could be achieved by the conversion of 50% of the haul roads to conveyors, which is estimated to cost $24M per year, and would reduce current emissions by 20%.
- The most cost-effective control measure would be the replacement of the current fleet with larger-capacity vehicles, which is shown not to incur any additional costs, but instead produces a significant cost saving due to the reduction in the number of vehicles required to be purchased, as well as reduced operating costs. The use of larger haul trucks is estimated to reduce costs by $105M per year across GMR mines and to reduce overall emissions by 10%.

Overburden emplacements:

- Rehabilitation of 80% of the overburden emplacements will reduce the current emissions by 20% and is estimated to cost $20M per year.
- Rehabilitation is a more cost-effective approach in minimising emissions than watering.

Coal stockpiles:

- The greatest reduction in emissions from coal stockpiles was achieved by the application of suppressants, which is expected to reduce the current emissions by 2.0% at an ongoing cost of $33M per year.
- A more cost effective approach would be the application of Level 2 watering, estimated to reduce current emissions by 1.0% and is estimated to cost $8M per year

Exposed areas:

- Full rehabilitation of other exposed areas is estimated to reduce current emissions by almost 3%, and is estimated to reduce the costs of current control measures (namely watering) by approximately $4M.
- Full or partial rehabilitation of the exposed areas is shown to reduce the ongoing operational costs and the current emissions.

Bulldozing:

- Watering while bulldozing coal will reduce the current emissions by almost 2.0% of the current emissions and is estimated to cost over $53M per year.
- Watering while bulldozing overburden will reduce the current emissions by less than 2% of the current emissions and is estimated to cost over $156M per year.

Trucks dumping coal to the ROM hopper:

- Enclosing the ROM hopper and the use of fabric filters is shown to reduce current PM_{10} emissions by less than 1% at a cost of $2M per year.

Graders:

- The application of level 2 watering to grading activities is estimated to reduce emissions by less than 1% at an estimated cost of $38M per year.

Drilling:

- The use of fabric filters on drill rigs is estimated to reduce emissions by less than 1% at an approximate cost of $150,000 per year.
- The cost of using the enclosure is significantly lower, estimated to cost $24,000 per year, and estimated to reduce emissions by less than 1%.

Table 139 Summary of cost effectiveness analysis for GMR coal mines

Activity	Reduction in emissions of PM_{10} from entire inventory (%)	Total Cost per year	Cost per tonne of PM_{10} reduced
Wheel generated dust (unpaved roads - coal mines)			
Level 2 Watering	11%	$26,723,874	$4,145
Level 2 Watering + Dust Suppressant	21%	$58,898,874	$4,710
Conversion of 50% of Haul Roads to Conveyor	20%	$23,949,845	$1,992
Truck Replacement	10%	-$105,111,320	-$17,240
Wind Erosion (overburden)			
Level 2 Watering	18%	$62,563,790	$5,827
Level 1 Watering	11%	$26,051,699	$3,980
Enclosure	17%	$18,684,716	$1,889
Rehab (56%)	12%	$12,387,531	$1,682
Rehab (81%)	20%	$20,424,971	$1,761
Coal Stockpiles			
Suppressants	2%	$32,801,897	$29,089
Level 2 Watering	1%	$8,186,396	$11,190
Enclosure	1%	$11,916,561	$18,839
Level 1 Watering	0%	$1,997,168	$8,358
Exposed area (wind erosion)			
100% Revegetation	3%	-$3,645,902	-$2,007
100% Hydromulch	3%	$533,082	$293
Level 2 Watering	2%	$12,447,721	$12,751
Enclosure	1%	$2,675,726	$3,203
61% Revegetation	1%	-$4,025,355	-$7,275
Level 1 Watering	0%	$3,952,865	$14,564
Bulldozing (coal)			
Watering	2%	$53,032,907	$38,933
Bulldozing (overburden)			
Watering	2%	$156,240,732	$141,103
Trucks dumping coal to ROM Hopper			
Enclosure + Fabric Filter	1%	$2,275,271	$5,812
Water Sprays + Enclosure	0%	$2,045,032	$8,493
Water Sprays	0%	$425,032	$2,799
Graders			
Level 2 Watering	0%	$37,530,061	$309,165
Level 1 Watering	0%	$20,239,481	$287,641
Drilling			
Enclosure + Fabric Filter	0%	$153,078	$935
Water Sprays + Enclosure	0%	$24,000	$235

Overall costs and benefits:

- Significant reductions in emissions of particulate matter could be achieved through the application of best practice control measures that are both technically and economically feasible.
- Including only those control measures that cost less than $40,000 per tonne of PM_{10} reduced, the cost of implementing best practice particulate emission controls in GMR coal mines was estimated to be $164M per year.
- The application of these best practice particulate emission controls was estimated to produce a 49% reduction in overall emissions of PM_{10}.

- This reduction relies heavily on achieving a substantial increase in the area of land rehabilitated per year and the application of suppressant to haul roads.
- Costs and benefits of the application of best practice control measures to different mine activities are based on generalised assumptions about mine activities, costs and effectiveness of those control measures. The actual cost and effectiveness will be dependent on site specific factors that need to be evaluated on a case-by-case basis.

Table 140 presents a summary of other control measures that can be applied to other activities. The table shows that:

- Minimising the drop height for trucks dumping overburden and draglines, not expected to incur direct operational costs will reduce current emissions by 1.3% and 0.12% respectively.

Table 140 Summary of emission reduction measures for other activities

Activity	Control Option	Reduction in emissions of PM_{10} from entire inventory (%)
Trucks (dumping overburden)	Minimise drop height	2.92%
Loaders (coal)	Watering	1.66%
Unloading from stockpiles (coal)	Watering	0.70%
Loading stockpiles (coal)	Level 1 Watering	0.18%
Dragline (Other)	Minimise Drop Height	0.13%
Material transfer (coal)	Enclosure	0.03%
Loading trains (coal)	Level 2 Watering	0.02%

13. Conclusions and Recommendations

The conclusions and recommendations of the review of coal mining activities in the Greater Metropolitan Region of NSW (GMR) are summarised below.

The analysis of coal mining in the GMR indicates that:

- There are about 57 open-cut and underground coal mines in the GMR that produce more than 92% of total NSW production of coal. More than half of the mines are located in the Hunter Coalfield between Singleton and Muswellbrook and in the Newcastle Coalfield where the majority of NSW coal production occurs. Coal is also mined west of Sydney in the Western Coalfield in the regions surrounding the towns of Lithgow, Kandos, Rylstone, Mudgee and Ulan. There are a number of mines in the Southern Coalfield in the region surrounding Wollongong, reaching Appin to the north of Wollongong, Tahmoor to the northwest and Berrima to the west.

The existing issues associated with particulate matter emissions from coal mining are illustrated by the following:

- Ambient monitoring data collected at Muswellbrook, Singleton and Camberwell indicate that concentrations of particulate matter exceed the Ambient Air Quality NEPM standard for 24-hour average PM_{10} of 50 µg/m³ on a number of occasions per year.
- 331 complaints were received by OEH between 2007 and 2009 about air quality issues associated with coal mining. Approximately, 86% of complainants cited dust as a reason for the complaint. Sixty percent of the complaints came from residents in Muswellbrook, Singleton and Camberwell. About 10% of complaints came from Wollar in the Western Coalfield.
- In 2009, the Department of Planning commissioned expert reports in relation to cumulative impacts on air quality and other issues in response to public concern over the potential impacts at Camberwell posed by existing and proposed future coal mining. In relation to best practice management of particulate matter emissions, the expert report concluded that there is a need to further improve operational management to ensure that human health is protected at Camberwell in the coming years.

The study has found the following in relation to international and Australian coal production:

- China is the world's largest coal producer with 44% of total world production. The United States (14%), India (8%) and Australia (6%) are the next highest coal producers. Four OECD countries are in the top ten coal producers. In addition to Australia and the United States, the others are Germany (2.6%) and Poland (1.9%).
- The Powder River basin (42%) in Wyoming and the Appalachian region of West Virginia (20%) produce the bulk of coal in the United States.
- The majority of Australian coal is black coal that is produced in Queensland (45%) and New South Wales (34%). The majority of the remainder is brown coal that is produced in Victoria (18%).
- Coal production in New South Wales comes from six coalfields. Four coalfields are located in the GMR and these produce 92% of New South Wales's coal. Namely, the Hunter Coalfield, Newcastle Coalfield, Southern Coalfield and Western Coalfield.
- Approximately 63% of coal produced in the GMR comes from open-cut mines and the remainder is produced by underground mines. Dragline and truck and shovel mining each represent about half of the open-cut production.
- New South Wales's coal production is expected to grow by 2% per year out to 2029-30. Coal production in New South Wales is projected to exceed 200 million tonnes

per year by the end of this period. About 41% of the 91 million tonnes of new coal projects are expected to be in the Hunter Coalfield.

The study has found the following in relation to emissions from coal mining in the GMR:

- The 2003 emissions inventory found that coal mining was the largest emitter of particulate matter (as PM_{10}) in the GMR as a whole and in the Newcastle and Non-Urban Regions.
- The 2008 emissions inventory is currently being prepared. The contribution of coal mining to particulate emissions in the inventory is likely to maintain its prominence.
- OEH provided data from the 2008 emissions inventory for use in this study. Analysis of the 2008 emissions inventory data shows:
    - The largest source of PM_{10} from coal mining activities is haul trucks travelling on unpaved roads (40%), followed by wind erosion of overburden (27%), bulldozers (8%), blasting (6%) and trucks dumping overburden (4%).
    - The top three activities are found to produce 75% of PM_{10} emissions associated with GMR coal mines, whilst the top ten activities produce 97% of PM_{10} emissions.

A review of regulatory frameworks for air quality management around the world has jointly focused on countries with a high degree of economic development (OECD countries), the quantity of coal produced and level of environmental regulation adopted in the country. This review has found that:

- The regulatory regime in place in New South Wales is very transparent with a substantial amount of licence and approval information available on the websites of OEH and Department of Planning.
- Best practice is not strictly defined in the New South Wales legislation, but a form of best practice is implicit in Section 128 of the POEO Act that requires "...*the occupier of a premises to carry on any activity, or operate any plant, in or on the premises by such practicable means as may be necessary to prevent or minimise air pollution*." As distinct from other aspects of New South Wales legislation (e.g. the Clean Air Regulation in relation to point source emissions), there is no legislation or guideline that might provide the regulator, community or coal mine with a detailed and practical interpretation of what Section 128 might mean for coal mining.
- In the United States and Canada, the legislation and project approvals provide specific and detailed expectations about controlling emissions of particulate matter from coal mining.
- The NSW approach is deliberately less prescriptive to allow the licensee to determine the optimal approach to achieving the ongoing minimisation. The less prescriptive approach means that conditions of development approval do not specifically state the commitments made during the Environmental Assessment, but include a statement that the project shall be carried out "generally in accordance with the Environmental Assessment." Additionally, the assumptions made in the Environmental Assessment can be optimistic with regard to a mine's ability to achieve an appropriate level of minimisation or lack specificity as to how the minimisation will be achieved in practice.
- No impact assessment criterion has been specified by OEH for 24-hour average TSP. The Canadian province of Alberta provides a 24-hour average TSP criterion of 100 µg/m³, which is the most stringent criterion of all jurisdictions considered in the review.
- The annual average TSP impact assessment criterion adopted by OEH is less stringent than the strictest limits adopted by other jurisdictions considered in the review. The Canadian provinces of Alberta, British Columbia and Ontario and the Government of Canada provide an annual average TSP criterion of 60 µg/m³, which is the most stringent criterion of all jurisdictions considered in the review.

- The 24-hour average PM_{10} impact assessment criterion adopted by OEH is consistent with the strictest limits adopted by other jurisdictions considered in the review.
- The annual average PM_{10} impact assessment criterion adopted by OEH is less stringent than the strictest limits adopted by other jurisdictions considered in the review. The World Health Organisation, California and Scotland provide annual average PM_{10} criteria that are equal to or less than 20 µg/m³, which are the most stringent criteria of all jurisdictions considered in the review.
- No impact assessment criteria have been specified by OEH for $PM_{2.5}$. Annual average and 24-hour average criteria have been specified by most jurisdictions considered in the review. The stated position of OEH is that there is currently an Ambient Air Quality NEPM process considering developing a standard for $PM_{2.5}$ in Australia and OEH is awaiting the outcome of this process prior to setting impact assessment criteria for $PM_{2.5}$.
- The impact assessment criteria for deposited dust adopted by OEH are consistent with the strictest limits adopted by other jurisdictions considered in the review.
- The differences between OEH's impact assessment criteria and the Department of Planning's land acquisition criteria, leaves a gap that is filled by the land acquisition process. The land acquisition process requires a person to be affected and for that affected party to make representations to the mine in order to trigger action.
- Emissions of particulate matter from coal mining are not captured under New South Wales Load Based Licensing scheme. In the United States coal mines that exceed a specified threshold are subject to a load-based licensing fee that is charged based on the emission rate of particulate matter.

A detailed review of international techniques for controlling emissions of particulate matter from coal mining has been completed and best practice measures have been determined. The European and Victorian definitions of best practice have been central to the determination of best practice measures. Techniques adopted by GMR coal mines have been benchmarked against international best practice. Overall, coal mines in the GMR have adopted many elements of best practice. However, no mine has completely implemented best practice across the full range of activities. Additional efforts are applied to minimise emissions in adverse circumstances, but commensurate efforts may not be consistently applied at other times. Activities are commonly relocated to within the pit when conditions are conducive to the generation of particulate matter emissions but anecdotal evidence suggests that this may not always be effective and the literature suggests that pit retention may only provide a small (5% or less) reduction in emissions of PM_{10} and $PM_{2.5}$.

The following activity-specific conclusions have been reached:

- <u>Haul roads:</u> control measures include watering, grading, well-defined haul routes, speed limits to 40 km/hr and/or the use of suppressants. Approximately 89% of underground mines and 96% of open-cut mines use either fixed sprays or water carts to control emissions of particulate matter from haul roads. The majority of mines that were visited indicated that haul roads were watered on a consistent routine basis under normal weather conditions and that, under adverse conditions, visible particulate matter above the deck, wheels or tray of the haul trucks was used as a trigger for the application of additional watering. At a number of mines that were visited, haul truck drivers were instrumental in identifying problematic conditions and ensuring that water was applied to roads.

  However, the degree of diligence of watering activities could not be determined for each mine from the available information. Hence, the fact that watering is implemented may not mean that emissions are minimised as far as is practicable.

Approximately 74% of underground mines and 64% of open-cut mines use speed restrictions to control emissions of particulate matter from unpaved haul roads.

Best practice was found to be the application of suppressant on haul roads and application of water to control emissions from grading.

- Wind erosion of exposed materials and stockpiles: control measures include watering exposed areas, minimising areas of disturbance, progressive rehabilitation and use of suppressants. The majority (78%) of underground mines use watering to control emissions of particulate from cleared areas. At open-cut mines and combined underground and open-cut mines, watering (92%), limiting areas of disturbance (84%) and progressive rehabilitation (84%) are the major techniques that are used to minimise emissions associated with wind erosion.

  One mine in the GMR was found to use suppressant to control emissions from ROM stockpiles, whilst approximately 67% use water application.

  Best practice was found to be:
  - Use of water application or suppressants on coal stockpiles
  - Implementation of rehabilitation

- Bulldozing: best practice control measures include minimising the travel speed and distance travelled by bulldozers and the application of water to keep travel routes moist.

- Blasting: best practice control measures include delaying shot to avoid unfavourable weather conditions and minimising the area blasted. Most mines (91%) restrict blasting to times of favourable weather conditions.

- Drilling: best practice control measures include air extraction to a bag filter. No mines were found to use this practice. Approximately 58% of mines control emissions using water sprays, which are less effective than the use of fabric filtration, but still have a good level of effectiveness. Approximately, 62% use curtains to limit emissions.

- Draglines: there are seven open-cut mines that utilise draglines. Best practice control measures for draglines is minimising the drop height of materials to 5 metres and the suspension of operations in adverse conditions. Three GMR coal mines reported that drop heights were minimised to between 6 and 12 metres. Six metres is equivalent to best practice.

- Loading and dumping overburden: current practices adopted to control emissions from loading and dumping overburden were found to be water application, minimisation of drop heights and suspension or modification of activities during adverse weather conditions. Best practice control measures were identified as minimising drop heights and or the application of water.

- Loading and dumping ROM coal: best practice control measures for minimising emissions from the ROM hopper is enclosure with air extraction to a fabric filter or other control device. No mines in the GMR adopt this approach. Three mines (13%) were found to utilise enclosure on three sides and water sprays. Most (83%) mines use water sprays activated by the movement of the truck.

- Monitoring, proactive and reactive management: Of the open-cut mines, 84% monitor meteorological conditions and 48% monitor using a TEOM or other continuous particulate monitoring technique. Forty eight percent modify or cease activities on dry or windy days based on consideration of monitoring data. At least three mines have continuous particulate matter monitoring data available in the control room with alarms to alert operators when trigger levels are being exceeded.

A number of mines use a forecasting system and inversion tower data to predict the potential for strong inversions for scheduling blasts to avoid noise impacts. Three mines were identified that adopt similar proactive approaches for management of particulate matter emissions.

A particulate matter emission control metric has been developed to quantify the progress towards achieving best practice in GMR mines, which shows that:

- The Hunter and Newcastle coalfields have a similar level of particulate matter emissions control as an aggregate of all sources of emissions. Particulate matter emission control metrics of 63.2 and 67.0 out of 100 were estimated for these coalfields, respectively. The metrics indicate a moderate level of progress towards achieving best practice.
- Whilst lower combined metrics are evident in the Southern (46.5 out of 100) and Western (51.4 out of 100) coalfields, the relatively low contribution of these coalfields to the overall emissions into the GMR airshed mean that the combined GMR metric (62.8) is marginally lower than the Hunter and Newcastle coalfield metrics.

A cost benefit analysis has been conducted to estimate the cost to implement best practice control measures in GMR mines and the reduction in emissions of particulate matter that would be achieved by its implementation. The conclusions of this cost benefit analysis are as follows:

- Overall costs and benefits:
    - Significant reductions in emissions of particulate matter could be achieved through the application of best practice control measures that are both technically and economically feasible.
    - The cost of implementing best practice particulate emission controls in GMR coal mines was estimated to be $164M per year.
    - The application of best practice particulate emission controls was estimated to produce a 49% reduction in overall emissions of PM_{10}.
    - This reduction relies heavily on achieving a substantial increase in the area of land rehabilitated per year and the application of suppressant to haul roads.
    - Costs and benefits of the application of best practice control measures to different mine activities are based on generalised assumptions about mine activities, costs and effectiveness of those control measures. The actual cost and effectiveness will be dependent on site specific factors that need to be evaluated on a case-by-case basis.

- Haul roads:
    - The greatest reduction in emissions would be achieved by the application of suppressants to haul roads, which will reduce the current emissions by 21%. The cost for this is $59M per year.
    - A similar reduction in emissions could be achieved by the conversion of 50% of the haul roads to conveyors, which is estimated to cost $24M per year, and would reduce current emissions by 20%.
    - The most cost-effective control measure would be the replacement of the current fleet with larger-capacity vehicles, which is shown not to incur any additional costs, but instead produces a significant cost saving due to the reduction in the number of vehicles required to be purchased, as well as reduced operating costs. The use of larger haul trucks is estimated to reduce

costs by $105M per year across GMR mines and to reduce overall emissions by 10%.

- Overburden emplacements:
    - Rehabilitation of 80% of the overburden emplacements will reduce the current emissions by 20% and is estimated to cost $20M per year.
    - Rehabilitation is a more cost-effective approach in minimising emissions than watering.

- Coal stockpiles:
    - The greatest reduction in emissions from coal stockpiles was achieved by the application of suppressants, which is expected to reduce the current emissions by 2.0% at an ongoing cost of $33M per year.
    - A more cost effective approach would be the application of Level 2 watering, estimated to reduce current emissions by 1.0% and is estimated to cost $8M per year

- Exposed areas:
    - Full rehabilitation of other exposed areas is estimated to reduce current emissions by almost 3%, and is estimated to reduce the costs of current control measures (namely watering) by approximately $4M.
    - Full or partial rehabilitation of the exposed areas is shown to reduce the ongoing operational costs and the current emissions.

- Bulldozing:
    - Watering while bulldozing coal will reduce the current emissions by almost 2.0% of the current emissions and is estimated to cost over $53M per year.
    - Watering while bulldozing overburden will reduce the current emissions by less than 2% of the current emissions and is estimated to cost over $156M per year.

- Trucks dumping coal to the ROM hopper:
    - Enclosing the ROM hopper and the use of fabric filters is shown to reduce current PM_{10} emissions by less than 1% at a cost of $2M per year.

- Graders:
    - The application of level 2 watering to grading activities is estimated to reduce emissions by less than 1% at an estimated cost of $38M per year.

- Drilling:
    - The use of fabric filters on drill rigs is estimated to reduce emissions by less than 1.0% at a cost of $150,000 per year.
    - The cost of using the enclosure is significantly lower, estimated to cost $24,000 per year, and estimated to reduce emissions by less than 1.0%.

Based on the findings and conclusions of this study, the following steps may be considered to reduce emissions of particulate matter from coal mining activities.

- Provide a definition of best management practices (BMP) in the *Protection of the Environment Operations (Clean Air Regulation) 2002* (CAR) that would be applied in instances where there is no standard of concentration defined under Section 128 of the *Protection of the Environment Operations Act 1997.*

- Include opacity as an indicator of fugitive emissions of particulate matter and specify a limit for opacity with reference to limits defined in other jurisdictions. In the United States coal mining activities are required to minimise emissions to be less than a 20% opacity level. Such an approach could provide for a greater degree of management and control of emissions from haul roads and other emission sources, but would require training of mine and regulatory personnel to implement and enforce. Open-path opacity monitoring equipment could provide a technological solution to this.

- Consideration should be given to the development of a handbook, guideline or regulation that defines BMP for the control of particulate matter emissions from coal mining activities. The handbook could be initially developed from the findings of this study, but would be a dynamic document that is updated regularly based on experience, future innovation, community and stakeholder input. The document could:

    - Define appropriate emissions estimation techniques
    - Be referenced in conditions of approval and EPL conditions
    - Used as a tool for auditing
    - Used as a tool for developing management programs
    - Used as a resource for impact assessment studies
    - Define acceptable control factors for the development of emissions inventories required under the legislation. Alternative control factors or control measures that deviate from best practice could be acceptable based on review and approval using a process similar to the Chief Scientist process that is used to approve alternative sampling methods under the CAR.

- Incorporate coal mining into the load-based-licensing scheme. This could be used to drive the take up of more effective emission controls, but would require the development of the handbook described above. This may also motivate the development of more robust techniques for the quantification of particulate matter emissions from coal mining.

- Undertake a review of the currency, adequacy and effectiveness of existing TSP, PM_{10} and dust deposition criteria in avoiding adverse impacts on human health and amenity. Consider within this review whether $PM_{2.5}$ criteria should be adopted. Revise the *Approved Methods for the Modelling and Assessment of Air Pollutants in NSW* accordingly.

- Develop a regional dispersion model for the Hunter Coalfield to assist the planning and development. The model would need to incorporate:
    - Existing activities and use mine plans to project future emissions. This may require ongoing provision of mine plans to an administrative body for incorporation into the model
    - Historical ambient air quality monitoring data
    - Historical surface meteorological measurements incorporated into a 3-dimensional meteorological model
    - Approved mining activities

  The model could be used to:
    - Provide an agreed and approved framework for the planning and approval of new coal mines or extension of existing mines
    - Forecast air quality to provide information and alerts to mine managers and to community about air quality.

- Require new coal mine developments (at EA stage) and existing coal mines to conduct site specific BMP determinations to identify the most technically and economically feasible options to reduce emissions. For new developments, the BMP determination should be transparently linked to the air quality impact assessment and detailed in the air quality management plan (AQMP), which should also accompany the EA. For existing premises, the BMP determination could be required through a pollution reduction program (PRP) and the outcomes implemented through EPL conditions.

14. References

[1] Department of Environment and Climate Change NSW 2007, *Air Emissions Inventory for the Greater Metropolitan Region in NSW*, viewed August 2010.
<http://www.environment.nsw.gov.au/air/airinventory.htm>

[2] US Environmental Protection Agency 2010, *Basic Concepts in Environmental Sciences, Module 3: Characteristics of Particles – Size Distribution*, viewed 4 November 2010.
<http://www.epa.gov/apti/bces/module3/distribu/distribu.htm>

[3] US Environmental Protection Agency 1996, *Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper*, Office of Office of Air Quality Planning and Standards U.S. Environmental Protection Agency, EPA-452\R-96-013, July 1996, viewed 4 November 2010.
<http://www.epa.gov/ttn/caaa/t1/reports/pmspcov.pdf>

[4] Santa Barbara County Air Pollution Control District 2010, *Air Pollution and Our Health*, viewed 2 November 2010.
< http://www.sbcapcd.org/sbc/pollut.htm>

[5] New South Wales Health 2007, *Mine Dust and You*, Factsheet developed with the NSW Minerals Council, viewed August 2010.
<http://www.health.nsw.gov.au/factsheets/environmental/mine_dust.html>

[6] Ono, D, 2005, *Ambient $PM_{2.5}/PM_{10}$ ratios for Dust Events from the Keeler Dunes*, Great Basin UAPCD, Bishop, CA.

[7] Cowherd, C, Donaldson, J, 2005, *Analysis of the Fine Fraction of Particulate Matter in Fugitive Dust*, Final report prepared for the Western Governors' Association, Western Regional Air Partnership (WRAP), MRI Project No. 110397.

[8] US Environmental Protection Agency (USEPA) 2006, *Background Document for Revisions to Fine Fraction Ratios Used for AP-42 Fugitive Dust Emission Factors*, Midwest Research Institute, Western Governors' Association Western Regional Air Partnership (WRAP), 1515 Cleveland Place, Suite 200, Denver Colorado 80202. MRI Project No. 110397.

[9] Drew, R 2009, *Screening Health Risk Assessment of Predicted Dust Emissions from the Wandoan Coal Mine*, Toxicos document: TR020909-Rd1 4 September 2009.

[10] Environment Australia 2001, *Emission Estimation Technique Manual for Mining Version 2.3*, Environment Australia, GPO Box 787, Canberra, ACT 2601, Australia.
<http://www.npi.gov.au/publications/emission-estimation-technique/pubs/mining.pdf>

[11] Heavy Equipment Machinery Information 2010, *Underground Coal Mining in the Bituminous Coalfields*, viewed 12 November 2010.
<http://www.heavymachineryinfo.com/articles/364/1/Underground-Coal-Mining-in-the-Bituminous-Coalfields/Underground-Coal-Mining-in-the-Bituminous-Coalfields.html>

[12] World Coal Association 2010, *Coal Mining,* viewed 20 August 2010.
<http://www.worldcoal.org/media/jpg/585/074647section2_diagram.jpg>

[13] Xstrata Coal Mt Owen Complex 2010, *Mining & Infrastructure Mining Methods,* viewed 12 November 2010.
<http://www.mtowencomplex.com.au/img/mining_methods2.jpg>

[14] Mine Machine Training 2010, *Hydraulic Shovel Operations Training for Coal Employment*, viewed 12 November 2010.
<http://www.minemachinetraining.com.au/hydraulic-shovel-training.html>

[15] Bulga Coal 2010, *Mining & Infrastructure Mining Methods & Equipment,* viewed 12 November 2010.
<http://www.bulgacoal.com.au/mining_methods.html>

[16] NSW Minerals Council 2010, *Mining in NSW Mining Methods*, viewed 12 November 2010.
<http://www.nswmin.com.au/Mining-in-NSW/About-the-Industry/How-we-mine/Mining-Methods/default.aspx>

[17] Department of Environment Climate Change and Water 2010, *Compendium of Upper Hunter Air Quality Monitoring Data*, viewed 10 November 2010.
<http://www.environment.nsw.gov.au/resources/air/UpperHunterAirQualityData.pdf>

[18] *National Environment Protection (Ambient Air Quality) Measure 1998* (Commonwealth of Australia).

[19] Department of Environment Climate Change and Water 2010, *Review of upper hunter air quality data*, viewed 5 August 2010.
< http://www.environment.nsw.gov.au/aqms/upperhunterreview.htm>

[20] DustWatch 2010, *DustWatch report for week ending 28 September 2009*, viewed 12 November 2010.
<http://www.environment.nsw.gov.au/resources/dustwatch/DWNL090928.pdf>

[21] Department of Environment and Conservation 2007, *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW*, Department of Environment and Conservation, Sydney, DEC 2007/1, ISBN 978 1 74122 373 6, January 2007, viewed 1 November 2010.
<http://www.environment.nsw.gov.au/resources/air/07001amsaap.pdf>

[22] *Protection of the Environment Operations Act 1997* (New South Wales, Australia).

[23] Environ Australia Pty Ltd., 2009, *Independent Review of Cumulative Dust Impacts – Camberwell Village*, prepared for Major Project Assessment – Industry and Mining NSW Department of Planning, viewed 2 September 2010.
<http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=waS1Eif7MY8%3d&tabid=70&language=en-AU>

[24] Wilkinson Murray 2009, *Independent Review of Cumulative Noise Impacts – Camberwell Village*, Report No. 09048, Version B, May 2010, prepared for Major Project Assessment – Industry and Mining NSW Department of Planning, viewed 2 September 2010.
<http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=QHTJY4NwLlA%3d&tabid=70&language=en-AU>

[25] Noller, B 2009, *Community Lead Issues at Camberwell NSW*, Report from Centre for Mined Land Rehabilitation, The University of Queensland to Ashton Coal Operations Pty. Ltd, viewed 2 September 2010.
<http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=n4iJb9CtYbc%3d&tabid=70&language=en-AU>

[26] PAE Holmes 2010, *Final Report, Additional Cumulative Air Quality Assessment for Proposed Ashton Coal Operations Ltd, Integra Coal Operations Pty Ltd and Ravensworth Operations Pty Ltd*, 1 July 2010, viewed 2 September 2010.
<http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=nfYnftFXXKI%3d&tabid=70&language=en-AU>

[27] Department of Planning 2010, *Camberwell Cumulative Impacts Review – Key Government Responses*, July 2010, viewed 21 August 2010. <http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=kGN73fl6Cx8%3D&tabid=70&language=en-AU>

[28] Department of Environment Climate Change and Water 2010, *Upper Hunter air quality monitoring network*, viewed 2 September 2010. <http://www.environment.nsw.gov.au/aqms/upperhunter.htm>

[29] BP 2010, *Statistical Review of World Energy*, viewed 15 August 2010. <http://www.bp.com/productlanding.do?categoryId=6929&contentId=7044622>

[30] World Coal Institute 2005, *The Coal Resource – A comprehensive overview of coal*, viewed 19 August 2010. <www.worldcoal.org/bin/pdf/original_pdf_file/coal_resource_overview_of_coal_report(03_06_2009).pdf>

[31] US Energy Information Administration 2010, *Annual Coal Report 2009, DOE/EIA-0584 (2009)*, viewed 28 August 2010. <http://www.eia.doe.gov/cneaf/coal/page/acr/acr_sum.html>

[32] ABARE 2010, *Australian Energy Resource Assessment*, viewed August 2010. <http://www.abare.gov.au/publications_html/energy/energy_10/foreword.pdf>

[33] ABARE 2010, *Australian energy statistics, Australian Production of Primary Fuels – Physical Units, 1960-61 to 07-08*, viewed August 2010. <http://www.abare.gov.au/publications_html/data/data/data.html>

[34] New South Wales Department of Primary Industries 2009, *Coal Industry Profile*, viewed August 2010. <http://www.dpi.nsw.gov.au/minerals/resources/coal/nsw-coal-industry-profile>

[35] Department of Primary Industries 2009, *2009 New South Wales Coal Industry Profile*, NSW Department of Primary Industries, 2009.

[36] ABARE 2010, Australian *energy projections to 2029-30, ABARE research report 10.02*, ABARE, March 2010, viewed 2 August 2010. <http://www.abare.gov.au/publications_html/energy/energy_10/energy_proj.pdf>

[37] ABARE 2010, *List of Minerals and Energy Projects*, viewed August 2010. <http://www.abare.gov.au/publications_html/energy/energy_10/ME10_AprListing.xls>

[38] Australian Government Department of Environment, Water, Heritage and Arts 2010, *NPI National Pollution Inventory, Version 5.1, February 2010*, viewed 29 August 2010. <http://www.npi.gov.au/publications/pubs/npiguide.pdf>

[39] Australian Government Department of Sustainability, Environment, Water, Population and Communities 2010, *National Pollutant Inventory*, viewed 12 November 2010. <http://www.npi.gov.au/>

[40] *National Environment Protection (Air Toxics) Measure* (Commonwealth of Australia)

[41] *Protection of the Environment Operations (General) Regulation 1998* (New South Wales, Australia)

[42] *Protection of the Environment Operations (Clean Air) Regulation 2002* (New South Wales, Australia)

[43] Department of Environment and Climate Change NSW 2007, *Technical Report No. 1 Air Emissions Inventory for the Greater Metropolitan Region in New South Wales Criteria Pollutant Emissions for all Sectors: Results*, viewed August 2010.
<http://www.environment.nsw.gov.au/resources/air/tr1aei0712.pdf>

[44] *Protection of the Environment Operations (Clean Air) Regulation 2002* (New South Wales, Australia)

[45] Department of Environment and Conservation 2005, *Approved methods for the modelling and assessment of air pollutants in New South Wales*, Department of Environment and Conservation, Sydney, DEC 2005/361, ISBN 1 74137 488 X, August 2005, viewed 5 November 2010.
<http://www.environment.nsw.gov.au/resources/air/ammodelling05361.pdf>

[46] Victorian Government, 2001, State Environment Protection Policy (Air Quality Management) Environment Protection Act 1970, Victoria Government Gazette, Special No. S 240 Friday 21 December 2001. Victorian Government Printer.

[47] Victorian Government, Environmental Protection Agency, 2006, State Environment Protection Policy Mining and Extractive Industry, Consultation Document, EPA Victoria.

[48] *Directive 2008/1/EC* of the European Parliament and of the Council, viewed 12 August 2010.
<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:EN:PDF>

[49] European Commission Directorate General JRC Joint Research Centre, 2004, Reference document of best available techniques for management of tailings and waste rock in mining activities, Reference Document on Best Available Techniques for Management of Tailings and Waste-rock in Mining Activities – 21.2 Mb accessed August 2010.
<http://eippcb.jrc.es/pub/english.cgi/d1056340/25>

[50] *Clean Air Act 1990* (United States)

[51] *40 CFR Part 60, Standards of Performance for Coal Preparation and Processing Plants; Final Rule part of EPA Title 40, Protection of Environment, Chapter 1, Environmental Protection Agency, Sub Chapter C Air Programs Standards of Performance for new Stationary Sources* (United States)
<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=/ecfrbrowse/Title40/40cfr60_main_02.tpl>

[52] *Environmental Planning and Assessment Act 1979* (New South Wales, Australia)

[53] *Environmental Protection Act 1994* (Queensland, Australia)

[54] *Environmental Protection (Air) Policy 2008* (Queensland, Australia)

[55] *Environmental Protection Regulation 1998* (Queensland, Australia)

[56] *Sustainable Planning Act 2009* (Queensland, Australia)

[57] *Mineral Resources (Sustainable Development) Act 1990* (Victoria, Australia)

[58] *Environmental Effects Act 1978* (Victoria, Australia)

[59] *Environment Protection Act 1970* (Victoria, Australia)

[60] *Public Law 95-97 Surface Mining Control and Reclamation Act 1977* (United States) accessed August 2010.
<http://www.osmre.gov>

[61] US Environmental Protection Agency 2010, *National Ambient Air Quality Standards (NAAQS), Air and Radiation*, viewed 10 August 2010.
<http://www.epa.gov/air/criteria.html>

[62] Maricopa County Air Quality Department 2010, *State Implementation Plan*, viewed 10 August 2010. <http://www.maricopa.gov/aq/divisions/planning_analysis/state_implementation_plan.aspx>

[63] *EPA Title 40, Protection of Environment, Chapter 1, Environmental Protection Agency, Sub Chapter C Air Programs Standards of Performance for new Stationary Sources* (United States)

[64] Wyoming Department of Environmental Quality USA Air Quality Division Standards and Regulations, Chapter 6 Permitting Requirements.

[65] West Virginia Coal Surface Reclamation Mining Rule

[66] *Air Pollution Control Act* (West Virginia, United States)

[67] United Nations, 2010, *National Reports, Canada, Mining*, viewed 10 August 2010. <http://www.un.org/esa/dsd/dsd_aofw_ni/ni_pdfs/NationalReports/canada/Mining.pdf>

[68] *Environmental Protection Act 1999* (Canada)

[69] *Canadian Environmental Assessment Act 1992* (Canada)

[70] *Fisheries Act 1985* (Canada)

[71] *Navigable Waters Protection Act 1985* (Canada)

[72] *Migratory Birds Convention Act 1994* (Canada)

[73] *Labour Code Part 11 1985* (Canada)

[74] *Mining Act 1990* (Ontario, Canada)

[75] Ministry of the Environment Ontario 2010, *Ontario's Ambient Air Quality Criteria*, viewed 10 August 2010.
<http://www.ene.gov.on.ca/publications/6570e-chem.pdf>

[76] *Environment Protection Act RSO 1990* (Ontario, Canada)

[77] Quebec, Editeur Officiel du Qjebec (Ministère du Développment durable, de l'Environnement et des Parcs, 2002, viewed 10 August 2010.
<http://www.mddep.gouv.qc.ca/industriel/inter_en.htm>

[78] *Mines Act (including Health, Safety & Reclamation Code & Mineral Exploration Code, RSBC 1996*, Chapter 293 (Victoria, British Columbia, Canada)

[79] *Environmental Assessment Act, SBC 2002*, Chapter 43 (Victoria, British Columbia, Canada)

[80] *Environmental Land Use Act, RSBC 1996*, Chapter 117 (Victoria, British Columbia, Canada)

[81] *Environmental Management Act 2004* (Victoria, British Columbia, Canada)

[82] *Health Act RSBC 1996* (Victoria, British Columbia, Canada)

[83] *Mines and Minerals Act O.C. 371/2008* (Alberta, Canada)

[84] *Mines and Minerals Administration Regulation, Alta, Reg 262.1997* (Canada)

[85] Government of Alberta, Ministry of Energy 2010, *Minerals Acts & Regulations*, viewed 20 August 2010.
<http://www.energy.gov.ab.ca/minerals/714.asp>

[86] *Environmental Protection and Enhancement Act RSA 2000* c.E-12 (Alberta, Canada)

[87] *Environment Assessment (Mandatory and exempted activities) Regulation 111/1993* (Alberta, Canada).

[88] Framework Directive 96/62/EC, 1-3 daughter Directives 1999/30/EC, 2000/69/EC, 2002/3/EC, and Decision on Exchange of Information 97/101/EC.

[89] European Union, European Law, Directive Eur – Lex, Access to European Law Directive, 2008/50/EC Effective 11 June 2008.

[90] EUR-Lex Access to European Law, 2004, Legislative Instrument Details: Questionnaire for Annual Reporting on Ambient Air Quality Assessment and Management (2004/461/EC).

[91] *Federal Mining Act 13.8 1980, 32004D0073* (Germany)

[92] United Nations 2010, *National Reports, Germany, Mining*, viewed 27 August 2010.
<http://www.un.org/esa/dsd/dsd_aofw_ni/ni_pdfs/NationalReports/germany/mining.pdf>

[93] United Nations 1990, *Ordinance on the Environmental Impact Assessment of Mining Projects of 1990*.

[94] European Commission Environment, 1985, Environmental Assessment, Council Directive of 27 June 1985 on the Assessment of the Effects of certain Public and Private Projects on the Environment, 85/337/EEC, Reference Official Journal No. L175 5/7/1985 P 0040 – 0048.

[95] European Commission Environment, Community Legislation, Summary of EU Legislation of Mining Waste, Directive 2006/21/EC of the European Parliament and of the Council on the Management of Waste from the Extractive Industries.

[96] *Federal Immission Control Act (Technical Instructions on Air Quality Control) 1990* (Germany) <http://www.bmu.de/files/pdfs/allgemein/application/pdf/taluft_engl.pdf>

[97] New Zealand Government, Ministry for Economic Development – Crown Minerals, accessed on 15 November 2010.
<http://www.crownminerals.govt.nz>

[98] *Crown Minerals Act 1991* (New Zealand)

[99] *Resource Management Act 1991* (New Zealand)

[100] *Crown Minerals (Minerals and Coal) Regulations 2007* (New Zealand)

[101] *Crown Minerals (Minerals fees) Regulations 2006* (New Zealand)

[102] *State Environmental Planning Policy (Major Developments) 2005* (New South Wales, Australia)

[103] Department of Planning 2006, *Instrument of Consent for the Wilpinjong Coal Project*, viewed 11 November 2010.
<http://majorprojects.planning.nsw.gov.au/files/9315/05_0021_instrument_of_consent.pdf>

[104] *State Development and Public Works Organisation Act 1971* (Queensland, Australia)

[105] *Mineral Resources Act 1989* (Queensland, Australia)

[106] *Petroleum and Gas Act 2004* (Queensland, Australia)

[107] Department of Environment and Resource Management 2010, *EIS processes*, viewed 2 November 2010.
<http://www.derm.qld.gov.au/environmental_management/impact_assessment/eis-processes/documents/generic-draft-tor.doc>

[108] *Region 9, National Environment Policy Act 1969* (United States)

[109] Council on Environment Quality (CEQ), 2007, *A Citizen's Guide to the NEPA, Having Your Voice Heard,* viewed 1 September 2010.
<http://ceq.hss.doe.gov/nepa/Citizens_Guide_Dec07.pdf>

[110] *Administrative Procedure Act 1949* (Germany).

[111] US Environmental Protection Agency 2010, *Technology Transfer Network, Clearinghouse for Inventories & Emissions Factors*, viewed 20 August 2010.
<http://www.epa.gov/ttn/chief/ap42/index.html>

[112] *40 CFR Part 51 - Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model* (United States).

[113] US Environmental Protection Agency 2010, *Support Center for Regulatory Atmospheric Modeling*, *Permit Modeling Guidance*, viewed 17 August 2010.
<http://www.epa.gov/ttn/scram/guidance_permit.htm>

[114] US Environmental Protection Agency 2010, *Support Center for Regulatory Atmospheric Modeling*, *State Implementation Plan (SIP) Attainment Demonstration Guidance*, viewed 17 August 2010.
<http://www.epa.gov/ttn/scram/guidance_sip.htm>

[115] Wyoming Department of Environmental Quality, WDEQ, 2010, Guidance for Submitting Major Source/PSD Modeling Analyses

[116] Wyoming Department of Environmental Quality, WDEQ, 2010, Guidance for Conducting Near-Field Modelling Analyses for Minor Sources

[117] Wyoming Department of Environmental Quality, WDEQ, 2006, Memorandum – PRB Coal Mine Permitting Guidance

[118] West Virginia Department of Environmental Protection 2010, *Permitting Handbook,* viewed 20 August 2010.
<http://www.dep.wv.gov/dmr/handbooks/Pages/page1.aspx>

[119] *Protection of the Environment Operations (General) Regulation 2009* (New South Wales, Australia), viewed 11 November 2010.
<http://www.legislation.nsw.gov.au/scanview/inforce/s/1/?SRTITLE=%22Protection%20of%20the%20Environment%20Operations%20%28General%29%20Regulation%202009%22&nohits=y>

[120] *40 CFR Title 40 Protection of Environment, Part 70, 1992, State Operating Permit Programs* (United States)

[121] *Environmental Quality Act* (Quebec, Canada)
<http://www2.publicationsduquebec.gouv.qc.ca/dynamicSearch/telecharge.php?type=2&file=/Q_2/Q2_A.html>

[122] *Air Quality Act 2004* (Republic of South Africa)

[123] *Mine Health and Safety Act 1996* (Republic of South Africa)

[124] World Health Organisation (2006), *Air quality guidelines. Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide,* ISBN 92 890 2192 6, World Health Organisation 2006.

<http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf>

[125] US Environmental Protection Agency 1998, AP 42, Fifth Edition, Volume I Chapter 11: Mineral Products Industry, 11.9 Western Surface Coal Mining, Technology Transfer Network, Clearinghouse for Inventories & Emission Factors, United States Environmental Protection Agency, Research Triangle Park, NC 27711, USA.
<http://www.epa.gov/ttn/chief/ap42/ch11/final/c11s09.pdf >

[126] NERDDC (1988), *Air Pollution from Surface Coal Mining: Volume 2 Emission Factors and Model Refinement*, National Energy Research and Demonstration Council, Project 921.

[127] US Environmental Protection Agency 2010, *Technology Transfer Network, Clearinghouse for Inventories & Emission Factors*, viewed 10 August 2010.
<http://www.epa.gov/ttn/chief/ap42/index.html>

[128] US Environmental Protection Agency 2006, AP 42, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources, 13.2.2 Unpaved Roads, Technology Transfer Network, Clearinghouse for Inventories & Emission Factors, United States Environmental Protection Agency, Research Triangle Park, NC 27711, USA.
<http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0202.pdf>

[129] Foley, G., Cropley S., Giummarra G., 1996, Road Dust Control Techniques - Evaluation of Chemical Dust Suppressants. Performance. Special Report 54 to ARRB Transport Research Limited, Australia.

[130] IEA Coal Research, 1994, Control of Coal Dust in Transit and in Stockpiles.

[131] Midwest Research Institute, 2006, Background document for revisions to fine fraction ratios used for AP-42 fugitive dust emission factors, MRI Project No. 110397, Western Governors' Association, Western Regional Air Partnership (WRAP).

[132] State and Territorial Air Pollution Program Administrators (STAPPA) and Association of Local Air Pollution Control Officials (ALACO), 2006, Controlling Fine Particulate Matter under the Clean Air Act. A Menu of Options, Chapter 20 Fugitive Dust. USA.

[133] Tannant, D.W., Regensburg, B., 2001, Guidelines for Mine Haul Road Design, Canada.

[134] Thompson, R.J., Visser, A.T., 2007, Selection, Performance and Economic Evaluation of Dust Palliatives on Surface Mine Haul Roads, The Journal of The Southern African Institute of Mining and Metallurgy, Volume 107.

[135] Organiscak, J.A., Page, S.J., Cecala, A.B., Kissell, F.N., Chapter 5. – Surface Mine Dust Control. Handbook for Dust Control in Mining. IC9465 Information Circular 2003.
<www.cdc.gov/NIOSH/Mining/pubs/pdfs/2003-147.pdf>

[136] US Environmental Protection Agency 1992, *Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures*, Document EPA-450/2-92-004.

[137] Thompson, R J, Visser, A T 2006, *Selection and maintenance of mine haul road wearing course materials*, Mining Technology Vol. 15 No. 4.

[138] Chaulya, S K 2004, *Assessment and Management of Air Quality for an Opencast Coal Mining Area*, Journal of Environmental Management 70, 1-14.

[139] Craig, A J, Director of Mining at Midwest Industrial Supply - comment in International Mining, 2010 Haul Roads and Tyres – Tread Carefully.

[140] Spraying Systems Co. 2008, A Guide to Spray Technology for Dust Control.

[141] Ghose, M.K., and Majee, S.R., 2001, Air Pollution Caused by Opencast Mining and its Abatement Measures in India. Journal of Environmental Management, 63, 193-202.

[142] Organiscak, J.A., Page, S.J., Cecala, A.B., Kissell., F.N., Chapter 5. – Surface Mine Dust Control. Handbook for Dust Control in Mining. IC9465 Information Circular 2003. <www.cdc.gov/NIOSH/Mining/pubs/pdfs/2003-147.pdf.>

[143] US Department of Agriculture, Forest Service, Technology and Development Program. 1999, Dust Palliative Selection and Application Guide.

[144] Bohn, R., Cuscinio, T., Cowherd, C., 1978, Fugitive Emissions from Integrated Iron and Steel Plants, Prepared by Midwest Research Institute for USEPA. EPA Report Mo. EPA-600/2-78-050, NTIS Report No. PB-281322.

[145] US Environmental Protection Agency 2006, AP 42, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources, 13.2.5 Industrial Wind Erosion, Technology Transfer Network, Clearinghouse for Inventories & Emission Factors, United States Environmental Protection Agency, Research Triangle Park, NC 27711, USA. <http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0205.pdf>

[146] Australian Government Department of Resources, Energy and Tourism 2009, *Leading Practice Sustainable Development Program for the Mining Industry, Airborne Contaminants, Noise and Vibration*, October 2009.

[147] Toy, T.J., 1979, Potential Evapotranspiration and Surface-mine Rehabilitation in the Powder River Basin, Wyoming and Montana. Journal of Range Management, Volume 32, No. 4, pp312-317.

[148] *Surface Mine Control and Reclamation Act of 1977* (United States)

[149] CARB, 2002, Evaluation of Air Quality Performance Claims for Soils-Cement Dust Suppressant.

[150] Park, C.W., Lee, S.J., 2002, Verification of the shelter effect of a windbreak on coal piles in the POSCO open storage yards at the Kwang-Yang works. Atmospheric Environment, Vol.36, 13, 2171-2185.

[151] US Environmental Protection Agency 2006, AP 42, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources, 13.2.5 Industrial Wind Erosion, Technology Transfer Network, Clearinghouse for Inventories & Emission Factors, United States Environmental Protection Agency, Research Triangle Park, NC 27711, USA. <http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0205.pdf>

[152] IEA Coal Research, 1994, Control of Coal Dust in Transit and in Stockpiles.

[153] Connell Hatch 2008, RG Tanna Dust Benchmarking Gladstone Port Coal Losses and Air Quality Study, Report to Central Queensland Ports Authority, Revision 4.1, 12 March 2008, viewed 29 August 2010. <http://www.cqpa.com.au/Pages/Publications/RGTCTBenchmarkingStudy/RGTCTBenchmarkingStudyFullReport2008.PDF>

[154] NSW Minerals Council 2000, Technical Paper Particulate Matter and Mining Interim Report.

[155] Billman, B.J., Arya, 1985, Windbreak effectiveness for storage-pile fugitive dust control, USEPA Report No. EPA/600/3 - 85/059.

[156] US Environmental Protection Agency 1986, *Field Evaluation of Windscreens as a Fugitive Dust Control Measure for Material Storage Piles,* Document EPA/600/S7-86/027.

[157] Carnes, D, Drehmel, D C 1981, *The Control of Fugitive Emissions using Windscreens*. Third Symposium on the Transfer and Utilization of Particulate Control Technology, Orlando, Florida.

[158] Stunder, B J B, Arya, S P S, 1988, ‘Windbreak effectiveness for storage pile fugitive dust control: a wind tunnel study’, *Journal Air Pollution Control Association,* Volume 38, No. 2.

[159] Faveri, D.M de., Converti, A., Vidili A., Campidonico A., Ferraiolo, G., 1990, Reduction of the environmental impact of coal storage piles: a wind tunnel study, *Atmospheric Environment*, 24A (11); 2787-2793.

[160] Martin, D., Drehmel, D.C., 1981, The Influence of Aggregate Pile Shape and Orientation on Particulate Fugitive Emissions. Third Symposium on the Transfer and Utilization of Particulate Control Technology, Orlando, Florida.

[161] Ohio EPA, 1980, Reasonably Available Control Measures for Fugitive Dust Sources, Office of Air Pollution Control, Division of Engineering, Columbus OH, 43216. NTIS Report No. PB82-103805.

[162] Currier, E.L., Neal, B.D., 1979, Fugitive Emission from Coal-Fired Power Plants, 72nd Annual Meeting of the Air Pollution Control Association, Cincinnati, OH. June 24-29, 1979. Paper 79-11.4.

[163] Jutze, G.A., Zoller J.M., Janszen T.A., Amick R.S., Zimmer C.E., 1977, Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions, prepared by PEDCo-Environmental, Inc. for USEPA. EPA Report No. EPA-450/3-77-010.

[164] Davis, E.A., 1981, Fugitive dust emissions from the Proposed Vienna Unit No. 9. Prepared by the Johns Hopkins University Applied Physics Laboratory for the Maryland Power Plant Siting Program. NTIS Report No. PB81-190175.

[165] Ohio EPA (1980), Reasonably Available Control Measures for Fugitive Dust Sources. Office of Air Pollution Control, Division of Engineering, Columbus OH, 43216. NTIS Report No. PB82-103805.

[166] TRW (1982), BACT and Fugitive Emissions Evaluation of Kentucky Utilities – Hancock Station PSD Application, Prepared for US EPA Region IV.

[167] Countess Environmental, 2006, WRAP Fugitive Dust Handbook, Western Governor’s Association

[168] US Environmental Protection Agency 1983, AP 42, Fourth Edition, Volume I Chapter 8: Mineral Products Industry, 8.24 Western Surface Coal Mining, Technology Transfer Network, Clearinghouse for Inventories & Emission Factors, United States Environmental Protection Agency, Research Triangle Park, NC 27711, USA.
<http://www.epa.gov/ttn/chief/ap42/oldeditions/4th_edition/ap42_4thed_orig.pdf>

[169] UK Coal 2007, *Surface Mining Operations,* viewed 20 August 2010.
<http://www.ukcoal.com/surface-mining-ops>

[170] Mattis, A.R., Cheskidov, V.I., Labutin, V.N., Zaitsez D., 2004, Blast Free Technology of Mineral Mining: State and Prospects, Source: *Journal of* Mining *Science*, Volume 40, Number 2, March *2004,* pp. 173-181(9).

[171] Mattis, A.R., Cheskidov, V.I., Labutin, V.N., Zaitsez D., 1995, Russian mining technique avoids blasting, Coal International 243(3) p,110.

[172] Reed, W.R., Organiscak, J.A., Page, S.J., 2004, New Approach Controls Dust at the Collector Dump Point.
<http://www.e-mj.com>

[173] US Bureau of Mines, 1994, Improved Dust Control for Surface Coal Mine Drilled with Rotoclone Collectors. Technology News. Bureau of Mines, US Department of the Interior.

[174] New South Wales Mineral Council, 2000, Particulate matter and mining, NSW Minerals Council Technical Paper.

[175] Buonicore, A J, Davis, W T (ed.) 1992, *Air Pollution Engineering Manual*, US Air and Water Management Association, Van Nostrand Reinhold Company, June 1992.

[176] BHP Billiton Sustainability Report 2005, Managing dust suppression issues at our operations, accessed August 2010 <http://sustainability.bhpbilliton.com/2005/repository/environment/>

[177] US Environmental Protection Agency 2006, AP 42, Fifth Edition, Volume I Chapter 13: Miscellaneous Sources, 13.2.4 Aggregate Handling and Storage Piles, Technology Transfer Network, Clearinghouse for Inventories & Emission Factors, United States Environmental Protection Agency, Research Triangle Park, NC 27711, USA.
<http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s0204.pdf>

[178] Bengalla Coal Mine 2010, *Processing*, viewed 15 August 2010. <http://www.bengallamine.com/pages/map/index.html>

[179] Connell Hatch, 2008, Environmental Evaluation Coal Dust Emissions Literature Review, Report to Queensland Rail.

[180] Australian Standard 1993, *Guide to the technical evaluation of higher rank coal deposits*, AS2519-1993, Standards Australia, Homebush, NSW.

[181] BHP Billiton 2010, *Mt Arthur Coal Annual Environmental Management Report 2009*, viewed 12 August 2010.
<http://www.bhpbilliton.com/bbContentRepository/docs/2009MtArthurCoalEnvironmentManagementReportWeb.pdf>

[182] Bengalla Mining Company Pty Limited 2010, *Annual Environmental Management Report 2009*, viewed 12 August 2010.
<http://www.coalandallied.com.au/documents/2009_Bengalla_Annaul_Environmental_Managment_Report.pdf>

[183] Hunter Water 2010, *Water Charges*, viewed 17 August 2010. <http://www.hunterwater.com.au/3217.aspx>

[184] Australian Institute of Petroleum 2010, Pricing, viewed 17 August 2010, <http://www.aip.com.au/pricing/>

[185] NSW Department of Industry & Investment 2010, *Primary Industries, Minerals and Petroleum, Mining rehabilitation security, DPI schedule of rehabilitation costs*, viewed 17 August 2010.
<http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/96114/DPI-Schedule-of-Rehabilitation-Costs.pdf>